# Technical Report Documentation Page

**1. REPORT No.**

FHWA/CA/TE-98/13

**2. GOVERNMENT ACCESSION No.**

**3. RECIPIENT'S CATALOG No.**

**4. TITLE AND SUBTITLE**

Effect of Ramp Type and Geometry on Accidents

**5. REPORT DATE**

November, 1998

**6. PERFORMING ORGANIZATION**

**7. AUTHOR(S)**

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**8. PERFORMING ORGANIZATION REPORT No.**

51-366-680406 S

**9. PERFORMING ORGANIZATION NAME AND ADDRESS**

California Department of Transportation
Traffic Operations Program
1120 N Street
Sacramento, CA 95814

**10. WORK UNIT No.**

**11. CONTRACT OR GRANT No.**

**12. SPONSORING AGENCY NAME AND ADDRESS**

California Department of Transportation
Traffic Operations Program
1120 N Street

**13. TYPE OF REPORT & PERIOD COVERED**

**14. SPONSORING AGENCY CODE**

51-366

**15. SUPPLEMENTARY NOTES**

**16. ABSTRACT**

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**17. KEYWORDS**

Ramp, Acceleration Deceleration lane, on-ramp, off-ramp, exit, entrance, diamond ramp, buttonhook ramp

**18. No. OF PAGES:**

126

**19. DRI WEBSITE LINK**

http://www.dot.ca.gov/hq/research/researchreports/1997-2001/ramp.pdf

**20. FILE NAME**

ramp.pdf

STATE OF CALIFORNIA. DEPARTMENT OF TRANSPORTATION

# TECHNICAL REPORT DOCUMENTATION PAGE

TROOO3 (REV. 10/98)

| 1. REPORT NUMBER | 2. GOVERNMENT ASSOCIATION NUMBER | 3. RECIPIENTS CATALOG NUMBER |
| --- | --- | --- |
| FHWA/CA/TE-98/13 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
| --- | --- |
| Effect of Ramp Type and Geometry on Accidents | November, 1998 |
| | 6. PERFORMING ORGANIZATION CODE<br>51-366-680406 S |
| 7. AUTHOR<br>Ahmad Khorashadi | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>California Department of Transportation<br>Traffic Operations Program<br>1120 N Street<br>Sacramento, CA 95814 | 10. WORK UNIT NUMBER<br><br>11. CONTRACT OR GRANT NUMBER |
| 12. SPONSORING AGENCY AND ADDRESS<br>California Department of Transportation<br>Traffic Operations Program<br>1120 N Street<br>Sacramento, CA 95814 | 13. TYPE OF REPORT AND PERIOD COVERED<br><br>14. SPONSORING AGENCY CODE<br>51-366 |

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| 17. KEY WORDS | 18. DISTRIBUTION STATEMENT |
| --- | --- |
| Ramp, Acceleration Deceleration lane, on-ramp, off-ramp, exit, entrance, diamond ramp, buttonhook ramp | |

| 19. 19. SECURITY CLASSIFICATION (of *this report*) | 20. NUMBER OF PAGES | 21. PRICE |
| --- | --- | --- |
| Unclassified | 117 | |

**Effect of Ramp Type and Geometry**
**On Accidents**

November, 1998

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## Executive Summary

Ramp design is influenced by many factors including: the speed, volume, and composition of traffic to be served, the standards and arrangement of the local street system including traffic control devices, topography, right of way controls, local planning, proximity of adjacent interchanges, community impact, consistency in the pattern of interchange ramps along a freeway and cost.

Of the total of 478,569 accidents occurring during 1992-94 on California State highways, approximately 15% occurred on ramps. Rural ramp accidents accounted for 2.82% of the accidents on rural highways, and urban ramp accidents accounted for 18.41% of the accidents on urban highways. The majority of ramps experienced single vehicle accidents or only one multiple-vehicle accident in the study period.

Ramp safety performances were compared with respect to a number of different types of accident rates (fatal, fatal + injury, total, wet, and dark accidents). A series of additional analyses were run where differences in mean accident rates between each pair of ramp configurations were estimated. The comparisons of accident rates were done for four groups of ramps stratified by ramp type (on/off), and urban/rural settings. Finally, accident occurrence on a sample of half diamond ramps was analyzed.

High accident ramps were summarized. Scissors ramps, rest area ramp, and slip ramp configurations were the most common among the ramp sample with high accident rates. Although, the percentage of the loop ramps with a left turn was relatively low in the sample, it comprises an overwhelming portion of loop ramp configuration (47%).

Accident rates for on-ramps were consistently lower than those for off-ramps (as summarized in tables 13 through 16). Most fatal and injury type

accidents occurred on off-ramps, while on-ramps tended to be linked with the less severe property damage only (PDO) accidents.

The independent variables, whose effects on accident frequency were most often found by other studies to be statistically significant, were: ramp AADT, mainline freeway AADT, area type (rural/urban), ramp type (off/on), ramp configuration, length of speed change lane, ramp length. The general consensus of many studies is that traffic volume is the strongest predictor of accidents on ramps. Ramp geometry in studies that developed accident prediction models found to be a much weaker variable than main line traffic volume and ramp traffic volume. The studies did not suggest that geometric variables are unimportant, rather, that they are generally improved to a point where further variance in geometric variables has little influence on accidents.

As a whole, literature review indicated that it is better to design ramps with flat horizontal curves (except in rural areas) avoiding the maximum degree of curvature, speed, and superelevation. Sharp curves at the end of the ramps and sudden changes from a straight alignment to sharp curves should be avoided. Ramp curves tend to be more critical than highway curves. Substantial downgrades leading to tight ramp curves may contribute to traffic accidents. Steeper grade (positive or negative) can be associated with increased accident rates. As the vertical grade of a highway increases, the accident involvement rate also increases (depending on the length of the grade). More conservative grade allowances of 3 or 4% for ramp down grades compared to the 8% found in the AASHTO "green book" has been suggested.

Truck loss of control on ramps is predominantly due to rollover and jackknifing. In designing horizontal curves to accommodate trucks, it is important to check for both rollover and skidding potential to determine which controls the design. Abrupt changes in compound curves lead to truck accidents. Jackknife accidents occur mainly at sites with low pavement friction during wet condition. Truck rollover accidents occur on ramps where truck speed is higher than ramp design speed. Design of ramps must also provide for adequate width to accommodate offtracking during low-speed and high-speed. Lowered friction levels on high-speed ramps can contribute to truck accidents. Therefore, it recommends the resurfacing of ramps with high-friction overlays. Poor transitions to superelevation may contribute to truck accidents, such as rollovers and jackknifing. Regardless of the urban/rural location of the highway, trucks have more accidents on the off-ramps than on the on-ramps.

A good portion of the accidents associated with ramps occurs at the entrance or exit of ramps. While additional lanes improve the safety at entrance terminals, studies indicated no safety benefits as a result of auxiliary lanes at off-ramps compared to direct off-ramp designs. Findings from literature review indicated that off-ramps with speed-change lanes have a lower accident rate than those ramps without speed-change lanes. Deceleration lanes are generally safer than acceleration lanes, regardless of the length of the speed change lanes and the percentage of diverging and merging traffic. Truck accident studies are even more adamant about speed change lane, claiming that the current AASHTO requirements for deceleration lane lengths are not sufficient for trucks.

The most common accidents in the entrance terminal is the rear-end collisions. These accidents can be reduced by changing the merging maneuver at the entrance terminal to a less complex lane-changing maneuver through the use of a parallel acceleration lane. Other studies found that rear-end accidents on urban off-ramps of four configurations (diamond, parclo loop, free-flow loop, and outer connection ramps) were generally related to the operation of the cross-road ramp terminal, rather than to the geometric design of the ramp itself.

# Introduction

## 1.1 General

The ramp is an element of an interchange system that is designed at the junction of two or more highways for the purpose of reducing or eliminating traffic conflicts, to improve safety, and increase traffic capacity. Crossing conflicts are eliminated by grade separations.

Ramp design is influenced by many factors including: the speed, volume, and composition of traffic to be served, the standards and arrangement of the local street system including traffic control devices, topography, right of way controls, local planning, proximity of adjacent interchanges, community impact, consistency in the pattern of interchange ramps along a freeway and cost. Consistency in the placement of interchanges is sometimes achieved at the cost of rearranging portions of the local street system. Figure 1 through 4 in Appendix A, illustrate typical local street interchanges, and typical freeway-to-freeway interchanges respectively.

## 1.2 Objective

This research project evaluates the effect of ramp configuration, type, and geometry on accidents. The analysis is aimed at investigating the accident rates and determining whether systematic differences exist between on-ramps and off-ramps, rural ramps and urban ramps and between ramps of different configurations. Since the different types of ramps are largely defined in terms of their geometric configuration, the analysis will begin to provide clues about the safety of certain geometric features.

First, a comprehensive literature review on this topic is conducted and discussed. Second, an overview of the accident experience of the ramps on the California State highways is given. Third, a statistical analysis of the accident rates on the ramps is presented. In all, accident data for 13,325 ramps are used with the main objective of updating Lundy's study that was done for the Division of Highways (or the current California Department of Transportation).

### 1.3 Methodology

Three years of accident data on the existing ramps (13,325 of them) on the California State highways was retrieved. The ramp accident data and traffic volume data was obtained from the California Department of Transportation (Caltrans) Traffic Accident Surveillance and Analysis System (TASAS). The data consists of accident frequency, and rate on different ramp configurations, ramp traffic volume, ramp location, and information on urban/rural settings. The accident types included: Total, Fatal, Fatal + Injury, accidents on Wet road pavement, accident in Dark lighting condition, number of vehicles involved in accidents. Accident location for the purpose of this report is described in figure 10 in section 3.2 of this report. Any accident in areas 1 through 4 described in figure 10 section 3.2 is considered a ramp accident.

The TASAS database does not contain detailed information on ramp geometry, but rather just the code of the ramp configuration that best describes a given ramp. For this reason, most of the analysis concentrates on characterizing the systematic effects of ramp configuration on accident rates. The ramp configuration and corresponding diagram describing these configurations are provided in section 3.2

Several analyses were run on summary accident data from the years 1992 through 1994. The results from these analyses are organized as in the following: First, descriptive statistics for every ramp configuration are derived using the data retrieved from the TASAS database. The statistics include a series of tabulated detail data on every ramp configuration that included ramp frequency distribution, mean accident rate, ramp type (on/off), and geographic area (rural and urban setting[1]). These tables are provided in Appendix B of this report

Second, a series of ANOVA models were run to look at the systematic differences in accident rates between ramps of different design. These models can tell that a certain factor is influential. The significant differences with respect to ramp type (on/off), and urban vs. rural differences led to the decision to stratify the data based on whether a ramp was in a rural or urban region, as well as whether it was an on-ramp or an off-ramp. Then ramp safety performances were compared with respect to a number of different types of accident rates (fatal, fatal + injury, total, wet, and dark). The accident rates were analyzed using analysis of variance (ANOVA) and analysis of covariance (ANCOVA) methods.

Since previous studies indicated ramp traffic volume as a key variable affecting ramp accidents, a series of ANCOVA models were run, again with stratified data which included the measured ramp traffic volume as a covariate and ramp geographical location as a predictor variable. All of the ANOVA and ANCOVA analyses are followed by pairwise comparisons where differences in mean accident rates between each pair of ramp configurations can be estimated using a Tukey-Kramer adjustment method. Most of the analyses concentrated on characterizing the systematic effects of ramp configurations.

Accident rates are typically expressed in terms of the number of accidents per vehicle mile of travel to express the relative safety of road sections. Accident rate for a ramp is defined by Breuning et. al. (1960) as the number of accidents per million vehicles (MV) entering or leaving a ramp. This definition is shown to be a practical basis for measuring accident experience on ramps. The *average*

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[1] The terms *rural* and *urban* (as viewed in Table 2) are not to be confused with *inside* and *outside cities*, since they are not necessarily the same. Urban areas are defined and approved by the Federal Highway Administration (FHWA) on the general basis of urban characteristics and do not necessarily coincide with city boundaries; all areas not classified as urban are considered rural.
Source: 1995 accident data on California State highways, California Department of Transportation

accident rate for a particular ramp configuration is the average across that given ramp configuration, rather than weighted according to their traffic volume. The assumption here is that accident rates on ramps are related to the number of vehicles entering or leaving the ramp without regard to the distance traveled on ramps.

Although fatal accident data is included in the analysis, it is difficult to draw sound conclusions based on results on this type of accident. The frequency of fatal accident occurrence on ramps of any type is small, so that the mean accident rates are highly variable. In other words, a few serious accidents can badly skew the statistics. Therefore, the focus of the interpretation of the results will be on, fatal + injury and total accident rates which are numerically more stable.

The accuracy of the accident data is subject to reporting levels of the law enforcement agencies supplying the collision reports. The department estimates that it receives collision reports for approximately 100 percent of all fatal accidents, 90 percent of all injury accidents, and 40 percent of all property-damage-Only (PDO) accidents occurring on state highways[2]. Therefore, PDO is not the best source of accurate accident statistics. Fatal + Injury, and Total accidents are better measures for accident analysis.

In constructing the database on the geometric configuration of ramps, ramp configurations that were particularly rare were excluded, unless they had unusually high accident rates associated with them.

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[2] 1995 accident data on California State highways. California Department of Transportation

## Literature Review

### 2.1 General

Ramp safety elements include acceleration lanes, deceleration lanes, weave section, alignment and ramp terminals. The following literature review discusses the relationship between ramp configuration and geometry, and traffic accidents. Previously published research on this topic was reviewed and used in conjunction with this report's analysis to arrive at findings and conclusions. A literature review discussion is provided in this section.

Among the literature reviewed, most citations pertain specifically to the geometry of ramps, some discuss issues related to interchange, and other related to highway geometry in general. Certain geometric characteristics may be determined to affect accidents in the same way whether they belong to a regular highway segment or to a ramp interchange, such as horizontal curvature. Many of the geometric characteristics are unique to ramps. The literature review identified whether the featured study is referring to highway geometry or ramp/interchange geometry. While there are many ramp configurations defined in the American Association of State Highway and Transportation Officials (AASHTO), previous safety research basically has been focused on a limited number of ramp configurations.

To find information from ongoing studies on this topic, letters were sent to all the state DOTs inquiring whether the state agencies had conducted research on this topic. Four state agencies replied--all indicating that they have not conducted any recent research on this issue. However, as the draft of this report was ready for review, a new report on this topic was published by Federal Highway Administration (Bauer and Harwood, 1997). Special emphasis will be placed on the most recent published report by Bauer and Harwood for its innovative statistical modeling approach, and on an older report published by Lundy (1965) of the California Division of Highways (currently California Department of Transportation). This report was initiated as an update of Lundy's study.

## 2.2 Literature Review Discussion

Maneuvering on ramps requires a vehicle to change speed and direction to varying degrees based upon the particulars of the ramp and the interchange design. The difficulty in maneuvering a vehicle along a ramp at speeds higher than what the geometric characteristics of the ramp are suited for is a main cause of truck accidents on ramps, according to Garber et al. (1992). Keller (1993), noted that interchanges present the motorist with a complex set of decisions that require quick evaluation and action. Oppenlander et. al (1970) noted that any discontinuity or change in driver, vehicle, roadway, traffic, and environmental conditions in the area of the interchange imposes greater demand on the highway drivers. These discontinuities are: necessity for driver decisions; changing proportion of vehicle types with different operating characteristics; roadway with varying geometric arrangements; changing concentrations of vehicles with resultant speed differentials; and varying environmental conditions within the interchange ( ice on structural pavement). Cirillo (1968) quantified accidents rates by proximity to interchange to examine the impact of the discontinuities on interchanges. Cirillo tabulated the increases in accident rates as the distance to the interchange decreased on the exit and entrance sides of interchanges in both rural and urban locations.

Crashes not associated with ramp and interchange design can still happen as a result of vehicular or human factors. Non-geometric characteristics, from fixed road-side objects to interchange lighting, may be a factor associated with an increases in accidents and/or their severity. In fact, ramp geometry is found to be a much weaker variable than main line traffic volume and ramp traffic volume in accident prediction models developed by Bauer and Harwood (1997), and Cirillo (1968).

Several studies throughout the past 30 years have addressed the issue of whether the design of the ramp has an effect on the safety of the interchange. In the mid-1960s, Lundy (1965) produced a report for the California Department of Transportation (then the Division of Highways) addressing this very issue. The objective of Lundy's study was to determine which geometric features play important roles in ramp safety. The study involved 722 freeway ramps. Lundy found a correlation between accident rates and ramp configurations, ramp grade, fixed objects, speed change lane (SCL) lengths, possible safe entrance speeds at on-ramp noses, and off-ramp radius. The study was not able to find a correlation between ramp accident rates and on-ramp curvature, ramp lighting, ramp traffic volume, and magnitude of the ramp central angle. Other findings of Lundy's study will be discussed in the following sections.

A study of *freeway* accidents in the southern California region (Golob and Recker 1986) found that approximately 17% of accidents they reviewed occurred on ramps (including connectors). This number is strikingly similar to the 18% value Lundy found in his analysis 20 years earlier, but slightly higher than the three-year (1992-1994) average value of 15% determined in this study for urban and rural settings combined. Note however, that while combined urban-rural accidents on California state highway ramps amounts to 15% of highway accidents, the rural ramp accidents is only 2.82% of accidents on rural highways. The corresponding percent for urban ramps is 18.41%. Higher travel on urban roads in addition to other factors is responsible for this difference. Investigating strictly the truck accidents, Bowman and Hummer (1989) in an FHWA study found that up to 23.1% of accidents occurring on urban freeways happen at interchanges, with 5.7% of the accidents occurring on ramp itself, and the remainder on merging and exit areas.

As to the potential cause of some of the vehicle crashes at ramps and interchanges, several studies have reviewed ramp geometry attributes that may affect the safe operation of an interchange. Cirillo (1967) identifies sub-standard design practices of urban interchanges as affecting the accident rate. Kihlberg and Tharp (1968) link highway geometry particularly gradients, curves, and structures to accident rates. Cirillo (1969) and Morgenstein et. al. (1978), find geometric design features of ramps to be a smaller effect than traffic volume as a predictor of accident occurrence. The general consensus of many studies is that traffic volume is the strongest predictor of accidents on ramps. When interchanges operate at or near capacity, the likelihood of increased speed differential between upstream freeway sections and interchange sections is high. Cirillo (1969) found no definitive correlation between capacity and safety other than the direct relationship of volume increase and accident frequency. Other factors identified by Cirillo associated with accident occurrence were the interchange spacing, where accident rates were shown to increase as interchange spacing decreased in urban areas as opposed to rural areas.

As many older interchanges reach the end of their design life, and are redesigned and/or rehabilitated, the consideration of safety improvements is crucial. The study by Harwood, and Graham (1983), documenting the evaluation of the effects of thirty seven interchange rehabilitation projects. In the following sections, findings of different literature on geometric and non-geometric variables affecting accident occurrence on ramps are discussed.

### 2.2.1 Ramp configuration

The question of whether a particular ramp configuration is operationally safer is addressed by many studies reviewed in this report, as well as the analyses performed in this study. Lundy (1965) found a correlation between accident rates and ramp configuration. According to his report, left side ramps, and scissors ramps have higher accident rates than others ramp configurations and their use is discouraged. Diamond ramps had the lowest rate, but these rates did not account for crossroad/ramp intersection accidents. Lundy did not find any significant design differences between accident-free and accident-prone ramps.

Section 3 and 4 of the current report provides a comprehensive pairwise comparison of ramps stratified by on/off and urban/rural settings.

Twomey's et al. (1992) report was primarily a literature review investigating interchange safety. The study concluded that cloverleaf, scissors, and left-side ramps should be avoided where possible. Collector distributor roads should be considered in high volume interchange design and especially designs where loop and cloverleaf ramps are used. Similarly, Leisch (1993) recommends that full-cloverleaf interchanges not be considered for an interchange. Hall (1993) studying the human factor impact suggests left-type ramps are prone to accidents. Hence, the study recommends a curvilinear design for the exit, rather than straight, to make drivers adjust their speed gradually before navigating the loop. Collector-distributor roads is a safety feature suggested by Twomey et al. (1993) and Hall (1993) to improve the safety and operation of cloverleaf interchanges. According to Hall (1993) study most of the accident problem with interchanges is related to the design of the inner loop ramps and outer connector ramps.

As a whole, research findings indicated that it is better to design ramps with flat horizontal curves (except in rural areas) avoiding the maximum degree of curvature, speed, and superelevation. Sharp curves at the end of the ramps and sudden changes from a straight alignment to sharp curves should be avoided.

Cirillo et. al. (1969) developed various mathematical models relating accidents to the a number of variables including geometric features. These models were developed for both ramp elements and six different ramp configurations. Of these variables, mainline traffic volume was found to be the most important predictor and accounted for as high as 84% of total variance in accidents while accident variance due to geometric factors accounted for 5 to 20 %. As noted by Cirillo, these results do not suggest that geometric variables are unimportant, rather that geometric factors are generally improved to a point where the variance in geometric which do occur have little influence on accidents. Excluding other variables at the cost of loosing minor accuracy, Cirillo et. al. (1969), developed a plot comparing the relative safety of the various interchange types.

The most recent study by Bauer and Harwood (1997), however, stated that the regression models developed by Cirillo et al. (1969) did not make use of statistical models appropriate for accident analysis. The statistical models developed by Bauer and Harwood also found mainline and ramp traffic volume to be the most important predictors of accidents on ramps.

**2.2.2 Ramp type (On-ramps vs. Off-ramps)**

Lundy observed that accident rates of on-ramps were consistently lower than off-ramps accident rates (0.59 Acc/MV vs. 0.95 Acc/MV). This conclusion has also been confirmed by several other studies, including Cirillo (1967), and accident rate comparisons developed for individual ramp configurations in this report. Golob and Recker (1986) indicated that 61% of the accidents occurred on off-ramps. A study on truck accidents (Vallette et al. 1981) reveals that regardless of the urban/rural location of the highway, trucks have more accidents on the off-ramps than on the on-ramps. A truck accident study (Garber et al. 1992), analyzed the severity of the accidents and identifies most fatal and injury type accidents occurring on off-ramps, but on-ramps tended to be linked with the less severe PDO accidents. In short, these studies seem to suggest that not only do most ramp accidents occur on the off-ramps, but also the more serious accidents.

Some controversy however exists in regard to relative safety of on-ramps and off-ramps. For example, in a study of urban freeways in Texas by Mullins et al. (1961), on-ramps have higher accidents than off-ramps. This controversy is clarified in part by Cirillo (1968), where she provides data attributing the controversial results to the urban/rural differences influencing the accident rates. In order to further clarify this controversy, accident experience on 13, 325 ramps stratified into four data sets based on ramp type (On/Off) and area type (urban/rural) are presented in section 3 and 4 of this report.

### 2.2.3 Ramp Deceleration/Acceleration Lanes

Studies by Lundy (1965), Fisher (1961), Golob and Recker (1986) suggest that a good portion of the accidents associated with ramps occur at the entrance or exit of ramps. Mullins et al. (1961) found that 23% of all through-lane accidents occur near entrance terminals. The entrance terminal accidents amount to 52% of the on-ramp accidents according to Lundy (1965). Bauer and Harwood (1997) considered the following factors as potential variables affecting accident occurrence on acceleration/deceleration lanes:

- Ramp AADT
- Mainline freeway AADT,
- Average lane width,
- Right shoulder width,
- Acceleration/Deceleration lane length
- Ramp area type (urban/rural), and
- Ramp configuration.

Not all variables however, were found to be statistically significant variables affecting accidents on speed change lanes (SCL). The key variables were ramp AADT, main line AADT, and SCL length. Higher traffic volumes were associated with higher accidents. The effect of acceleration lane length was more complicated since on one hand longer lengths provide safer traffic maneuvering and on the other hand corresponding increased length may provide longer exposure and more accidents.

In studies by Cirillo (1967, 1968, 1970), it was shown that accident rates decrease as length of weaving area, or acceleration and deceleration lane increases. The statistical model developed by Cirillo provided a relationship between the length of weaving and acceleration/deceleration lanes and traffic volume levels and percentage of merging and diverging traffic. Increases in traffic volume was associated with an increase in accident rates. The effect of acceleration lane length on accident rate was significant when merging traffic percentage exceeded 6 percent of the main line traffic volume. As the percentage of merging traffic increases beyond this volume, the additional length of acceleration lane provides a significant reduction in accidents. The effect was not as great for deceleration lanes compared to acceleration lanes.

Human factors research (Hall 1993) associates higher accident rates with the inadequate length of acceleration and deceleration lanes, suggesting that the use of collector/distributor roads enhance safety. A study on two-lane loop ramps (Walker 1993) alludes many times to the fact that a speed transition zone design that accommodates enough distance for vehicles to change their speeds is important in the safety of the ramp. According to Lundy (1965), on-ramps with acceleration lane lengths greater than 800 feet had below average accident rates. The relationship between accident rate and acceleration lane length is demonstrated in figure 5.

Truck accident studies are even more adamant about this subject. Ervin et al. (1986) basically claims that the AASHTO "green book"[3] requirements for deceleration lane lengths are not sufficient for trucks. Longer acceleration and deceleration lanes are also a recommendation by Jackson (1985) to improve truck safety on these highway segments, who also notes that a truck's acceleration is in general much slower than that of other vehicles on the roadway.

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[3] A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, D.C.

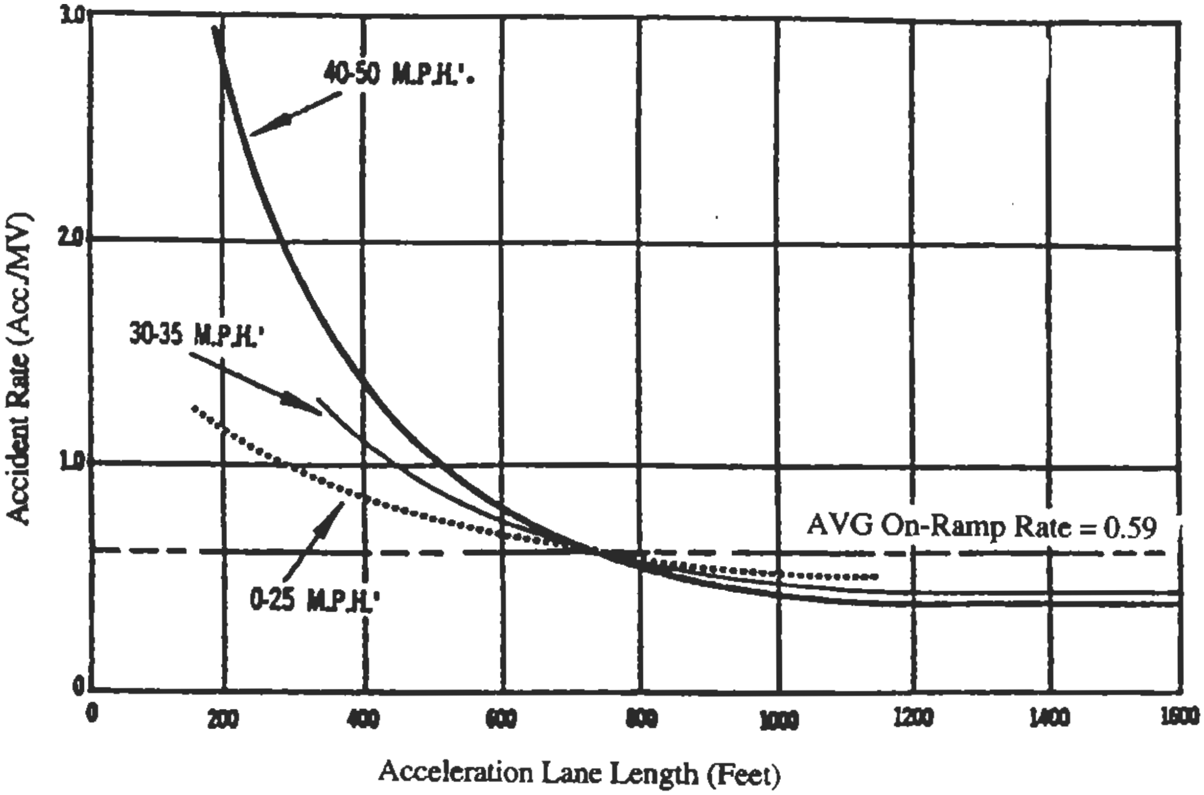



**Figure 5 Accident Rate and Acceleration Lane Length (On-Ramps)**

Source: "The Effect of Ramp Type and Geometry on Accidents" by R. A. Lundy, Highway Research Board Record 163, 1967, p.113

The most common accident in the entrance terminal is the rear-end collision. These accidents can be reduced by changing the merging maneuver at the entrance terminal to a less complex lane-changing maneuver through the use of a parallel acceleration lane.

Lundy (1965) found that about 44 percent of the off-ramp accidents occurred in the diverging area. Fifty percent of the off-ramp accidents are single vehicle accidents. The off-ramps with the long (900 feet +) deceleration lane lengths had lower rates than the ramps with shorter deceleration lengths. While additional lanes improves the safety at entrance terminals, Mullins et al. (1961) indicated no safety benefits as a result of auxiliary lanes at off-ramps compared to direct off-ramp designs. The study however, found off-ramps with speed-change lanes have a lower accident rate than those ramps without speed-change lanes.

Accident rates increase for increasing volume of diverging traffic regardless of the length of deceleration lane. A study by Cirillo (1969) shows very small benefits resulting from increasing the length deceleration lane when the diverging traffic is less than 6% of the main line traffic volume. Short deceleration lanes preceding tight-radius exits are found to contribute to truck accidents, according to Firestine et al. (1989).

Finally, Cirillo (1970) concludes that deceleration lane are generally safer than acceleration lanes, regardless of the length of the speed change lanes and the percentage of diverging and merging traffic.

### 2.2.4 Ramp grade.

Generally, the studies attempting to link vertical grades of ramps with accident rates suggest that a steeper grade (positive or negative) can be associated with increased accident rates. Miaou et al. (1993-1, 1993-2), used a Poisson regression model to analyze truck accident data on highways, found that as the vertical grade of a highway increases, the accident-involvement rate also increases (depending on the length of the grade).

Lundy found ramps associated with an overcrossing had slightly lower rates than those of undercrossings, especially the off-ramps. This may be attributed to better speed reduction on upgrade vs. down grade. Based on Lundy's report, trumpet ramps, cloverleaf ramps without collector-distributor roads and left side ramps have consistently higher accident rates than their ramps regardless of grade situations. Ervin et al. (1986), suggests more conservative grade allowances of 3 or 4% for ramp down grades compared to the 8% found in the AASHTO "green book". This would support the Firestine et al. (1989) conclusion that substantial downgrades leading to tight ramp curves contribute to traffic accidents.

### 2.2.5 Ramp Curvature/Radius

Ramp curves tend to be more critical than highway curves. In terms of the curvature of the ramps, Lundy (1965) makes only general observations stating a higher accident rate for ramps that are designated as "curved" than on those which were considered "straight." The straight ramps according to Lundy have lower accident rates than the curved classifications. However, he noted that the short radius, large central angle curved off-ramps, seemed to have lower rates than the ramps with medium range radii and deltas. He postulated that this was perhaps a case where the tight turns appear as obvious to the drivers and they take the necessary precautions; whereas, the medium range curves do not appear dangerous and the drivers do not compensate. Fisher (1961) studying the on-ramps without acceleration lanes, indicated that increasing ramp radius provided little benefits in term of safety and that the important factor was whether or not traffic slows down or stops before entering the freeway.

Other studies, though, analyze the curvature-accident relationship in more detail. Garber et. at. (1992), for instance, developed a linear model showing that an increase in the radius of a ramp curve produces a lower involvement of truck accidents. Likewise, Heath and Kynaston (1981) noted that many tank truck overturns occured on ramps where the sharpness of the curve increased at the end of the ramp. The change in the curve-sharpness during the course of the ramp is pointed out as a feature to be avoided by Twomey et al. (1992). Yates (1970), investigated the accident rates for loop and outer connection ramps in cloverleaf interchanges. Twomey (1992) summarized the findings of the study by Yates as follows:

- except for loop ramps in rural areas, all right-hand side and outer-connection ramps showed an increases in accident rates with increasing maximum curvature;
- outer-connection ramps in urban areas tend to show increasing accident rates with increasing average daily traffic (ADT);

- straight outer-connections have lower accident rates than curved connections in urban and rural areas for all ADTs, except 0 to 499 in urban areas;
- rural loops with low curvature have higher accident rates than rural loops with high curvature, while the reverse is true for urban loops.

Table 1 and table 2 provide accident rates on outer connections and loops by curvature and ADT.

**Table 1 Accident Rates on outer connections by curvature and ADT.**

| ADT | Urban Straight Curvature< 1 deg | Urban Curved Curvature>1 deg | Rural Straight Curvature< 1 deg | Rural Curved Curvature>1 deg |
|---|---|---|---|---|
| 0-499 | 0.74 | 0.64 | | |
| 500-1000 | 0.34 | 0.72 | 0.13 | 0.49 |
| 1001-1500 | 0.64 | 0.84 | 0.00 | 0.61 |
| 1501-2000 | 0.15 | 0.93 | 0.00* | 0.20 |
| >2000 | 0.49 | 0.82 | 0.00* | 0.72 |
| all volumes | 0.44 | 0.81 | 0.05 | 0.56 |

Source Cirillo (1992)
* Less than 10 units

**Table 2 Accident Rates on loops by curvature and ADT.**

| ADT | Urban Straight Curvature< 1 deg | Urban Curved Curvature>1 deg | Rural Straight Curvature< 1 deg | Rural Curved Curvature>1 deg |
|---|---|---|---|---|
| 0-499 | 0.00* | 0.84 | 1.00 | 0.26 |
| 500-1000 | 0.00* | 0.96 | 0.81 | 0.37 |
| 1001-1500 | 1.32* | 0.69 | 0.00* | 0.00 |
| 1501-2000 | 0.00 | 0.72 | 0.00* | 0.00 |
| >2000 | 0.14 | 1.00 | 0.00* | 0.00 |
| all volumes | 0.20 | 0.94 | 0.63 | 0.25 |

Source Cirillo (1992)
* Less than 10 units

Sharp curves at the end of the ramps and sudden change from straight alignment to sharp curves should be avoided. A decrease in sharp turning radii is also recommended by the truck accident study by Jackson (1985). Twomey (1992), found that in designing horizontal curves to accommodate trucks, it is important to check for both rollover and skidding potential to determine which controls the design. Firestine et al. (1989) found that abrupt changes in compound curves lead to truck accidents.

Recent studies on ramp geometric design involved truck accidents. The general findings from the NCHRP Synthesis 241 (1997) study indicated that: 1) truck loss of control on ramps are predominantly due to rollover and jackknifing; 2) jackknife accidents occur mainly at sites with low pavement friction during wet condition; 3) truck rollover accidents occurs on ramps where truck speed is higher than ramp design speed. Design of ramps must also provide for adequate width to accommodate offtracking during low-speed and high-speed use as described in detail in the NCHRP Synthesis 241 (1997). Ramps are usually designed with adequate superelevation to reduce rollover during high-speed, but with consideration to sliding during slow speed or stopping under slippery road condition. Short radii curves such as those used on ramps may cause truck roll over. The above report provides the relationship between swept path width and ramp radius for low-speed offtracking analysis.

The selection of superelevation is part of the design process for horizontal curves based on AASHTO (1990) policy. The policy provides for establishing relationship among curvature, radius, superelevation, design speed, and length of superelevation transition and tabulated the maximum friction factor and minimum radii for various curves.

### 2.2.6 Ramp superelevation

Firestine et al. (1989) concludes that poor transitions to superelevation contribute to truck accidents, such as rollovers and jackknifing. Improved margin of safety in design, with special consideration of side friction factors, is suggested by this study. Since superevelation is, in most cases, left to the discretion of the highway design engineer, Keller (1993) suggests creating a larger margin of safety by going beyond the standard criteria when designing ramps to better accommodate today's truck traffic. This view is also supported by Zador et al. (1985), who found that inadequate superelevation in the design of roadway curves, particularly on curves with grades, affects the number of fatal rollover incidents. The study suggests that care in the design must be taken to consider the behavior of some drivers taking a curve at a sharper angle than the actual curvature of the curve.

### 2.2.7 Non-geometric characteristics of ramps

Studies in the past have shown that accidents on ramps are not related only to the design geometry, but to other physical characteristics of the ramps. For example, Lundy (1965) stated that thirty two percent of the ramps investigated in his report were accident free. No design differences were noted between the accident-free ramps and ramps with accidents. Bauer and Harwood (1997) indicate that the accident free ramps range between 50 to 80% depending on configuration, type, and area type setting. A summary of the conclusions from various studies on accidents and non-geometric characteristics of highway and ramps is presented in this section.

### 2.2.8 Pavement surface conditions

Pavement design is also a factor that can be considered in the analysis of traffic accidents. Firestine et al. (1989) in an interchange/ramp accident study points out that lowered friction levels on high-speed ramps can contribute to truck accidents. Therefore, it recommends the resurfacing of ramps with high-friction overlays. The study does not give specific information on the overlays.

### 2..2.9 Ramp lighting

Lundy (1965) suggests that lighting is beneficial. He found that ramp areas, that have illumination at night, have a lower nighttime accident rate than other segments of freeways (generally non illuminated). It was not possible to separate the positive effects that lighting alone had on these lower accident rates.

Examining a slightly different take on interchange illumination is a study by Griffith (1994). The study compares accidents occurring on highway segments with interchange lighting only versus accidents occurring on continuously-lit segments (i.e., lighting beyond the interchange area). The study finds that the night/day accident ratio is 12% higher on segments with interchange lighting only. Therefore, the report concludes, illuminating urban freeway segments between interchanges could theoretically reduce night accidents.

**2.2.10 Traffic Volume Effect**

There is strong consensus among studies attributing both the ramp traffic volume and the through-lane traffic volume to the accident occurrence on ramps. Cirillo et. al. (1969) developed various mathematical models relating accident to the a number of variables including geometric features. Of these variables, mainline ADT was found to be the most important predictor and accounted for as high as 84% of total variance on average in accidents while accident variance due to geometric factors accounted for 5 to 20 %. In a recent study using more appropriate mathematical models of accident analysis, Bauer and Harwood (1997) concluded that among all variables including geometric variables, ramp volume and main line volume were the strongest predictors of accidents on ramps. Oppenlander (1970) concluded that it is safer to merge or diverge a given volume of vehicles from a freeway at several minor-flow ramps than at a single high-volume on-and-off ramps.

Lundy (1965) reported a decrease in ramp accident rates with an increase in daily traffic volume on the sample of ramps he studied. However, he did not attribute the decrease to the volume and hypothesized that high volume ramps were associated with better design standards.

### 2.2.11 Signing, striping, and signal visibility

Advisories and guidance to drivers approaching and navigating along a ramp is achieved through signs and striping. Walker (1993) noted that accidents were occurring at a particular ramp that lacked an advisory speed sign. Ervin et al. (1986) recommends proper placement of warning signs in advance of challenging curves and curves designed with a downgrade.

FitzPatrick et al. (1992) points out that many ramps with tight curves have posted speed signs that are inappropriate for trucks, not considering the dynamic differences between passenger-cars and trucks. Furthermore, ramps with the tight-flat-tight curve sequences should have special signing according to Ervin et al. (1986). No examples of the special signing are given, but the study suggests that the current signing practices warrant a careful evaluation.

Innovative signs are another feature for driver-warning that may help improve the safety of an interchange. For example, Fitz Patrick et al. (1992) suggest the implementation of active signs, which can alert drivers of their speed as they approach or negotiate a ramp. Also, Bonneson and Messer (1989) suggest marking and striping improvements to improve driver guidance for single-point urban interchanges. Of course, not only are signs important, but so is signal visibility, which is noted by Bonneson and Messer (1989).

### 2.2.12 Type of Collisions

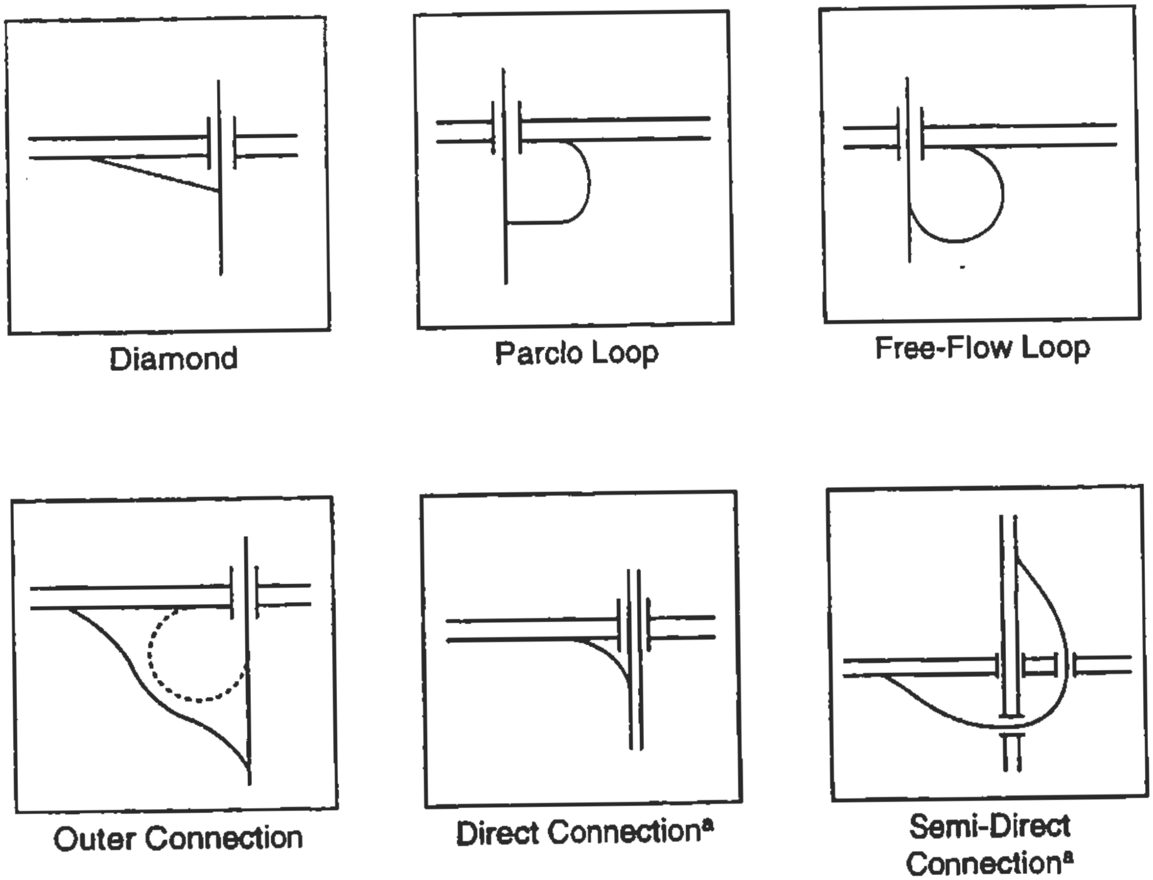
Mullins et al. (1961) providing the accident breakdown on ramps reported that rear-end accidents accounted for 82% of all accidents. Lundy (1965) found that 42% of off-ramp accidents and 22% of on-ramp accidents involved fixed-objects, with guardrails and signs being the most frequent fixed objects involved in accidents. Lundy groups freeway fixed objects along ramps into four types: guardrails, light standards, signs, and piers, abutments, and bridge rails. Major improvement projects initiated by California Department of Transportation in the years following the study cleared fixed objects that contributed to accidents on ramps and other road sections.

Hall and Mulinazzi (1978) include the factor of roadside objects in their analysis of highway safety. This interesting study calculated hazard indexes for 8000 combinations of speed, objects, distance, and geometric parameters for various categories of roadway volume. The research found that each type of object parameter used in the study (construction barrier, sign support, fence, curb or wall, building, guardrail, culvert or ditch, embankment, bridge, poles, light support, tree or shrubbery) appears in the top 150 hazard indices. The study also notes that objects more than 3 meters from the edge of the roadway do not appear in the top 150 indices, while most are within 1.5 meter from the road.

Some studies also focused on the effect of curbs on accidents. Two studies in particular, Ervin et al. (1986) and Firestine et al. (1989), point out that curbs on the outside of ramp curves (or, locations that have a high probability of truck rollover) is undesirable.

**2.2.13 Statistical Modeling of Ramp Accidents**

Accident prediction models developed in the past (Cirillo et. al 1969) modeled the dependent variable (Accident rate) as a function of highway -related parameters using simple multiple-linear regression. The results from these models have not been promising both in terms of the models ability to explain a proportion of the variability in accident rates and the role of geometric design variables as predictors of accidents in the models. The most recent effort in this area by Bauer and Harwood (1997) used an innovative approach to modeling accident analysis. These statistical models have greater reliability than previous work and they explained between 10 percent and 42 percent of the variability in the accident data. Developed statistical models establish relationship between traffic accidents, geometric design elements, and traffic volumes for interchange ramps and speed change lanes. Poisson and negative binomial regression models provide better representation of accident occurrences that are sporadic, random, and discrete events. The models developed were for five ramp configurations: diamond, parclo loop, free-flow loop, outer connection, direct or semi-direct connection shown below.




Source: K.M. Bauer and D.W. Harwood (1997)

Two dependent variables most extensively used in the modeling effort were: Total multiple-vehicle accidents, and fatal plus injury multiple-vehicle accidents. Because of the limitation in availability of sufficient ramp sample sizes, statistical modeling of accidents was performed for the following combination of elements:

- Ramp proper (off- and on-ramp combined and off-ramp only)

- Entire ramp (off- and on-ramp combined and off-ramp only)
- Acceleration lanes.
- Deceleration lanes.
- Entire ramps plus adjacent speed-change lanes.
- Selected types of urban off-ramps: diamond, parclo loops, free-flow loops and outer connection ramps.

Accident prediction models for elements of ramps were initially done with the intention of combining the predicted accidents from separate models to determine the safety performance of ramps as a whole. The separate models however, by themselves, did not provide an adequate fit to the data. The best models explaining the safety performance of ramps however, were developed by combining the ramps and their adjacent speed change lane into a single model. The developed models were revised to include variables that were significant at the 20-percent significance level or better. The independent variables included in this model were:

- Ramp AADT.
- Mainline freeway AADT.
- Area type (rural/urban).
- Ramp type (off/on).
- Ramp configuration ( not statistically significant for fatal + Injury Model).
- Length of SCL .
- Ramp length.

The predictive accident occurrence model for 3-year *total* multiple vehicle accident frequency for ramp, including the adjacent SCL, developed by Bauer and Harwood was:

$$Y= [e^{-7.27}(X1)^{0.78}][e^{0.13X2}][e^{0.45X3}][e^{0.78X4}][e^{-0.02X5}]$$
$$[e^{0.69X6}][e^{-0.37X7}][e^{0.37X8}][e^{-2.59X9}][e^{1.62X10}]$$

where:

Y = expected number of total multiple-vehicle accidents in a 3-year period for entire ramp plus adjacent SCL
X1 = AADT of the ramp segment (veh/day)
X2 = mainline freeway AADT for the direction of travel in which the ramp is located (veh/day)
X3 = 1 if the ramp is a diamond ramp; 0 otherwise
X4 = 1 if the ramp is a parclo loop ramp; 0 otherwise
X5 = 1 if the ramp is a free-flow loop ramp; 0 otherwise
X6 = 1 if the ramp is a outer connection ramp; 0 otherwise
X7 = 1 if the area type is rural; 0 otherwise
X8 = 1 if the ramp is an off-ramp; 0 otherwise
X9 = Speed-change lane length (ml)
X10 = Ramp length (ml)

In the above model, the relative effect of each variable (all other variables being constant) can be calculated by simply taking the exponent of the corresponding coefficient. For example, the relative effect of the difference in accident frequency between on-ramps and off-ramps is: $e^{0.37} = 1.44$. In other word, off-ramps have more *total* multiple vehicle accidents than on-ramps by a factor of 1.44.

The expected 3-year fatal and injury multiple vehicle accident frequency for ramp, including the adjacent SCL, was estimated using the following model:

$$Y = [e^{-9.67}(X1)^{0.78}][e^{0.23X2}][e^{2.85X3}][e^{-4.42X4}][e^{0.48X5}][e^{-0.26X6}]$$

where:

Y = expected number of fatal and injury multiple-vehicle accidents in a 3-year period for entire ramp plus adjacent SCL.
X1 = AADT of the ramp segment (veh/day)
X2 = mainline freeway AADT for the direction of travel in which the ramp is located (veh/day)
X3 = ramp length (ml)
X4 = Speed-change lane length (ml)
X5 = 1 if the ramp is an off-ramp; 0 otherwise
X6 = 1 if the area type is rural; 0 otherwise

Since the level of significance for the above models are set at 20 percent, caution should be exercised due to increased risk that some variables may appear to be statistically significant due to chance alone. Statistical significance is normally evaluated at 5 to 10 percent significant level.

Bauer and Harwood (1997) also modeled the expected values of accident frequency for rural off-ramps with various ramp lengths, SCL length, ramp configurations, and various levels of ramp and mainline freeway AADT. Similar information is provided for rural and urban on-ramps.

Following is a summary of the findings and conclusions derived by Bauer and Harwood (1997): Accident frequencies on interchange ramps and speed-change lanes are so low at most locations that they are very difficult to model. Between 50 percent and 80 percent of the ramps in the study experienced no multiple-vehicle accidents or only one multiple-vehicle accident in the 3-year study period; The ramp AADT was the strongest predictor of multiple-vehicle accident frequency; the other variables, while they were generally statistically significant, had much less predictive ability. This is consistent with the same conclusion drawn in virtually every study of ramp accidents. By contrast, geometric design features of ramps were found to have much less ability to predict ramp accidents; The independent variables, whose effects on accident frequency were most often found to be statistically significant, were: Ramp AADT, Mainline freeway AADT, Area type (rural/urban), Ramp type (off/on), Ramp configuration ( not statistically significant for fatal + Injury Model), Length of SCL, Ramp length. Other geometric design variables considered in the modeling were Traveled-way width, right shoulder width, and left shoulder width for ramp and SCL, ramp grade, and radii of horizontal curves on ramp. None of these geometric design variables were found to have a statistically significant relationship to accident frequency, except in limited situations in models that were not ultimately recommended for use. The study indicated that rear-end accidents on urban off-ramps of diamond, parclo loop, free-flow loop, and outer connection ramps were generally related to the operation of the cross-road ramp terminal, rather than to the geometric design of the ramp itself.

The analysis presented in the next section of this report build upon many of these conclusions by adding further insight into the potential safety issues inherent in the various designs of ramps.

## Ramp Database Coding Instruction

### 3.1 Ramp Geometric Coding .

Figure 6 through 9 provide the ramp configuration as specified in TASAS database. A brief description of these ramp configurations is provided in Section 3.1.1.

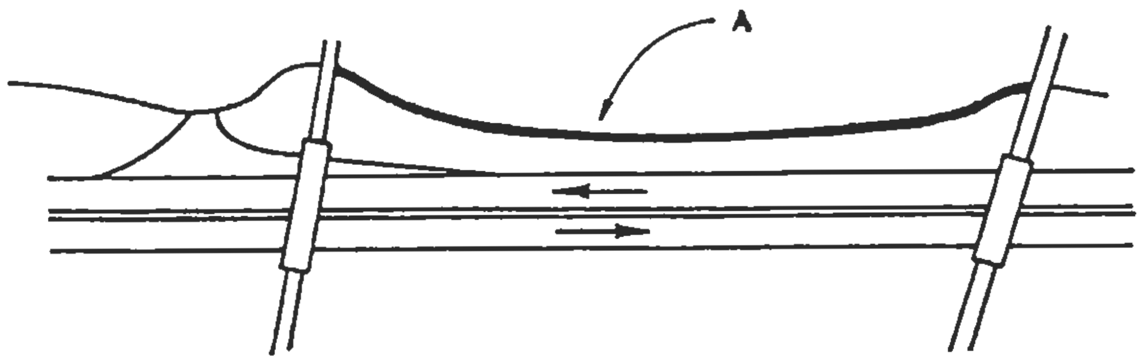



**Figure 6 Frontage Roads designated as "A" in TASAS database**

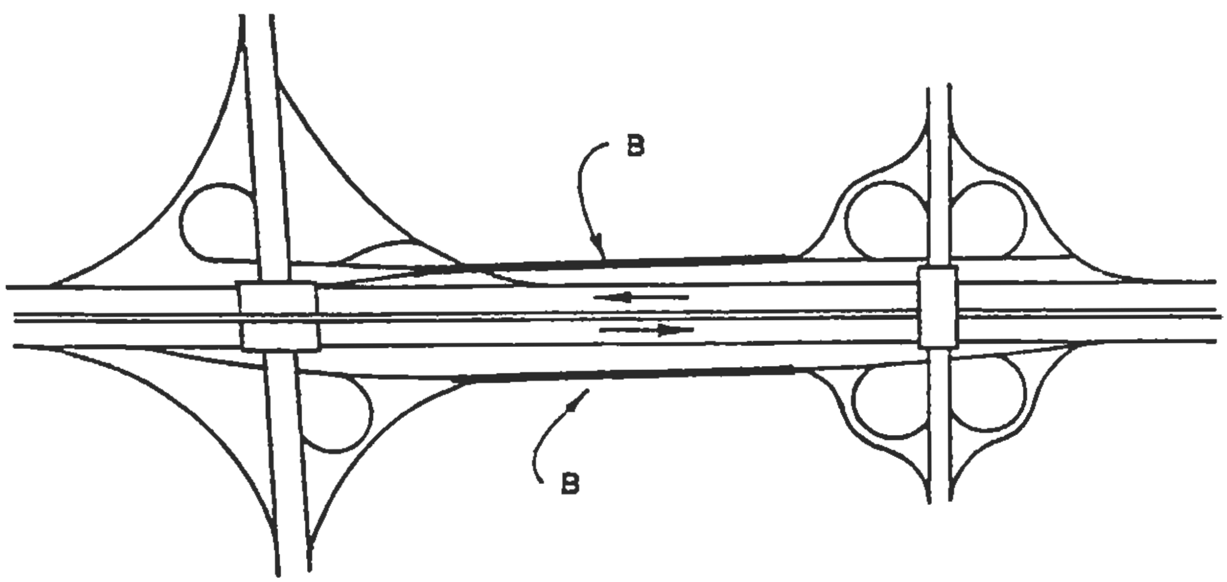
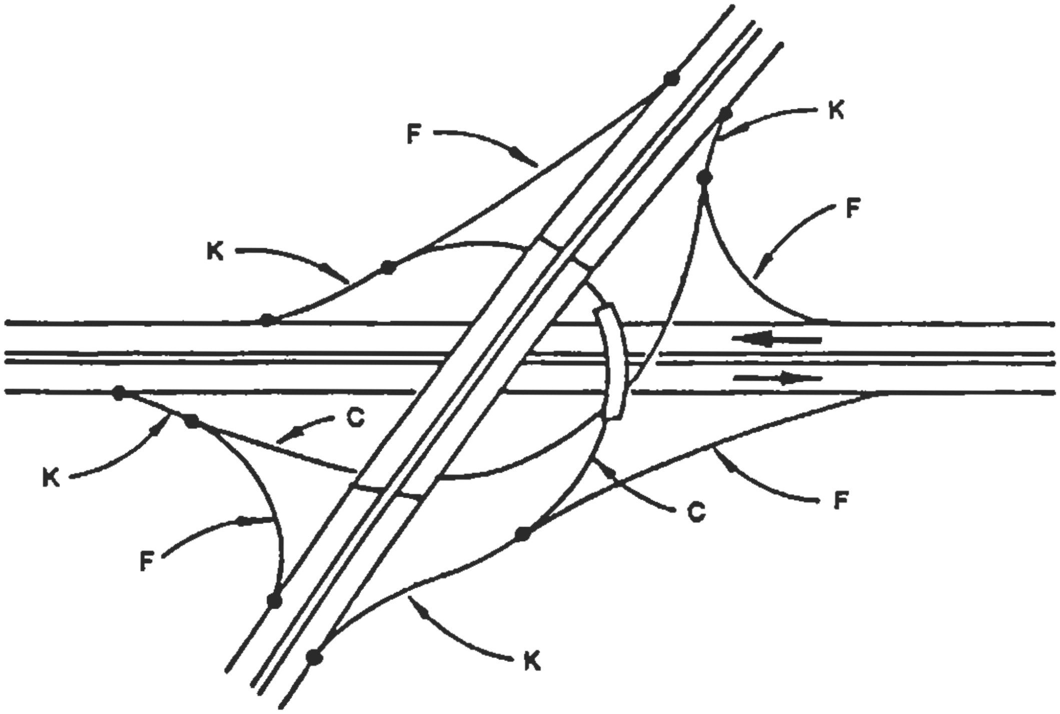



**Figure 7 Collector roads designated as "B" in TASAS database**

**E. Slip Off-Ramp**

**H. Button hook**

**J. Scissors Ramp**




C. Direct or Semi-direct Connector
F. Direct or Semi-direct Connector
K. Split Ramp

D. Diamond Interchange Ramp
G. Loop with Left Turn
L. Loop

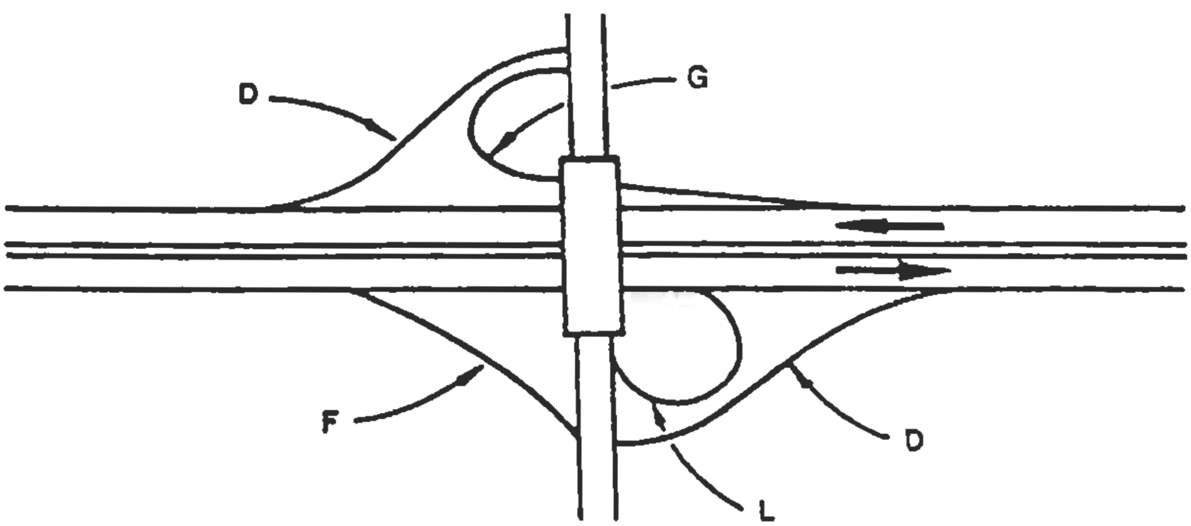
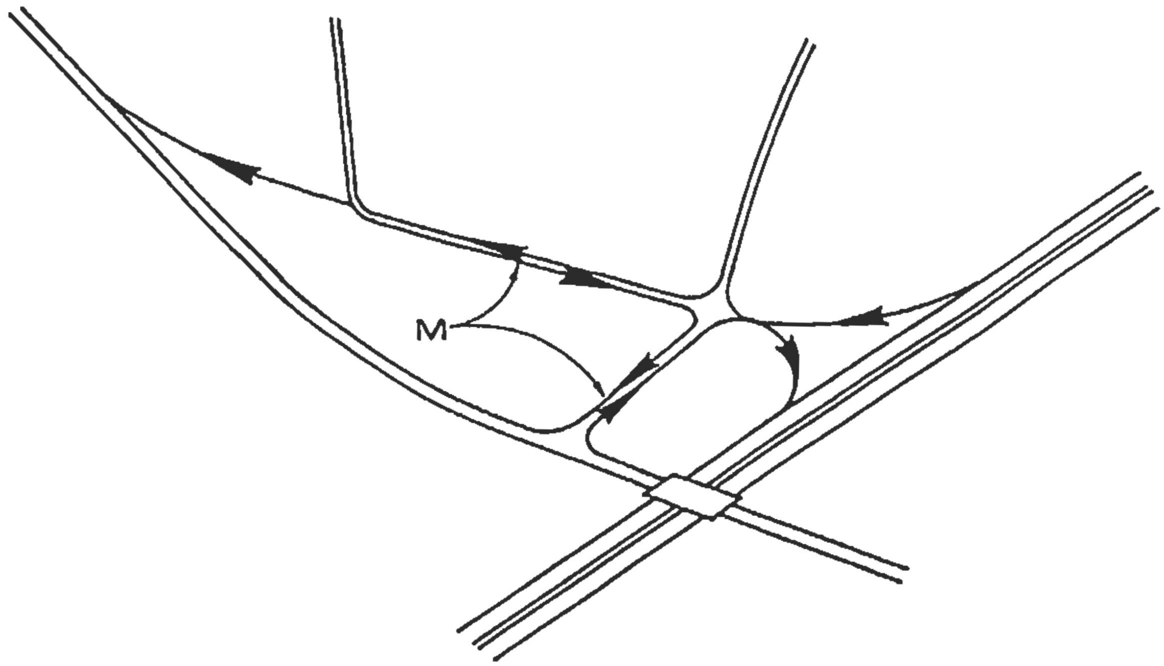



**Figure 8 Ramp Configurations Designated in the TASAS data base**




M. Two-Way Ramp

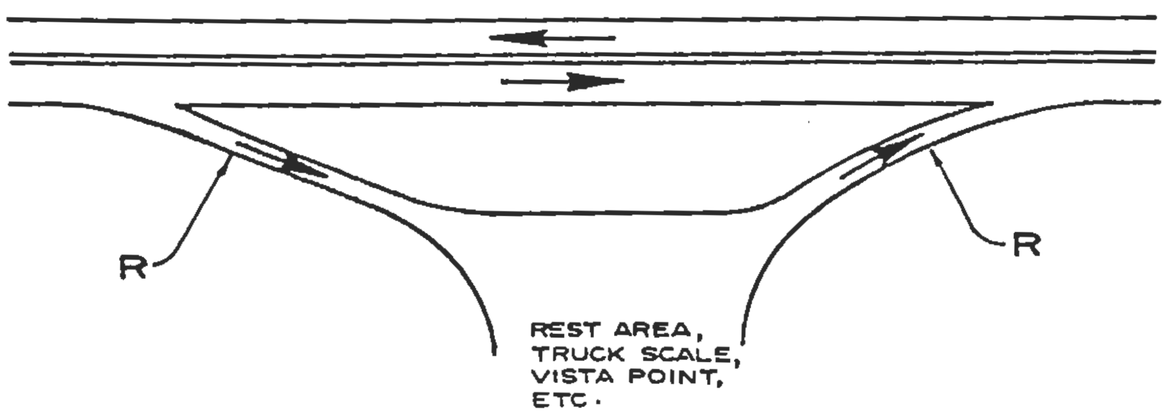



Figure 9 Ramp Configurations Designated in the TASAS data base

### 3.1.1 Ramp Description

The following ramp descriptions corrspond to the ramp codings shown in figure 6 through 9 as specified in the TASAS database.

A. Frontage Roads

City streets or county roads generally running parallel to the freeways and providing local access.

B. Collector Roads

Separate from and generally parallel to the freeway main line and providing no local access. They carry traffic from freeway off-ramp and/or to freeway on-ramps.

C. Direct or Semi-direct Connector

Left Turning Traffic Direct connections with no left turning movements at the intersecting street terminal.

D. Diamond Interchange Ramp

Carries traffic to or from the freeway (direct-not looping movement) and there are turning and/or potential broadside accidents at the ramp terminal with the local facility.

F. Direct or Semi-direct Connector

Right Turning Traffic Direct connections with no left turning movements at the intersecting street terminal.

G. Loop with Left Turn

One-way traffic in which the turning movement is approximately 180 degrees or more. These loops also have a left-turning movement at the cross street with potential broadside accidents.

K. Split Ramp

One-way traffic from a freeway where that traffic diverges to two separate ramps or an on-ramp developed by a merge of two other ramps.

L. Loop

One-way traffic in which the turning movement is approximately 270 degrees. There may be weaving on the main line, on a collector road or on the crossing road. These loops do not have a left turning movement at the cross street.

E. Slip Ramp

Carries traffic to/from a one-way parallel facility and merges with the lane nearest the freeway of that facility and not a street crossing.

H. Button Hook

One-way ramps with a general hook maneuver approximately 90 degrees which usually terminate at streets other than the over/under crossing street.

J. Scissors

Direct one-way thru ramp traffic to or from a local two-way facility where local traffic can cross in front of the ramp traffic in generally a scissors movement which can be an angle of 90 degrees or less.

M. Two-Way Ramp

Two-way ramp segment providing no local access and where the length is so great that a separate accounting of accidents must be made for the ramp movements to or from the freeway. This element is used very seldom.

R. Rest Areas, Vista Points and Truck Scales

This ramp type used for service within the freeway Ares right of way as distinguished from interchanges which provide local ingress and egress to the freeway.

Z. All Other

All ramps that cannot be categorized in any of the above.

### 3.2 TASAS Accident Coding Instructions

Accident location designation on ramps are specified in the TASAS database by one of the four areas shown in figure 10. Some ramps however are specified by 3 areas. Area 4 can only be specified for a ramp interchange on a *state* road crossing a *local* road. In the case where a ramp is on a state route, any accident on a local road is specified as area 4 and as a ramp accident. When a ramp is on a state route that crosses another state route, the accident occurring in area 4 is not coded as a ramp accident rather, it is coded an accident on the state highway ( i.e. the second state route). The TASAS database is set up to distinguish ramps with the above two characteristics by indicating whether the ramp has a four area accident location field or a three area accident location field.

In the remainder of this analysis, ramps with three areas are described by a Suffix "3". For instance, *loopleft3* designation refers to ramp configuration "Loop with Left Turn" for which the accidents could occur in any of the 3 areas. Similarly, *loopleft4* means that accidents on this ramp configuration are coded in areas 1 through 4. In the remainder of this report, the following ramp short designation will be used in tabulating and plotting the results:

| | |
|---|---|
| dir/semi | = Direct or Semi-direct Connector |
| loopnoleft | = Loop with no Left Turn |
| loopleft | = Loop with Left Turn |
| buttonhook | = Button Hook |
| twoway | = Two-Way Ramp |
| restarea | = R. Rest Areas, Vista Points and Truck Scales |

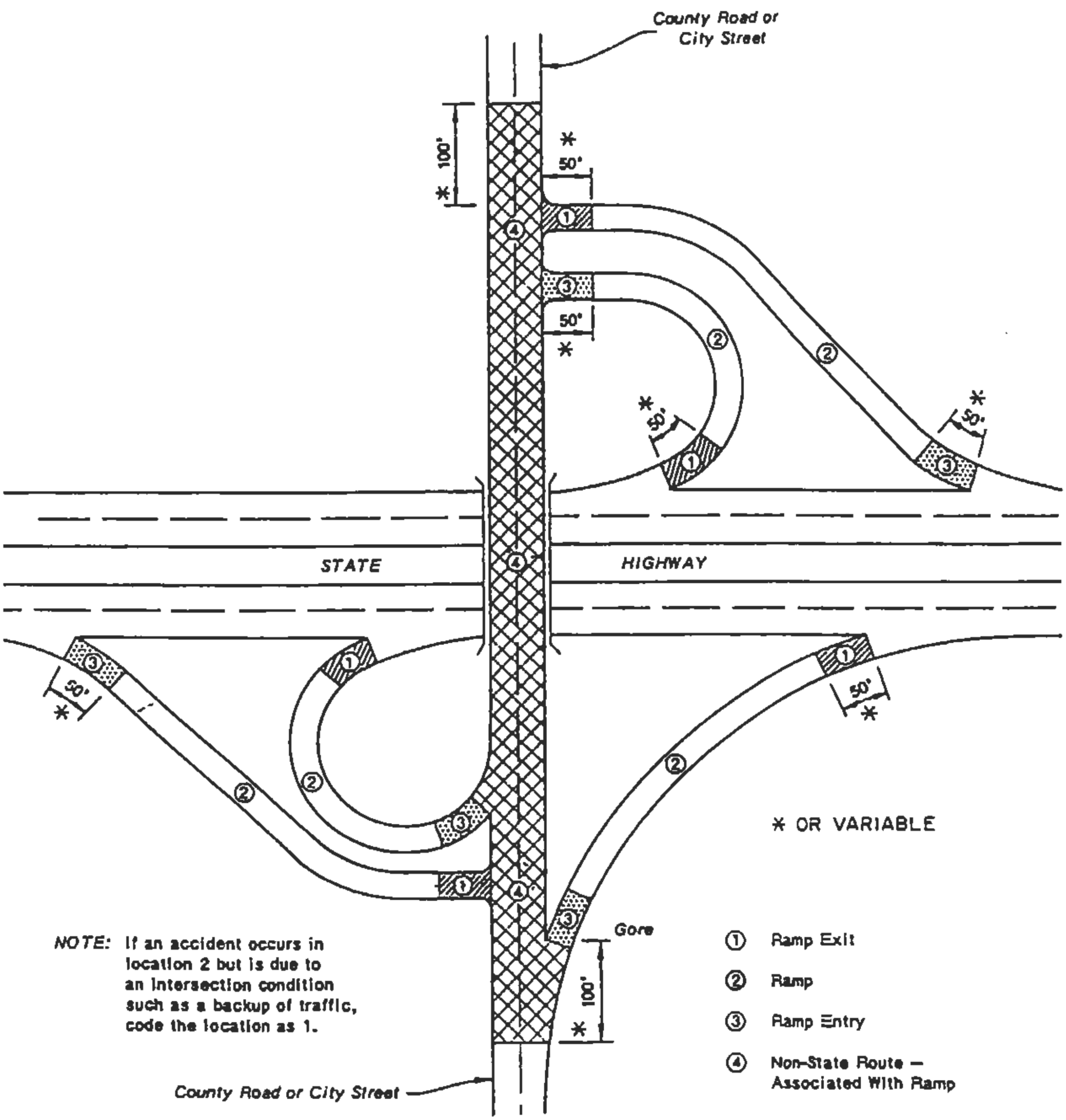



**Figure 10 Ramp Accident Location as coded in the TASAS database**

## Statistical Analysis and Results

### 4.1 Introduction

The data analysis on ramp is organized in two parts: In part I, descriptive statistics on ramps are provided for aggregated and stratified data. In part II, the data was stratified into four subsets of data by ramp type (on/off), and ramp area (urban/rural). Then, the four data set were analyzed with respect to accident rates (fatal, fatal + injury, total, wet, and dark) using analysis of variance (ANOVA) and analysis of covariance (ANCOVA) methods. The ANOVA and ANCOVA analyses were followed by pairwise comparison of ramps. In the summary of results that are presented in the following sections, the focus of the result interpretation is fatal + injury and total accident rates as discussed before.

### 4.2 Descriptive Statistics on Ramps Distribution (Part I)

In aggregated level, table 3 provides distribution of ramp *type* (on/off) on California State highways. As expected, the split between on-ramps and off-ramps is just about 50/50, with two-way ramp segments only comprising 0.2% of the ramp sample.

**Table 3 Off-ramp vs. On-ramp--Frequency Distribution**

| Ramp | Frequency | Percent |
|---|---|---|
| Off | 6,672 | 50.1% |
| On | 6,621 | 49.7% |
| Total | 13,325 | 100.0% |

Table 4 provides ramp frequency distribution by urban and rural settings.

**Table 4 Location and Frequency Distribution**

| Ramp Location | Frequency | Percent |
|---|---|---|
| Rural | 2,739 | 20.6% |
| Urban | 10,586 | 79.4% |
| Total | 13,325 | 100.0% |

Close to 20% of ramps are in rural areas and the remaining ramps in urban areas. Table 5 provides ramp accident frequency distribution by urban and rural settings within Caltrans districts (see map in Appendix E for Caltrans districts).

**Table 5 Ramp Accident Frequency by Caltrans District and Urban Rural Setting**

| | Urban | Ramp | No. Accidents | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dist | Rural | Freq | Total | Fat | F+I | Mul Veh | Wet | Dark | MV |
| 1 | Urban | 86 | 105 | 0 | 42 | 66 | 29 | 32 | 195 |
| 1 | Rural | 243 | 81 | 1 | 27 | 47 | 18 | 15 | 205 |
| 2 | Urban | 116 | 302 | 0 | 125 | 226 | 56 | 82 | 358 |
| 2 | Rural | 252 | 99 | 0 | 34 | 48 | 21 | 33 | 214 |
| 3 | Urban | 708 | 3541 | 15 | 1656 | 2689 | 858 | 911 | 4634 |
| 3 | Rural | 458 | 358 | 6 | 131 | 199 | 31 | 100 | 500 |
| 4 | Urban | 2541 | 15208 | 50 | 5768 | 11307 | 3309 | 4359 | 20581 |
| 4 | Rural | 112 | 98 | 1 | 42 | 58 | 14 | 34 | 156 |
| 5 | Urban | 400 | 1323 | 3 | 486 | 1013 | 175 | 358 | 1605 |
| 5 | Rural | 258 | 257 | 2 | 86 | 176 | 22 | 71 | 373 |
| 6 | Urban | 447 | 1555 | 11 | 646 | 1059 | 248 | 482 | 1699 |
| 6 | Rural | 374 | 415 | 8 | 136 | 251 | 46 | 123 | 406 |
| 7 | Urban | 3015 | 19270 | 87 | 6881 | 13709 | 2906 | 6694 | 31606 |
| 7 | Rural | 142 | 193 | 1 | 79 | 90 | 30 | 67 | 211 |
| 8 | Urban | 789 | 5001 | 23 | 1828 | 3994 | 623 | 1447 | 4872 |
| 8 | Rural | 325 | 330 | 5 | 113 | 224 | 24 | 119 | 447 |
| 9 | Urban | 21 | 23 | 0 | 12 | 8 | 1 | 2 | 22 |
| 9 | Rural | 80 | 12 | 0 | 2 | 5 | 1 | 5 | 29 |
| 10 | Urban | 554 | 2418 | 16 | 933 | 1765 | 446 | 621 | 2219 |
| 10 | Rural | 239 | 334 | 3 | 128 | 170 | 41 | 115 | 372 |
| 11 | Urban | 1186 | 5611 | 33 | 2700 | 4115 | 785 | 1637 | 11422 |
| 11 | Rural | 255 | 185 | 1 | 47 | 110 | 16 | 70 | 321 |
| 12 | Urban | 723 | 6654 | 20 | 2282 | 5178 | 733 | 2058 | 7753 |
| 12 | Rural | 1 | 2 | 0 | 0 | 1 | 1 | 2 | 5 |
| All | Urban | 10,586 | 61,011 | 258 | 23,35 | 45,129 | 10,169 | 18,683 | 86968 |
| All | Rural | 2,739 | 2,364 | 28 | 825 | 1,379 | 265 | 754 | 3239 |
| | Total | 13,325 | 63,375 | 286 | 24,18 | 46,508 | 10,434 | 19,437 | 90206 |

* Accidents/MV

Every ramp configuration can be located in both an urban and rural setting, with the exception of the slip-3 ramps, which are only present in urban areas. Note from Table 4 that most ramps occur in an urban setting. This is also reflected in Table 5, where the Districts with the most ramps contain the major metropolitan areas of Los Angeles and Ventura counties (District 7), the San Francisco Bay Area (District 4), San Diego county (District 11), and the Sacramento metropolitan area (District 3). The only ramp configuration that is an exception is the rest area/truck scale/vista point ramps. The majority of this type of ramp is found in rural areas.

### 4.3 Ramp Accidents Frequency and Severity

Of the total of 478,569 accidents occurring during 1992-94 on California State highway ramps, approximately 15% occurred on ramps as demonstrated in table 6. However, rural ramps accounted for 2.8% of the accidents occurring on rural highways, where as the urban ramp accidents accounted for 18.41% of the accidents of the urban highways.

**Table 6 Ramp vs. Highways Accidents (1992-94)**

| State Highway Type | Total Acc. | F+I Acc. |
|---|---|---|
| Rural Non-Freeway | 56,012 | [illegible] |
| Rural Freeway | 27,735 | [illegible] |
| Urban Non-Freeway | [illegible] | [illegible] |
| Urban Freeway | [illegible] | [illegible] |
| Total Rural | 83,747 | 40,099 |
| Total Urban | 331,447 | 120,963 |
| Total (Urban + Rural) | 415,194 | 161,062 |
| **Ramps (Rural)** | 2,364 | 825 |
| **Ramps (Urban)** | 61,011 | 23,359 |
| **Ramps (Urban + Rural)** | 63,375 | 24,184 |
| **Ramp Acc. As % of** | % | % |
| Ramps (Rural) | 2.82% | 2.06% |
| Ramps (Urban) | 18.41% | 19.31% |
| Ramps (Urban + Rural) | 15.26% | 15.02% |

The accident frequency and severity ratio calculated based on 1992-1994 accident data on California are presented in table 7, and table 8 respectively. These severity ratios show improvement from the severity rations measured by Lundy

(1965) where the fatal, injury and PDO accounted for 1.8, 42.9, and 55.3 percent respectively.

**Table 7 Three year Accident Frequencies**

| Acc Type | Off-Rural | Off-Urban | On-Rural | On-Urban |
|---|---|---|---|---|
| **Fatal** | 23 | 167 | 4 | 91 |
| **Injury** | 547 | 15115 | 248 | 7948 |
| **PDO** | 1058 | 23654 | 478 | 13931 |
| **Total** | **1628** | **38936** | **730** | **21970** |

1992-through 1994 accident data

**Table 8 Accident Severity Ratio**

| Acc Type | Off-Rural | Off-Urban | On-Rural | On-Urban |
|---|---|---|---|---|
| **Fatal** | 1.4 % | 0.4 % | 0.5 % | 0.4 % |
| **Injury** | 33.6 % | 38.8 % | 34.0 % | 36.2 % |
| **PDO** | 65.0 % | 60.8 % | 65.5 % | 63.4 % |

Attention should be paid to the level of aggregation of data considered in tabulating or plotting data since some level of detail is lost as a result of aggregating information. For example, in figure 11, differences in urban vs. rural and differences in individual ramp configurations are ignored in the interest of providing a comparison of on-ramps vs. off-ramps in general.

Note that off ramps are clearly more accident prone than on ramps both in terms of frequency of accident occurrence and the average accident rates. The total number of accidents on off-ramps are approximately twice the number of accidents on the on-ramps aggregating all configurations in urban and rural settings.

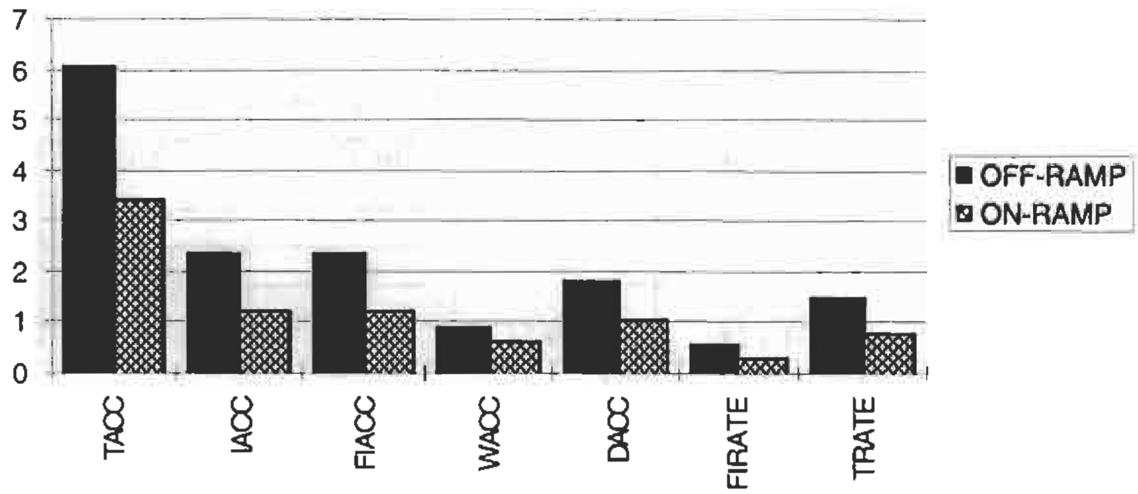



**Figure 11. On-Ramp vs. Off-Ramp Average Accident Frequencies**

**Legends**

| | |
|---|---|
| TACC | = Total Accident, |
| IACC | = Injury Accident , |
| FIACC | = Fatal + Injury (F+I) Accidents, |
| WACC | = Accidents occurring in wet pavement surface conditions, |
| DACC | = Accidents occurring during dark lighting conditions, |
| TRATE | = Total Accident_(No. of Accidents/MV) |
| FIRATE | = Fatal + Injury Accident *Rate* (No. of Accidents/MV) |

When interpreting the *average* accident rates, the reader should take into consideration the wide *variability* in number of accidents occurring on ramps within a particular configuration. For example, while the average frequency of *total* accident for the off-ramps is 6.08 accidents, its variability ranges from a minimum of zero accidents to a maximum of 117 accidents in the three year period.

For the remaining analyses, the data is stratified into 4 groups of data:

1) on ramps in rural area;
2) on-ramps in urban area;
3) off-ramps in rural area;
4) off-ramps in urban area.

### 4.3 Accident Frequency and rate (Urban/Rural Differences)

Aggregating ramps of different configurations, figure 12 and 13 and corresponding tables 9 demonstrate that accident *rates* on urban ramps are lower for both on-ramps and off-ramps. When accident *frequencies* are considered however, the opposite is true, meaning that accident frequencies are significantly higher on urban ramps (see figure 14 and 15).

**Figure 12 Rural vs. Urban Accident Rate, All Off-Ramps Combined**

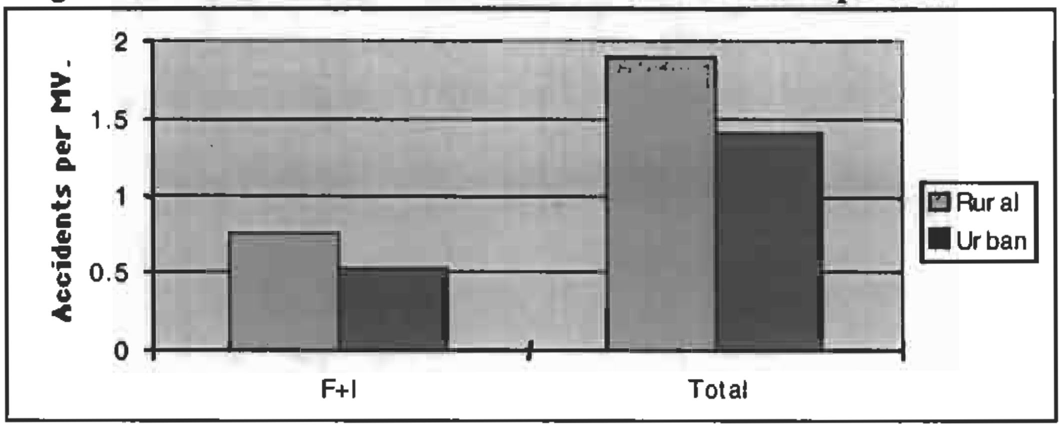



**Figure 13 Rural vs. Urban Accident Rate, All On-Ramps Combined**

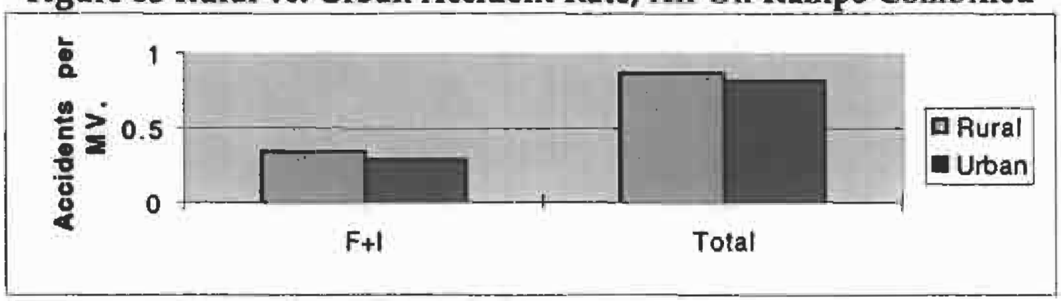



**Table 9 Urban vs. Rural Ramp Accident Rate**

| | Accident Type | Off- Ramp | | | | On- Ramp | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std Dev | Min. | Max. | Mean | Std Dev | Min. | Max. |
| Rural | Fatal +Injury | 0.75 | 3.65 | 0.00 | 82.19 | 0.35 | 2.82 | 0.00 | 82.94 |
| Rural | Total | 1.87 | 5.63 | 0.00 | 82.19 | 0.88 | 4.13 | 0.00 | 82.94 |
| Urban | Fatal+Injury | 0.53 | 1.81 | 0.00 | 96.08 | 0.30 | 1.02 | 0.00 | 30.44 |
| Urban | Total | 1.39 | 5.34 | 0.00 | 198.39 | 0.81 | 3.77 | 0.00 | 234.45 |

Total number of ramps in urban area = 10,564 and in rural area =2729

Figure 14 Average Accident Frequency (Off-Ramps Combined)

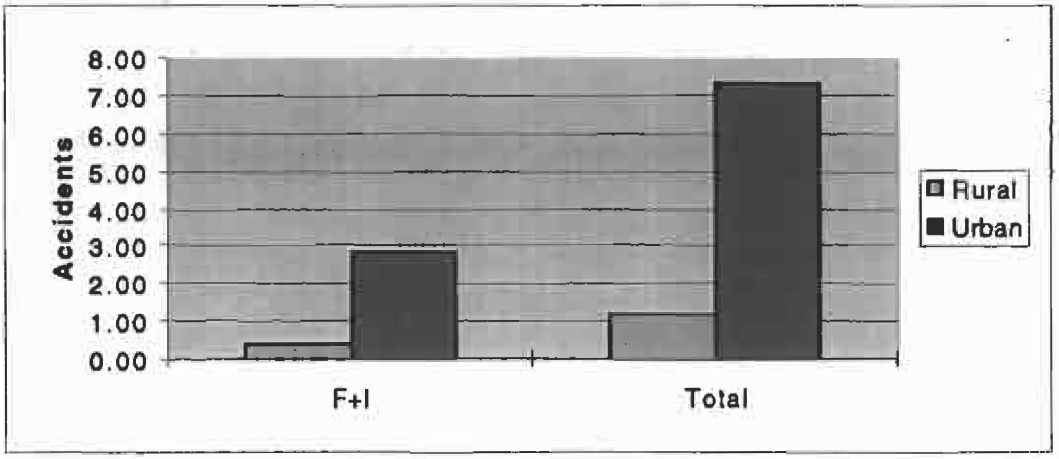
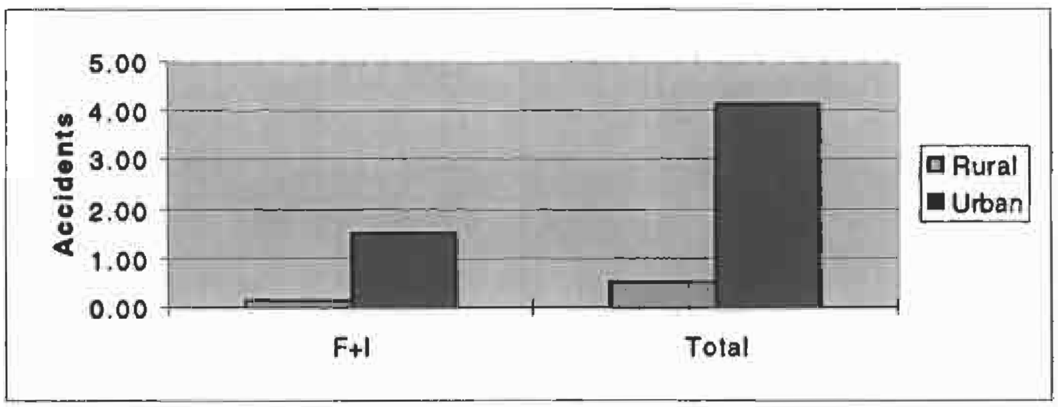



Figure 15 Average Accident Frequency (On-Ramps Combined)




## 4.5 Descriptive Statistics on Individual Ramp Configurations

Table 10 provides a sample of descriptive statistics on individual ramps. Complete statistics similar to the information in table 10 on 15 ramp configurations is provided in Appendix B. This includes a total of 60 tables [15x4 settings : on/off by urban/rural) All statistics are based on averaging three years of accident data (1992-1994).

**Table 10 Sample of Descriptive Statistics on buttonhook Ramps (see Appendix B for other ramp configurations)**

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**buttonhook**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC* | 111 | 1.3513514 | 1.7666025 | 0 | 8.0000000 |
| FACC* | 111 | 0.0090090 | 0.0949158 | 0 | 1.0000000 |
| IACC* | 111 | 0.4774775 | 0.9327072 | 0 | 5.0000000 |
| FIACC* | 111 | 0.4864865 | 0.9328828 | 0 | 5.0000000 |
| MVACC* | 111 | 0.5585586 | 1.3258595 | 0 | 8.0000000 |
| WACC* | 111 | 0.0630631 | 0.2441787 | 0 | 1.0000000 |
| DACC* | 111 | 0.3963964 | 0.6505841 | 0 | 2.0000000 |
| XVOL* | 111 | 0.7531532 | 0.8146187 | 0 | 3.7000000 |
| RVOL* | 111 | 0.8185586 | 0.8891281 | 0.0200000 | 4.0500000 |
| FRATE* | 111 | 0.0433063 | 0.4562602 | 0 | 4.8070000 |
| FIRATE* | 111 | 1.6695495 | 8.1557984 | 0 | 82.1900000 |
| TRATE* | 111 | 4.1284685 | 11.3893260 | 0 | 82.1900000 |
| WRATE* | 111 | 0.1269562 | 0.7101832 | 0 | 6.5200000 |
| DRATE* | 111 | 1.3286379 | 5.5941815 | 0 | 54.7933333 |

*** Legend**

| | |
|---|---|
| N | = Number of ramps for this configuration |
| TACC | = Total Accidents |
| FACC | = Fatal Accidents |
| IACC | = Injury Accidents |
| FIACC | = Fatal + Injury Accidents |
| MVACC | = Multi-vehicle Accidents |
| WACC | = Wet Accidents |
| DACC | = Dark Accidents |
| XVOL | = Ramp Cross Street Traffic Volume (MV) |
| RVOL | = Ramp Traffic Volume (MV) |
| FRATE | = Fatal Accident Rate (Acc/MV) |
| FIRATE | = Fatal + Injury Accident Rate (Acc/MV) |
| TRATE | = Total Accident Rate (Acc/MV) |
| WRATE | = Wet Accident Rate (Acc/MV) |
| DRATE | = Dark Accident Rate (Acc/MV) |

Part II of the statistical analysis that follows provides accident rates comparison of the stratified data after adjustment is made for ramp volume, and geographical effect (Caltrans districts) is included in the ANOVA analysis as a predictor.

### 4.6 Statistical Analysis Part II ( Stratified Data)

It is important to realize that an apparent ramp-type effect might be explainable in terms of other systematic factors, such as traffic patterns differing between rural and urban regions, differences attributed to Caltrans districts. The types of ramps that are predominantly featured can differ between urban and rural freeways or among Caltrans districts. For instance, although approximately 80% of ramps are in urban areas, nearly 85% of diamond ramps are in rural area. This could result in rural/urban differences in accident rates being falsely attributed to the types of ramps that are common in those areas.

In response to this possibility, a series of analysis of variance (ANOVA) and analysis of covariance models were run in which urban and rural differences, differences between districts, and differences between on-ramps and off-ramps were taken into account. The statistically significant differences in ramp configurations, type, and urban/rural setting resulting from these models led to the decision to split the data into four groups. The analysis in Part II dealt with analysis of each group separately.

Each separate analysis included a comparison of ramp configurations with respect to different types of accident rates (fatal, fatal + injury, total, wet, and dark). These analyses were performed to determine if in fact the apparent difference between ramps are statistically significant. In the following section only a summary of ANOVA and ANCOVA results are provided. More detail information but, still in a summarized format extracted form the statistical analyses is provided in Appendix C of this report. All ANOVA/ANCOVA analyses in Appendix C are followed by pairwise comparison tables. To present the results in a usable format for engineers, only the pairwise comparisons data that provide average accident rates are presented in the report. Complete ANOVA and ANCOVA tables can be made available upon request from the author of this report.

### 4.6.1 Example of Ramp Pairwise Comparison

Table 11 is presented as a sample of pairwise comparison. Notice that rarely a value of the accident mean is calculated as negative. This due to the very small number of accidents or accidents, and a higher than average ramp volume, in the subgroup and how the software program performing the LSMEAN provide relative comparison of the subgroups. In other word the program may figure that "if the ramp volume was even lower, the accidents would be negative". Of course, this makes no practical sense, but since the program knows nothing about the data being bounded below by zero, some LSMEANs are translated into negative values. In a way, the means have relative values. One option is to assume the negative means as zero and adjust the other means when comparison is made. This compensation is made in figure 16 through 19 and corresponding tables 13 through 16. As noted before, statistical analysis that follows provides accident rates comparison of the stratified data *after* adjustment is made for ramp volume, and the geographical effect (Caltrans districts) is included in the ANOVA analysis as a predictor.

**Table 11 Sample of Least Squares Means for Fatal + Injury Accident Rate (see Appendix C for other cases)**

Adjustment for multiple comparisons: Tukey-Kramer

| DESCR** | FIRATE* LSMEAN | LSMEAN*** Number |
|---|---|---|
| buttonhook | 0.20219715 | 1 |
| diamond3 | 0.17053038 | 2 |
| diamond4 | 0.37598087 | 3 |
| dir/semi3 | 0.24141925 | 4 |
| dir/semi4 | 0.26064053 | 5 |
| direct | 0.34373484 | 6 |
| loopleft3 | 0.30416232 | 7 |
| loopleft4 | 0.40222718 | 8 |
| loopnoleft3 | 0.19102482 | 9 |
| loopnoleft4 | 0.26318905 | 10 |
| restarea | -0.03051604 | 11 |
| scissors | 0.20071572 | 12 |
| slip3 | 0.29200270 | 13 |
| slip4 | 0.53264205 | 14 |
| split | 0.19501126 | 15 |

* FIRATE= Fatal + Injury Accident Rate
** DESCR = Ramp Description
*** LSMEAN = Least Mean Square accident rate

Table 12 provides the p-value matrix. Each entry determines whether the pairwise comparison is significant. For example, from table 11, the mean fatal + injury accident rate (FIRATE) for diamond4 and direct ramp (row 3, and 6) are 0.37598087 and 0.34373484 respectively. The entry in row 3 and column 6 of table 12 provide a p-value = 1.0 which is greater than 0.05. Therefore, the difference between the two mean accident rates is not statistically significant.

**Table 12 Matrix of Statistical Significance (p-values <0.05) for i/j Ramp Pairs**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 0.0697 | 1.0000 | 0.9998 | 0.9679 | 1.0000 | 0.4036 | 1.0000 | 0.9998 | 0.9893 | 1.0000 | 1.0000 | 0.3318 | 1.0000 |
| 2 | 1.0000 | . | 0.7168 | 1.0000 | 0.9999 | 0.9851 | 1.0000 | 0.7633 | 1.0000 | 0.9999 | 0.9992 | 1.0000 | 1.0000 | 0.4823 | 1.0000 |
| 3 | 0.0697 | 0.7168 | . | 0.7514 | 0.3928 | 1.0000 | 1.0000 | 1.0000 | 0.6918 | 0.5628 | 0.4567 | 0.7992 | 1.0000 | 0.9920 | 0.2372 |
| 4 | 1.0000 | 1.0000 | 0.7514 | . | 1.0000 | 0.9992 | 1.0000 | 0.8791 | 1.0000 | 1.0000 | 0.9658 | 1.0000 | 1.0000 | 0.6242 | 1.0000 |
| 5 | 0.9998 | 0.9999 | 0.3928 | 1.0000 | . | 0.9998 | 1.0000 | 0.8373 | 1.0000 | 1.0000 | 0.9186 | 1.0000 | 1.0000 | 0.6305 | 0.9999 |
| 6 | 0.9679 | 0.9851 | 1.0000 | 0.9992 | 0.9998 | . | 1.0000 | 1.0000 | 0.9907 | 0.9999 | 0.7525 | 0.9959 | 1.0000 | 0.9896 | 0.9602 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.4036 | 0.7633 | 1.0000 | 0.8791 | 0.8373 | 1.0000 | 1.0000 | . | 0.7715 | 0.8797 | 0.4492 | 0.8446 | 1.0000 | 0.9997 | 0.5248 |
| 9 | 1.0000 | 1.0000 | 0.6918 | 1.0000 | 1.0000 | 0.9907 | 1.0000 | 0.7715 | . | 1.0000 | 0.9969 | 1.0000 | 1.0000 | 0.4996 | 1.0000 |
| 10 | 0.9998 | 0.9999 | 0.5628 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 0.8797 | 1.0000 | . | 0.9165 | 1.0000 | 1.0000 | 0.6640 | 0.9999 |
| 11 | 0.9893 | 0.9992 | 0.4567 | 0.9658 | 0.9186 | 0.7525 | 0.9998 | 0.4492 | 0.9969 | 0.9165 | . | 0.9954 | 0.9655 | 0.2316 | 0.9940 |
| 12 | 1.0000 | 1.0000 | 0.7992 | 1.0000 | 1.0000 | 0.9959 | 1.0000 | 0.8446 | 1.0000 | 1.0000 | 0.9954 | . | 1.0000 | 0.5686 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9655 | 1.0000 | . | 0.9858 | 1.0000 |
| 14 | 0.3318 | 0.4823 | 0.9920 | 0.6242 | 0.6305 | 0.9896 | 1.0000 | 0.9997 | 0.4996 | 0.6640 | 0.2316 | 0.5686 | 0.9858 | . | 0.3478 |
| 15 | 1.0000 | 1.0000 | 0.2372 | 1.0000 | 0.9999 | 0.9602 | 1.0000 | 0.5248 | 1.0000 | 0.9999 | 0.9940 | 1.0000 | 1.0000 | 0.3478 | . |

In the absence of a statistically significant difference between a particular pair of ramp types, any of the following explanations is plausible:

- there is no difference between the ramp types;
- there is a difference, which went undetected due to the conservatism of the *post hoc* analysis;
- there is a difference, which went undetected because the magnitude of the difference was small; or
- there is a difference, which went undetected because there were relatively few ramps for the two types being compared.

In view of these four possibilities, it's appropriate that the distinction between a significant difference and an insignificant one should be interpreted as being between those differences for which there was sufficient evidence to declare a difference, and those for which there simply was insufficient evidence.

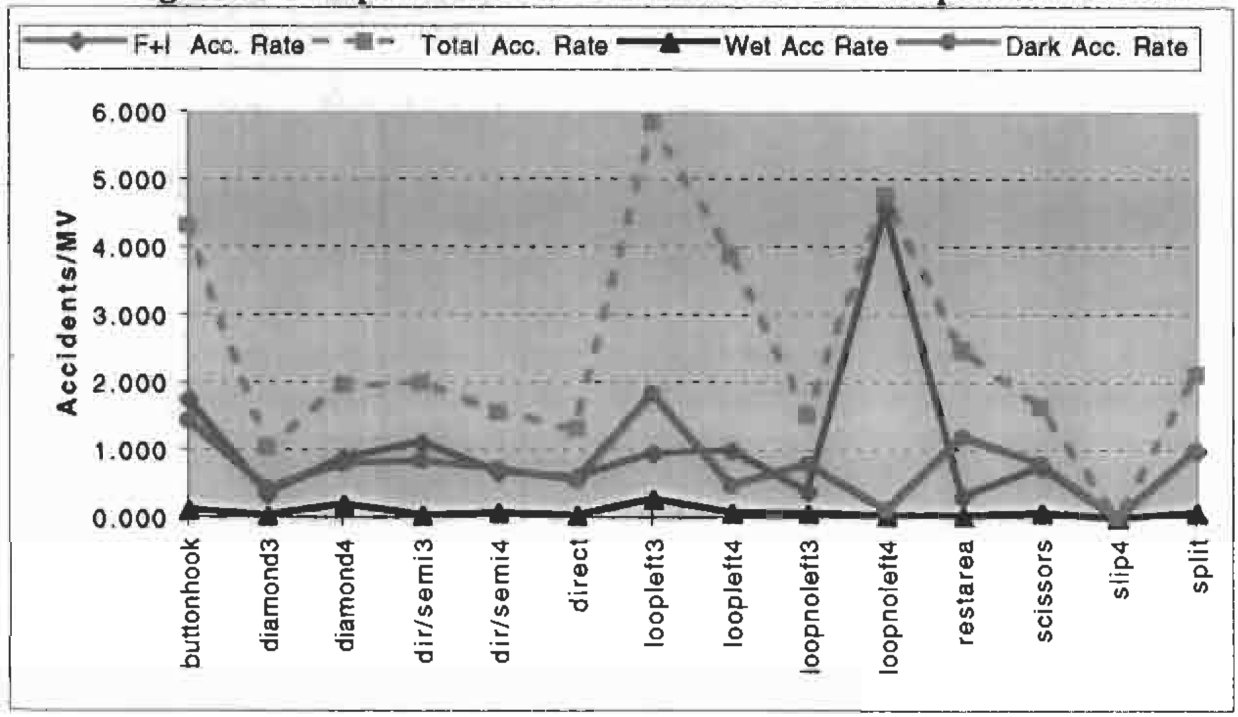
Similar tables to table 11 and 12 are presented in Appendix C, organized into four sets of tables as follows:

1) Analysis of Off-ramps in rural area
2) Analysis of Off-ramps in urban area
3) Analysis of On-ramps in rural area
4) Analysis of On-ramps in urban area

For each of the above analyses, a summarized ANOVA table is first presented. These tables provide information as to whether the factors in the model are significant or not. These tables are then followed by pairwise comparison similar to table 11 and 12 where average accident rates for different ramp configurations are compared. The matrix of p-values similar to table 12 indicate whether the difference in mean accident rates are significant.

Because the ANCOVA analyses for urban areas (Appendix C) indicated district effect as being significant ( meaning some accident rate differences in ramps attributed to Caltrans district and not just to ramp volumes), comparison tables for urban ramps were selected from ANCOVA analyses that accounted for the geographical effect (Caltrans Districts). Results for rural ramps were extracted from ANCOVA analyses with ramp volume as covariate, but without the district effect as a predictor in the model.

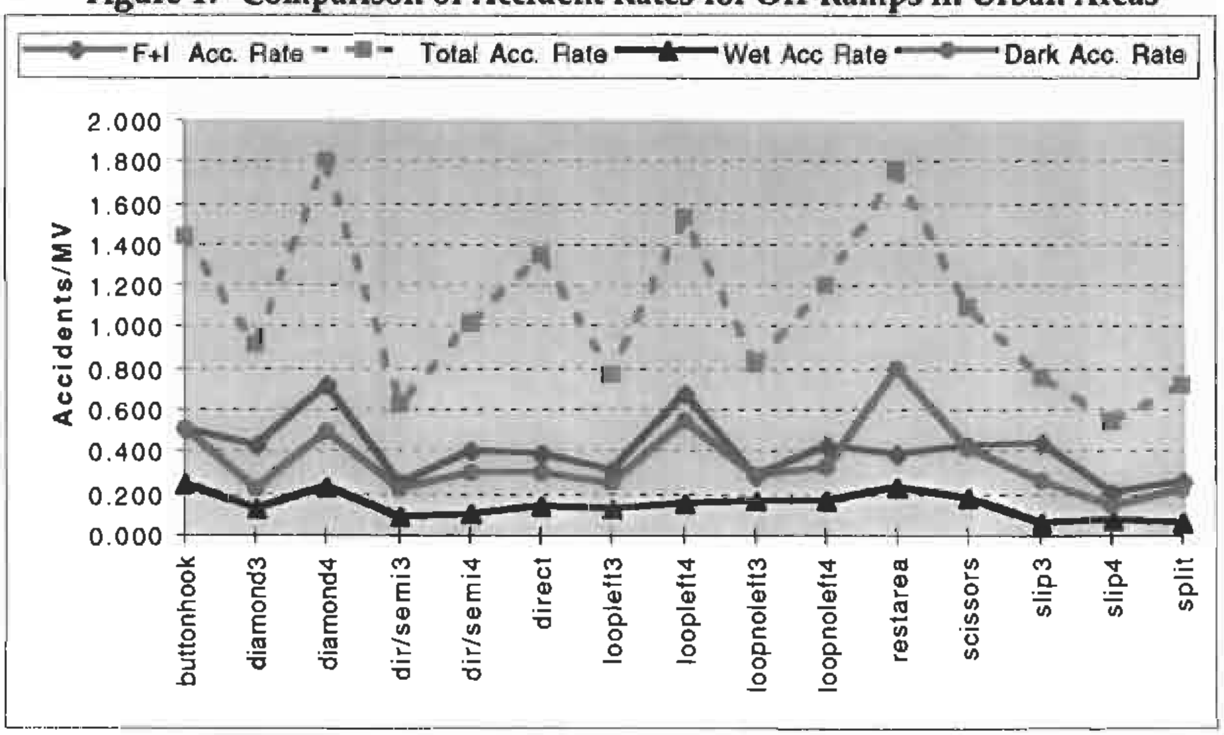
**Figure 16 Comparison of Accident Rates for Off-Ramps in Rural Areas ***




**Notes : 1)** For suffix 3 and 4 in ramp designation (i.e. loopleft3, ect.) see section 3.2.

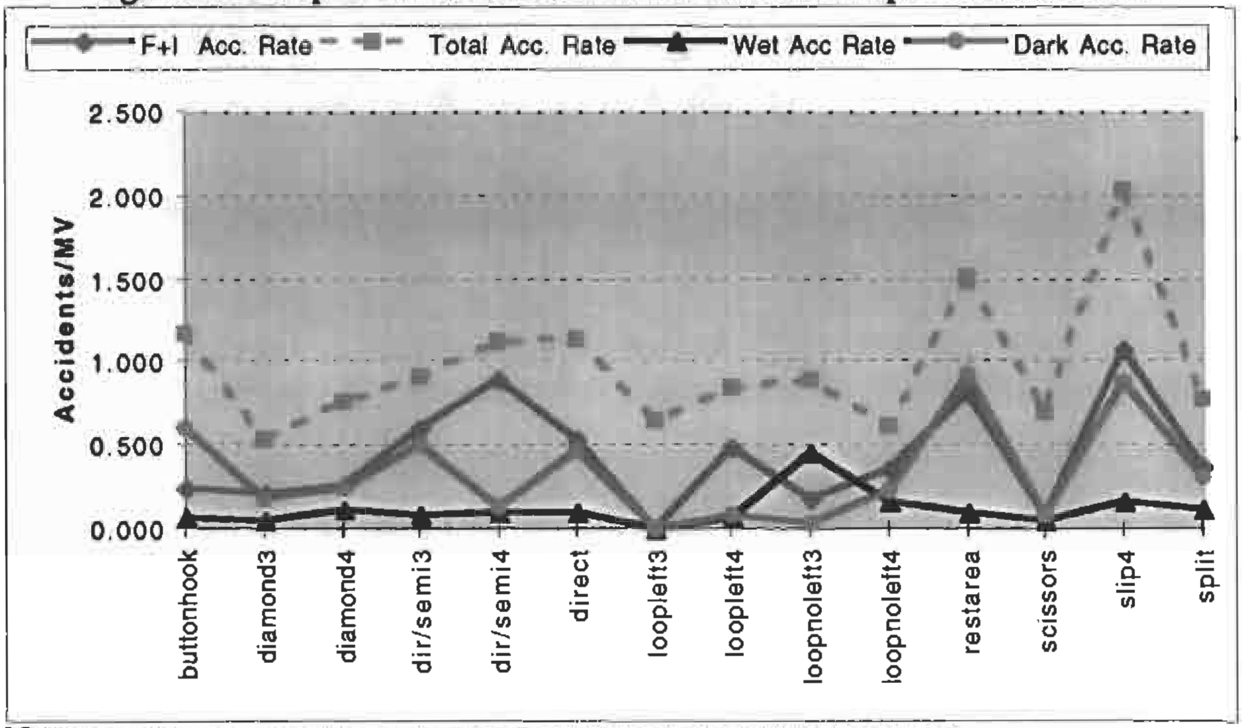
**2)** dir/semi = Direct or Semi-direct Connector; loopnoleft = Loop with no Left Turn; loopleft = Loop with Left Turn; buttonhook= Button Hook; twoway = Two-Way Ramp; restarea= Rest Areas, Vista Points and Truck Scales

**Figure 17 Comparison of Accident Rates for Off-Ramps in Urban Areas**




* (With Ramp Volume Adjusted)

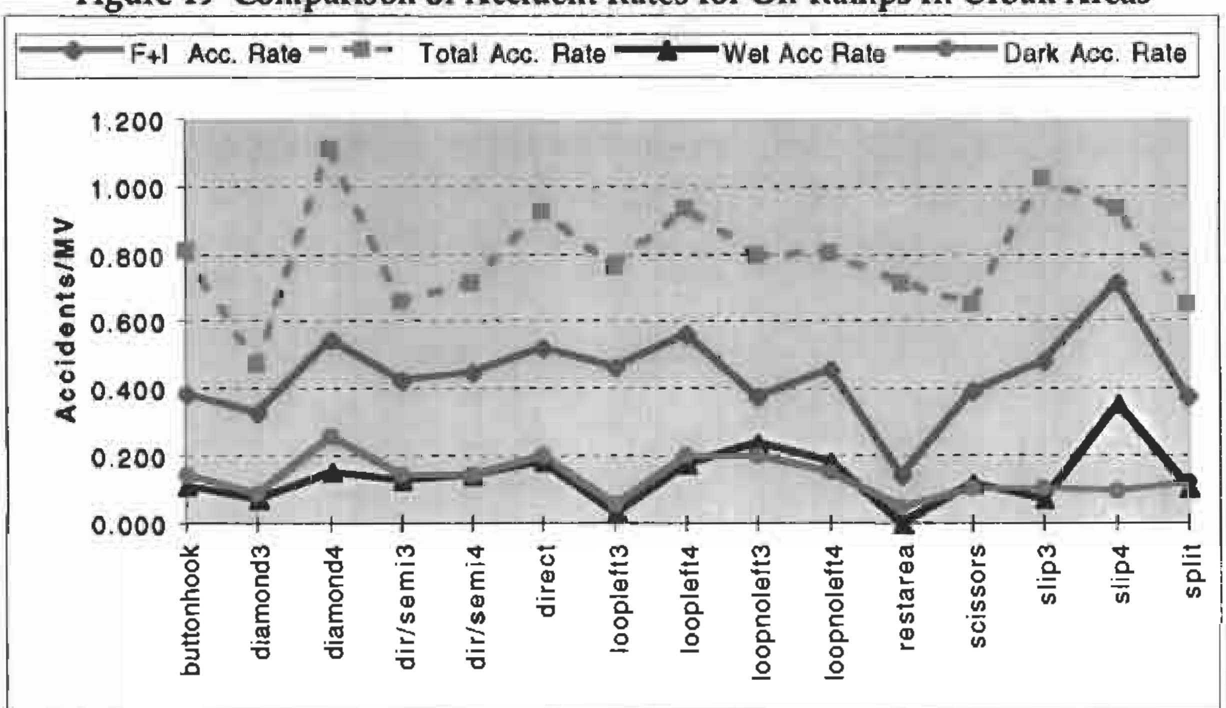
**Figure 18 Comparison of Accident Rates for On-Ramps in Rural Areas**




**Notes: 1)** For suffix 3 and 4 in ramp designation (i.e. loopleft3, ect.) see section 3.2.

**2)** dir/semi = Direct or Semi-direct Connector; loopnoleft = Loop with no Left Turn; loopleft = Loop with Left Turn; buttonhook= Button Hook; twoway = Two-Way Ramp; restarea= Rest Areas, Vista Points and Truck Scales

**Figure 19 Comparison of Accident Rates for On-Ramps in Urban Areas**




* (With Ramp Volume Adjusted)

**Table 13 Comparison of Accident Rates for Off-Ramps in Rural Areas**

| | F+I Acc. Rate | Total Acc. Rate | Wet Acc Rate | Dark Acc. Rate |
|---|---|---|---|---|
| buttonhook | 1.758 | 4.325 | 0.132 | 1.424 |
| diamond3 | 0.348 | 1.057 | 0.028 | 0.452 |
| diamond4 | 0.878 | 1.961 | 0.200 | 0.804 |
| dir/semi3 | 1.111 | 2.005 | 0.027 | 0.845 |
| dir/semi4 | 0.661 | 1.549 | 0.083 | 0.726 |
| direct | 0.590 | 1.328 | 0.055 | 0.564 |
| loopleft3 | 0.952 | 5.833 | 0.278 | 1.843 |
| loopleft4 | 0.995 | 3.881 | 0.062 | 0.462 |
| loopnoleft3 | 0.385 | 1.531 | 0.099 | 0.783 |
| loopnoleft4 | 4.568 | 4.745 | 0.059 | 0.129 |
| restarea | 0.301 | 2.472 | 0.055 | 1.198 |
| scissors | 0.750 | 1.627 | 0.081 | 0.816 |
| slip4 | 0.000 | 0.000 | 0.000 | 0.000 |
| split | 0.984 | 2.106 | 0.090 | 0.980 |

**Notes:** 1) For suffix 3 and 4 in ramp designation (i.e. loopleft3, ect.) see section 3.2.

2) dir/semi = Direct or Semi-direct Connector; loopnoleft = Loop with no Left Turn; loopleft = Loop with Left Turn; buttonhook= Button Hook; twoway = Two-Way Ramp; restarea= Rest Areas, Vista Points and Truck Scales

**Table 14 Comparison of Accident Rates for Off-Ramps in Urban Areas**

| | F+I Acc. Rate | Total Acc. Rate | Wet Acc Rate | Dark Acc. Rate |
|---|---|---|---|---|
| buttonhook | 0.503 | 1.435 | 0.243 | 0.506 |
| diamond3 | 0.429 | 0.921 | 0.126 | 0.221 |
| diamond4 | 0.724 | 1.808 | 0.239 | 0.501 |
| dir/semi3 | 0.246 | 0.633 | 0.085 | 0.229 |
| dir/semi4 | 0.399 | 1.022 | 0.102 | 0.304 |
| direct | 0.393 | 1.352 | 0.148 | 0.296 |
| loopleft3 | 0.307 | 0.765 | 0.126 | 0.247 |
| loopleft4 | 0.684 | 1.531 | 0.162 | 0.546 |
| loopnoleft3 | 0.293 | 0.821 | 0.171 | 0.288 |
| loopnoleft4 | 0.436 | 1.197 | 0.164 | 0.323 |
| restarea | 0.398 | 1.759 | 0.238 | 0.793 |
| scissors | 0.431 | 1.096 | 0.184 | 0.424 |
| slip3 | 0.441 | 0.764 | 0.066 | 0.266 |
| slip4 | 0.211 | 0.554 | 0.085 | 0.145 |
| split | 0.257 | 0.717 | 0.059 | 0.221 |

**Table 15 Comparison of Accident Rates for On-Ramps in Rural Areas**

| | F+I Acc. Rate | Total Acc. Rate | Wet Acc Rate | Dark Acc. Rate |
|---|---|---|---|---|
| buttonhook | 0.243 | 1.172 | 0.061 | 0.598 |
| diamond3 | 0.218 | 0.532 | 0.042 | 0.176 |
| diamond4 | 0.256 | 0.761 | 0.110 | 0.243 |
| dir/semi3 | 0.600 | 0.914 | 0.084 | 0.498 |
| dir/semi4 | 0.889 | 1.127 | 0.090 | 0.129 |
| direct | 0.528 | 1.137 | 0.091 | 0.473 |
| loopleft3 | 0.002 | 0.657 | 0.000 | 0.002 |
| loopleft4 | 0.480 | 0.840 | 0.062 | 0.076 |
| loopnoleft3 | 0.175 | 0.886 | 0.455 | 0.029 |
| loopnoleft4 | 0.356 | 0.624 | 0.167 | 0.221 |
| restarea | 0.814 | 1.518 | 0.091 | 0.925 |
| scissors | 0.080 | 0.703 | 0.042 | 0.081 |
| slip4 | 1.064 | 2.023 | 0.160 | 0.879 |
| split | 0.379 | 0.777 | 0.114 | 0.313 |

**Notes :** 1) For suffix 3 and 4 in ramp designation (i.e. loopleft3, ect.) see section 3.2.
2) dir/semi = Direct or Semi-direct Connector; loopnoleft = Loop with no Left Turn; loopleft = Loop with Left Turn; buttonhook= Button Hook; twoway = Two-Way Ramp; restarea= Rest Areas, Vista Points and Truck Scales

**Table 16 Comparison of Accident Rates for On-Ramps in Urban Areas**

| | F+I Acc. Rate | Total Acc. Rate | Wet Acc Rate | Dark Acc. Rate |
|---|---|---|---|---|
| buttonhook | 0.389 | 0.817 | 0.109 | 0.144 |
| diamond3 | 0.327 | 0.473 | 0.075 | 0.088 |
| diamond4 | 0.546 | 1.108 | 0.153 | 0.261 |
| dir/semi3 | 0.426 | 0.663 | 0.129 | 0.147 |
| dir/semi4 | 0.451 | 0.713 | 0.143 | 0.141 |
| direct | 0.520 | 0.928 | 0.186 | 0.201 |
| loopleft3 | 0.468 | 0.762 | 0.029 | 0.056 |
| loopleft4 | 0.566 | 0.937 | 0.176 | 0.204 |
| loopnoleft3 | 0.381 | 0.798 | 0.242 | 0.198 |
| loopnoleft4 | 0.457 | 0.807 | 0.185 | 0.151 |
| restarea | 0.145 | 0.714 | 0.000 | 0.046 |
| scissors | 0.396 | 0.653 | 0.119 | 0.105 |
| slip3 | 0.486 | 1.023 | 0.075 | 0.106 |
| slip4 | 0.715 | 0.938 | 0.352 | 0.098 |
| split | 0.382 | 0.649 | 0.101 | 0.122 |

### 4.7 Ramps with Relatively High Accident Rates

As stated earlier in this report, not all ramps experienced accidents. On the other hand, certain ramps did experience multiple accidents or had higher accident rates. This section provides some information on selected sample of ramps that have relatively high accident rates for future close monitoring purpose. The process by which these ramps were selected started by defining cutoffs for the fatal, fatal/injury and total accident rates (these cutoff points were specific to any ramp configuration under consideration), and then picked a handful of ramps that figured prominently on one or more of these lists. In essence, approximately the top 2.5% were analyzed here as a subset sample. A complete list of these ramps is provided in the Appendix D. Table 17 below summarizes information on high accident ramp. Appendix D provide the complete list of high accident ramps.

**Table 17 Ramps with a relatively high accident rate**

| Ramp configuration | Ramp population (1) | High Rate Sample (2) | % [(2)/(1)] =(3) | % (2)/381 | % (1)/13325 |
|---|---|---|---|---|---|
| loopleft3 | 34 | 16 | 47.06 % | 4.2% | 0.3% |
| slip3 | 145 | 34 | 23.45 % | 8.9% | 1.1% |
| twowayseg4 | 32 | 6 | 18.75 % | 1.6% | 0.2% |
| Restarea | 316 | 40 | 12.66 % | 10.5% | 2.4% |
| scissors | 352 | 42 | 11.93 % | 11.0% | 2.6% |
| slip4 | 176 | 14 | 7.95 % | 3.7% | 1.3% |
| loopnoleft3 | 318 | 21 | 6.60 % | 5.5% | 2.4% |
| direct | 470 | 24 | 5.11 % | 6.3% | 3.5% |
| diamond3 | 447 | 22 | 4.92 % | 5.8% | 3.4% |
| loopleft4 | 544 | 22 | 4.04 % | 5.8% | 4.1% |
| dir/semi3 | 738 | 23 | 3.12 % | 6.0% | 5.5% |
| split | 870 | 21 | 2.41 % | 5.5% | 6.5% |
| loopnoleft4 | 881 | 21 | 2.38 % | 5.5% | 6.6% |
| buttonhook | 1,179 | 27 | 2.29 % | 7.1% | 8.8% |
| dir/semi4 | 1,205 | 23 | 1.91 % | 6.0% | 9.0% |
| diamond4 | 5,618 | 25 | 0.44 % | 6.6% | 42.2% |
| **Total Ramps** | **13,325** | **381** | **2.86 %** | **100%** | **100%** |

**Notes:** 1) For suffix 3 and 4 in ramp designation (i.e. loopleft3, ect.) see section 3.2.

2) dir/semi = Direct or Semi-direct Connector; loopnoleft = Loop with no Left Turn; loopleft = Loop with Left Turn; buttonhook= Button Hook; twoway = Two-Way Ramp; restarea= Rest Areas, Vista Points and Truck Scales

Notice that the scissors, rest area, and slip3 ramp configurations are the most common ramp among the ramp sample with a high accident rate. They comprise 11, 10, and 9 percent of the sampled 382 ramps respectively. Although, the percentage of the loop ramps with a left turn is relatively low in the sample, it comprises an overwhelming portion of this specific ramp configuration (47%). The other three types of ramps with over 10% of their population present in the sample are: slip3-ramp (23.45%), the two-waySeg4 ramp (18.75%), and the rest area/truck scale/vista point type of ramp (12.66%).

The rural/urban split for high accident sample is approximately 30/70, which is slightly different than the rural/urban split ratio (20/80) for all ramps population. From table 18, almost 80% of all ramps are found in an urban location, while only 70% of the ramps in the sample are high accident rates ramps.

**Table 18 High Accident Rate Ramp Sample Distribution by Rural/Urban**

| Ramp Group | All Ramps | Percent of All Ramps | Sampled High Acc. Rate | Percent of Total Sample |
|---|---|---|---|---|
| Rural | 2,739 | 20.6% | 113 | 29.7% |
| Urban | 10,586 | 79.4% | 268 | 70.3% |
| Total | 13,325 | 100.0% | 381 | 100.0% |

This may also indicates that rural ramps have a higher share of the ramps with high accident rates than urban ramps. The distribution between the ramps with relatively high rates grouped by <u>on/off</u> ramps is not much different than the distribution found for all the ramps. As seen in the table 19, off-ramps comprise the majority of the high accident rate ramp sample, at almost 51%. At first glance this may seem to contradict the previous findings of this report that off-ramps have higher accident rates. However, a closer look at the variability of accident occurrence between different ramp configurations and within each configuration clarifies this point. Although, off-ramps have higher accident rates than on-ramps in their aggregate form the vast variability among and within each configuration lead to an equal selected sample size of on-ramps and off-ramps which have higher accident rates among the entire 13, 325 ramps in California.

**Table 19 Higher Accident Rate Ramp Sample--Distribution by Off/On**

| Ramp Group | Total population | % of population | Higher Acc. Rate Sample | % of Sample |
|---|---|---|---|---|
| Off | 6,672 | 50.1% | 193 | 50.9% |
| On | 6,621 | 49.7% | 181 | 47.5% |
| Two-Way Ramp | 32 | 0.2% | 6 | 1.6% |
| Total | *13,325* | *100.0%* | *381* | *100.0%* |

Another important observation from table 19 is that while the top five ramps comprise a very small portion of the ramp population, they make relatively a much higher percentage of the high accident ramp sample and especially a much higher percentage of their corresponding ramp configuration ( e.g. two-way ramps make up only 0.2% of the entire ramp population, 1.6% of high accident rate sample, and over 18% of two-way ramps). Furthermore, two-way ramp segments stand out as being problematic, as seen earlier in the high accident rate ramp.

## Findings

Approximately 15% of accidents on California state highways occurred on ramps. The rural ramp accidents were only 2.82% of accidents on rural highways, but the urban ramps accounted for 18.41% of the accidents on urban highways. The majority of ramps experienced no multiple-vehicle accidents or only one multiple-vehicle accident in the study period.

Accident rates of on-ramps were consistently lower than off-ramps accident rates as summarized in tables 13 through 16. Most fatal and injury type accidents occur on off-ramps, but on-ramps tended to be linked with the less sever PDO accidents. Not only do most ramp accidents occur on the off-ramps, but so do the more serious accidents. Fatal accidents constituted between 0.4 to 1.4 percent of ramp accidents; injury accidents between 34 to 38.8 percent, and property damage accidents between 60.8 to 65 percent as detailed in Table 8.

Descriptive statistics for every ramp configuration is derived and presented in Appendix B of this report. A series of analysis of variance models were run to determine the systematic differences in accident rates between ramps of different designs. These statistical models included the measured ramp traffic volume as a covariate and ramp geographical location as a predictor variable. The statistical models were followed by pairwise comparison where differences in mean accident rates between each pair of ramp configurations were estimated (see Appendix C). The comparisons are done for four sets of ramp groups stratified by ramp type (on/off ), and ramp area (urban/rural)as presented in figure 16 through 19 and corresponding tables 13 through 16.

A list of ramps on California state highways with relatively higher than average accidents are summarized in table 17. Scissor ramps, rest area ramps, and slip ramps configurations are the most common among the ramp sample with high accident rates. They comprised 11, 10, and 9 percent of the high accident ramp sample respectively. Although, the percentage of the loop ramps with a left turn is relatively low in the sample of ramp configurations, it comprised an overwhelming portion of its own ramp configuration (47%). The other three types of ramps with over 10% of their population present in the sample were: slip-ramps (23.45%), the two-way ramps (18.75%), and the rest area/truck scale/vista point ramps (12.66%).

The independent variables most often found by studies to be statistically significant were: ramp AADT, mainline freeway AADT, area type (rural/urban), ramp type (off/on), ramp configuration, length of SCL, ramp length. Ramp geometry in studies that developed accident prediction models found to be a much weaker variable than main line traffic volume and ramp traffic volume. The studies did not suggest that geometric variables are unimportant, rather geometric factors are generally improved to a point where further variance in geometric features has little influence on accidents. The general consensus of many studies is that traffic volume is the strongest predictor of accidents on ramps. Potential variables affecting accident occurrence on acceleration/deceleration lanes according to a study were: ramp AADT; mainline freeway AADT; average lane width; right shoulder width; acceleration/ deceleration lane length; ramp area type (urban/rural), and; ramp configuration. The key variables were ramp AADT, main line AADT, and SCL length. Higher traffic volumes were associated with higher accidents. The effect of acceleration lane length on accident rate was significant when merging traffic percentage exceeded 6 percent of the main line traffic volume. As the percentage of merging traffic increases beyond this volume, the additional length of acceleration lane provides a significant reduction in accidents. The effect was not as great for deceleration lanes compared to acceleration lane. Truck accident studies are even more adamant about speed change lane, claiming that the current AASHTO requirements for deceleration lane lengths are not sufficient for trucks.

As a whole, research findings indicated that it is better to design ramps with flat horizontal curves (except in rural areas) avoiding the maximum degree of curvature, speed, and superelevation. Sharp curves at the end of the ramps and sudden changes from a straight alignment to sharp curves should be avoided. Ramp curves tend to be more critical than highway curves. Studies indicated that except for loop ramps in rural areas, all right-hand side and outer-connection ramps showed an increases in accident rates with increasing curvature. Outer-connection ramps in urban areas showed an increase in accident rates with increasing average daily traffic (ADT). Straight outer-connections have lower accident rates than curved connections in urban and rural areas for all ADTs, except 0 to 499 in urban areas. Rural loops with low curvature have higher accident rates than rural loops with high curvature, while the reverse is true for urban loops. In designing horizontal curves to accommodate trucks, it is important to check for both rollover and skidding potential to determine which controls the design. Abrupt changes in compound curves is associated with truck accidents. Many tank truck overturns were produced on ramps where the sharpness of the curve increased at the end of the ramp.

A good portion of the accidents associated with ramps occurs at the entrance or exit of ramps. Entrance terminal accidents estimated by a previous study to be as high as 52% for the on-ramps. About 44 percent of the off-ramp accidents occurred in the diverging area. While additional lanes improve the safety at entrance terminals, studies indicated no safety benefits as a result of auxiliary lanes at off-ramps compared to direct off-ramp designs. Studies found off-ramps with speed-change lanes have a lower accident rate than those ramps without speed-change lanes. Deceleration lanes are generally safer than acceleration lanes, regardless of the length of the speed change lanes and the percentage of diverging and merging traffic.

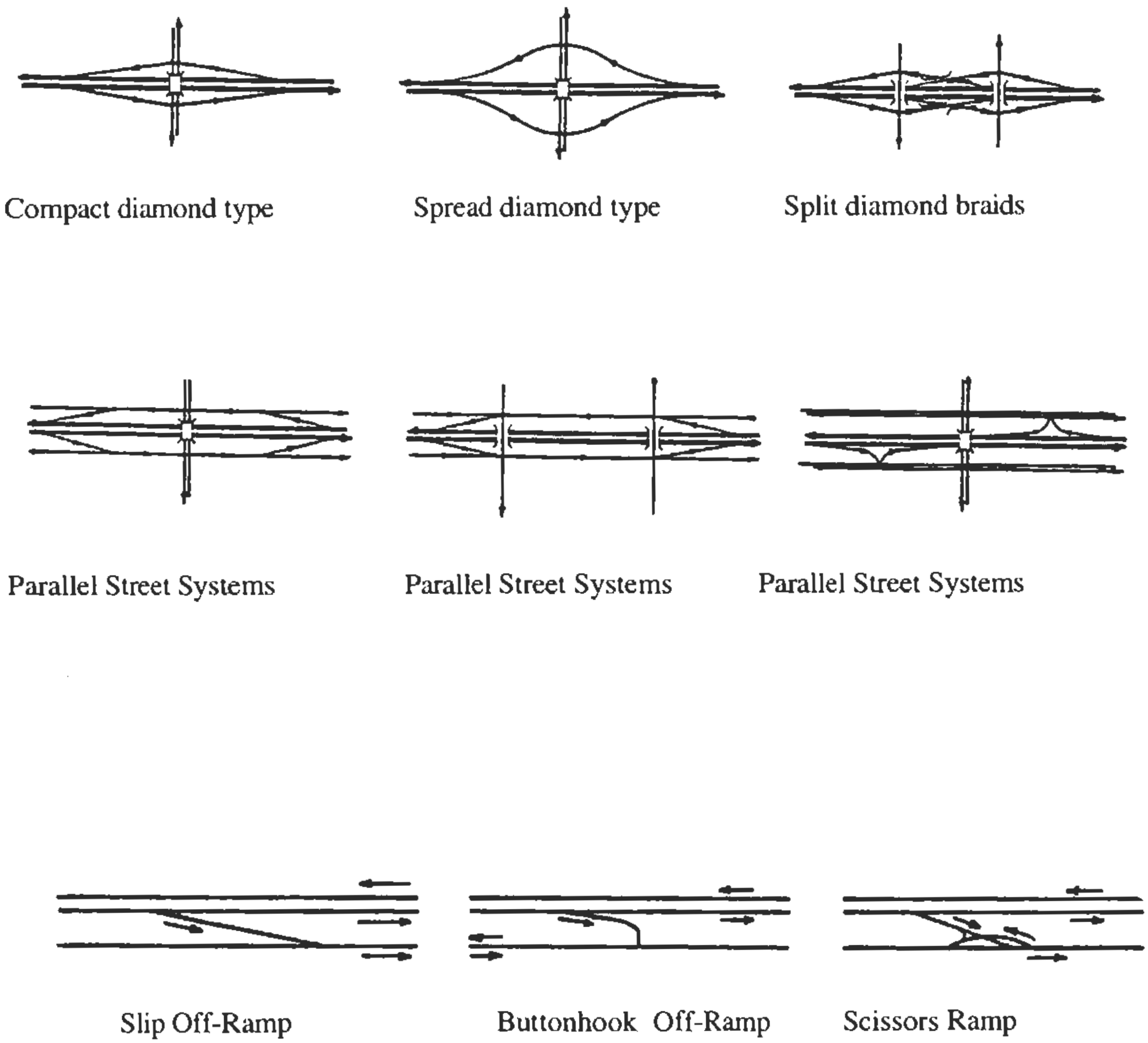
The most common accident in the entrance terminal is the rear-end collision. These accidents can be reduced by changing the merging maneuver at the entrance terminal to a less complex lane-changing maneuver through the use of a parallel acceleration lane. Other studies found that rear-end accidents on urban off-ramps of four configurations (diamond, parclo loop, free-flow loop, and outer connection ramps) were generally related to the operation of the cross-road ramp terminal, rather than to the geometric design of the ramp itself.

Steeper grade (positive or negative) can be associated with increased accident rates. As the vertical grade of a highway increases, the accident-involvement rate also increases (depending on the length of the grade). Substantial downgrades leading to tight ramp curves contribute to traffic accidents. More conservative grade allowances of 3 or 4% for ramp down grades compared to the 8% found in the AASHTO "green book" has been suggested.

Truck loss of control on ramps is predominantly due to rollover and jackknifing. Jackknife accidents occur mainly at sites with low pavement friction during wet condition. Truck rollover accidents occur on ramps where truck speed is higher than ramp design speed. Design of ramps must also provide for adequate width to accommodate offtracking during low-speed and high-speed. Lowered friction levels on high-speed ramps can contribute to truck accidents. Therefore, it recommends the resurfacing of ramps with high-friction overlays. Poor transitions to superelevation contribute to truck accidents, such as rollovers and jackknifing. Regardless of the urban/rural location of the highway, trucks have more accidents on the off-ramps than on the on-ramps.

Finally, a separate analysis of half diamond ramps with discussion of analysis results is presented in Appendix F.

## Appendix A



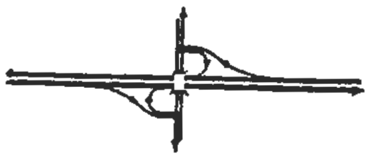
Compact diamond type — Spread diamond type — Split diamond braids

Parallel Street Systems — Parallel Street Systems — Parallel Street Systems

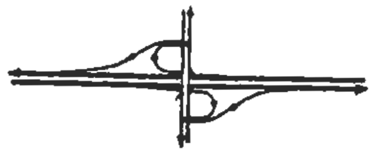
Slip Off-Ramp — Buttonhook Off-Ramp — Scissors Ramp

**Figure 1 Typical Local Street Interchanges**

## Appendix A



Parclo Interchanges



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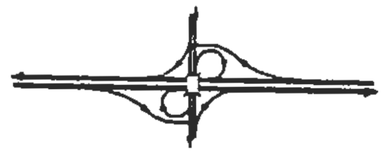
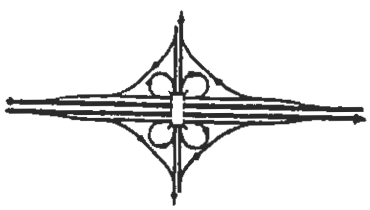
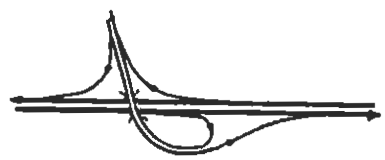


Parclo Interchanges



Cloverleaf Interchanges

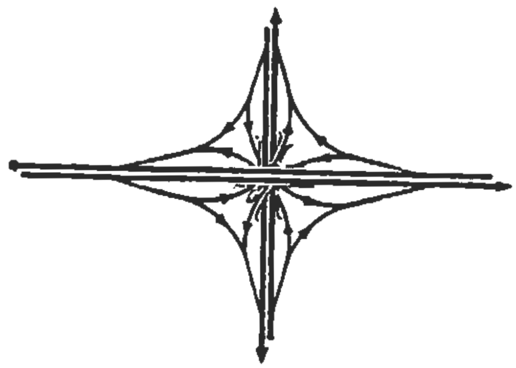
Trumpet



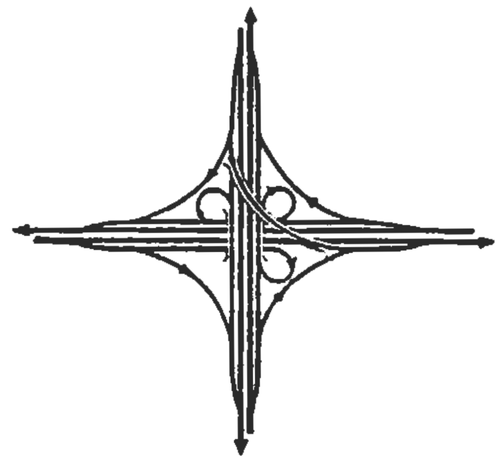
Trumpet

**Figure 2 Typical Local Street Interchanges**

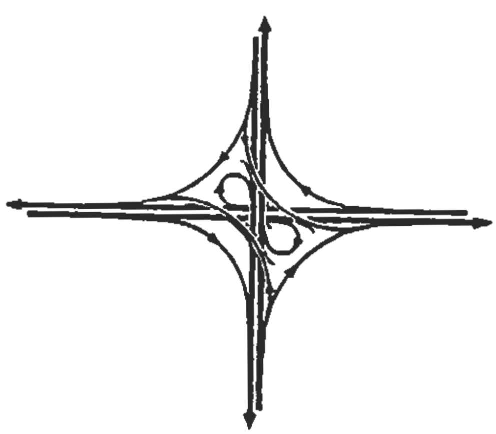
## Appendix A



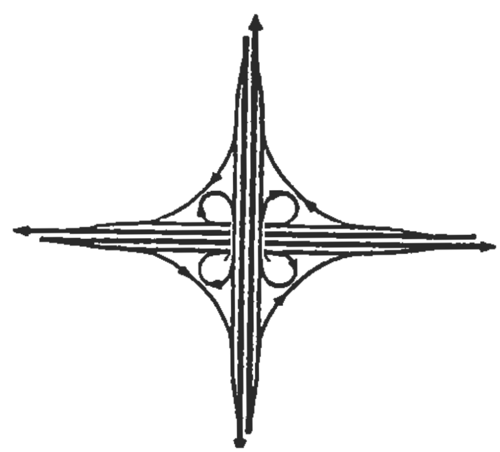
Direct connections



Three quadrant cloverleaf



Two-loop, two-direct connection

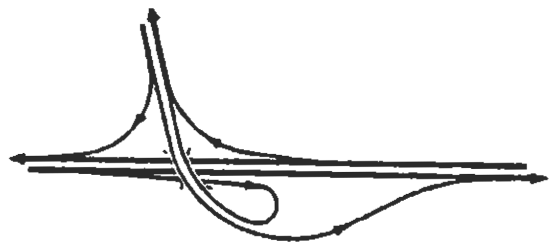


Cloverleaf with collector-distributor roa

**Figure 3 Typical Freeway-to-Freeway Interchange**

## Appendix A

Freeway Terminal Junction



Freeway Terminal Junction

Freeway Terminal Junction

Freeway Terminal Junction

**Figure 4 Typical Freeway-to-Freeway Interchange**

# Appendix B

## Descriptive Statistics on Individual Ramp Configurations

**Note:** 60 tables provided in this Appendix provide detail information on 15 ramp configurations. (Each configuration occurs in urban and rural setting and as on-ramp or off-ramp, thus 15 x 2 x 2 =60). Each table precedes with a line of information specifying the ramp configuration and information on ramp type (on/off) and area location (urban/ rural setting). The following legends apply to each table.

*** Legend**

| | |
|---|---|
| N | = Number of ramps for this configuration |
| TACC | = Total Accidents |
| FACC | = Fatal Accidents |
| IACC | = Injury Accidents |
| FIACC | = Fatal + Injury Accidents |
| MVACC | = Multi-vehicle Accidents |
| WACC | = Wet Accidents |
| DACC | = Dark Accidents |
| XVOL | = Ramp Cross Street Traffic Volume |
| RVOL | = Ramp Traffic Volume |
| FRATE | = Fatal Accident Rate |
| FIRATE | = Fatal + Injury Accident Rate |
| TRATE | = Total Accident Rate |
| WRATE | = Wet Accident Rate |
| DRATE | = Dark Accident Rate |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**buttonhook**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 111 | 1.3513514 | 1.7666025 | 0 | 8.0000000 |
| FACC | 111 | 0.0090090 | 0.0949158 | 0 | 1.0000000 |
| IACC | 111 | 0.4774775 | 0.9327072 | 0 | 5.0000000 |
| FIACC | 111 | 0.4864865 | 0.9328828 | 0 | 5.0000000 |
| MVACC | 111 | 0.5585586 | 1.3258595 | 0 | 8.0000000 |
| WACC | 111 | 0.0630631 | 0.2441787 | 0 | 1.0000000 |
| DACC | 111 | 0.3963964 | 0.6505841 | 0 | 2.0000000 |
| XVOL | 111 | 0.7531532 | 0.8146187 | 0 | 3.7000000 |
| RVOL | 111 | 0.8185586 | 0.8891281 | 0.0200000 | 4.0500000 |
| FRATE | 111 | 0.0433063 | 0.4562602 | 0 | 4.8070000 |
| FIRATE | 111 | 1.6695495 | 8.1557984 | 0 | 82.1900000 |
| TRATE | 111 | 4.1234685 | 11.3893260 | 0 | 82.1900000 |
| WRATE | 111 | 0.1269562 | 0.7101832 | 0 | 6.5200000 |
| DRATE | 111 | 1.3286379 | 5.5941815 | 0 | 54.7933333 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**diamond3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 92 | 1.0108696 | 1.8126210 | 0 | 9.0000000 |
| FACC | 92 | 0 | 0 | 0 | 0 |
| IACC | 92 | 0.3260870 | 0.7428590 | 0 | 4.0000000 |
| FIACC | 92 | 0.3260870 | 0.7428590 | 0 | 4.0000000 |
| MVACC | 92 | 0.7717391 | 1.5342483 | 0 | 7.0000000 |
| WACC | 92 | 0.0652174 | 0.2482620 | 0 | 1.0000000 |
| DACC | 92 | 0.2608696 | 0.6266879 | 0 | 3.0000000 |
| XVOL | 92 | 1.3391304 | 1.5638749 | 0 | 7.5000000 |
| RVOL | 92 | 1.4567391 | 1.7100402 | 0.0200000 | 8.2100000 |
| FRATE | 92 | 0 | 0 | 0 | 0 |
| FIRATE | 92 | 0.1832609 | 0.5639307 | 0 | 4.3500000 |
| TRATE | 92 | 0.6898913 | 1.4253101 | 0 | 9.4500000 |
| DIST | 92 | 5.8369565 | 3.1000786 | 1.0000000 | 11.0000000 |
| WRATE | 92 | 0.0184530 | 0.0757196 | 0 | 0.4950000 |
| DRATE | 92 | 0.2745892 | 1.2458816 | 0 | 9.4500000 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**diamond4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 841 | 1.0927467 | 2.0790239 | 0 | 17.0000000 |
| FACC | 841 | 0.0190250 | 0.1366940 | 0 | 1.0000000 |
| IACC | 841 | 0.3828775 | 0.8470632 | 0 | 7.0000000 |
| FIACC | 841 | 0.4019025 | 0.8702469 | 0 | 7.0000000 |
| MVACC | 841 | 0.7205707 | 1.8045360 | 0 | 17.0000000 |
| WACC | 841 | 0.1379310 | 0.4472136 | 0 | 4.0000000 |
| DACC | 841 | 0.3305589 | 0.7512724 | 0 | 5.0000000 |
| XVOL | 841 | 0.8777646 | 1.2325516 | 0 | 9.3000000 |
| RVOL | 841 | 0.9472295 | 1.3464071 | 0 | 10.1800000 |
| FRATE | 841 | 0.0417015 | 0.4603627 | 0 | 8.2650000 |
| FIRATE | 841 | 0.7737931 | 3.1071513 | 0 | 45.6600000 |
| TRATE | 841 | 1.7295006 | 4.3968616 | 0 | 45.6600000 |
| WRATE | 841 | 0.1937981 | 1.0447615 | 0 | 15.6600000 |
| DRATE | 841 | 0.6928683 | 2.7112742 | 0 | 36.5300000 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**dir/semi3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 40 | 0.8000000 | 1.1591332 | 0 | 5.0000000 |
| FACC | 40 | 0 | 0 | 0 | 0 |
| IACC | 40 | 0.4500000 | 0.8458041 | 0 | 4.0000000 |
| FIACC | 40 | 0.4500000 | 0.8458041 | 0 | 4.0000000 |
| MVACC | 40 | 0.2250000 | 0.6196566 | 0 | 3.0000000 |
| WACC | 40 | 0.0500000 | 0.2207214 | 0 | 1.0000000 |
| DACC | 40 | 0.3500000 | 0.5334936 | 0 | 2.0000000 |
| XVOL | 40 | 3.3575000 | 5.3689940 | 0.1000000 | 27.0000000 |
| RVOL | 40 | 3.5972500 | 5.9066985 | 0.0900000 | 29.5700000 |
| FRATE | 40 | 0 | 0 | 0 | 0 |
| FIRATE | 40 | 0.6912500 | 2.5939448 | 0 | 15.2200000 |
| TRATE | 40 | 1.0672500 | 2.9171298 | 0 | 15.2200000 |
| WRATE | 40 | 0.0030833 | 0.0137414 | 0 | 0.0700000 |
| DRATE | 40 | 0.3922917 | 1.5071332 | 0 | 9.4500000 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**dir/semi4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 49 | 1.2448980 | 1.7740093 | 0 | 7.0000000 |
| FACC | 49 | 0 | 0 | 0 | 0 |
| IACC | 49 | 0.4693878 | 0.7932539 | 0 | 3.0000000 |
| FIACC | 49 | 0.4693878 | 0.7932539 | 0 | 3.0000000 |
| MVACC | 49 | 0.4693878 | 0.8190961 | 0 | 3.0000000 |
| WACC | 49 | 0.1224490 | 0.4844521 | 0 | 3.0000000 |
| DACC | 49 | 0.4489796 | 0.6788846 | 0 | 2.0000000 |
| XVOL | 49 | 1.9224490 | 2.6830692 | 0.1000000 | 13.3000000 |
| RVOL | 49 | 2.1032653 | 2.9417210 | 0.0700000 | 14.6000000 |
| FRATE | 49 | 0 | 0 | 0 | 0 |
| FIRATE | 49 | 0.4195918 | 1.4801829 | 0 | 10.1500000 |
| TRATE | 49 | 1.0097959 | 2.0473382 | 0 | 10.1500000 |
| WRATE | 49 | 0.0688309 | 0.3027513 | 0 | 1.9600000 |
| DRATE | 49 | 0.4662119 | 1.4515969 | 0 | 9.7800000 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**direct**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 19 | 2.2105263 | 2.7804665 | 0 | 9.0000000 |
| FACC | 19 | 0.0526316 | 0.2294157 | 0 | 1.0000000 |
| IACC | 19 | 0.9473684 | 1.2681432 | 0 | 4.0000000 |
| FIACC | 19 | 1.0000000 | 1.3743685 | 0 | 4.0000000 |
| MVACC | 19 | 0.8421053 | 1.1672931 | 0 | 4.0000000 |
| WACC | 19 | 0.1578947 | 0.3746343 | 0 | 1.0000000 |
| DACC | 19 | 0.8421053 | 1.2588865 | 0 | 4.0000000 |
| XVOL | 19 | 2.8578947 | 1.8771479 | 0.1000000 | 6.1000000 |
| RVOL | 19 | 3.0500000 | 1.9432533 | 0.0700000 | 6.6800000 |
| FRATE | 19 | 0.0085789 | 0.0373948 | 0 | 0.1630000 |
| FIRATE | 19 | 0.2352632 | 0.2969917 | 0 | 0.9900000 |
| TRATE | 19 | 0.5363158 | 0.5852370 | 0 | 2.0300000 |
| WRATE | 19 | 0.0349781 | 0.0846815 | 0 | 0.2537500 |
| DRATE | 19 | 0.1820175 | 0.2408641 | 0 | 0.6533333 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**loopleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 4 | 4.0000000 | 3.5590261 | 1.0000000 | 8.0000000 |
| FACC | 4 | 0.2500000 | 0.5000000 | 0 | 1.0000000 |
| IACC | 4 | 0.5000000 | 0.5773503 | 0 | 1.0000000 |
| FIACC | 4 | 0.7500000 | 0.9574271 | 0 | 2.0000000 |
| MVACC | 4 | 1.2500000 | 1.2583057 | 0 | 3.0000000 |
| WACC | 4 | 0.2500000 | 0.5000000 | 0 | 1.0000000 |
| DACC | 4 | 1.5000000 | 1.9148542 | 0 | 4.0000000 |
| XVOL | 4 | 0.5500000 | 0.2645751 | 0.2000000 | 0.8000000 |
| RVOL | 4 | 0.6150000 | 0.2859487 | 0.2400000 | 0.9100000 |
| FRATE | 4 | 0.2740000 | 0.5480000 | 0 | 1.0960000 |
| FIRATE | 4 | 0.8875000 | 1.0793632 | 0 | 2.1900000 |
| TRATE | 4 | 5.6900000 | 3.3413470 | 1.7600000 | 8.7700000 |
| WRATE | 4 | 0.2740625 | 0.5481250 | 0 | 1.0962500 |
| DRATE | 4 | 1.7745833 | 2.1597700 | 0 | 4.3850000 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**loopleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 25 | 2.1600000 | 4.4128600 | 0 | 21.0000000 |
| FACC | 25 | 0.0400000 | 0.2000000 | 0 | 1.0000000 |
| IACC | 25 | 0.8400000 | 2.0550750 | 0 | 10.0000000 |
| FIACC | 25 | 0.8800000 | 2.0477630 | 0 | 10.0000000 |
| MVACC | 25 | 1.5200000 | 4.3312816 | 0 | 21.0000000 |
| WACC | 25 | 0.1600000 | 0.5537749 | 0 | 2.0000000 |
| DACC | 25 | 0.2400000 | 0.4358899 | 0 | 1.0000000 |
| XVOL | 25 | 1.2320000 | 1.8254497 | 0 | 8.5000000 |
| RVOL | 25 | 1.3372000 | 2.0013215 | 0.0300000 | 9.2900000 |
| FRATE | 25 | 0.0332000 | 0.1660000 | 0 | 0.8300000 |
| FIRATE | 25 | 0.8444000 | 1.5678491 | 0 | 5.5900000 |
| TRATE | 25 | 3.5464000 | 7.9889647 | 0 | 39.1300000 |
| WRATE | 25 | 0.0533511 | 0.1883771 | 0 | 0.7960000 |
| DRATE | 25 | 0.3001137 | 0.8737495 | 0 | 3.5133333 |

Ramp Type= **Off** Urban/Rural =**Rural** DESCR=**loopnoleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 14 | 1.2142857 | 2.2592910 | 0 | 8.0000000 |
| FACC | 14 | 0 | 0 | 0 | 0 |
| IACC | 14 | 0.4285714 | 1.0894096 | 0 | 4.0000000 |
| FIACC | 14 | 0.4285714 | 1.0894096 | 0 | 4.0000000 |
| MVACC | 14 | 0.1428571 | 0.3631365 | 0 | 1.0000000 |
| WACC | 14 | 0.2142857 | 0.5789342 | 0 | 2.0000000 |
| DACC | 14 | 0.6428571 | 1.4468609 | 0 | 4.0000000 |
| XVOL | 14 | 1.1928571 | 1.0380931 | 0 | 3.6000000 |
| RVOL | 14 | 1.3014286 | 1.1350151 | 0.0400000 | 3.9400000 |
| FRATE | 14 | 0 | 0 | 0 | 0 |
| FIRATE | 14 | 0.2385714 | 0.6189055 | 0 | 2.2800000 |
| TRATE | 14 | 1.2050000 | 2.5930907 | 0 | 9.4500000 |
| WRATE | 14 | 0.0905357 | 0.2492068 | 0 | 0.8775000 |
| DRATE | 14 | 0.6257143 | 1.3901520 | 0 | 4.7250000 |

Ramp Type= **Off** Urban/Rural =**Rural** DESCR=**loopnoleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 11 | 0.6363636 | 1.2060454 | 0 | 3.0000000 |
| FACC | 11 | 0.0909091 | 0.3015113 | 0 | 1.0000000 |
| IACC | 11 | 0.4545455 | 0.9341987 | 0 | 3.0000000 |
| FIACC | 11 | 0.5454545 | 1.0357255 | 0 | 3.0000000 |
| MVACC | 11 | 0.0909091 | 0.3015113 | 0 | 1.0000000 |
| WACC | 11 | 0.0909091 | 0.3015113 | 0 | 1.0000000 |
| DACC | 11 | 0.0909091 | 0.3015113 | 0 | 1.0000000 |
| XVOL | 11 | 0.6000000 | 0.7523297 | 0 | 2.4000000 |
| RVOL | 11 | 0.6572727 | 0.8327916 | 0.0200000 | 2.6600000 |
| FRATE | 11 | 0.0915455 | 0.3036219 | 0 | 1.0070000 |
| FIRATE | 11 | 4.4990909 | 13.6730688 | 0 | 45.6600000 |
| TRATE | 11 | 4.5909091 | 13.6580653 | 0 | 45.6600000 |
| WRATE | 11 | 0.0551515 | 0.1829169 | 0 | 0.6066667 |
| DRATE | 11 | 0.0551515 | 0.1829169 | 0 | 0.6066667 |

Ramp Type= **Off** Urban/Rural =**Rural** DESCR=**restarea**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 119 | 1.4453782 | 2.2349211 | 0 | 11.0000000 |
| FACC | 119 | 0.0084034 | 0.0916698 | 0 | 1.0000000 |
| IACC | 119 | 0.1512605 | 0.4041869 | 0 | 2.0000000 |
| FIACC | 119 | 0.1596639 | 0.4113474 | 0 | 2.0000000 |
| MVACC | 119 | 0.9495798 | 1.7066606 | 0 | 9.0000000 |
| WACC | 119 | 0.0924370 | 0.2908665 | 0 | 1.0000000 |
| DACC | 119 | 0.6134454 | 1.1055273 | 0 | 7.0000000 |
| XVOL | 119 | 1.3193277 | 1.4120713 | 0 | 6.3000000 |
| RVOL | 119 | 1.4410924 | 1.5374653 | 0 | 6.9000000 |
| FRATE | 119 | 0.0020168 | 0.0220008 | 0 | 0.2400000 |
| FIRATE | 119 | 0.1384874 | 0.5055315 | 0 | 3.1100000 |
| TRATE | 119 | 2.1096639 | 7.7883665 | 0 | 78.2700000 |
| WRATE | 119 | 0.0453494 | 0.1522043 | 0 | 0.7000000 |
| DRATE | 119 | 1.0227620 | 4.1060696 | 0 | 39.1350000 |

Ramp Type= **Off** Urban/Rural =**Rural** DESCR=**scissors**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 37 | 1.7027027 | 2.2343886 | 0 | 8.0000000 |
| FACC | 37 | 0.0270270 | 0.1643990 | 0 | 1.0000000 |
| IACC | 37 | 0.7837838 | 1.0576477 | 0 | 3.0000000 |
| FIACC | 37 | 0.8108108 | 1.0498105 | 0 | 3.0000000 |
| MVACC | 37 | 1.0810811 | 1.8764384 | 0 | 7.0000000 |
| WACC | 37 | 0.1351351 | 0.3465835 | 0 | 1.0000000 |
| DACC | 37 | 0.6756757 | 1.1560001 | 0 | 6.0000000 |
| XVOL | 37 | 1.5864865 | 1.3254270 | 0.1000000 | 7.0000000 |
| RVOL | 37 | 1.7275676 | 1.4555324 | 0.0500000 | 7.6700000 |
| FRATE | 37 | 0.0667027 | 0.4057367 | 0 | 2.4680000 |
| FIRATE | 37 | 0.5532432 | 0.8686741 | 0 | 4.1260000 |
| TRATE | 37 | 1.1881081 | 2.4513317 | 0 | 14.4200000 |
| WRATE | 37 | 0.0692342 | 0.1871681 | 0 | 0.7900000 |
| DRATE | 37 | 0.6037741 | 2.0436827 | 0 | 12.3600000 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**slip3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 0 | . | . | . | . |
| FACC | 0 | . | . | . | . |
| IACC | 0 | . | . | . | . |
| FIACC | 0 | . | . | . | . |
| MVACC | 0 | . | . | . | . |
| WACC | 0 | . | . | . | . |
| DACC | 0 | . | . | . | . |
| XVOL | 0 | . | . | . | . |
| RVOL | 0 | . | . | . | . |
| FRATE | 0 | . | . | . | . |
| FIRATE | 0 | . | . | . | . |
| TRATE | 0 | . | . | . | . |
| WRATE | 0 | . | . | . | . |
| DRATE | 0 | . | . | . | . |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**slip4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 1 | 0 | . | 0 | 0 |
| FACC | 1 | 0 | . | 0 | 0 |
| IACC | 1 | 0 | . | 0 | 0 |
| FIACC | 1 | 0 | . | 0 | 0 |
| MVACC | 1 | 0 | . | 0 | 0 |
| WACC | 1 | 0 | . | 0 | 0 |
| DACC | 1 | 0 | . | 0 | 0 |
| XVOL | 1 | 0.1000000 | . | 0.1000000 | 0.1000000 |
| RVOL | 1 | 0.0800000 | . | 0.0800000 | 0.0800000 |
| FRATE | 1 | 0 | . | 0 | 0 |
| FIRATE | 1 | 0 | . | 0 | 0 |
| TRATE | 1 | 0 | . | 0 | 0 |
| WRATE | 1 | 0 | . | 0 | 0 |
| DRATE | 1 | 0 | . | 0 | 0 |

Ramp Type= **Off** Urban/Rural **=Rural** DESCR=**split**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 2 | 1.0000000 | 1.4142136 | 0 | 2.0000000 |
| FACC | 2 | 0 | 0 | 0 | 0 |
| IACC | 2 | 1.0000000 | 1.4142136 | 0 | 2.0000000 |
| FIACC | 2 | 1.0000000 | 1.4142136 | 0 | 2.0000000 |
| MVACC | 2 | 0.5000000 | 0.7071068 | 0 | 1.0000000 |
| WACC | 2 | 0.5000000 | 0.7071068 | 0 | 1.0000000 |
| DACC | 2 | 0 | 0 | 0 | 0 |
| XVOL | 2 | 7.0500000 | 6.7175144 | 2.3000000 | 11.8000000 |
| RVOL | 2 | 7.7000000 | 7.3821948 | 2.4800000 | 12.9200000 |
| FRATE | 2 | 0 | 0 | 0 | 0 |
| FIRATE | 2 | 0.0750000 | 0.1060660 | 0 | 0.1500000 |
| TRATE | 2 | 0.0750000 | 0.1060660 | 0 | 0.1500000 |
| WRATE | 2 | 0.0375000 | 0.0530330 | 0 | 0.0750000 |
| DRATE | 2 | 0 | 0 | 0 | 0 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**buttonhook**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 499 | 5.4108216 | 5.6725899 | 0 | 42.0000000 |
| FACC | 499 | 0.0160321 | 0.1257248 | 0 | 1.0000000 |
| IACC | 499 | 1.8296593 | 2.3975058 | 0 | 19.0000000 |
| FIACC | 499 | 1.8456914 | 2.4111181 | 0 | 19.0000000 |
| MVACC | 499 | 3.2184369 | 4.3669971 | 0 | 30.0000000 |
| WACC | 499 | 0.8396794 | 1.6520490 | 0 | 24.0000000 |
| DACC | 499 | 1.8416834 | 2.3722344 | 0 | 25.0000000 |
| XVOL | 499 | 4.7458918 | 3.8627765 | 0 | 22.9000000 |
| RVOL | 499 | 5.0327455 | 4.2256676 | 0.0300000 | 25.0800000 |
| FRATE | 499 | 0.0114790 | 0.1288163 | 0 | 2.1230000 |
| FIRATE | 499 | 0.5677756 | 1.2226280 | 0 | 14.9900000 |
| TRATE | 499 | 1.6131864 | 2.6071293 | 0 | 33.7700000 |
| WRATE | 499 | 0.2694204 | 0.8534159 | 0 | 13.5080000 |
| DRATE | 499 | 0.5802522 | 1.3424963 | 0 | 18.2600000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**diamond3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 160 | 6.6937500 | 6.3859091 | 0 | 37.0000000 |
| FACC | 160 | 0.0375000 | 0.1905800 | 0 | 1.0000000 |
| IACC | 160 | 2.6625000 | 2.9670889 | 0 | 19.0000000 |
| FIACC | 160 | 2.7000000 | 2.9922331 | 0 | 19.0000000 |
| MVACC | 160 | 5.1437500 | 5.5918257 | 0 | 35.0000000 |
| WACC | 160 | 0.9937500 | 1.7997095 | 0 | 12.0000000 |
| DACC | 160 | 1.7375000 | 2.1026713 | 0 | 12.0000000 |
| XVOL | 160 | 6.8331250 | 5.3123059 | 0.5000000 | 29.2000000 |
| RVOL | 160 | 7.3558750 | 5.8459524 | 0.5400000 | 32.0100000 |
| FRATE | 160 | 0.0111125 | 0.0856336 | 0 | 1.0150000 |
| FIRATE | 160 | 0.4668750 | 0.6671560 | 0 | 6.0900000 |
| TRATE | 160 | 1.1195625 | 1.3669823 | 0 | 9.8300000 |
| WRATE | 160 | 0.1518493 | 0.3454330 | 0 | 3.0100000 |
| DRATE | 160 | 0.2915496 | 0.3768905 | 0 | 1.9600000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**diamond4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 2193 | 9.3693570 | 10.8343706 | 0 | 99.0000000 |
| FACC | 2193 | 0.0259918 | 0.1619882 | 0 | 2.0000000 |
| IACC | 2193 | 3.9010488 | 4.6318640 | 0 | 46.0000000 |
| FIACC | 2193 | 3.9270406 | 4.6461627 | 0 | 46.0000000 |
| MVACC | 2193 | 7.9844961 | 10.1331346 | 0 | 98.0000000 |
| WACC | 2193 | 1.3210214 | 2.3668946 | 0 | 33.0000000 |
| DACC | 2193 | 2.5253078 | 3.0871500 | 0 | 22.0000000 |
| XVOL | 2193 | 6.1149111 | 4.6661472 | 0.1000000 | 45.0000000 |
| RVOL | 2193 | 6.5139535 | 5.0997772 | 0.0100000 | 49.2800000 |
| FRATE | 2193 | 0.0062535 | 0.0749332 | 0 | 2.9780000 |
| FIRATE | 2193 | 0.7665253 | 2.5679519 | 0 | 96.0800000 |
| TRATE | 2193 | 1.9674008 | 7.6767981 | 0 | 198.3900000 |
| WRATE | 2193 | 0.2645482 | 1.4683084 | 0 | 54.1050000 |
| DRATE | 2193 | 0.5596604 | 2.8390527 | 0 | 98.0400000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**dir/semi3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 363 | 5.4710744 | 8.7416015 | 0 | 117.0000000 |
| FACC | 363 | 0.0468320 | 0.2362451 | 0 | 2.0000000 |
| IACC | 363 | 2.0798898 | 3.0104253 | 0 | 26.0000000 |
| FIACC | 363 | 2.1267218 | 3.0266636 | 0 | 26.0000000 |
| MVACC | 363 | 2.7217631 | 4.7567626 | 0 | 32.0000000 |
| WACC | 363 | 1.0192837 | 1.9867413 | 0 | 14.0000000 |
| DACC | 363 | 2.3498623 | 5.0299016 | 0 | 82.0000000 |
| XVOL | 363 | 13.1752066 | 11.7355291 | 0.1000000 | 64.0000000 |
| RVOL | 363 | 13.9816253 | 12.9668736 | 0.0600000 | 70.0800000 |
| FRATE | 363 | 0.0035014 | 0.0211957 | 0 | 0.2370000 |
| FIRATE | 363 | 0.1884848 | 0.2661183 | 0 | 2.6000000 |
| TRATE | 363 | 0.4555372 | 0.6698474 | 0 | 9.1300000 |
| WRATE | 363 | 0.0832336 | 0.1470661 | 0 | 1.1175000 |
| DRATE | 363 | 0.1898803 | 0.3124045 | 0 | 3.6520000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**dir/semi4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 387 | 5.6692506 | 6.6946085 | 0 | 47.0000000 |
| FACC | 387 | 0.0310078 | 0.1878975 | 0 | 2.0000000 |
| IACC | 387 | 2.2144703 | 2.7500348 | 0 | 23.0000000 |
| FIACC | 387 | 2.2454780 | 2.7886147 | 0 | 23.0000000 |
| MVACC | 387 | 3.9431525 | 5.9385343 | 0 | 47.0000000 |
| WACC | 387 | 0.8087855 | 1.4122430 | 0 | 11.0000000 |
| DACC | 387 | 1.7545220 | 2.1878608 | 0 | 18.0000000 |
| XVOL | 387 | 6.1586563 | 4.8878401 | 0 | 34.0000000 |
| RVOL | 387 | 6.6673902 | 5.3139279 | 0.0500000 | 37.2300000 |
| FRATE | 387 | 0.0057364 | 0.0652740 | 0 | 1.2180000 |
| FIRATE | 387 | 0.4249354 | 0.6717873 | 0 | 7.6100000 |
| TRATE | 387 | 1.0619121 | 1.4592982 | 0 | 15.2200000 |
| WRATE | 387 | 0.1333667 | 0.2466853 | 0 | 1.6600000 |
| DRATE | 387 | 0.3272626 | 0.4918484 | 0 | 3.8066667 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**direct**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 250 | 8.7040000 | 12.1543117 | 0 | 83.0000000 |
| FACC | 250 | 0.1160000 | 0.3989746 | 0 | 3.0000000 |
| IACC | 250 | 3.1440000 | 4.1762457 | 0 | 25.0000000 |
| FIACC | 250 | 3.2600000 | 4.3298256 | 0 | 27.0000000 |
| MVACC | 250 | 4.8600000 | 8.6405461 | 0 | 67.0000000 |
| WACC | 250 | 1.9360000 | 3.5403446 | 0 | 31.0000000 |
| DACC | 250 | 3.2000000 | 4.9194312 | 0 | 42.0000000 |
| XVOL | 250 | 15.1392000 | 13.2061224 | 0 | 80.0000000 |
| RVOL | 250 | 16.0500800 | 14.5995841 | 0 | 87.6000000 |
| FRATE | 250 | 0.0091360 | 0.0394637 | 0 | 0.3650000 |
| FIRATE | 250 | 0.3070800 | 0.8322630 | 0 | 10.0000000 |
| TRATE | 250 | 1.0975200 | 6.9351034 | 0 | 107.3300000 |
| WRATE | 250 | 0.1399853 | 0.3166131 | 0 | 3.7515789 |
| DRATE | 250 | 0.2323961 | 0.5410222 | 0 | 7.5031579 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**loopleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 12 | 7.0000000 | 9.0453403 | 0 | 32.0000000 |
| FACC | 12 | 0 | 0 | 0 | 0 |
| IACC | 12 | 1.7500000 | 2.3011855 | 0 | 8.0000000 |
| FIACC | 12 | 1.7500000 | 2.3011855 | 0 | 8.0000000 |
| MVACC | 12 | 5.8333333 | 9.0134580 | 0 | 31.0000000 |
| WACC | 12 | 0.8333333 | 0.8348471 | 0 | 2.0000000 |
| DACC | 12 | 1.3333333 | 1.5569979 | 0 | 5.0000000 |
| XVOL | 12 | 5.5916667 | 5.9527623 | 0.5000000 | 22.0000000 |
| RVOL | 12 | 6.1141667 | 6.5253651 | 0.5300000 | 24.0900000 |
| FRATE | 12 | 0 | 0 | 0 | 0 |
| FIRATE | 12 | 0.3866667 | 0.5932244 | 0 | 1.9700000 |
| TRATE | 12 | 1.0100000 | 0.6695317 | 0 | 1.9700000 |
| WRATE | 12 | 0.1699033 | 0.2101437 | 0 | 0.5700000 |
| DRATE | 12 | 0.3134090 | 0.3906719 | 0 | 1.1400000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**loopleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 185 | 7.2810811 | 7.9205922 | 0 | 39.0000000 |
| FACC | 185 | 0.0162162 | 0.1266489 | 0 | 1.0000000 |
| IACC | 185 | 2.7297297 | 3.1142087 | 0 | 17.0000000 |
| FIACC | 185 | 2.7459459 | 3.1094696 | 0 | 17.0000000 |
| MVACC | 185 | 5.0270270 | 6.5958093 | 0 | 31.0000000 |
| WACC | 185 | 1.0162162 | 1.5758906 | 0 | 10.0000000 |
| DACC | 185 | 2.2810811 | 2.7695783 | 0 | 18.0000000 |
| XVOL | 185 | 5.3394595 | 3.9016036 | 0.1000000 | 22.0000000 |
| RVOL | 185 | 5.6358919 | 4.3454501 | 0.0800000 | 24.1300000 |
| FRATE | 185 | 0.0076054 | 0.0862270 | 0 | 1.1610000 |
| FIRATE | 185 | 0.7392432 | 2.1656808 | 0 | 27.4000000 |
| TRATE | 185 | 1.6637297 | 3.1605463 | 0 | 36.5300000 |
| WRATE | 185 | 0.1916954 | 0.3227278 | 0 | 2.3725000 |
| DRATE | 185 | 0.5983756 | 1.1866396 | 0 | 9.1325000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**loopnoleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 131 | 5.6717557 | 6.2590768 | 0 | 32.0000000 |
| FACC | 131 | 0.0229008 | 0.1501614 | 0 | 1.0000000 |
| IACC | 131 | 1.9083969 | 2.0132270 | 0 | 10.0000000 |
| FIACC | 131 | 1.9312977 | 2.0198661 | 0 | 10.0000000 |
| MVACC | 131 | 2.6412214 | 4.2154819 | 0 | 21.0000000 |
| WACC | 131 | 1.1374046 | 2.3395047 | 0 | 19.0000000 |
| DACC | 131 | 1.9618321 | 2.2647961 | 0 | 13.0000000 |
| XVOL | 131 | 6.9763359 | 5.3137388 | 0.1000000 | 28.0000000 |
| RVOL | 131 | 7.3060305 | 5.4927639 | 0.1000000 | 24.2000000 |
| FRATE | 131 | 0.0027939 | 0.0223051 | 0 | 0.2400000 |
| FIRATE | 131 | 0.3176336 | 0.4173042 | 0 | 2.2500000 |
| TRATE | 131 | 0.8915267 | 0.9091564 | 0 | 5.2600000 |
| WRATE | 131 | 0.2078579 | 0.5594739 | 0 | 4.9800000 |
| DRATE | 131 | 0.3152949 | 0.4076692 | 0 | 2.2500000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**loopnoleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 255 | 7.5803922 | 9.5657900 | 0 | 82.0000000 |
| FACC | 255 | 0.0156863 | 0.1245030 | 0 | 1.0000000 |
| IACC | 255 | 2.7137255 | 3.5891909 | 0 | 30.0000000 |
| FIACC | 255 | 2.7294118 | 3.6090053 | 0 | 30.0000000 |
| MVACC | 255 | 5.3529412 | 8.8651834 | 0 | 78.0000000 |
| WACC | 255 | 1.2666667 | 2.1461068 | 0 | 17.0000000 |
| DACC | 255 | 2.0627451 | 2.4583107 | 0 | 17.0000000 |
| XVOL | 255 | 5.7266667 | 3.8102631 | 0.2000000 | 27.8000000 |
| RVOL | 255 | 6.1716471 | 4.1823531 | 0.1700000 | 30.4400000 |
| FRATE | 255 | 0.0041176 | 0.0403884 | 0 | 0.5710000 |
| FIRATE | 255 | 0.4759608 | 0.5579467 | 0 | 3.1100000 |
| TRATE | 255 | 1.2716863 | 1.2898174 | 0 | 8.9000000 |
| WRATE | 255 | 0.2029027 | 0.3089501 | 0 | 2.0300000 |
| DRATE | 255 | 0.3505607 | 0.4084097 | 0 | 2.4900000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**restarea**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 40 | 2.5750000 | 3.1040709 | 0 | 14.0000000 |
| FACC | 40 | 0.0250000 | 0.1581139 | 0 | 1.0000000 |
| IACC | 40 | 0.3750000 | 0.7741828 | 0 | 3.0000000 |
| FIACC | 40 | 0.4000000 | 0.7778999 | 0 | 3.0000000 |
| MVACC | 40 | 1.7000000 | 2.9369442 | 0 | 14.0000000 |
| WACC | 40 | 0.2000000 | 0.4050957 | 0 | 1.0000000 |
| DACC | 40 | 0.9250000 | 1.3085028 | 0 | 5.0000000 |
| XVOL | 40 | 2.2975000 | 2.5231734 | 0 | 9.6000000 |
| RVOL | 40 | 2.5100000 | 2.7606326 | 0 | 10.5100000 |
| FRATE | 40 | 0.0596000 | 0.3769435 | 0 | 2.3840000 |
| FIRATE | 40 | 0.5227500 | 1.5333188 | 0 | 9.0400000 |
| TRATE | 40 | 2.0845000 | 3.4797487 | 0 | 18.0800000 |
| WRATE | 40 | 0.2923453 | 1.4316195 | 0 | 9.0400000 |
| DRATE | 40 | 0.8984646 | 1.7703354 | 0 | 9.0400000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**scissors**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 135 | 4.9407407 | 4.9742065 | 0 | 23.0000000 |
| FACC | 135 | 0.0296296 | 0.1701948 | 0 | 1.0000000 |
| IACC | 135 | 1.7259259 | 2.0494980 | 0 | 11.0000000 |
| FIACC | 135 | 1.7555556 | 2.0605269 | 0 | 11.0000000 |
| MVACC | 135 | 2.8814815 | 3.7257712 | 0 | 18.0000000 |
| WACC | 135 | 0.8518519 | 1.5670036 | 0 | 9.0000000 |
| DACC | 135 | 1.7703704 | 2.0440695 | 0 | 12.0000000 |
| XVOL | 135 | 5.4192593 | 4.1649120 | 0.2000000 | 21.0000000 |
| RVOL | 135 | 5.9762222 | 4.9704275 | 0.1900000 | 23.0300000 |
| FRATE | 135 | 0.0069704 | 0.0479944 | 0 | 0.4810000 |
| FIRATE | 135 | 0.4678519 | 0.8034964 | 0 | 5.1700000 |
| TRATE | 135 | 1.1990370 | 1.4885929 | 0 | 7.4800000 |
| WRATE | 135 | 0.2167232 | 0.4840192 | 0 | 3.4250000 |
| DRATE | 135 | 0.4694709 | 0.8711206 | 0 | 6.2333333 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**slip3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 79 | 2.6962025 | 4.0330507 | 0 | 17.0000000 |
| FACC | 79 | 0.0379747 | 0.1923564 | 0 | 1.0000000 |
| IACC | 79 | 0.8481013 | 1.3017602 | 0 | 7.0000000 |
| FIACC | 79 | 0.8860759 | 1.3396071 | 0 | 7.0000000 |
| MVACC | 79 | 1.9367089 | 3.4094205 | 0 | 16.0000000 |
| WACC | 79 | 0.5063291 | 1.2797578 | 0 | 9.0000000 |
| DACC | 79 | 0.9240506 | 1.5087110 | 0 | 7.0000000 |
| XVOL | 79 | 13.9556962 | 14.9395856 | 0.1000000 | 73.1000000 |
| RVOL | 79 | 14.8993671 | 16.5906629 | 0.0800000 | 80.0500000 |
| FRATE | 79 | 0.1152532 | 1.0172272 | 0 | 9.0420000 |
| FIRATE | 79 | 0.3558228 | 1.7000246 | 0 | 12.2900000 |
| TRATE | 79 | 0.5165823 | 1.7088059 | 0 | 12.2900000 |
| WRATE | 79 | 0.0436098 | 0.1188707 | 0 | 0.7000000 |
| DRATE | 79 | 0.2118783 | 1.0300544 | 0 | 9.0400000 |

**Ramp Type= Off Urban/Rural =Urban DESCR=slip4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 96 | 3.3958333 | 3.9349424 | 0 | 19.0000000 |
| FACC | 96 | 0.0104167 | 0.1020621 | 0 | 1.0000000 |
| IACC | 96 | 1.2604167 | 1.4885160 | 0 | 7.0000000 |
| FIACC | 96 | 1.2708333 | 1.5112154 | 0 | 7.0000000 |
| MVACC | 96 | 2.5833333 | 3.2008771 | 0 | 16.0000000 |
| WACC | 96 | 0.5937500 | 1.4979152 | 0 | 11.0000000 |
| DACC | 96 | 1.2083333 | 1.7285020 | 0 | 9.0000000 |
| XVOL | 96 | 9.0281250 | 6.8731316 | 0.7000000 | 50.0000000 |
| RVOL | 96 | 9.7757292 | 7.6104671 | 0.7800000 | 54.7500000 |
| FRATE | 96 | 0.000427083 | 0.0041845 | 0 | 0.0410000 |
| FIRATE | 96 | 0.1864583 | 0.2947255 | 0 | 1.9100000 |
| TRATE | 96 | 0.4558333 | 0.6523152 | 0 | 4.4200000 |
| WRATE | 96 | 0.0759679 | 0.1799204 | 0 | 0.9100000 |
| DRATE | 96 | 0.1464949 | 0.2267652 | 0 | 1.1775000 |

Ramp Type= **Off** Urban/Rural **=Urban** DESCR=**split**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 522 | 5.4521073 | 9.9112475 | 0 | 92.0000000 |
| FACC | 522 | 0.0363985 | 0.2069263 | 0 | 2.0000000 |
| IACC | 522 | 1.7605364 | 3.0159738 | 0 | 30.0000000 |
| FIACC | 522 | 1.7969349 | 3.0531049 | 0 | 30.0000000 |
| MVACC | 522 | 3.7432950 | 7.9378103 | 0 | 90.0000000 |
| WACC | 522 | 0.8812261 | 3.1036589 | 0 | 58.0000000 |
| DACC | 522 | 1.9923372 | 3.8273612 | 0 | 37.0000000 |
| XVOL | 522 | 19.6344828 | 15.2471576 | 0.1000000 | 99.5000000 |
| RVOL | 522 | 20.1913027 | 16.0025263 | 0.0900000 | 91.7600000 |
| FRATE | 522 | 0.0036954 | 0.0495117 | 0 | 1.0740000 |
| FIRATE | 522 | 0.1074138 | 0.3070790 | 0 | 3.7500000 |
| TRATE | 522 | 0.2833333 | 0.6468865 | 0 | 8.9200000 |
| WRATE | 522 | 0.0383917 | 0.1062506 | 0 | 1.3200000 |
| DRATE | 522 | 0.1021197 | 0.2384433 | 0 | 3.2200000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**buttonhook**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 109 | 0.6055046 | 1.3334607 | 0 | 8.0000000 |
| FACC | 109 | 0 | 0 | 0 | 0 |
| IACC | 109 | 0.2110092 | 0.5785261 | 0 | 3.0000000 |
| FIACC | 109 | 0.2110092 | 0.5785261 | 0 | 3.0000000 |
| MVACC | 109 | 0.4587156 | 1.2287611 | 0 | 8.0000000 |
| WACC | 109 | 0.0550459 | 0.2291232 | 0 | 1.0000000 |
| DACC | 109 | 0.1192661 | 0.3528920 | 0 | 2.0000000 |
| XVOL | 109 | 0.9642202 | 1.1480679 | 0 | 5.5000000 |
| RVOL | 109 | 1.0495413 | 1.2534607 | 0.0200000 | 6.0600000 |
| FRATE | 109 | 0 | 0 | 0 | 0 |
| FIRATE | 109 | 0.2535780 | 1.0168265 | 0 | 7.9400000 |
| TRATE | 109 | 1.1911009 | 5.1214439 | 0 | 49.8200000 |
| WRATE | 109 | 0.0627248 | 0.4296977 | 0 | 4.3500000 |
| DRATE | 109 | 0.6067164 | 4.8017690 | 0 | 49.8200000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**diamond3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 78 | 0.6025641 | 1.3420254 | 0 | 10.0000000 |
| FACC | 78 | 0 | 0 | 0 | 0 |
| IACC | 78 | 0.2307692 | 0.7546062 | 0 | 6.0000000 |
| FIACC | 78 | 0.2307692 | 0.7546062 | 0 | 6.0000000 |
| MVACC | 78 | 0.1666667 | 0.4082483 | 0 | 2.0000000 |
| WACC | 78 | 0.0512821 | 0.2743321 | 0 | 2.0000000 |
| DACC | 78 | 0.2435897 | 0.5390202 | 0 | 2.0000000 |
| XVOL | 78 | 1.3756410 | 1.2205157 | 0 | 4.6000000 |
| RVOL | 78 | 1.5082051 | 1.3355496 | 0.0200000 | 5.0700000 |
| FRATE | 78 | 0 | 0 | 0 | 0 |
| FIRATE | 78 | 0.1860256 | 0.6186377 | 0 | 4.1700000 |
| TRATE | 78 | 0.4715385 | 1.0527356 | 0 | 6.9600000 |
| WRATE | 78 | 0.0375897 | 0.2106962 | 0 | 1.3920000 |
| DRATE | 78 | 0.1502607 | 0.3966029 | 0 | 2.0800000 |

Ramp Type= **On** Urban/Rural =**Rural** DESCR=**diamond4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 759 | 0.4479578 | 1.0142093 | 0 | 9.0000000 |
| FACC | 759 | 0.0026350 | 0.0512988 | 0 | 1.0000000 |
| IACC | 759 | 0.1581028 | 0.4886950 | 0 | 5.0000000 |
| FIACC | 759 | 0.1607378 | 0.4932125 | 0 | 5.0000000 |
| MVACC | 759 | 0.2542819 | 0.7755529 | 0 | 7.0000000 |
| WACC | 759 | 0.0474308 | 0.2417299 | 0 | 3.0000000 |
| DACC | 759 | 0.1475626 | 0.4615464 | 0 | 4.0000000 |
| XVOL | 759 | 0.8096179 | 1.1399091 | 0 | 11.3000000 |
| RVOL | 759 | 0.8724769 | 1.2427067 | 0.0100000 | 12.3400000 |
| FRATE | 759 | 0.0068419 | 0.1649592 | 0 | 4.4910000 |
| FIRATE | 759 | 0.2826087 | 1.6227174 | 0 | 26.0900000 |
| TRATE | 759 | 0.8111199 | 3.5156941 | 0 | 68.4900000 |
| WRATE | 759 | 0.1144566 | 1.2941216 | 0 | 23.8300000 |
| DRATE | 759 | 0.2643806 | 1.5125195 | 0 | 23.8300000 |

Ramp Type= **On** Urban/Rural =**Rural** DESCR=**dir/semi3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 41 | 0.9268293 | 1.4385799 | 0 | 6.0000000 |
| FACC | 41 | 0.0243902 | 0.1561738 | 0 | 1.0000000 |
| IACC | 41 | 0.4878049 | 1.2066887 | 0 | 6.0000000 |
| FIACC | 41 | 0.5121951 | 1.2066887 | 0 | 6.0000000 |
| MVACC | 41 | 0.2682927 | 0.5012180 | 0 | 2.0000000 |
| WACC | 41 | 0.1951220 | 0.4593208 | 0 | 2.0000000 |
| DACC | 41 | 0.3658537 | 0.8875837 | 0 | 5.0000000 |
| XVOL | 41 | 2.1878049 | 2.4860808 | 0 | 10.6000000 |
| RVOL | 41 | 2.3936585 | 2.7274665 | 0.0300000 | 11.6400000 |
| FRATE | 41 | 0.0032683 | 0.0209273 | 0 | 0.1340000 |
| FIRATE | 41 | 0.4875610 | 1.6754325 | 0 | 10.1500000 |
| TRATE | 41 | 0.6992683 | 1.7003785 | 0 | 10.1500000 |
| WRATE | 41 | 0.0674390 | 0.1655790 | 0 | 0.6100000 |
| DRATE | 41 | 0.4046341 | 1.6359082 | 0 | 10.1500000 |

Ramp Type= **On** Urban/Rural =**Rural** DESCR=**dir/semi4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 65 | 0.6153846 | 1.1949413 | 0 | 7.0000000 |
| FACC | 65 | 0 | 0 | 0 | 0 |
| IACC | 65 | 0.2615385 | 0.7131997 | 0 | 4.0000000 |
| FIACC | 65 | 0.2615385 | 0.7131997 | 0 | 4.0000000 |
| MVACC | 65 | 0.2769231 | 0.9602684 | 0 | 7.0000000 |
| WACC | 65 | 0.1538462 | 0.4412613 | 0 | 2.0000000 |
| DACC | 65 | 0.2153846 | 0.5151549 | 0 | 2.0000000 |
| XVOL | 65 | 1.2969231 | 1.3753374 | 0 | 5.0000000 |
| RVOL | 65 | 1.3936923 | 1.4777248 | 0.0200000 | 5.4800000 |
| FRATE | 65 | 0 | 0 | 0 | 0 |
| FIRATE | 65 | 0.8681538 | 4.2318402 | 0 | 30.2100000 |
| TRATE | 65 | 1.0867692 | 4.2699580 | 0 | 30.2100000 |
| WRATE | 65 | 0.0872125 | 0.2900626 | 0 | 1.7171429 |
| DRATE | 65 | 0.1116484 | 0.2984670 | 0 | 1.7171429 |

Ramp Type= **On** Urban/Rural =**Rural** DESCR=**direct**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 20 | 1.2000000 | 1.8524521 | 0 | 8.0000000 |
| FACC | 20 | 0 | 0 | 0 | 0 |
| IACC | 20 | 0.4000000 | 0.5026247 | 0 | 1.0000000 |
| FIACC | 20 | 0.4000000 | 0.5026247 | 0 | 1.0000000 |
| MVACC | 20 | 0.4500000 | 0.6048053 | 0 | 2.0000000 |
| WACC | 20 | 0.1500000 | 0.4893605 | 0 | 2.0000000 |
| DACC | 20 | 0.4000000 | 0.9403247 | 0 | 4.0000000 |
| XVOL | 20 | 4.9250000 | 6.3806348 | 0.2000000 | 25.5000000 |
| RVOL | 20 | 5.3905000 | 6.9885007 | 0.2300000 | 27.9200000 |
| FRATE | 20 | 0 | 0 | 0 | 0 |
| FIRATE | 20 | 0.1405000 | 0.3017401 | 0 | 1.3000000 |
| TRATE | 20 | 0.4000000 | 0.6008678 | 0 | 1.9400000 |
| WRATE | 20 | 0.0322500 | 0.1123959 | 0 | 0.4850000 |
| DRATE | 20 | 0.1535000 | 0.3589645 | 0 | 1.3000000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**loopleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 7 | 0.7142857 | 0.7559289 | 0 | 2.0000000 |
| FACC | 7 | 0 | 0 | 0 | 0 |
| IACC | 7 | 0 | 0 | 0 | 0 |
| FIACC | 7 | 0 | 0 | 0 | 0 |
| MVACC | 7 | 0.1428571 | 0.3779645 | 0 | 1.0000000 |
| WACC | 7 | 0 | 0 | 0 | 0 |
| DACC | 7 | 0 | 0 | 0 | 0 |
| XVOL | 7 | 1.1000000 | 0.9380832 | 0 | 2.6000000 |
| RVOL | 7 | 1.1828571 | 1.0056294 | 0.0500000 | 2.8100000 |
| FRATE | 7 | 0 | 0 | 0 | 0 |
| FIRATE | 7 | 0 | 0 | 0 | 0 |
| TRATE | 7 | 0.6528571 | 0.8438545 | 0 | 2.0000000 |
| WRATE | 7 | 0 | 0 | 0 | 0 |
| DRATE | 7 | 0 | 0 | 0 | 0 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**loopleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 72 | 0.5833333 | 0.9604870 | 0 | 4.0000000 |
| FACC | 72 | 0.0138889 | 0.1178511 | 0 | 1.0000000 |
| IACC | 72 | 0.2361111 | 0.4594257 | 0 | 2.0000000 |
| FIACC | 72 | 0.2500000 | 0.4964664 | 0 | 2.0000000 |
| MVACC | 72 | 0.4027778 | 0.7250007 | 0 | 3.0000000 |
| WACC | 72 | 0.0972222 | 0.2983392 | 0 | 1.0000000 |
| DACC | 72 | 0.1388889 | 0.3865906 | 0 | 2.0000000 |
| XVOL | 72 | 1.1013889 | 1.2942444 | 0 | 8.8000000 |
| RVOL | 72 | 1.2002778 | 1.4084333 | 0.0300000 | 9.6000000 |
| FRATE | 72 | 0.0044444 | 0.0377124 | 0 | 0.3200000 |
| FIRATE | 72 | 0.4768056 | 2.6967084 | 0 | 22.8300000 |
| TRATE | 72 | 0.8334722 | 2.8773159 | 0 | 22.8300000 |
| WRATE | 72 | 0.0619444 | 0.2298952 | 0 | 1.2850000 |
| DRATE | 72 | 0.0731944 | 0.2228091 | 0 | 1.0850000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**loopnoleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 21 | 1.2380952 | 3.2543012 | 0 | 15.0000000 |
| FACC | 21 | 0 | 0 | 0 | 0 |
| IACC | 21 | 0.4285714 | 1.5352989 | 0 | 7.0000000 |
| FIACC | 21 | 0.4285714 | 1.5352989 | 0 | 7.0000000 |
| MVACC | 21 | 0.2380952 | 0.8890873 | 0 | 4.0000000 |
| WACC | 21 | 0.4285714 | 1.1212238 | 0 | 5.0000000 |
| DACC | 21 | 0.0952381 | 0.4364358 | 0 | 2.0000000 |
| XVOL | 21 | 1.3142857 | 2.7492337 | 0 | 10.0000000 |
| RVOL | 21 | 1.4338095 | 3.0242825 | 0.0300000 | 10.9900000 |
| FRATE | 21 | 0 | 0 | 0 | 0 |
| FIRATE | 21 | 0.1504762 | 0.4103959 | 0 | 1.6200000 |
| TRATE | 21 | 0.8385714 | 1.4136346 | 0 | 5.6000000 |
| WRATE | 21 | 0.4510317 | 1.2860530 | 0 | 5.6000000 |
| DRATE | 21 | 0.0086984 | 0.0398611 | 0 | 0.1826667 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**loopnoleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 34 | 0.5294118 | 1.4613256 | 0 | 7.0000000 |
| FACC | 34 | 0 | 0 | 0 | 0 |
| IACC | 34 | 0.1764706 | 0.4586270 | 0 | 2.0000000 |
| FIACC | 34 | 0.1764706 | 0.4586270 | 0 | 2.0000000 |
| MVACC | 34 | 0.1176471 | 0.3270350 | 0 | 1.0000000 |
| WACC | 34 | 0.2647059 | 1.1364171 | 0 | 6.0000000 |
| DACC | 34 | 0.0882353 | 0.2879022 | 0 | 1.0000000 |
| XVOL | 34 | 0.6970588 | 0.9366236 | 0 | 3.8000000 |
| RVOL | 34 | 0.7385294 | 1.0194477 | 0.0200000 | 4.1600000 |
| FRATE | 34 | 0 | 0 | 0 | 0 |
| FIRATE | 34 | 0.3950000 | 1.4724670 | 0 | 8.0600000 |
| TRATE | 34 | 0.6979412 | 1.8789533 | 0 | 8.0600000 |
| WRATE | 34 | 0.1729664 | 0.7524581 | 0 | 4.0380000 |
| DRATE | 34 | 0.2531513 | 1.3810035 | 0 | 8.0600000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**restarea**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 118 | 0.5762712 | 1.1723800 | 0 | 8.0000000 |
| FACC | 118 | 0 | 0 | 0 | 0 |
| IACC | 118 | 0.0593220 | 0.2372338 | 0 | 1.0000000 |
| FIACC | 118 | 0.0593220 | 0.2372338 | 0 | 1.0000000 |
| MVACC | 118 | 0.4067797 | 0.9717135 | 0 | 8.0000000 |
| WACC | 118 | 0.0254237 | 0.1580795 | 0 | 1.0000000 |
| DACC | 118 | 0.3050847 | 0.9291893 | 0 | 8.0000000 |
| XVOL | 118 | 1.3313559 | 1.3919610 | 0 | 6.3000000 |
| RVOL | 118 | 1.4538983 | 1.5154611 | 0.0100000 | 6.9000000 |
| FRATE | 118 | 0 | 0 | 0 | 0 |
| FIRATE | 118 | 0.7870339 | 7.6395954 | 0 | 82.9400000 |
| TRATE | 118 | 1.4667797 | 8.6516262 | 0 | 82.9400000 |
| WRATE | 118 | 0.0873051 | 0.8355936 | 0 | 9.0420000 |
| DRATE | 118 | 0.9024294 | 7.6404105 | 0 | 82.9400000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**scissors**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 36 | 0.4166667 | 0.6491753 | 0 | 2.0000000 |
| FACC | 36 | 0 | 0 | 0 | 0 |
| IACC | 36 | 0.0833333 | 0.3683942 | 0 | 2.0000000 |
| FIACC | 36 | 0.0833333 | 0.3683942 | 0 | 2.0000000 |
| MVACC | 36 | 0.2500000 | 0.5000000 | 0 | 2.0000000 |
| WACC | 36 | 0.0555556 | 0.2323107 | 0 | 1.0000000 |
| DACC | 36 | 0.0555556 | 0.2323107 | 0 | 1.0000000 |
| XVOL | 36 | 1.1000000 | 0.9742396 | 0.1000000 | 3.8000000 |
| RVOL | 36 | 1.1969444 | 1.0651219 | 0.1100000 | 4.2000000 |
| FRATE | 36 | 0 | 0 | 0 | 0 |
| FIRATE | 36 | 0.0769444 | 0.3643297 | 0 | 2.1000000 |
| TRATE | 36 | 0.6972222 | 1.4240377 | 0 | 5.5300000 |
| WRATE | 36 | 0.0411111 | 0.1872016 | 0 | 1.0500000 |
| DRATE | 36 | 0.0780556 | 0.3372478 | 0 | 1.7600000 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**slip3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 0 | . | . | . | . |
| FACC | 0 | . | . | . | . |
| IACC | 0 | . | . | . | . |
| FIACC | 0 | . | . | . | . |
| MVACC | 0 | . | . | . | . |
| WACC | 0 | . | . | . | . |
| DACC | 0 | . | . | . | . |
| XVOL | 0 | . | . | . | . |
| RVOL | 0 | . | . | . | . |
| FRATE | 0 | . | . | . | . |
| FIRATE | 0 | . | . | . | . |
| TRATE | 0 | . | . | . | . |
| WRATE | 0 | . | . | . | . |
| DRATE | 0 | . | . | . | . |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**slip4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 1 | 0 | . | 0 | 0 |
| FACC | 1 | 0 | . | 0 | 0 |
| IACC | 1 | 0 | . | 0 | 0 |
| FIACC | 1 | 0 | . | 0 | 0 |
| MVACC | 1 | 0 | . | 0 | 0 |
| WACC | 1 | 0 | . | 0 | 0 |
| DACC | 1 | 0 | . | 0 | 0 |
| XVOL | 1 | 11.7000000 | . | 11.7000000 | 11.7000000 |
| RVOL | 1 | 12.7800000 | . | 12.7800000 | 12.7800000 |
| FRATE | 1 | 0 | . | 0 | 0 |
| FIRATE | 1 | 0 | . | 0 | 0 |
| TRATE | 1 | 0 | . | 0 | 0 |
| WRATE | 1 | 0 | . | 0 | 0 |
| DRATE | 1 | 0 | . | 0 | 0 |

Ramp Type= **On** Urban/Rural **=Rural** DESCR=**split**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 3 | 0.3333333 | 0.5773503 | 0 | 1.0000000 |
| FACC | 3 | 0 | 0 | 0 | 0 |
| IACC | 3 | 0 | 0 | 0 | 0 |
| FIACC | 3 | 0 | 0 | 0 | 0 |
| MVACC | 3 | 0 | 0 | 0 | 0 |
| WACC | 3 | 0.3333333 | 0.5773503 | 0 | 1.0000000 |
| DACC | 3 | 0 | 0 | 0 | 0 |
| XVOL | 3 | 4.8666667 | 0.9291573 | 3.8000000 | 5.5000000 |
| RVOL | 3 | 5.3000000 | 0.9945351 | 4.1600000 | 5.9900000 |
| FRATE | 3 | 0 | 0 | 0 | 0 |
| FIRATE | 3 | 0 | 0 | 0 | 0 |
| TRATE | 3 | 0.0566667 | 0.0981495 | 0 | 0.1700000 |
| WRATE | 3 | 0.0566667 | 0.0981495 | 0 | 0.1700000 |
| DRATE | 3 | 0 | 0 | 0 | 0 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**buttonhook**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 460 | 2.8152174 | 4.4680647 | 0 | 51.0000000 |
| FACC | 460 | 0.0130435 | 0.1135843 | 0 | 1.0000000 |
| IACC | 460 | 1.0021739 | 1.7156195 | 0 | 11.0000000 |
| FIACC | 460 | 1.0152174 | 1.7269449 | 0 | 11.0000000 |
| MVACC | 460 | 2.2065217 | 4.0678827 | 0 | 49.0000000 |
| WACC | 460 | 0.4695652 | 1.0710835 | 0 | 14.0000000 |
| DACC | 460 | 0.7826087 | 1.2561490 | 0 | 8.0000000 |
| XVOL | 460 | 4.6158696 | 3.6483960 | 0 | 21.9000000 |
| RVOL | 460 | 4.8896304 | 3.9506893 | 0.0300000 | 23.9800000 |
| FRATE | 460 | 0.0045196 | 0.0583989 | 0 | 1.1710000 |
| FIRATE | 460 | 0.2289565 | 0.5204801 | 0 | 6.9900000 |
| TRATE | 460 | 0.7879348 | 2.8392068 | 0 | 54.7900000 |
| WRATE | 460 | 0.1044082 | 0.4671305 | 0 | 9.1316667 |
| DRATE | 460 | 0.2123784 | 0.7013309 | 0 | 9.1316667 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**diamond3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 117 | 2.4529915 | 3.0300100 | 0 | 18.0000000 |
| FACC | 117 | 0.0256410 | 0.1587417 | 0 | 1.0000000 |
| IACC | 117 | 0.8547009 | 1.3407728 | 0 | 8.0000000 |
| FIACC | 117 | 0.8803419 | 1.3656020 | 0 | 8.0000000 |
| MVACC | 117 | 1.7008547 | 2.6822050 | 0 | 16.0000000 |
| WACC | 117 | 0.4188034 | 0.9213869 | 0 | 5.0000000 |
| DACC | 117 | 0.9059829 | 1.3832926 | 0 | 9.0000000 |
| XVOL | 117 | 5.6675214 | 4.3474493 | 0.2000000 | 26.5000000 |
| RVOL | 117 | 6.0610598 | 4.7823573 | 0.2500000 | 29.6200000 |
| FRATE | 117 | 0.0061282 | 0.0582421 | 0 | 0.5070000 |
| FIRATE | 117 | 0.1853846 | 0.3209188 | 0 | 1.7400000 |
| TRATE | 117 | 0.4611966 | 0.6186389 | 0 | 4.7800000 |
| WRATE | 117 | 0.0580635 | 0.1198827 | 0 | 0.6100000 |
| DRATE | 117 | 0.1630225 | 0.2665691 | 0 | 1.8300000 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**diamond4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 1825 | 4.7452055 | 5.8692124 | 0 | 51.0000000 |
| FACC | 1825 | 0.0131507 | 0.1139511 | 0 | 1.0000000 |
| IACC | 1825 | 1.8410959 | 2.5887660 | 0 | 23.0000000 |
| FIACC | 1825 | 1.8542466 | 2.6001043 | 0 | 23.0000000 |
| MVACC | 1825 | 3.9041096 | 5.3041391 | 0 | 46.0000000 |
| WACC | 1825 | 0.7150685 | 1.4704389 | 0 | 18.0000000 |
| DACC | 1825 | 1.4043836 | 2.1720873 | 0 | 26.0000000 |
| XVOL | 1825 | 5.8280548 | 4.4483392 | 0 | 45.0000000 |
| RVOL | 1825 | 6.1903342 | 4.8358753 | 0.0100000 | 49.2800000 |
| FRATE | 1825 | 0.0032460 | 0.0490180 | 0 | 1.7790000 |
| FIRATE | 1825 | 0.3896110 | 1.3121398 | 0 | 30.4400000 |
| TRATE | 1825 | 1.0967123 | 5.9695134 | 0 | 234.4500000 |
| WRATE | 1825 | 0.1393905 | 0.6055333 | 0 | 18.0346154 |
| DRATE | 1825 | 0.3400819 | 2.3159457 | 0 | 90.1730769 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**dir/semi3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 294 | 4.5850340 | 6.4658130 | 0 | 51.0000000 |
| FACC | 294 | 0.0374150 | 0.2072775 | 0 | 2.0000000 |
| IACC | 294 | 1.6292517 | 2.3677212 | 0 | 23.0000000 |
| F1ACC | 294 | 1.6666667 | 2.4448409 | 0 | 24.0000000 |
| MVACC | 294 | 2.2959184 | 4.1107763 | 0 | 43.0000000 |
| WACC | 294 | 1.0204082 | 2.6099557 | 0 | 28.0000000 |
| DACC | 294 | 1.8095238 | 2.5554154 | 0 | 14.0000000 |
| XVOL | 294 | 11.8612245 | 12.3476460 | 0 | 85.1000000 |
| RVOL | 294 | 12.4763265 | 13.5733202 | 0.0100000 | 93.1900000 |
| FRATE | 294 | 0.0034796 | 0.0320673 | 0 | 0.5070000 |
| F1RATE | 294 | 0.1915986 | 0.4393951 | 0 | 5.6200000 |
| TRATE | 294 | 0.4622789 | 0.7181631 | 0 | 5.7100000 |
| WRATE | 294 | 0.0983579 | 0.2673550 | 0 | 3.2000000 |
| DRATE | 294 | 0.1726593 | 0.2829240 | 0 | 2.8550000 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**dir/semi4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 704 | 3.5042614 | 3.9939476 | 0 | 34.0000000 |
| FACC | 704 | 0.0156250 | 0.1350840 | 0 | 2.0000000 |
| 1ACC | 704 | 1.3281250 | 1.7354160 | 0 | 12.0000000 |
| FIACC | 704 | 1.3437500 | 1.7572498 | 0 | 12.0000000 |
| MVACC | 704 | 2.3764205 | 3.1800517 | 0 | 32.0000000 |
| WACC | 704 | 0.7116477 | 1.4264642 | 0 | 15.0000000 |
| DACC | 704 | 1.0440341 | 1.5631036 | 0 | 12.0000000 |
| XVOL | 704 | 5.6170455 | 4.0716512 | 0.1000000 | 32.3000000 |
| RVOL | 704 | 6.0266051 | 4.4793381 | 0.0600000 | 35.3700000 |
| FRATE | 704 | 0.0021974 | 0.0233021 | 0 | 0.4760000 |
| F1RATE | 704 | 0.2759233 | 0.4724064 | 0 | 4.8100000 |
| TRATE | 704 | 0.6806108 | 0.8568501 | 0 | 9.6100000 |
| WRATE | 704 | 0.1342215 | 0.3450026 | 0 | 4.8050000 |
| DRATE | 704 | 0.2063812 | 0.4460250 | 0 | 6.0900000 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**direct**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 181 | 8.4254144 | 13.2296475 | 0 | 98.0000000 |
| FACC | 181 | 0.0994475 | 0.3512671 | 0 | 2.0000000 |
| IACC | 181 | 2.7624309 | 4.2653543 | 0 | 33.0000000 |
| FIACC | 181 | 2.8618785 | 4.3624324 | 0 | 35.0000000 |
| MVACC | 181 | 4.4198895 | 7.9036168 | 0 | 55.0000000 |
| WACC | 181 | 2.2928177 | 5.4444062 | 0 | 50.0000000 |
| DACC | 181 | 3.3535912 | 5.8534748 | 0 | 45.0000000 |
| XVOL | 181 | 14.3475138 | 11.0017048 | 0.7000000 | 52.0000000 |
| RVOL | 181 | 15.0644199 | 12.3210489 | 0.3100000 | 56.9400000 |
| FRATE | 181 | 0.0081326 | 0.0328428 | 0 | 0.2540000 |
| F1RATE | 181 | 0.2677901 | 0.9715478 | 0 | 12.7700000 |
| TRATE | 181 | 0.6595580 | 1.8737019 | 0 | 23.9400000 |
| WRATE | 181 | 0.1508528 | 0.3880652 | 0 | 3.3650000 |
| DRATE | 181 | 0.2113195 | 0.3354148 | 0 | 3.1920000 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**loopleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 11 | 4.2727273 | 5.7635217 | 0 | 19.0000000 |
| FACC | 11 | 0 | 0 | 0 | 0 |
| IACC | 11 | 1.0000000 | 1.0000000 | 0 | 3.0000000 |
| FIACC | 11 | 1.0000000 | 1.0000000 | 0 | 3.0000000 |
| MVACC | 11 | 3.7272727 | 5.3120789 | 0 | 17.0000000 |
| WACC | 11 | 0.1818182 | 0.4045199 | 0 | 1.0000000 |
| DACC | 11 | 1.3636364 | 1.7477258 | 0 | 6.0000000 |
| XVOL | 11 | 5.7000000 | 5.4713801 | 0.4000000 | 18.2000000 |
| RVOL | 11 | 6.2418182 | 5.9968088 | 0.4700000 | 19.9300000 |
| FRATE | 11 | 0 | 0 | 0 | 0 |
| FIRATE | 11 | 0.3172727 | 0.6101490 | 0 | 2.1100000 |
| TRATE | 11 | 0.8627273 | 1.1964121 | 0 | 4.2100000 |
| WRATE | 11 | 0.0172727 | 0.0433799 | 0 | 0.1400000 |
| DRATE | 11 | 0.1805368 | 0.1524541 | 0 | 0.4933333 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**loopleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 262 | 4.6145038 | 5.8846071 | 0 | 49.0000000 |
| FACC | 262 | 0.0114504 | 0.1065957 | 0 | 1.0000000 |
| IACC | 262 | 1.7938931 | 2.6077326 | 0 | 27.0000000 |
| FIACC | 262 | 1.8053435 | 2.6122849 | 0 | 27.0000000 |
| MVACC | 262 | 3.5725191 | 5.2164352 | 0 | 47.0000000 |
| WACC | 262 | 0.7977099 | 1.4625316 | 0 | 9.0000000 |
| DACC | 262 | 1.3091603 | 2.1352344 | 0 | 18.0000000 |
| XVOL | 262 | 5.2083969 | 3.9509839 | 0.1000000 | 20.0000000 |
| RVOL | 262 | 5.5681679 | 4.3218418 | 0.0700000 | 21.9000000 |
| FRATE | 262 | 0.0061641 | 0.0583757 | 0 | 0.6090000 |
| FIRATE | 262 | 0.4221374 | 0.9271722 | 0 | 10.6500000 |
| TRATE | 262 | 0.9328244 | 1.3298309 | 0 | 13.7000000 |
| WRATE | 262 | 0.1669900 | 0.3475415 | 0 | 3.0400000 |
| DRATE | 262 | 0.2735564 | 0.4837937 | 0 | 4.5666667 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**loopnoleft3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 152 | 4.9605263 | 9.4110556 | 0 | 89.0000000 |
| FACC | 152 | 0.0131579 | 0.1143274 | 0 | 1.0000000 |
| IACC | 152 | 1.3750000 | 2.7855172 | 0 | 24.0000000 |
| FIACC | 152 | 1.3881579 | 2.7908302 | 0 | 24.0000000 |
| MVACC | 152 | 2.3815789 | 6.9224026 | 0 | 80.0000000 |
| WACC | 152 | 1.1842105 | 1.9203375 | 0 | 11.0000000 |
| DACC | 152 | 1.8618421 | 3.5918402 | 0 | 30.0000000 |
| XVOL | 152 | 6.7782895 | 7.2827922 | 0.2000000 | 50.0000000 |
| RVOL | 152 | 7.0621053 | 7.8777432 | 0.1600000 | 54.7500000 |
| FRATE | 152 | 0.0029671 | 0.0308677 | 0 | 0.3710000 |
| FIRATE | 152 | 0.1958553 | 0.3066880 | 0 | 1.7700000 |
| TRATE | 152 | 0.7202632 | 0.9224657 | 0 | 7.6600000 |
| WRATE | 152 | 0.2251360 | 0.4396908 | 0 | 3.5353846 |
| DRATE | 152 | 0.2560791 | 0.3689140 | 0 | 1.9114286 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**loopnoleft4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 581 | 3.6643718 | 4.4600820 | 0 | 36.0000000 |
| FACC | 581 | 0.0051635 | 0.0717336 | 0 | 1.0000000 |
| IACC | 581 | 1.2530120 | 2.0543508 | 0 | 20.0000000 |
| FIACC | 581 | 1.2581756 | 2.0549661 | 0 | 20.0000000 |
| MVACC | 581 | 2.4647160 | 3.5638333 | 0 | 36.0000000 |
| WACC | 581 | 0.9535284 | 1.8771518 | 0 | 20.0000000 |
| DACC | 581 | 0.9896730 | 1.5051280 | 0 | 9.0000000 |
| XVOL | 581 | 5.0271945 | 3.6544707 | 0 | 25.5000000 |
| RVOL | 581 | 5.3875387 | 4.0392559 | 0.0500000 | 27.9200000 |
| FRATE | 581 | 0.0013012 | 0.0234061 | 0 | 0.5370000 |
| FIRATE | 581 | 0.2849225 | 1.2115448 | 0 | 27.4000000 |
| TRATE | 581 | 0.7857659 | 2.0336718 | 0 | 45.6600000 |
| WRATE | 581 | 0.1770545 | 0.4859096 | 0 | 9.1320000 |
| DRATE | 581 | 0.2172759 | 0.5326046 | 0 | 9.1320000 |

Ramp Type= **On** Urban/Rural **=Urban** DESCR=**restarea**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 39 | 1.1282051 | 2.7926547 | 0 | 16.0000000 |
| FACC | 39 | 0 | 0 | 0 | 0 |
| IACC | 39 | 0.0769231 | 0.3542684 | 0 | 2.0000000 |
| FIACC | 39 | 0.0769231 | 0.3542684 | 0 | 2.0000000 |
| MVACC | 39 | 0.5384615 | 1.1886780 | 0 | 6.0000000 |
| WACC | 39 | 0.0769231 | 0.3542684 | 0 | 2.0000000 |
| DACC | 39 | 0.4358974 | 1.5007870 | 0 | 9.0000000 |
| XVOL | 39 | 2.4179487 | 2.6511042 | 0 | 9.6000000 |
| RVOL | 39 | 2.6376923 | 2.9083459 | 0 | 10.5100000 |
| FRATE | 39 | 0 | 0 | 0 | 0 |
| FIRATE | 39 | 0.0189744 | 0.0827105 | 0 | 0.3800000 |
| TRATE | 39 | 0.7758974 | 2.7266354 | 0 | 16.5000000 |
| WRATE | 39 | 0.0159402 | 0.0710806 | 0 | 0.3766667 |
| DRATE | 39 | 0.1413942 | 0.4726420 | 0 | 2.7393750 |

Ramp Type= **On** Urban/Rural =**Urban** DESCR=**scissors**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 144 | 3.3402778 | 4.3903314 | 0 | 27.0000000 |
| FACC | 144 | 0 | 0 | 0 | 0 |
| IACC | 144 | 1.1388889 | 1.7644949 | 0 | 11.0000000 |
| FIACC | 144 | 1.1388889 | 1.7644949 | 0 | 11.0000000 |
| MVACC | 144 | 2.5347222 | 3.7823905 | 0 | 26.0000000 |
| WACC | 144 | 0.6388889 | 1.2381529 | 0 | 9.0000000 |
| DACC | 144 | 0.8750000 | 1.3320944 | 0 | 7.0000000 |
| XVOL | 144 | 6.0173611 | 5.2394994 | 0.4000000 | 33.0000000 |
| RVOL | 144 | 6.4695139 | 5.7468211 | 0.4400000 | 36.1400000 |
| FRATE | 144 | 0 | 0 | 0 | 0 |
| FIRATE | 144 | 0.2115278 | 0.4197724 | 0 | 3.6500000 |
| TRATE | 144 | 0.5910417 | 0.7650181 | 0 | 3.9600000 |
| WRATE | 144 | 0.1093061 | 0.2302294 | 0 | 1.2876923 |
| DRATE | 144 | 0.1697463 | 0.2799748 | 0 | 1.8250000 |

Ramp Type= **On** Urban/Rural =**Urban** DESCR=**slip3**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 66 | 2.3030303 | 3.0833034 | 0 | 13.0000000 |
| FACC | 66 | 0.0303030 | 0.1727334 | 0 | 1.0000000 |
| IACC | 66 | 0.5606061 | 0.8966397 | 0 | 4.0000000 |
| FIACC | 66 | 0.5909091 | 0.9110817 | 0 | 4.0000000 |
| MVACC | 66 | 1.7424242 | 2.4388560 | 0 | 11.0000000 |
| WACC | 66 | 0.3787879 | 0.9074928 | 0 | 5.0000000 |
| DACC | 66 | 0.7121212 | 1.1471054 | 0 | 6.0000000 |
| XVOL | 66 | 14.2651515 | 13.2502017 | 0.1000000 | 46.3000000 |
| RVOL | 66 | 14.1034848 | 14.3114306 | 0.0800000 | 50.7000000 |
| FRATE | 66 | 0.0010455 | 0.0059754 | 0 | 0.0370000 |
| FIRATE | 66 | 0.2257576 | 1.1370502 | 0 | 9.0400000 |
| TRATE | 66 | 0.7713636 | 2.2527063 | 0 | 12.2900000 |
| WRATE | 66 | 0.0396120 | 0.1293264 | 0 | 0.9123077 |
| DRATE | 66 | 0.1119434 | 0.3600892 | 0 | 2.2807692 |

Ramp Type= **On** Urban/Rural =**Urban** DESCR=**slip4**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 78 | 2.4487179 | 2.4844840 | 0 | 13.0000000 |
| FACC | 78 | 0.0128205 | 0.1132277 | 0 | 1.0000000 |
| IACC | 78 | 0.8205128 | 1.1018708 | 0 | 4.0000000 |
| FIACC | 78 | 0.8333333 | 1.0980108 | 0 | 4.0000000 |
| MVACC | 78 | 1.9358974 | 2.2409399 | 0 | 11.0000000 |
| WACC | 78 | 0.3333333 | 0.8477115 | 0 | 6.0000000 |
| DACC | 78 | 0.8589744 | 1.0778087 | 0 | 4.0000000 |
| XVOL | 78 | 8.9320513 | 8.4231359 | 0.1000000 | 50.0000000 |
| RVOL | 78 | 9.5170513 | 9.3052037 | 0.0400000 | 54.7500000 |
| FRATE | 78 | 0.0334615 | 0.2955243 | 0 | 2.6100000 |
| FIRATE | 78 | 0.5126923 | 2.6253983 | 0 | 22.6100000 |
| TRATE | 78 | 0.7679487 | 2.6881406 | 0 | 22.6100000 |
| WRATE | 78 | 0.3296317 | 2.5571140 | 0 | 22.6100000 |
| DRATE | 78 | 0.1299409 | 0.2261726 | 0 | 1.2800000 |

Ramp Type= **On** Urban/Rural =**Urban** DESCR=**split**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| TACC | 343 | 4.0262391 | 6.9300523 | 0 | 76.0000000 |
| FACC | 343 | 0.0204082 | 0.1415985 | 0 | 1.0000000 |
| IACC | 343 | 1.2448980 | 1.9098303 | 0 | 15.0000000 |
| FIACC | 343 | 1.2653061 | 1.9367613 | 0 | 15.0000000 |
| MVACC | 343 | 2.7521866 | 5.7312970 | 0 | 70.0000000 |
| WACC | 343 | 0.8454810 | 1.6796081 | 0 | 15.0000000 |
| DACC | 343 | 1.4285714 | 2.6863310 | 0 | 29.0000000 |
| XVOL | 343 | 17.8084548 | 13.6049876 | 0.8000000 | 92.9000000 |
| RVOL | 343 | 18.3916910 | 14.3410589 | 0.9100000 | 82.3400000 |
| FRATE | 343 | 0.0024373 | 0.0259238 | 0 | 0.4490000 |
| FIRATE | 343 | 0.0854810 | 0.1675407 | 0 | 2.2000000 |
| TRATE | 343 | 0.2400875 | 0.3601945 | 0 | 4.4000000 |
| WRATE | 343 | 0.0599630 | 0.2038571 | 0 | 3.3000000 |
| DRATE | 343 | 0.0879887 | 0.2071668 | 0 | 3.3000000 |

## Appendix C

### Analysis Variance and Covariance Models
( Detail Description)

This portion of the analyses included a series of ANOVA and ANCOVA models, again stratified by rural/urban and on/off-ramp, where the ramp traffic volume were specified as a covariate. The analyses were done after performing a linear adjustment for ramps traffic volume effect (ANCOVA). The rational for doing this analysis was that previous studies indicated traffic volume as a strong predictor of accidents. A series of ANCOVA models were run where location of ramp (Caltrans district) was used as a predictor. The motivation for these latter analyses was to account for district differences could otherwise be attributed to differences in ramp volumes. In these later analyses, if the differences in ramps were significant, then pairwise comparisons from ANCOVA with district as predictor were selected.

While the ANOVA/ANCOVA can tell that a certain factor is influential, they don't tell the nature (direction) of any significant effects that are detected. For example, from ANOVA tables which will be discussed later in this report, we know that there are systematic differences between two ramp configuration, but we can not tell which of the two have higher overall accident rates. For this reason, the ANOVA/ANCOVA analyses were followed by *post hoc* analyses.

The post hoc analysis used for the pairwise comparisons is Tukey's[4] method which exercises extra caution in declaring differences as significant.

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[4] Statistical comparisons ordinarily involve an inherent false positive error rate of 5%, this means that you would expect on the order of 10 false positive comparisons among the 210 comparisons. Since the purpose of this analysis is to identify differences according to ramp type with some degree of confidence, this high error rate is unacceptable. Tukey's method exercises extra caution in declaring differences as significant, and consequently the overall Type I error rate will be approximately 5%. By exercising this caution however, the likelihood of a false negative (Type II) error increases, and for this reason, it's important to remember that in the absence of a statistically significant difference between a particular pair of ramp types, any of the following explanations is plausible: (i) there in fact *is* no difference between the ramp types, (ii) there *is* a difference, which went undetected due to the conservatism of the *post hoc* analysis, (iii) there *is* a difference, which went undetected because the magnitude of the difference was small, or (iv) there *is* a difference, which went undetected because there were relatively few ramps for the two types being compared. In view of these four possibilities, it's appropriate that the distinction between a significant difference and an insignificant one should be interpreted as being between those differences for which there was sufficient evidence to declare a difference, and those for which there simply was insufficient evidence.

Since the pairwise comparison were done after adjustment for the covariate, comparisons method used was the *least square means*, (LSM). The results from LSM were printed as a matrix of p-values for comparing each pair of ramps.

In pairwise comparisons, the overall Type I error rate will be approximately 5%; in other words, the probability that any of the differences found to be statistically significant among the comparisons will be 5% or less. By exercising this caution, however, the likelihood of a false-negative (Type II) error increases. For this reason, it is important to remember that in the absence of a statistically significant difference between a particular pair of ramp types, any of the following explanations is plausible:

- there is no difference between the ramp types;
- there is a difference, which went undetected due to the conservatism of the *post hoc* analysis;
- there is a difference, which went undetected because the magnitude of the difference was small; or
- there is a difference, which went undetected because there were relatively few ramps for the two types being compared.

In view of these four possibilities, it is appropriate that the distinction between a significant difference and an insignificant one should be interpreted as being between those differences for which there is sufficient evidence to declare a difference, and those for which there simply is insufficient evidence.

In the *post hoc* results, many of the ramp types that are comparatively rare fail to be significantly different from any of the other ramp types. All this means is that there is too little information available on those ramp types to draw meaningful conclusions.

**Interpretation of ANOVA/ANCOVA Results**

In reading the ANOVA/ANCOVA tables, the F-values reflect the size of a systematic effect. The p-value is used to determine whether the effect in question is statistically significant. In other words, the p-value represents the probability that the result in question could have occurred by chance alone, and it's customary to ascribe statistical significance to any tests with p-values less than or equal to 0.05. The smaller a p-value, the less likely a result could have occurred simply by chance. The following analyses consists of two sets of ANCOVA models.

- ANCOVA for stratified data by on/off, urban/rural, with adjustment for traffic volume
- ANCOVA for stratified data by on/off, urban/rural, with adjustment for traffic volume and district as predictor.

## Appendix C Analysis Variance and Covariance Models

Each of the two models were run with the following four data sets:

- ONOFF=off RURAL=r-------->(off-ramps in rural area)
- ONOFF=off RURAL=u-------->(off-ramps in urban area)
- ONOFF=on RURAL=r-------->(on-ramps in rural area)
- ONOFF=on RURAL=u-------->(on-ramps in urban area)

For each of the above eight cases, mean accident rate tables and p-value matrix is provided for four accident rate types (total, fatal+injury, wet, and dark accident rates). Because the ANCOVA analyses indicated district effect as being significant ( meaning some differences attributed to Caltrans district and not just to ramp volumes) in urban area, comparison tables for urban settings were presented from ANCOVA models that modeled district as predictor. The tables for rural settings are from ANCOVA models without district as predictor.

## Comparison of Accident Rates by Type of Ramp Stratified by on/off, urban/rural, Adjusting for Traffic Volume

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| DESCR | 14 | buttonhook diamond3 diamond4 dir/semi3 dir/semi4 direct loopleft3 loopleft4 loopnoleft3 loopnoleft4 restarea scissors slip4 split |

Number of observations in by group : 1368

Dependent Variable: **FIRATE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 400.84198626 | 28.63157045 | 2.18 | 0.0070 |
| Error | 1350 | 17758.53283308 | 13.15446877 | | |
| Corrected Total | 1364 | 18159.37481934 | | | |
| | R-Square | C.V. | Root MSE | | FIRATE Mean |
| | 0.022074 | 485.2659 | 3.62690898 | | 0.74740659 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DESCR | 13 | 340.37527522 | 26.18271348 | 1.99 | 0.0185 |
| RVOL | 1 | 60.46671103 | 60.46671103 | 4.60 | 0.0322 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 310.85585084 | 23.91198853 | 1.82 | 0.0358 |
| RVOL | 1 | 60.46671103 | 60.46671103 | 4.60 | 0.0322 |

Dependent Variable: **TRATE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 1358.85731752 | 97.06123697 | 3.13 | 0.0001 |
| Error | 1350 | 41822.42328248 | 30.97957260 | | |
| Corrected Total | 1364 | 43181.28060000 | | | |
| | R-Square | C.V. | Root MSE | | TRATE Mean |
| | 0.031469 | 297.6433 | 5.56592964 | | 1.87000000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DESCR | 13 | 1056.96651260 | 81.30511635 | 2.62 | 0.0013 |
| RVOL | 1 | 301.89080492 | 301.89080492 | 9.74 | 0.0018 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 926.26541013 | 71.25118539 | 2.30 | 0.0052 |
| RVOL | 1 | 301.89080492 | 301.89080492 | 9.74 | 0.0018 |

Dependent Variable: **WRATE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 6.87386262 | 0.49099019 | 0.67 | 0.8020 |
| Error | 1350 | 984.11029018 | 0.72897059 | | |
| Corrected Total | 1364 | 990.98415279 | | | |
| | R-Square | C.V. | Root MSE | | WRATE Mean |
| | 0.006936 | 596.8256 | 0.85379774 | | 0.14305650 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DESCR | 13 | 6.67198867 | 0.51322990 | 0.70 | 0.7608 |
| RVOL | 1 | 0.20187395 | 0.20187395 | 0.28 | 0.5988 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 5.89090530 | 0.45314656 | 0.62 | 0.8377 |
| RVOL | 1 | 0.20187395 | 0.20187395 | 0.28 | 0.5988 |

Dependent Variable: **DRATE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 169.83452327 | 12.13103738 | 1.36 | 0.1674 |
| Error | 1350 | 12076.58894263 | 8.94562144 | | |
| Corrected Total | 1364 | 12246.42346591 | | | |
| | R-Square | C.V. | Root MSE | | DRATE Mean |
| | 0.013868 | 422.8695 | 2.99092318 | | 0.70729217 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DESCR | 13 | 99.52629849 | 7.65586911 | 0.86 | 0.6003 |
| RVOL | 1 | 70.30822479 | 70.30822479 | 7.86 | 0.0051 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 83.69801995 | 6.43830923 | 0.72 | 0.7451 |
| RVOL | 1 | 70.30822479 | 70.30822479 | 7.86 | 0.0051 |

## Least Squares Means

Adjustment for multiple comparisons: Tukey-Kramer

| DESCR | FIRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 1.62399444 | 1 |
| diamond3 | 0.21383081 | 2 |
| diamond4 | 0.74358644 | 3 |
| dir/semi3 | 0.97714972 | 4 |
| dir/semi4 | 0.52728234 | 5 |
| direct | 0.45588443 | 6 |
| loopleft3 | 0.81766351 | 7 |
| loopleft4 | 0.86071078 | 8 |
| loopnoleft3 | 0.25081523 | 9 |
| loopnoleft4 | 4.43429690 | 10 |
| restarea | 0.16719093 | 11 |
| scissors | 0.61611882 | 12 |
| slip4 | -0.13365370 | 13 |
| split | 0.85029422 | 14 |

**FIRATE** Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.2512 | 0.4783 | 0.9996 | 0.8968 | 0.9917 | 1.0000 | 0.9996 | 0.9882 | 0.4433 | 0.1269 | 0.9742 | 1.0000 | 1.0000 |
| 2 | 0.2512 | . | 0.9888 | 0.9983 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0195 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.4783 | 0.9888 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0511 | 0.9416 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 0.9996 | 0.9983 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.2382 | 0.9956 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.8968 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0759 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 0.9917 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.1867 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 0.9133 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.2672 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 0.9882 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.1956 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 0.4433 | 0.0195 | 0.0511 | 0.2382 | 0.0759 | 0.1867 | 0.9133 | 0.2672 | 0.1956 | . | 0.0143 | 0.1185 | 0.9955 | 0.9924 |
| 11 | 0.1269 | 1.0000 | 0.9416 | 0.9956 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 0.0143 | . | 1.0000 | 1.0000 | 1.0000 |
| 12 | 0.9742 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.1185 | 1.0000 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9955 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9924 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **TRATE**

| | | |
|---|---|---|
| buttonhook | 4.02667877 | 1 |
| diamond3 | 0.75819771 | 2 |
| diamond4 | 1.66200593 | 3 |
| dir/semi3 | 1.70607294 | 4 |
| dir/semi4 | 1.25042281 | 5 |
| direct | 1.02927861 | 6 |
| loopleft3 | 5.53395525 | 7 |
| loopleft4 | 3.58284530 | 8 |
| loopnoleft3 | 1.23191103 | 9 |
| loopnoleft4 | 4.44613141 | 10 |
| restarea | 2.17379991 | 11 |
| scissors | 1.32859920 | 12 |
| slip4 | -0.29863984 | 13 |
| split | 1.80734072 | 14 |

Dependent Variable: **TRATE**

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.0028 | 0.0022 | 0.6277 | 0.1835 | 0.6670 | 1.0000 | 1.0000 | 0.8893 | 1.0000 | 0.3974 | 0.3765 | 1.0000 | 1.0000 |
| 2 | 0.0028 | . | 0.9719 | 0.9998 | 1.0000 | 1.0000 | 0.9231 | 0.5926 | 1.0000 | 0.7184 | 0.8614 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.0022 | 0.9719 | . | 1.0000 | 1.0000 | 1.0000 | 0.9833 | 0.9162 | 1.0000 | 0.9329 | 0.9997 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 0.6277 | 0.9998 | 1.0000 | . | 1.0000 | 1.0000 | 0.9903 | 0.9900 | 1.0000 | 0.9779 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.1835 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9713 | 0.9150 | 1.0000 | 0.9100 | 0.9995 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 0.6670 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.9730 | 0.9674 | 1.0000 | 0.9429 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 0.9231 | 0.9833 | 0.9903 | 0.9713 | 0.9730 | . | 1.0000 | 0.9858 | 1.0000 | 0.9961 | 0.9777 | 0.9997 | 1.0000 |
| 8 | 1.0000 | 0.5926 | 0.9162 | 0.9900 | 0.9150 | 0.9674 | 1.0000 | . | 0.9928 | 1.0000 | 0.9971 | 0.9549 | 1.0000 | 1.0000 |
| 9 | 0.8893 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9858 | 0.9928 | . | 0.9780 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 0.7184 | 0.9329 | 0.9779 | 0.9100 | 0.9429 | 1.0000 | 1.0000 | 0.9780 | . | 0.9911 | 0.9384 | 0.9999 | 1.0000 |
| 11 | 0.3974 | 0.8614 | 0.9997 | 1.0000 | 0.9995 | 0.9999 | 0.9961 | 0.9971 | 1.0000 | 0.9911 | . | 0.9999 | 1.0000 | 1.0000 |
| 12 | 0.3765 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9777 | 0.9549 | 1.0000 | 0.9384 | 0.9999 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9997 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **WRATE**

| DESCR | WRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.12432404 | 1 |
| diamond3 | 0.02021938 | 2 |
| diamond4 | 0.19205276 | 3 |
| dir/semi3 | 0.01960279 | 4 |
| dir/semi4 | 0.07505332 | 5 |
| direct | 0.04772570 | 6 |
| loopleft3 | 0.27002731 | 7 |
| loopleft4 | 0.05429356 | 8 |
| loopnoleft3 | 0.09123161 | 9 |
| loopnoleft4 | 0.05140768 | 10 |
| restarea | 0.04700795 | 11 |
| scissors | 0.07286722 | 12 |
| slip4 | -0.00772259 | 13 |
| split | 0.08229696 | 14 |

Dependent Variable: **WRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 2 | 0.9999 | . | 0.8633 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 1.0000 | 0.8633 | . | 0.9953 | 0.9997 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 0.9054 | 0.9999 | 1.0000 | 1.0000 |
| 4 | 1.0000 | 1.0000 | 0.9953 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 1.0000 | 1.0000 | 0.9997 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 1.0000 | 1.0000 | 0.9054 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **DRATE**

Adjustment for multiple comparisons: Tukey-Kramer

| DESCR | DRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 1.27951525 | 1 |
| diamond3 | 0.30755313 | 2 |
| diamond4 | 0.66029609 | 3 |
| dir/semi3 | 0.70058109 | 4 |
| dir/semi4 | 0.58233594 | 5 |
| direct | 0.41991636 | 6 |
| loopleft3 | 1.69927773 | 7 |
| loopleft4 | 0.31770178 | 8 |
| loopnoleft3 | 0.63870128 | 9 |
| loopnoleft4 | -0.01471671 | 10 |
| restarea | 1.05371337 | 11 |
| scissors | 0.67157370 | 12 |
| slip4 | -0.14412054 | 13 |
| split | 0.83600993 | 14 |

Dependent Variable: **DRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.5557 | 0.7356 | 0.9991 | 0.9869 | 0.9972 | 1.0000 | 0.9754 | 1.0000 | 0.9852 | 1.0000 | 0.9987 | 1.0000 | 1.0000 |
| 2 | 0.5557 | . | 0.9986 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 0.8776 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.7356 | 0.9986 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9879 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 0.9991 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.9869 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9997 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 0.9972 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.9999 | 1.0000 | 0.9994 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.9754 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | . | 1.0000 | 1.0000 | 0.9978 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 0.9852 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9994 | 1.0000 | 1.0000 | . | 0.9976 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 1.0000 | 0.8776 | 0.9879 | 1.0000 | 0.9997 | 0.9999 | 1.0000 | 0.9978 | 1.0000 | 0.9976 | . | 1.0000 | 1.0000 | 1.0000 |
| 12 | 0.9987 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

## Comparison of accident rates by type of ramp stratified by on/off, urban/rural, adjusting for traffic volume

Class Level Information

| Class | Levels | Values |
|---|---|---|
| DESCR | 14 | buttonhook diamond3 diamond4 dir/semi3 dir/semi4 direct loopleft3 loopleft4 loopnoleft3 loopnoleft4 restarea scissors slip4 split |

Number of observations in by group = 1367

NOTE: All dependent variable are consistent with respect to the presence or absence of missing values. However only 1364 observations can be used in this analysis.

### Dependent Variable: FIRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 83.78260263 | 5.98447162 | 0.75 | 0.7264 |
| Error | 1349 | 10792.16917450 | 8.00012541 | | |
| Corrected Total | 1363 | 10875.95177713 | | | |
| | R-Square | C.V. | Root MSE | | FIRATE Mean |
| | 0.007703 | 799.6859 | 2.82844929 | | 0.35369501 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 54.27620398 | 4.17509261 | 0.52 | 0.9124 |
| RVOL | 1 | 29.50639865 | 29.50639865 | 3.69 | 0.0550 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 61.18945453 | 4.70688112 | 0.59 | 0.8651 |
| RVOL | 1 | 29.50639865 | 29.50639865 | 3.69 | 0.0550 |

### Dependent Variable: TRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 188.86458016 | 13.49032715 | 0.79 | 0.6814 |
| Error | 1349 | 23046.82544001 | 17.08437764 | | |
| Corrected Total | 1363 | 23235.69002016 | | | |
| | R-Square | C.V. | Root MSE | | TRATE Mean |
| | 0.008128 | 472.2495 | 4.13332525 | | 0.87524194 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 82.17873622 | 6.32144125 | 0.37 | 0.9789 |
| RVOL | 1 | 106.68584393 | 106.68584393 | 6.24 | 0.0126 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 86.51599703 | 6.65507669 | 0.39 | 0.9735 |
| RVOL | 1 | 106.68584393 | 106.68584393 | 6.24 | 0.0126 |

### Dependent Variable: WRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 4.53064701 | 0.32361764 | 0.30 | 0.9937 |
| Error | 1349 | 1437.32527182 | 1.06547463 | | |
| Corrected Total | 1363 | 1441.85591883 | | | |
| | R-Square | C.V. | Root MSE | | WRATE Mean |
| | 0.003142 | 1024.073 | 1.03221830 | | 0.10079536 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 3.86139897 | 0.29703069 | 0.28 | 0.9945 |
| RVOL | 1 | 0.66924804 | 0.66924804 | 0.63 | 0.4282 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 3.62350045 | 0.27873080 | 0.26 | 0.9960 |
| RVOL | 1 | 0.66924804 | 0.66924804 | 0.63 | 0.4282 |

### Dependent Variable: DRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 87.13382083 | 6.22384434 | 0.75 | 0.7270 |
| Error | 1349 | 11231.88600992 | 8.32608303 | | |
| Corrected Total | 1363 | 11319.01983075 | | | |
| | R-Square | C.V. | Root MSE | | DRATE Mean |
| | 0.007698 | 917.8869 | 2.88549528 | | 0.31436284 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 67.01713284 | 5.15516406 | 0.62 | 0.8398 |
| RVOL | 1 | 20.11668799 | 20.11668799 | 2.42 | 0.1203 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DESCR | 13 | 70.57697110 | 5.42899778 | 0.65 | 0.8107 |
| RVOL | 1 | 20.11668799 | 20.11668799 | 2.42 | 0.1203 |

## Appendix C Analysis of On-Ramps in Rural Area

Dependent Variable: **FIRATE**

| DESCR | FIRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.24334023 | 1 |
| diamond3 | 0.21779679 | 2 |
| diamond4 | 0.25615367 | 3 |
| dir/semi3 | 0.60043056 | 4 |
| dir/semi4 | 0.88943680 | 5 |
| direct | 0.52784949 | 6 |
| loopleft3 | 0.00197261 | 7 |
| loopleft4 | 0.48037372 | 8 |
| loopnoleft3 | 0.17543346 | 9 |
| loopnoleft4 | 0.35627676 | 10 |
| restarea | 0.81383110 | 11 |
| scissors | 0.08020731 | 12 |
| slip4 | 1.06415180 | 13 |
| split | 0.37906062 | 14 |

Dependent Variable: **FIRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 1.0000 | 1.0000 | 0.9747 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9648 | 1.0000 | 1.0000 | 1.0000 |
| 2 | 1.0000 | . | 1.0000 | 1.0000 | 0.9804 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9765 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 1.0000 | 1.0000 | . | 1.0000 | 0.9058 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.7785 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 |
| 5 | 0.9747 | 0.9804 | 0.9058 | 1.0000 | . | 1.0000 | 1.0000 | 0.9999 | 0.9993 | 0.9998 | 1.0000 | 0.9844 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9993 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 0.9648 | 0.9765 | 0.7785 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9996 | 0.9999 | . | 0.9859 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 0.9844 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9859 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **TRATE**

| DESCR | TRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 1.17163388 | 1 |
| diamond3 | 0.53195115 | 2 |
| diamond4 | 0.76081578 | 3 |
| dir/semi3 | 0.91388930 | 4 |
| dir/semi4 | 1.12723866 | 5 |
| direct | 1.13654330 | 6 |
| loopleft3 | 0.65660806 | 7 |
| loopleft4 | 0.84025707 | 8 |
| loopnoleft3 | 0.88602757 | 9 |
| loopnoleft4 | 0.62430910 | 10 |
| restarea | 1.51773442 | 11 |
| scissors | 0.70342655 | 12 |
| slip4 | 2.02347983 | 13 |
| split | 0.77744872 | 14 |

Dependent Variable: **TRATE**

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9990 | 0.9995 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 2 | 0.9990 | . | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9370 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.9995 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.8568 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 0.9983 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.9980 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 1.0000 | 0.9370 | 0.8568 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 0.9983 | 1.0000 | 0.9980 | . | 0.9990 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9990 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **WRATE**

| DESCR | WRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.06118293 | 1 |
| diamond3 | 0.04237459 | 2 |
| diamond4 | 0.11047235 | 3 |
| dir/semi3 | 0.08443759 | 4 |
| dir/semi4 | 0.09041774 | 5 |
| direct | 0.09058624 | 6 |
| loopleft3 | 0.00029708 | 7 |
| loopleft4 | 0.06248182 | 8 |
| loopnoleft3 | 0.45479040 | 9 |
| loopnoleft4 | 0.16713453 | 10 |
| restarea | 0.09114084 | 11 |
| scissors | 0.04160251 | 12 |
| slip4 | 0.16026513 | 13 |
| split | 0.11375457 | 14 |

Dependent Variable: **WRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9464 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 2 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9395 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9666 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9882 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9813 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 0.9981 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9993 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.9617 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 0.9464 | 0.9395 | 0.9666 | 0.9882 | 0.9813 | 0.9981 | 0.9993 | 0.9617 | . | 0.9993 | 0.9700 | 0.9745 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9993 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9700 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9745 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **DRATE**

| DESCR | DRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.59826309 | 1 |
| diamond3 | 0.17649399 | 2 |
| diamond4 | 0.24253680 | 3 |
| dir/semi3 | 0.49783010 | 4 |
| dir/semi4 | 0.12922160 | 5 |
| direct | 0.47333289 | 6 |
| loopleft3 | 0.00162878 | 7 |
| loopleft4 | 0.07614066 | 8 |
| loopnoleft3 | 0.02930553 | 9 |
| loopnoleft4 | 0.22117764 | 10 |
| restarea | 0.92455572 | 11 |
| scissors | 0.08074969 | 12 |
| slip4 | 0.87866580 | 13 |
| split | 0.31298880 | 14 |

Dependent Variable: **DRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9994 | 0.9956 | 1.0000 | 0.9990 | 1.0000 | 1.0000 | 0.9960 | 0.9999 | 1.0000 | 0.9999 | 0.9997 | 1.0000 | 1.0000 |
| 2 | 0.9994 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.8865 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.9956 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.4977 | 1.0000 | 1.0000 | 1.0000 |
| 4 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.9990 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.8831 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.9960 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 0.7891 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9901 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 0.9936 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 0.9999 | 0.8865 | 0.4977 | 0.9999 | 0.8831 | 1.0000 | 0.9999 | 0.7891 | 0.9901 | 0.9936 | . | 0.9610 | 1.0000 | 1.0000 |
| 12 | 0.9997 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9610 | . | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

## Comparison of accident rates by ramp configuration, traffic volume as covariate, and district= predictor

### General Linear Models Procedure
### Class Level Information

| Class | Levels | Values |
|---|---|---|
| DISTRICT | 12 | 1 2 3 4 5 6 7 8 9 10 11 12 |
| DESCR | 15 | buttonhook diamond3 diamond4 dir/semi3 dir/semi4 direct loopleft3 loopleft4 loopnoleft3 loopnoleft4 restarea scissors slip3 slip4 split |

Number of observations in by group = 5309

NOTE: All dependent variable are consistent with respect to the presence or absence of missing values. However only 5307 observations can be used in this analysis.

### Dependent Variable: FIRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 475.84036167 | 18.30155237 | 5.72 | 0.0001 |
| Error | 5280 | 16901.52131253 | 3.20104570 | | |
| Corrected Total | 5306 | 17377.36167420 | | | |
| | R-Square | C.V. | Root MSE | | FIRATE Mean |
| | 0.027383 | 334.4276 | 1.78914664 | | 0.53498775 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DISTRICT | 11 | 153.89012730 | 13.99001157 | 4.37 | 0.0001 |
| RVOL | 1 | 155.28265817 | 155.28265817 | 48.51 | 0.0001 |
| DESCR | 14 | 166.66757620 | 11.90482687 | 3.72 | 0.0001 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 104.25870264 | 9.47806388 | 2.96 | 0.0006 |
| RVOL | 1 | 51.01326659 | 51.01326659 | 15.94 | 0.0001 |
| DESCR | 14 | 166.66757620 | 11.90482687 | 3.72 | 0.0001 |

### Dependent Variable: TRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 36 | 3940.39630420 | 151.55370401 | 5.42 | 0.0001 |
| Error | 5280 | 147518.83717769 | 27.93917371 | | |
| Corrected Total | 5106 | 151459.23348189 | | | |
| | R-Square | C.V. | Root MSE | | TRATE Mean |
| | 0.026016 | 379.6888 | 5.28575195 | | 1.39212738 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DISTRICT | 11 | 1941.00866803 | 176.45533346 | 6.32 | 0.0001 |
| RVOL | 1 | 1042.60099487 | 1042.60099487 | 37.32 | 0.0001 |
| DESCR | 14 | 956.78664130 | 68.34190295 | 2.45 | 0.0019 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 1414.06659190 | 128.55150835 | 4.60 | 0.0001 |
| RVOL | 1 | 377.48531314 | 377.48531314 | 13.51 | 0.0002 |
| DESCR | 14 | 956.78664130 | 68.34190295 | 2.45 | 0.0019 |

### Dependent Variable: WRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 83.32227668 | 3.20470295 | 3.18 | 0.0001 |
| Error | 5280 | 5323.27820217 | 1.00819663 | | |
| Corrected Total | 5306 | 5406.60047885 | | | |
| | R-Square | C.V. | Root MSE | | WRATE Mean |
| | 0.015411 | 510.4535 | 1.00408995 | | 0.19670548 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DISTRICT | 11 | 48.74671622 | 4.43151966 | 4.40 | 0.0001 |
| RVOL | 1 | 12.92978785 | 12.92978785 | 12.82 | 0.0003 |
| DESCR | 14 | 21.64577262 | 1.54612662 | 1.53 | 0.0906 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 40.92160724 | 3.72014611 | 3.69 | 0.0001 |
| RVOL | 1 | 2.42605006 | 2.42605006 | 2.41 | 0.1209 |
| DESCR | 14 | 21.64577262 | 1.54612662 | 1.53 | 0.0906 |

### Dependent Variable: DRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 329.56005941 | 12.67538690 | 3.47 | 0.0001 |
| Error | 5280 | 19297.14089122 | 3.65476153 | | |
| Corrected Total | 5306 | 19626.70095064 | | | |
| | R-Square | C.V. | Root MSE | | DRATE Mean |
| | 0.016791 | 451.7622 | 1.91174306 | | 0.42317462 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DISTRICT | 11 | 152.94477134 | 13.90407012 | 3.80 | 0.0001 |
| RVOL | 1 | 100.64803479 | 100.64803479 | 27.54 | 0.0001 |
| DESCR | 14 | 75.96725328 | 5.42623238 | 1.48 | 0.1077 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 111.44055022 | 10.13095911 | 2.77 | 0.0014 |
| RVOL | 1 | 35.67477867 | 35.67477867 | 9.76 | 0.0018 |
| DESCR | 14 | 75.96725328 | 5.42623238 | 1.48 | 0.1077 |

Dependent Variable: **FIRATE**

General Linear Models Procedure
Least Squares Means
Adjustment for multiple comparisons: Tukey-Kramer

| DESCR | FIRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.50341603 | 1 |
| diamond3 | 0.42852379 | 2 |
| diamond4 | 0.72351217 | 3 |
| dir/semi3 | 0.24637697 | 4 |
| dir/semi4 | 0.39873186 | 5 |
| direct | 0.39275325 | 6 |
| loopleft3 | 0.30722402 | 7 |
| loopleft4 | 0.68375638 | 8 |
| loopnoleft3 | 0.29283242 | 9 |
| loopnoleft4 | 0.43639101 | 10 |
| restarea | 0.39750200 | 11 |
| scissors | 0.43147053 | 12 |
| slip3 | 0.44117279 | 13 |
| slip4 | 0.21072101 | 14 |
| split | 0.25721170 | 15 |

Dependent Variable: **FIRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 0.4690 | 0.7818 | 0.9999 | 1.0000 | 1.0000 | 0.9980 | 0.9975 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9814 | 0.7789 |
| 2 | 1.0000 | . | 0.7964 | 0.9993 | 1.0000 | 1.0000 | 1.0000 | 0.9932 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 0.9995 |
| 3 | 0.4690 | 0.7964 | . | 0.0005 | 0.0752 | 0.3111 | 1.0000 | 1.0000 | 0.3269 | 0.5123 | 0.9985 | 0.8854 | 0.9901 | 0.2838 | 0.0001 |
| 4 | 0.7818 | 0.9993 | 0.0005 | . | 0.9984 | 0.9997 | 1.0000 | 0.3209 | 1.0000 | 0.9948 | 1.0000 | 0.9996 | 0.9999 | 1.0000 | 1.0000 |
| 5 | 0.9999 | 1.0000 | 0.0752 | 0.9984 | . | 1.0000 | 1.0000 | 0.9070 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 0.9988 |
| 6 | 1.0000 | 1.0000 | 0.3111 | 0.9997 | 1.0000 | . | 1.0000 | 0.9471 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9997 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.9980 | 0.9932 | 1.0000 | 0.3209 | 0.9070 | 0.9471 | 1.0000 | . | 0.8488 | 0.9849 | 0.9999 | 0.9961 | 0.9996 | 0.7396 | 0.3161 |
| 9 | 0.9975 | 1.0000 | 0.3269 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.8488 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 0.5123 | 0.9948 | 1.0000 | 1.0000 | 1.0000 | 0.9849 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9994 | 0.9959 |
| 11 | 1.0000 | 1.0000 | 0.9985 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 0.8854 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | 0.9961 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9999 | 0.9997 |
| 13 | 1.0000 | 1.0000 | 0.9901 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9999 |
| 14 | 0.9814 | 0.9998 | 0.2838 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 0.7396 | 1.0000 | 0.9994 | 1.0000 | 0.9999 | 1.0000 | . | 1.0000 |
| 15 | 0.7789 | 0.9995 | 0.0001 | 1.0000 | 0.9988 | 0.9997 | 1.0000 | 0.3161 | 1.0000 | 0.9959 | 1.0000 | 0.9997 | 0.9999 | 1.0000 | . |

Dependent Variable: **TRATE**

| DESCR | TRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 1.43518009 | 1 |
| diamond3 | 0.92078871 | 2 |
| diamond4 | 1.80765971 | 3 |
| dir/semi3 | 0.63320863 | 4 |
| dir/semi4 | 1.02215120 | 5 |
| direct | 1.35150340 | 6 |
| loopleft3 | 0.76486285 | 7 |
| loopleft4 | 1.53141051 | 8 |
| loopnoleft3 | 0.82078505 | 9 |
| loopnoleft4 | 1.19714423 | 10 |
| restarea | 1.75940474 | 11 |
| scissors | 1.09597585 | 12 |
| slip3 | 0.76406084 | 13 |
| slip4 | 0.55398667 | 14 |
| split | 0.71747941 | 15 |

Dependent Variable: **TRATE**

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9993 | 0.9866 | 0.7066 | 0.9983 | 1.0000 | 1.0000 | 1.0000 | 0.9978 | 1.0000 | 1.0000 | 1.0000 | 0.9995 | 0.9780 | 0.7954 |
| 2 | 0.9993 | . | 0.7747 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9993 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.9866 | 0.7747 | . | 0.0114 | 0.3248 | 0.9957 | 1.0000 | 1.0000 | 0.7570 | 0.9241 | 1.0000 | 0.9749 | 0.9310 | 0.6183 | 0.0112 |
| 4 | 0.7066 | 1.0000 | 0.0114 | . | 0.9997 | 0.9470 | 1.0000 | 0.8733 | 1.0000 | 0.9946 | 0.9952 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.9983 | 1.0000 | 0.3248 | 0.9997 | . | 1.0000 | 1.0000 | 0.9992 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 0.9957 | 0.9470 | 1.0000 | . | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 0.9959 | 0.9681 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 0.9993 | 1.0000 | 0.8733 | 0.9992 | 1.0000 | 1.0000 | . | 0.9979 | 1.0000 | 1.0000 | 1.0000 | 0.9992 | 0.9810 | 0.9233 |
| 9 | 0.9978 | 1.0000 | 0.7570 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 0.9979 | . | 1.0000 | 0.9997 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 0.9241 | 0.9946 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9996 | 0.9986 |
| 11 | 1.0000 | 0.9999 | 1.0000 | 0.9952 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9997 | 1.0000 | . | 1.0000 | 0.9998 | 0.9971 | 0.9977 |
| 12 | 1.0000 | 1.0000 | 0.9749 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 |
| 13 | 0.9995 | 1.0000 | 0.9310 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 0.9992 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | . | 1.0000 | 1.0000 |
| 14 | 0.9780 | 1.0000 | 0.6183 | 1.0000 | 1.0000 | 0.9959 | 1.0000 | 0.9810 | 1.0000 | 0.9996 | 0.9971 | 1.0000 | 1.0000 | . | 1.0000 |
| 15 | 0.7954 | 1.0000 | 0.0112 | 1.0000 | 1.0000 | 0.9681 | 1.0000 | 0.9233 | 1.0000 | 0.9986 | 0.9977 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **WRATE**

| DESCR | WRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.24293221 | 1 |
| diamond3 | 0.12550320 | 2 |
| diamond4 | 0.23872360 | 3 |
| dir/semi3 | 0.08546999 | 4 |
| dir/semi4 | 0.10178322 | 5 |
| direct | 0.14797564 | 6 |
| loopleft3 | 0.12609693 | 7 |
| loopleft4 | 0.16180246 | 8 |
| loopnoleft3 | 0.17119149 | 9 |
| loopnoleft4 | 0.16392787 | 10 |
| restarea | 0.23802129 | 11 |
| scissors | 0.18433324 | 12 |
| slip3 | 0.06581891 | 13 |
| slip4 | 0.08481518 | 14 |
| split | 0.05931988 | 15 |

Dependent Variable: **WRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9948 | 1.0000 | 0.6543 | 0.7593 | 0.9976 | 1.0000 | 0.9998 | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 0.9835 | 0.9869 | 0.3037 |
| 2 | 0.9948 | . | 0.9898 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 1.0000 | 0.9898 | . | 0.3535 | 0.4782 | 0.9932 | 1.0000 | 0.9996 | 1.0000 | 0.9988 | 1.0000 | 1.0000 | 0.9778 | 0.9812 | 0.0637 |
| 4 | 0.6543 | 1.0000 | 0.3535 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 0.9999 | 0.9998 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.7593 | 1.0000 | 0.4782 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 0.9976 | 1.0000 | 0.9932 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9984 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.9998 | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9983 |
| 9 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9988 |
| 10 | 0.9996 | 1.0000 | 0.9988 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9939 |
| 11 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 0.9999 | 1.0000 | 0.9993 |
| 12 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 0.9959 |
| 13 | 0.9835 | 1.0000 | 0.9778 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | . | 1.0000 | 1.0000 |
| 14 | 0.9869 | 1.0000 | 0.9812 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 15 | 0.3037 | 1.0000 | 0.0637 | 1.0000 | 1.0000 | 0.9984 | 1.0000 | 0.9983 | 0.9988 | 0.9939 | 0.9993 | 0.9959 | 1.0000 | 1.0000 | . |

Dependent Variable: **DRATE**

| DESCR | DRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.50559134 | 1 |
| diamond3 | 0.22101448 | 2 |
| diamond4 | 0.50145992 | 3 |
| dir/semi3 | 0.22855588 | 4 |
| dir/semi4 | 0.30414788 | 5 |
| direct | 0.29588247 | 6 |
| loopleft3 | 0.24681041 | 7 |
| loopleft4 | 0.54585430 | 8 |
| loopnoleft3 | 0.28805515 | 9 |
| loopnoleft4 | 0.32265925 | 10 |
| restarea | 0.79293064 | 11 |
| scissors | 0.42416136 | 12 |
| slip3 | 0.26587741 | 13 |
| slip4 | 0.14498643 | 14 |
| split | 0.22128444 | 15 |

Dependent Variable: **DRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9525 | 1.0000 | 0.7707 | 0.9693 | 0.9895 | 1.0000 | 1.0000 | 0.9983 | 0.9964 | 0.9999 | 1.0000 | 0.9995 | 0.9382 | 0.6674 |
| 2 | 0.9525 | . | 0.9052 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9657 | 1.0000 | 1.0000 | 0.9377 | 0.9999 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 1.0000 | 0.9052 | . | 0.4740 | 0.8759 | 0.9660 | 1.0000 | 1.0000 | 0.9964 | 0.9874 | 0.9998 | 1.0000 | 0.9993 | 0.9067 | 0.2935 |
| 4 | 0.7707 | 1.0000 | 0.4740 | . | 1.0000 | 1.0000 | 1.0000 | 0.8922 | 1.0000 | 1.0000 | 0.9142 | 0.9996 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 0.9693 | 1.0000 | 0.8759 | 1.0000 | . | 1.0000 | 1.0000 | 0.9865 | 1.0000 | 1.0000 | 0.9710 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 0.9835 | 1.0000 | 0.9660 | 1.0000 | 1.0000 | . | 1.0000 | 0.9925 | 1.0000 | 1.0000 | 0.9746 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 0.9657 | 1.0000 | 0.8922 | 0.9865 | 0.9925 | 1.0000 | . | 0.9978 | 0.9972 | 1.0000 | 1.0000 | 0.9991 | 0.9447 | 0.8485 |
| 9 | 0.9983 | 1.0000 | 0.9964 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9978 | . | 1.0000 | 0.9817 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 0.9964 | 1.0000 | 0.9874 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9972 | 1.0000 | . | 0.9833 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 0.9999 | 0.9377 | 0.9998 | 0.9142 | 0.9710 | 0.9746 | 0.9999 | 1.0000 | 0.9817 | 0.9833 | . | 0.9992 | 0.9865 | 0.9010 | 0.9014 |
| 12 | 1.0000 | 0.9999 | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9992 | . | 1.0000 | 0.9991 | 0.9993 |
| 13 | 0.9995 | 1.0000 | 0.9993 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9991 | 1.0000 | 1.0000 | 0.9865 | 1.0000 | . | 1.0000 | 1.0000 |
| 14 | 0.9382 | 1.0000 | 0.9067 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9447 | 1.0000 | 1.0000 | 0.9010 | 0.9991 | 1.0000 | . | 1.0000 |
| 15 | 0.6674 | 1.0000 | 0.2935 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.8485 | 1.0000 | 1.0000 | 0.9014 | 0.9993 | 1.0000 | 1.0000 | . |

## Comparison of accident rates by ramp configuration, traffic volume as covariate, and district= predictor

```
Class Level Information
Class      Levels    Values
DISTRICT       12    1 2 3 4 5 6 7 8 9 10 11 12
DESCR          15    buttonhook diamond3 diamond4 dir/semi3 dir/semi4 direct loopleft3 loopleft4 loopnoleft3 loopnoleft4 restarea
                     scissors slip3 slip4 split

                         Number of observations in by group = 5259

         NOTE: All dependent variable are consistent with respect to the presence or absence of missing values.  However
               only 5257 observations can be used in this analysis.
```

### Dependent Variable: FIRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 165.32157264 | 6.35852202 | 6.29 | 0.0001 |
| Error | 5230 | 5290.30003615 | 1.01152964 | | |
| Corrected Total | 5256 | 5455.62160879 | | | |
| | R-Square | C.V. | Root MSE | | FIRATE Mean |
| | 0.030303 | 338.5098 | 1.00574830 | | 0.29711052 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 100.11934546 | 9.10175868 | 9.00 | 0.0001 |
| RVOL | 1 | 32.89377267 | 32.89377267 | 32.52 | 0.0001 |
| DESCR | 14 | 32.30845451 | 2.30774675 | 2.28 | 0.0042 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 85.98862751 | 7.81714796 | 7.73 | 0.0001 |
| RVOL | 1 | 22.14391661 | 22.14391661 | 21.89 | 0.0001 |
| DESCR | 14 | 32.30845451 | 2.30774675 | 2.28 | 0.0042 |

### Dependent Variable: TRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 903.78661289 | 34.76102357 | 2.46 | 0.0001 |
| Error | 5230 | 73778.18724303 | 14.10672796 | | |
| Corrected Total | 5256 | 74681.97385592 | | | |
| | R-Square | C.V. | Root MSE | | TRATE Mean |
| | 0.012102 | 461.2413 | 3.75589243 | | 0.81430093 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 430.19509826 | 39.10864530 | 2.77 | 0.0014 |
| RVOL | 1 | 299.23450332 | 299.23450332 | 21.21 | 0.0001 |
| DESCR | 14 | 174.35701131 | 12.45407224 | 0.88 | 0.5775 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 377.27849756 | 34.29804523 | 2.43 | 0.0051 |
| RVOL | 1 | 191.44764261 | 191.44764261 | 13.57 | 0.0002 |
| DESCR | 14 | 174.35701131 | 12.45407224 | 0.88 | 0.5775 |

### Dependent Variable: WRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 20.68595232 | 0.79561355 | 2.57 | 0.0001 |
| Error | 5230 | 1616.32801314 | 0.30904933 | | |
| Corrected Total | 5256 | 1637.01396546 | | | |
| | R-Square | C.V. | Root MSE | | WRATE Mean |
| | 0.012636 | 413.8275 | 0.55592206 | | 0.13433665 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 7.83406017 | 0.71236911 | 2.31 | 0.0082 |
| RVOL | 1 | 3.37069613 | 3.37069613 | 10.91 | 0.0010 |
| DESCR | 14 | 9.47919602 | 0.67708543 | 2.19 | 0.0063 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 7.68404923 | 0.69854993 | 2.26 | 0.0097 |
| RVOL | 1 | 1.95356511 | 1.95356511 | 6.32 | 0.0120 |
| DESCR | 14 | 9.47919602 | 0.67708543 | 2.19 | 0.0063 |

### Dependent Variable: DRATE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 99.30808887 | 3.81954188 | 1.92 | 0.0034 |
| Error | 5230 | 10427.78232444 | 1.99383983 | | |
| Corrected Total | 5256 | 10527.09041331 | | | |
| | R-Square | C.V. | Root MSE | | DRATE Mean |
| | 0.009434 | 576.2335 | 1.41203393 | | 0.24504542 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 58.53748459 | 5.32158951 | 2.67 | 0.0020 |
| RVOL | 1 | 22.57745418 | 22.57745418 | 11.32 | 0.0008 |
| DESCR | 14 | 18.19315009 | 1.29951072 | 0.65 | 0.8228 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| DISTRICT | 11 | 51.61639499 | 4.69239954 | 2.35 | 0.0068 |
| RVOL | 1 | 14.58346620 | 14.58346620 | 7.31 | 0.0069 |
| DESCR | 14 | 18.19315009 | 1.29951072 | 0.65 | 0.8228 |

**comparison of accident rates by ramp configuration, traffic volume as covariate, and district= predictor**

Least Squares Means

Adjustment for multiple comparisons: Tukey-Kramer

Dependent Variable: **FIRATE**

| DESCR | FIRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.38907782 | 1 |
| diamond3 | 0.32651993 | 2 |
| diamond4 | 0.54636588 | 3 |
| dir/semi3 | 0.42581529 | 4 |
| dir/semi4 | 0.45081843 | 5 |
| direct | 0.52004433 | 6 |
| loopleft3 | 0.46790138 | 7 |
| loopleft4 | 0.56589071 | 8 |
| loopnoleft3 | 0.38117742 | 9 |
| loopnoleft4 | 0.45690042 | 10 |
| restarea | 0.14467324 | 11 |
| scissors | 0.39647271 | 12 |
| slip3 | 0.48581635 | 13 |
| slip4 | 0.71471026 | 14 |
| split | 0.38219968 | 15 |

Dependent Variable: **FIRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 0.1671 | 1.0000 | 0.9996 | 0.9832 | 1.0000 | 0.6196 | 1.0000 | 0.9992 | 0.9822 | 1.0000 | 1.0000 | 0.3487 | 1.0000 |
| 2 | 1.0000 | . | 0.6043 | 0.9999 | 0.9968 | 0.9592 | 1.0000 | 0.7163 | 1.0000 | 0.9955 | 0.9997 | 1.0000 | 0.9996 | 0.3555 | 1.0000 |
| 3 | 0.1671 | 0.6043 | . | 0.8693 | 0.7356 | 1.0000 | 1.0000 | 1.0000 | 0.8338 | 0.8884 | 0.4683 | 0.9291 | 1.0000 | 0.9837 | 0.4047 |
| 4 | 1.0000 | 0.9999 | 0.8693 | . | 1.0000 | 0.9997 | 1.0000 | 0.9554 | 1.0000 | 1.0000 | 0.9527 | 1.0000 | 1.0000 | 0.6290 | 1.0000 |
| 5 | 0.9996 | 0.9968 | 0.7356 | 1.0000 | . | 1.0000 | 1.0000 | 0.9643 | 1.0000 | 1.0000 | 0.8794 | 1.0000 | 1.0000 | 0.6739 | 0.9998 |
| 6 | 0.9832 | 0.9592 | 1.0000 | 0.9997 | 1.0000 | . | 1.0000 | 1.0000 | 0.9962 | 1.0000 | 0.7401 | 0.9991 | 1.0000 | 0.9856 | 0.9785 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 0.6196 | 0.7163 | 1.0000 | 0.9554 | 0.9643 | 1.0000 | 1.0000 | . | 0.9000 | 0.9829 | 0.4871 | 0.9551 | 1.0000 | 0.9984 | 0.7219 |
| 9 | 1.0000 | 1.0000 | 0.8338 | 1.0000 | 1.0000 | 0.9962 | 1.0000 | 0.9000 | . | 1.0000 | 0.9936 | 1.0000 | 1.0000 | 0.5318 | 1.0000 |
| 10 | 0.9992 | 0.9955 | 0.8884 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9829 | 1.0000 | . | 0.8674 | 1.0000 | 1.0000 | 0.7268 | 0.9996 |
| 11 | 0.9822 | 0.9997 | 0.4683 | 0.9527 | 0.8794 | 0.7401 | 0.9998 | 0.4871 | 0.9936 | 0.8674 | . | 0.9888 | 0.9430 | 0.2069 | 0.9896 |
| 12 | 1.0000 | 1.0000 | 0.9291 | 1.0000 | 1.0000 | 0.9991 | 1.0000 | 0.9551 | 1.0000 | 1.0000 | 0.9888 | . | 1.0000 | 0.6332 | 1.0000 |
| 13 | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9430 | 1.0000 | . | 0.9907 | 1.0000 |
| 14 | 0.3487 | 0.3555 | 0.9837 | 0.6290 | 0.6739 | 0.9856 | 1.0000 | 0.9984 | 0.5318 | 0.7268 | 0.2069 | 0.6332 | 0.9907 | . | 0.3668 |
| 15 | 1.0000 | 1.0000 | 0.4047 | 1.0000 | 0.9998 | 0.9785 | 1.0000 | 0.7219 | 1.0000 | 0.9996 | 0.9896 | 1.0000 | 1.0000 | 0.3668 | . |

Dependent Variable: **TRATE**

| DESCR | TRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.81705397 | 1 |
| diamond3 | 0.47346185 | 2 |
| diamond4 | 1.10762758 | 3 |
| dir/semi3 | 0.66347515 | 4 |
| dir/semi4 | 0.71276631 | 5 |
| direct | 0.92782892 | 6 |
| loopleft3 | 0.76173667 | 7 |
| loopleft4 | 0.93666120 | 8 |
| loopnoleft3 | 0.79830398 | 9 |
| loopnoleft4 | 0.80708579 | 10 |
| restarea | 0.71435237 | 11 |
| scissors | 0.65261127 | 12 |
| slip3 | 1.02260976 | 13 |
| slip4 | 0.93772796 | 14 |
| split | 0.64860854 | 15 |

Dependent Variable: **TRATE**

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 0.9999 | 0.9806 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 2 | 0.9999 | . | 0.9128 | 1.0000 | 1.0000 | 0.9996 | 1.0000 | 0.9989 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 |
| 3 | 0.9806 | 0.9128 | . | 0.8807 | 0.5729 | 1.0000 | 1.0000 | 1.0000 | 0.9997 | 0.9495 | 1.0000 | 0.9880 | 1.0000 | 1.0000 | 0.8490 |
| 4 | 1.0000 | 1.0000 | 0.8807 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 1.0000 | 1.0000 | 0.5729 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 0.9996 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 0.9989 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 |
| 9 | 1.0000 | 1.0000 | 0.9997 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 0.9999 | 0.9495 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 0.9880 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 |
| 13 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 |
| 14 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 15 | 1.0000 | 1.0000 | 0.8490 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

Dependent Variable: **WRATE**

| DESCR | WRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.07569713 | 1 |
| diamond3 | 0.04107740 | 2 |
| diamond4 | 0.11912743 | 3 |
| dir/semi3 | 0.09499567 | 4 |
| dir/semi4 | 0.10965142 | 5 |
| direct | 0.15273463 | 6 |
| loopleft3 | -0.00504391 | 7 |
| loopleft4 | 0.14239196 | 8 |
| loopnoleft3 | 0.20869104 | 9 |
| loopnoleft4 | 0.15178763 | 10 |
| restarea | -0.03357429 | 11 |
| scissors | 0.08508472 | 12 |
| slip3 | 0.04168596 | 13 |
| slip4 | 0.31851993 | 14 |
| split | 0.06733281 | 15 |

Dependent Variable: **WRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 0.9789 | 1.0000 | 0.9996 | 0.9708 | 1.0000 | 0.9698 | 0.4079 | 0.6862 | 0.9978 | 1.0000 | 1.0000 | 0.0299 | 1.0000 |
| 2 | 1.0000 | . | 0.9609 | 0.9999 | 0.9968 | 0.9423 | 1.0000 | 0.9525 | 0.4900 | 0.8345 | 1.0000 | 1.0000 | 1.0000 | 0.0506 | 1.0000 |
| 3 | 0.9789 | 0.9609 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.8530 | 0.9972 | 0.9355 | 1.0000 | 0.9989 | 0.1227 | 0.9820 |
| 4 | 1.0000 | 0.9999 | 1.0000 | . | 1.0000 | 0.9990 | 1.0000 | 0.9997 | 0.7777 | 0.9879 | 0.9913 | 1.0000 | 1.0000 | 0.1036 | 1.0000 |
| 5 | 0.9996 | 0.9968 | 1.0000 | 1.0000 | . | 0.9999 | 1.0000 | 1.0000 | 0.8074 | 0.9911 | 0.9665 | 1.0000 | 0.9998 | 0.1080 | 0.9991 |
| 6 | 0.9708 | 0.9423 | 1.0000 | 0.9990 | 0.9999 | . | 0.9999 | 1.0000 | 0.9999 | 1.0000 | 0.8638 | 0.9992 | 0.9886 | 0.6723 | 0.9438 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | . | 0.9999 | 0.9966 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 0.8976 | 1.0000 |
| 8 | 0.9698 | 0.9525 | 1.0000 | 0.9997 | 1.0000 | 1.0000 | 0.9999 | . | 0.9980 | 1.0000 | 0.8810 | 0.9997 | 0.9937 | 0.4804 | 0.9656 |
| 9 | 0.4079 | 0.4900 | 0.8530 | 0.7777 | 0.8074 | 0.9999 | 0.9966 | 0.9980 | . | 0.9987 | 0.4991 | 0.8495 | 0.7822 | 0.9860 | 0.4125 |
| 10 | 0.6862 | 0.8345 | 0.9972 | 0.9879 | 0.9911 | 1.0000 | 0.9999 | 1.0000 | 0.9987 | . | 0.7927 | 0.9946 | 0.9749 | 0.4613 | 0.7497 |
| 11 | 0.9978 | 1.0000 | 0.9355 | 0.9913 | 0.9665 | 0.8638 | 1.0000 | 0.8810 | 0.4991 | 0.7927 | . | 0.9978 | 1.0000 | 0.0854 | 0.9993 |
| 12 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9992 | 1.0000 | 0.9997 | 0.8495 | 0.9946 | 0.9978 | . | 1.0000 | 0.1628 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 0.9989 | 1.0000 | 0.9998 | 0.9886 | 1.0000 | 0.9937 | 0.7822 | 0.9749 | 1.0000 | 1.0000 | . | 0.1662 | 1.0000 |
| 14 | 0.0299 | 0.0506 | 0.1227 | 0.1036 | 0.1080 | 0.6723 | 0.8976 | 0.4804 | 0.9860 | 0.4613 | 0.0854 | 0.1628 | 0.1662 | . | 0.0290 |
| 15 | 1.0000 | 1.0000 | 0.9820 | 1.0000 | 0.9991 | 0.9438 | 1.0000 | 0.9656 | 0.4125 | 0.7497 | 0.9993 | 1.0000 | 1.0000 | 0.0290 | . |

Dependent Variable: **DRATE**

| DESCR | DRATE LSMEAN | LSMEAN Number |
|---|---|---|
| buttonhook | 0.14420832 | 1 |
| diamond3 | 0.08817077 | 2 |
| diamond4 | 0.25074289 | 3 |
| dir/semi3 | 0.14731179 | 4 |
| dir/semi4 | 0.14119938 | 5 |
| direct | 0.20078626 | 6 |
| loopleft3 | 0.05629188 | 7 |
| loopleft4 | 0.20392013 | 8 |
| loopnoleft3 | 0.19759483 | 9 |
| loopnoleft4 | 0.15065034 | 10 |
| restarea | 0.04812046 | 11 |
| scissors | 0.10548876 | 12 |
| slip3 | 0.10646089 | 13 |
| slip4 | 0.09822058 | 14 |
| split | 0.12196675 | 15 |

Dependent Variable: **DRATE**

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

| i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | . | 1.0000 | 0.9659 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 2 | 1.0000 | . | 0.9950 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3 | 0.9659 | 0.9950 | . | 0.9958 | 0.8677 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9591 | 0.9998 | 0.9954 | 0.9999 | 0.9997 | 0.9711 |
| 4 | 1.0000 | 1.0000 | 0.9958 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 5 | 1.0000 | 1.0000 | 0.8677 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 8 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 9 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 10 | 1.0000 | 1.0000 | 0.9591 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 11 | 1.0000 | 1.0000 | 0.9998 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 12 | 1.0000 | 1.0000 | 0.9954 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 | 1.0000 |
| 13 | 1.0000 | 1.0000 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 | 1.0000 |
| 14 | 1.0000 | 1.0000 | 0.9997 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . | 1.0000 |
| 15 | 1.0000 | 1.0000 | 0.9711 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | . |

## Appendix D Ramps with Relatively High Accident Rtaes

### Appendix D

### Ramps with a relatively high accident rate

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 1 | 101 | DN | 3.64 | r | buttonhook | off |
| 1 | 101 | DN | 4.76 | r | diamond3 | on |
| 1 | 101 | HUM | 85.129 | u | dir/semi4 | off |
| 1 | 101 | HUM | 27.973 | r | loopleft3 | off |
| 1 | 101 | HUM | 64.404 | r | loopleft3 | off |
| 1 | 101 | HUM | 61.384 | u | scissors | off |
| 1 | 101 | HUM | 61.384 | u | scissors | off |
| 1 | 101 | HUM | 70.851 | r | twowayseg4 | |
| 1 | 101 | MEN | 82.43 | r | restarea | off |
| 1 | 101 | MEN | 82.43 | r | restarea | off |
| 2 | 5 | SHA | 66 | r | dir/semi4 | off |
| 2 | 5 | SHA | 49.375 | r | dir/semi4 | on |
| 2 | 5 | SIS | 19.61 | r | diamond3 | off |
| 2 | 5 | SIS | 25.345 | r | restarea | off |
| 2 | 5 | SIS | 25.345 | r | restarea | off |
| 3 | 5 | SAC | 12.188 | r | loopnoleft4 | on |
| 3 | 5 | YOL | 0.67 | r | buttonhook | on |
| 3 | 5 | YOL | 8.191 | u | loopleft3 | off |
| 3 | 50 | SAC | 15.811 | u | loopnoleft4 | on |
| 3 | 51 | SAC | 6.181 | u | scissors | off |
| 3 | 51 | SAC | 6.181 | u | scissors | off |
| 3 | 80 | NEV | 8.86 | r | diamond4 | off |
| 3 | 80 | NEV | 29.39 | r | diamond4 | off |
| 3 | 80 | NEV | 59.83 | r | loopnoleft3 | off |
| 3 | 80 | PLA | 28.45 | r | buttonhook | on |
| 3 | 80 | PLA | 37.93 | r | buttonhook | on |
| 3 | 80 | PLA | 43.27 | r | diamond4 | off |
| 3 | 80 | PLA | 33.08 | r | loopleft4 | off |
| 3 | 80 | PLA | 56.755 | r | loopnoleft4 | off |
| 3 | 80 | YOL | 11.04 | u | diamond3 | off |
| 3 | 80 | YOL | 11.219 | u | loopleft3 | on |
| 3 | 99 | SAC | 5.925 | r | loopleft4 | off |
| 3 | 99 | SAC | 19.71 | u | loopnoleft4 | on |
| 3 | 99 | SUT | 5.534 | r | twowayseg4 | |
| 3 | 113 | YOL | 10.079 | u | loopleft3 | on |
| 3 | 160 | SAC | 44.983 | u | dir/semi4 | on |
| 3 | 505 | YOL | 10.86 | r | dir/semi3 | on |
| 3 | 505 | YOL | 0.67 | r | dir/semi4 | on |
| 3 | 8 0 | PLA | 3.611 | u | dir/semi4 | on |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 3 | 99 | SAC | 17.913 | u | dir/semi4 | on |
| 4 | 1 | SM | 47.604 | u | dir/semi3 | off |
| 4 | 1 | SM | 46.884 | u | dir/semi3 | on |
| 4 | 1 | SM | 46.811 | u | direct | off |
| 4 | 4 | CC | 4.627 | u | scissors | off |
| 4 | 4 | CC | 4.627 | u | scissors | off |
| 4 | 12 | SON | 14.255 | u | dir/semi4 | on |
| 4 | 13 | ALA | 5.48 | u | buttonhook | on |
| 4 | 80 | ALA | 2.17 | u | direct | on |
| 4 | 80 | ALA | 5.81 | u | scissors | off |
| 4 | 80 | ALA | 5.81 | u | scissors | off |
| 4 | 80 | CC | 12.535 | u | diamond4 | on |
| 4 | 80 | CC | 9.99 | u | dir/semi3 | on |
| 4 | 85 | SCL | 7.96 | u | buttonhook | off |
| 4 | 85 | SCL | 4.031 | u | dir/semi4 | on |
| 4 | 87 | SCL | 1.53 | u | buttonhook | on |
| 4 | 87 | SCL | 4.994 | u | direct | off |
| 4 | 87 | SCL | 6.097 | u | slip3 | on |
| 4 | 87 | SCL | 6.097 | u | slip3 | on |
| 4 | 92 | SM | 11 321 | u | dir/semi3 | off |
| 4 | 92 | SM | 7.361 | u | loopnoleft3 | off |
| 4 | 101 | MRN | 18.725 | u | direct | on |
| 4 | 101 | MRN | 0.312 | u | scissors | on |
| 4 | 101 | MRN | 0.312 | u | scissors | on |
| 4 | 101 | MRN | 19.036 | u | split | on |
| 4 | 101 | MRN | 19.257 | u | split | on |
| 4 | 101 | SCL | 30.15 | u | buttonhook | on |
| 4 | 101 | SCL | 50.401 | u | dir/semi4 | off |
| 4 | 101 | SCL | 33.171 | u | loopnoleft4 | off |
| 4 | 101 | SCL | 50.271 | u | loopnoleft4 | off |
| 4 | 101 | SCL | 36.078 | u | slip3 | on |
| 4 | 101 | SCL | 36.078 | u | slip3 | on |
| 4 | 101 | SF | 2.741 | u | slip4 | off |
| 4 | 101 | SM | 25.844 | u | loopnoleft4 | on |
| 4 | 101 | SM | 23.261 | u | scissors | off |
| 4 | 101 | SM | 23.261 | u | scissors | off |
| 4 | 101 | SM | 11.354 | u | split | on |
| 4 | 101 | SON | 3.747 | u | loopleft3 | off |
| 4 | 101 | SON | 18.82 | u | scissors | on |
| 4 | 101 | SON | 18.82 | u | scissors | on |
| 4 | 101 | SON | 26.476 | u | split | on |
| 4 | 280 | SM | 8 416 | r | restarea | off |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 4 | 280 | SM | 7.562 | r | restarea | on |
| 4 | 280 | SM | 8.871 | r | restarea | on |
| 4 | 280 | SM | 8.416 | r | restarea | off |
| 4 | 280 | SM | 7.562 | r | restarea | on |
| 4 | 280 | SM | 8.871 | r | restarea | on |
| 4 | 580 | ALA | 28.36 | u | loopleft4 | on |
| 4 | 580 | ALA | 45.581 | u | slip3 | off |
| 4 | 580 | ALA | 45.581 | u | slip3 | off |
| 4 | 580 | CC | 4.898 | u | slip3 | off |
| 4 | 580 | CC | 4.898 | u | slip3 | off |
| 4 | 580 | MRN | 4.622 | u | slip3 | off |
| 4 | 580 | MRN | 4.622 | u | slip3 | off |
| 4 | 680 | ALA | 7.481 | u | loopleft4 | off |
| 4 | 680 | ALA | 8.684 | r | restarea | off |
| 4 | 680 | ALA | 8.861 | r | restarea | on |
| 4 | 680 | ALA | 8.684 | r | restarea | off |
| 4 | 680 | ALA | 8.861 | r | restarea | on |
| 4 | 680 | CC | 10.211 | u | dir/semi4 | off |
| 4 | 680 | CC | 19.702 | u | dir/semi4 | on |
| 4 | 680 | CC | 16.251 | u | restarea | off |
| 4 | 680 | CC | 16.704 | u | restarea | on |
| 4 | 680 | CC | 16.251 | u | restarea | off |
| 4 | 680 | CC | 16.704 | u | restarea | on |
| 4 | 680 | SCL | 3.713 | u | dir/semi4 | off |
| 4 | 680 | SCL | 3.547 | u | split | off |
| 4 | 880 | ALA | 27.882 | u | direct | on |
| 4 | 880 | ALA | 15.516 | u | loopnoleft4 | off |
| 4 | 880 | ALA | 27.541 | u | scissors | off |
| 4 | 880 | ALA | 27.541 | u | scissors | off |
| 4 | 880 | ALA | 32.089 | u | split | on |
| 4 | 880 | SCL | 10.484 | u | loopleft4 | off |
| 4 | 880 | SCL | 8.613 | u | loopnoleft3 | off |
| 4 | 85 | SCL | 8.234 | u | diamond4 | on |
| 5 | 1 | SLO | 29.84 | u | scissors | on |
| 5 | 1 | SLO | 29.84 | u | scissors | on |
| 5 | 68 | MON | 4.22 | u | split | off |
| 5 | 101 | MON | 63.166 | r | diamond4 | on |
| 5 | 101 | MON | 61.49 | r | loopleft3 | off |
| 5 | 101 | MON | 2.09 | r | loopleft4 | off |
| 5 | 101 | MON | 60.45 | r | loopleft4 | off |
| 5 | 101 | MON | 1.94 | r | scissors | on |
| 5 | 101 | MON | 1.94 | r | scissors | on |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 5 | 101 | MON | 95.484 | u | twowayseg4 | |
| 5 | 101 | SB | 29.74 | r | buttonhook | off |
| 5 | 101 | SB | 78.83 | r | buttonhook | off |
| 5 | 101 | SB | 11.74 | u | dir/semi3 | off |
| 5 | 101 | SB | 34.2 | r | dir/semi4 | off |
| 5 | 101 | SBT | 4.70 | r | diamond3 | on |
| 5 | 101 | SBT | 2.74 | r | dir/semi3 | on |
| 5 | 101 | SBT | 2.88 | r | loopnoleft3 | off |
| 5 | 101 | SLO | 54.26 | u | diamond3 | off |
| 6 | 5 | FRE | 0.41 | r | diamond3 | on |
| 6 | 5 | FRE | 30.11 | r | diamond3 | on |
| 6 | 5 | FRE | 59.86 | r | diamond4 | off |
| 6 | 5 | KER | 4 749 | r | buttonhook | on |
| 6 | 5 | KER | 19.83 | r | diamond3 | off |
| 6 | 5 | KER | 56.525 | r | diamond4 | on |
| 6 | 5 | KER | 10.281 | r | loopnoleft4 | off |
| 6 | 5 | KER | 0.691 | r | restarea | off |
| 6 | 5 | KER | 1.512 | r | scissors | on |
| 6 | 5 | KER | 0.691 | r | restarea | off |
| 6 | 5 | KER | 1.512 | r | scissors | on |
| 6 | 65 | TUL | 18.041 | u | loognoleft3 | off |
| 6 | 99 | FRE | 25.81 | u | buttonhook | off |
| 6 | 99 | FRE | 16.698 | u | diamond4 | on |
| 6 | 99 | FRE | 26.419 | u | dir/semi4 | on |
| 6 | 99 | FRE | 10.777 | r | scissors | on |
| 6 | 99 | FRE | 10.777 | r | scissors | on |
| 6 | 99 | FRE | 20.908 | u | slip4 | off |
| 6 | 99 | KER | 5.10 | r | buttonhook | off |
| 6 | 99 | KER | 57 453 | u | buttonhook | off |
| 6 | 99 | KER | 10.531 | r | direct | on |
| 6 | 99 | KER | 44.319 | r | loopleft3 | off |
| 6 | 99 | KER | 2.528 | r | loopleft3 | on |
| 6 | 99 | KER | 5.414 | r | loopleft4 | on |
| 6 | 99 | KER | 26.874 | u | twowayseg4 | |
| 6 | 99 | MAD | 22.88 | r | diamond3 | off |
| 6 | 99 | MAD | 12.722 | u | loopleft4 | off |
| 6 | 99 | TUL | 18.396 | r | loopleft3 | on |
| 6 | 99 | TUL | 9.105 | r | scissors | off |
| 6 | 99 | TUL | 9.105 | r | scissors | off |
| 6 | 198 | KIN | 8.679 | r | dir/semi3 | off |
| 6 | 198 | KIN | 4 981 | r | loopleft4 | on |
| 6 | 198 | TUL | 9.51 | u | slip3 | on |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 6 | 198 | TUL | 9.51 | u | slip3 | on |
| 6 | 198 | TUL | 10.187 | u | slip4 | off |
| 7 | 1 | LA | 34.829 | u | slip3 | off |
| 7 | 1 | LA | 34.829 | u | slip3 | off |
| 7 | 1 | VEN | 13.611 | r | scissors | off |
| 7 | 1 | VEN | 16.001 | u | scissors | on |
| 7 | 1 | VEN | 13.611 | r | scissors | off |
| 7 | 1 | VEN | 16.001 | u | scissors | on |
| 7 | 2 | LA | 14.989 | u | slip3 | off |
| 7 | 2 | LA | 14.989 | u | slip3 | off |
| 7 | 2 | LA | 14.851 | u | split | off |
| 7 | 5 | LA | 20 452 | u | dir/semi3 | off |
| 7 | 5 | LA | 18.208 | u | direct | on |
| 7 | 5 | LA | 36.155 | u | loopleft3 | on |
| 7 | 5 | LA | 55.531 | u | loopleft3 | on |
| 7 | 5 | LA | 52.46 | u | loopleft4 | on |
| 7 | 5 | LA | 25.852 | u | loopnoleft3 | on |
| 7 | 5 | LA | 15.165 | u | scissors | off |
| 7 | 5 | LA | 20.802 | u | slip3 | on |
| 7 | 5 | LA | 15.165 | u | scissors | off |
| 7 | 5 | LA | 20.802 | u | slip3 | on |
| 7 | 5 | LA | 44.175 | u | slip4 | off |
| 7 | 10 | LA | 31.21 | u | loognoleft3 | on |
| 7 | 10 | LA | 23.288 | u | loopnoleft4 | off |
| 7 | 10 | LA | 23.376 | u | loopnoleft4 | off |
| 7 | 10 | LA | 25.296 | u | loopnoleft4 | off |
| 7 | 10 | LA | 2.347 | u | slip3 | off |
| 7 | 10 | LA | 42.5 | u | slip3 | on |
| 7 | 10 | LA | 21.636 | u | slip3 | on |
| 7 | 10 | LA | 2.347 | u | slip3 | off |
| 7 | 10 | LA | 42.5 | u | slip3 | on |
| 7 | 10 | LA | 21.636 | u | slip3 | on |
| 7 | 10 | LA | 14.985 | u | split | off |
| 7 | 10 | LA | 0.09 | u | split | on |
| 7 | 14 | LA | 54.38 | r | buttonhook | off |
| 7 | 14 | LA | 51.75 | r | buttonhook | on |
| 7 | 14 | LA | 28.50 | u | diamond3 | off |
| 7 | 14 | LA | 73.84 | r | diamond3 | on |
| 7 | 14 | LA | 59.97 | u | dir/semi3 | on |
| 7 | 14 | LA | 73.965 | r | loopnoleft3 | on |
| 7 | 14 | LA | 56.783 | u | restarea | of f |
| 7 | 14 | LA | 56.783 | u | restarea | off |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 7 | 23 | VEN | 7.135 | u | loopnoleft4 | on |
| 7 | 33 | VEN | 0.453 | u | direct | off |
| 7 | 60 | LA | 2.974 | u | split | off |
| 7 | 60 | LA | 0.511 | u | twowayseg4 | |
| 7 | 90 | LA | 1.589 | u | dir/semi4 | on |
| 7 | 101 | LA | 5.46 | u | diamond3 | on |
| 7 | 101 | LA | 0.606 | u | split | on |
| 7 | 103 | LA | 1.429 | u | dir/semi3 | on |
| 7 | 103 | LA | 1.488 | u | loopnoleft3 | off |
| 7 | 105 | LA | 13.018 | u | direct | on |
| 7 | 105 | LA | 13.999 | u | slip3 | on |
| 7 | 105 | LA | 13.999 | u | slip3 | on |
| 7 | 105 | LA | 14.901 | u | slip4 | on |
| 7 | 105 | LA | 14 | u | split | on |
| 7 | 110 | LA | 14.093 | u | direct | off |
| 7 | 110 | LA | 29.989 | u | direct | off |
| 7 | 110 | LA | 24 727 | u | scissors | off |
| 7 | 110 | LA | 24.727 | u | scissors | off |
| 7 | 110 | LA | 18.829 | u | slip4 | off |
| 7 | 110 | LA | 14.31 | u | slip4 | on |
| 7 | 110 | LA | 18.647 | u | slip4 | on |
| 7 | 110 | LA | 25.418 | u | split | on |
| 7 | 110 | LA | 26.176 | u | split | on |
| 7 | 118 | LA | 10.21 | u | diamond3 | off |
| 7 | 118 | LA | 12.375 | u | loopleft4 | on |
| 7 | 126 | VEN | 1.564 | u | loopnoleft4 | off |
| 7 | 126 | VEN | 5.143 | u | loopnoleft4 | off |
| 7 | 134 | LA | 11.425 | u | loopleft4 | off |
| 7 | 170 | LA | 15.03 | u | buttonhook | on |
| 7 | 210 | LA | 36.206 | u | dir/semi3 | on |
| 7 | 210 | LA | 0.4 | u | direct | off |
| 7 | 405 | LA | 20.29 | u | buttonhook | off |
| 7 | 405 | LA | 20.34 | u | buttonhook | on |
| 7 | 405 | LA | 21.19 | u | buttonhook | on |
| 7 | 405 | LA | 20.354 | u | dir/semi3 | on |
| 7 | 405 | LA | 17.625 | u | loopleft3 | on |
| 7 | 405 | LA | 46.286 | u | loopnoleft3 | on |
| 7 | 405 | LA | 20.353 | u | loopnoleft4 | on |
| 7 | 405 | LA | 22.201 | u | loopnoleft4 | on |
| 7 | 405 | LA | 32.134 | u | scissors | off |
| 7 | 405 | LA | 32.134 | u | scissors | off |
| 7 | 605 | LA | 8.58 | u | diamond3 | off |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 7 | 605 | LA | 19.296 | u | direct | on |
| 7 | 605 | LA | 9.686 | u | loopnoleft3 | on |
| 7 | 605 | LA | 22.366 | u | slip4 | on |
| 7 | 605 | LA | 14.234 | u | split | on |
| 7 | 710 | LA | 23.50 | u | buttonhook | on |
| 7 | 710 | LA | 12.156 | u | dir/semi4 | off |
| 7 | 710 | LA | 21.808 | u | dir/semi4 | off |
| 7 | 710 | LA | 15.899 | u | direct | on |
| 8 | 10 | RIV | 12.69 | u | diamond3 | off |
| 8 | 10 | RIV | 26.07 | r | restarea | off |
| 8 | 10 | RIV | 15.408 | u | restarea | on |
| 8 | 10 | RIV | 26.07 | r | restarea | off |
| 8 | 10 | RIV | 15.408 | u | restarea | on |
| 8 | 10 | SBD | 25.62 | u | buttonhook | off |
| 8 | 10 | SBD | 11.465 | u | split | off |
| 8 | 10 | SBD | 29.687 | u | split | off |
| 8 | 15 | SBD | 55 795 | r | diamond4 | off |
| 8 | 15 | SBD | 76.25 | r | diamond4 | off |
| 8 | 15 | SBD | 55.815 | r | diamond4 | on |
| 8 | 15 | SBD | 31.256 | r | direct | off |
| 8 | 15 | SBD | 41.496 | u | loopleft4 | off |
| 8 | 15 | SBD | 87.157 | r | restarea | of f |
| 8 | 15 | SBD | 60.996 | r | restarea | on |
| 8 | 15 | SBD | 70.72 | r | restarea | on |
| 8 | 15 | SBD | 87.157 | r | restarea | off |
| 8 | 15 | SBD | 60.996 | r | restarea | on |
| 8 | 15 | SBD | 70.72 | r | restarea | on |
| 8 | 30 | SBD | 26.52 | u | diamond4 | off |
| 8 | 30 | SBD | 27.063 | u | diamond4 | off |
| 8 | 30 | SBD | 26.644 | u | diamond4 | on |
| 8 | 40 | SBD | 99.469 | r | diamond4 | on |
| 8 | 40 | SBD | 38.812 | u | direct | off |
| 8 | 40 | SBD | 0.769 | u | loopleft3 | on |
| 8 | 40 | SBD | 48.988 | r | restarea | off |
| 8 | 40 | SBD | 5.641 | r | restarea | on |
| 8 | 40 | SBD | 48.988 | r | restarea | off |
| 8 | 40 | SBD | 5.641 | r | restarea | on |
| 8 | 60 | RIV | 30.41 | u | dir/semi3 | on |
| 8 | 60 | RIV | 20.368 | u | loopleft4 | on |
| 8 | 71 | SBD | 0.198 | u | dir/semi4 | off |
| 8 | 91 | RIV | 2.573 | u | direct | on |
| 8 | 215 | RIV | 26.46 | u | diamond3 | off |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 8 | 215 | RIV | 23.545 | u | loopleft3 | off |
| 8 | 215 | RIV | 23 716 | u | loopleft4 | on |
| 8 | 215 | RiV | 43.342 | u | loopnoleft3 | on |
| 8 | 215 | RIV | 36.474 | u | loopnoleft4 | on |
| 8 | 215 | SBD | 0.055 | u | scissors | on |
| 8 | 215 | SBD | 0.055 | u | scissors | on |
| 8 | 3 0 | SBD | 29.216 | u | diamond4 | off |
| 9 | 14 | KER | 0.17 | u | diamond4 | on |
| 9 | 58 | KER | 42.819 | r | loopleft4 | on |
| 10 | 4 | SJ | 17.969 | u | slip4 | on |
| 10 | 5 | MER | 17.38 | r | dir/semi3 | off |
| 10 | 5 | MER | 17.57 | r | loopnoleft3 | off |
| 10 | 5 | MER | 17.488 | r | loopnoleft3 | on |
| 10 | 5 | SJ | 23.49 | u | diamond4 | off |
| 10 | 5 | SJ | 3.175 | , r | dir/semi3 | off |
| 10 | 5 | SJ | 39.36 | r | dir/semi3 | on |
| 10 | 5 | SJ | 26.454 | u | split | on |
| 10 | 12 | SOL | 4.277 | u | direct | off |
| 10 | 80 | SOL | 2.89 | u | buttonhook | off |
| 10 | 80 | SOL | 5.89 | u | diamond3 | off |
| 10 | 80 | SOL | 38.18 | r | dir/semi3 | off |
| 10 | 80 | SOL | 43.483 | u | dir/semi3 | off |
| 10 | 80 | SOL | 5.442 | u | dir/semi4 | off |
| 10 | 80 | SOL | 0.954 | u | direct | off |
| 10 | 80 | SOL | 12.981 | u | loopnoleft3 | on |
| 10 | 80 | SOL | 1.219 | u | scissors | off |
| 10 | 80 | SOL | 1.219 | u | scissors | off |
| 10 | 99 | MER | 15.93 | u | diamond3 | off |
| 10 | 99 | MER | 15.95 | u | diamond3 | on |
| 10 | 99 | SJ | 22.07 | u | buttonhook | off |
| 10 | 99 | SJ | 6.84 | u | diamond3 | on |
| 10 | 99 | SJ | 11.655 | r | diamond4 | on |
| 10 | 99 | SJ | 19.136 | u | dir/semi4 | on |
| 10 | 99 | SJ | 18.443 | u | direct | off |
| 10 | 99 | SJ | 21.723 | u | direct | on |
| 10 | 99 | SJ | 27 514 | u | loopleft4 | on |
| 10 | 99 | SJ | 16.684 | u | split | off |
| 10 | 99 | STA | 15.377 | u | slip4 | off |
| 10 | 99 | STA | 15.454 | u | slip4 | on |
| 10 | 99 | STA | 13.617 | u | split | off |
| 10 | 120 | SJ | 4.087 | u | diamond4 | off |
| 10 | 120 | SJ | 3.031 | u | diamond4 | on |

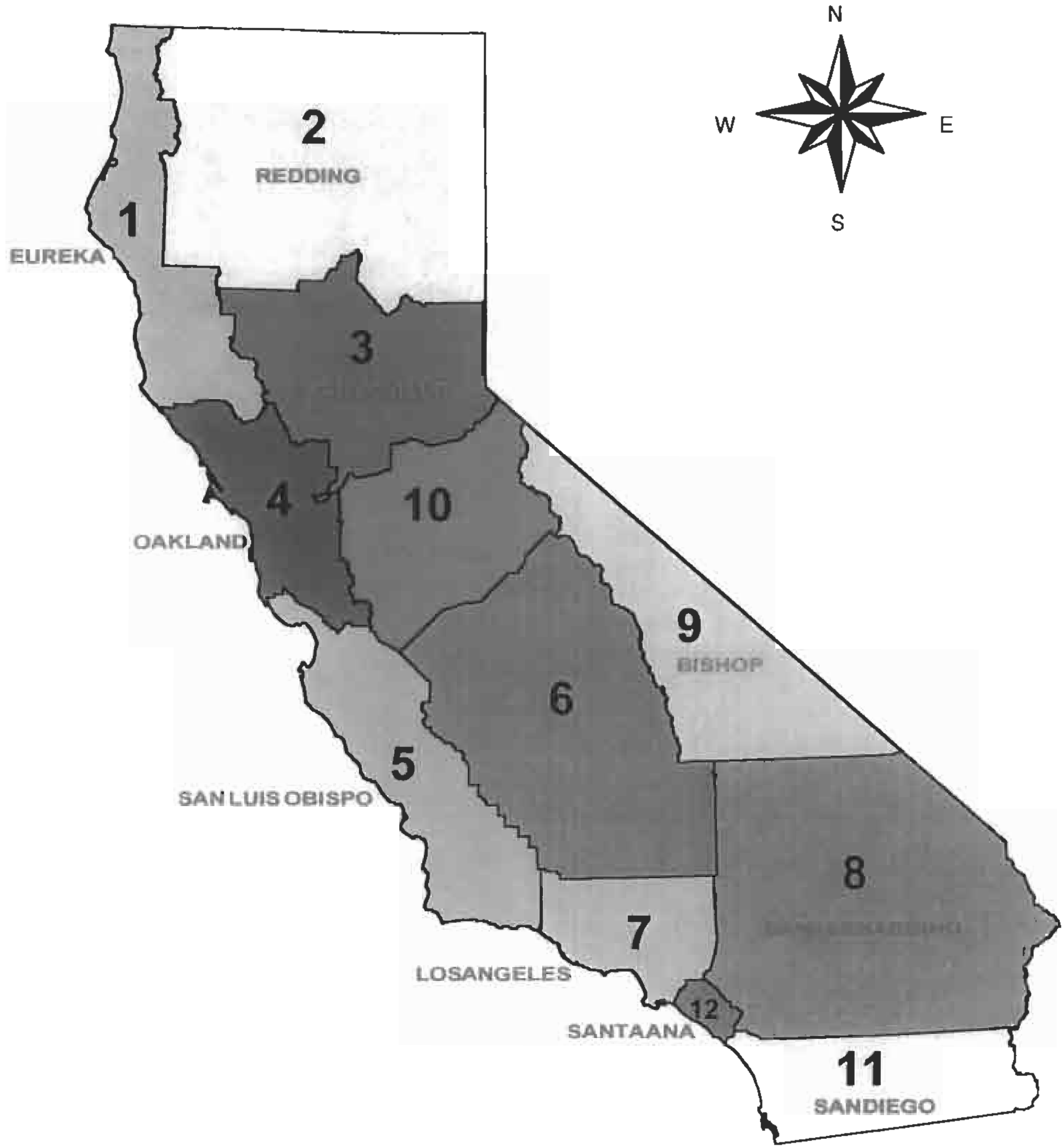
## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 10 | 505 | SOL | 10.35 | r | buttonhook | off |
| 10 | 505 | SOL | 10.43 | r | buttonhook | on |
| 10 | 505 | SOL | 10.383 | r | loopleft4 | off |
| 11 | 5 | SD | 0.24 | u | buttonhook | on |
| 11 | 5 | SD | 3.355 | u | dir/semi3 | on |
| 11 | 5 | SD | 11.13 | u | loopleft4 | off |
| 11 | 5 | SD | 12.688 | u | loopnoleft3 | off |
| 11 | 5 | SD | 51.252 | u | loopnoleft3 | off |
| 11 | 5 | SD | 15.772 | u | slip4 | off |
| 11 | 8 | IMP | 41.166 | r | dir/semi3 | on |
| 11 | 8 | IMP | 3.73 | r | restarea | off |
| 11 | 8 | IMP | 3.73 | r | restarea | off |
| 11 | 8 | SD | 2.642 | u | dir/semi3 | off |
| 11 | 8 | SD | 35.623 | r | restarea | on |
| 11 | 8 | SD | 10.69 | u | scissors | off |
| 11 | 8 | SD | 35.623 | r | restarea | on |
| 11 | 8 | SD | 10.69 | u | scissors | off |
| 11 | 8 | SD | 5.726 | u | slip3 | on |
| 11 | 10 | RIV | 49.01 | r | diamond3 | on |
| 11 | 10 | RIV | 59.06 | u | diamond3 | on |
| 11 | 15 | SD | 6.205 | u | loopnoleft3 | on |
| 11 | 15 | SD | 43.17 | r | loopnoleft4 | on |
| 11 | 67 | SD | 4.856 | u | loopnoleft4 | on |
| 11 | 94 | SD | 2.703 | u | loopleft4 | on |
| 11 | 125 | SD | 15.208 | u | direct | on |
| 11 | 125 | SD | 15.47 | u | loognoleft3 | off |
| 11 | 163 | SD | 1.52 | u | direct | off |
| 11 | 163 | SD | 2.699 | u | direct | on |
| 11 | 163 | SD | 0.753 | u | twowayseg4 | |
| 11 | 209 | SD | 7.764 | u | loognoleft3 | off |
| 11 | 805 | SD | 21.499 | u | dir/semi3 | off |
| 11 | 805 | SD | 8.592 | u | loopnoleft3 | off |
| 12 | 5 | ORA | 28.456 | u | diamond4 | off |
| 12 | 5 | ORA | 23.772 | u | diamond4 | on |
| 12 | 5 | ORA | 28.417 | u | diamond4 | on |
| 12 | 5 | ORA | 28.224 | u | loopleft4 | off |
| 12 | 55 | ORA | 2.512 | u | slip3 | off |
| 12 | 55 | ORA | 3.506 | u | slip3 | off |
| 12 | 55 | ORA | 2.512 | u | slip3 | off |
| 12 | 55 | ORA | 3.506 | u | slip3 | off |
| 12 | 55 | ORA | 3.091 | u | slip3 | on |
| 12 | 55 | ORA | 3.589 | u | slip3 | on |

## Appendix D Ramps with Relatively High Accident Rtaes

| Dist | Route | County | Post Mile | Rural | Descrition | On/Off |
|---|---|---|---|---|---|---|
| 12 | 55 | ORA | 3.988 | u | slip3 | on |
| 12 | 57 | ORA | 17.413 | u | slip4 | off |
| 12 | 405 | ORA | 20.851 | u | dir/semi4 | off |
| 12 | 405 | ORA | 3.04 | u | dir/semi4 | on |
| 12 | 405 | ORA | 7.758 | u | loopleft3 | on |
| 12 | 405 | ORA | 9.631 | u | loopnoleft4 | off |

Appendix E




# CALTRANS DISTRICT MAP

## Appendix F

### Accident Analysis for Half Diamond Ramps

Analysis of the following half diamond ramp sample is included in this appendix at the request of Caltras Office of Project Planning and Design (OPPD). Five years of accident data for the following 50 half diamond ramps was included in this analysis. The ramp identification designation number and corresponding location of ramps are shown in Table 20. All the ramps in the table are in urban or suburban area[5]. Since fatal accidents are very rare on ramps their random occurrence could not provide a reliable means of describing the safety of a ramp. Therefore, this analysis focused on *total* and *fatal + injury* accidents. Accident frequency, accident rate, and traffic volume for ramp cross street and ramp itself are plotted in figure 20 through 25. Consideration of either accident frequency or accident rate alone may lead to unrealistic assessment of how safe a ramp is.

Since the accident occurrence for off-ramps are significantly different than on-ramps, comparison of ramp accident frequency, accident rate and traffic volume are done separately. Figure 20 through 22 correspond to off-ramps and figure 23 through 25 correspond to the on-ramps. Each of the above plots are accompanied by descriptive statistics which provide the mean, standard deviation, maximum and the minimum for the ramps specified with ramp identification numbers.

Notice that in figure 21 and figure 24, total, and fatal + injury accident rates are compared to their corresponding *average* accident rates. The average values plotted are slightly different than the mean values in the descriptive statistics provided with each of above figures. The mean values in the descriptive statistics represent the average accident rate of the ramp sample specified in the plots

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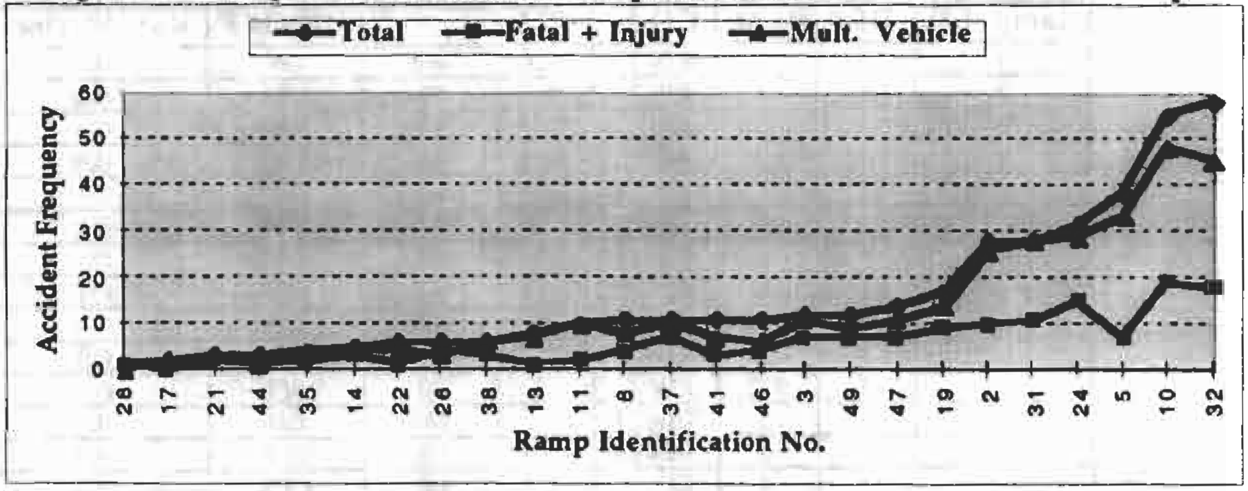
[5] Suburban is defined as urbanized area (population over 50,000) which is entirely insise city limit.

(Ramp Identification No.). The average accident rate lines plotted in figure 19 through 25 however, are based on averaging much larger number of ramps in TASAS database. TASAS database provides the mean values for every single ramp based on averaging accident rates for the entire population of ramps on California state highways which has similar characteristics to the specific ramp.

Table 20 Half Diamond Ramp Location and Characteristics

| Ramp I.D. | Dist | Route | CO. | | PM | | ON/OFF | Rural/Urban |
|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 91 | RIV | | 10.6 | WB | ON | (U) |
| 2 | 8 | 91 | RIV | | 10.6 | EB | OFF | (U) |
| 3 | 8 | 91 | RIV | | 20.7 | WB | OFF | (U) |
| 4 | 8 | 91 | RIV | | 20.7 | EB | ON | (U) |
| 5 | 8 | 60 | RIV | R | 1.51 | EB | OFF | (S) |
| 6 | 8 | 60 | RIV | R | 1.56 | WB | ON | (S) |
| 7 | 8 | 60 | RIV | R | 2.22 | EB | ON | (S) |
| 8 | 8 | 60 | RIV | R | 2.23 | WB | OFF | (S) |
| 9 | 8 | 215 | RIV | | 43 | NB | ON | (U) |
| 10 | 8 | 215 | RIV | | 43 | NB | OFF | (U) |
| 11 | 8 | 215 | RIV | | 43 | SB | OFF | (U) |
| 12 | 2 | 5 | SHA | R | 4.42 | NB | ON | (U) |
| 13 | 2 | 5 | SHA | R | 4.45 | SB | OFF | (U) |
| 14 | 4 | 4 | CC | | 26.8 | EB | OFF | (U) |
| 15 | 4 | 4 | CC | | 26.8 | WB | ON | (U) |
| 16 | 8 | 10 | RIV | | 8.42 | EB | ON | (U) |
| 17 | 8 | 10 | RIV | | 8.44 | WB | OFF | (U) |
| 18 | 3 | 5 | SAC | | 18.8 | NB | ON | (U) |
| 19 | 3 | 5 | SAC | | 18.8 | SB | OFF | (U) |
| 20 | 8 | 10 | SBD | | 33 | WB | ON | (U) |
| 21 | 8 | 10 | SBD | | 33 | EB | OFF | (U) |
| 22 | 8 | 10 | SBD | | 31.2 | WB | OFF | (U) |
| 23 | 8 | 10 | SBD | | 31.2 | EB | ON | (U) |
| 24 | 8 | 10 | SBD | | 31.7 | EB | OFF | (U) |
| 25 | 8 | 10 | SBD | | 31.8 | WB | ON | (U) |
| 26 | 8 | 10 | SBD | | 32.3 | WB | OFF | (U) |
| 27 | 8 | 10 | SBD | | 32.3 | EB | ON | (U) |
| 28 | 8 | 10 | SBD | | 34.4 | WB | OFF | (S) |
| 29 | 8 | 10 | SBD | | 34.4 | EB | ON | (S) |
| 30 | 4 | 580 | ALA | R | 40.2 | WB | ON | (U) |
| 31 | 4 | 580 | ALA | R | 40.2 | EB | OFF | (U) |
| 32 | 4 | 580 | ALA | R | 40.8 | EB | OFF | (U) |
| 33 | 4 | 580 | ALA | R | 40.8 | WB | ON | (U) |
| 34 | 4 | 85 | SCL | R | 11.2 | NB | ON | (U) |
| 35 | 4 | 85 | SCL | R | 11.2 | SB | OFF | (U) |
| 36 | 4 | 680 | CC | R | 12.4 | SB | ON | (U) |
| 37 | 4 | 680 | CC | R | 12.5 | NB | OFF | (U) |
| 38 | 11 | 125 | SD | | 14.6 | NB | OFF | (U) |
| 39 | 11 | 125 | SD | | 14.6 | SB | ON | (U) |
| 40 | 7 | 5 | LA | | 36.2 | SB | ON | (U) |
| 41 | 7 | 5 | LA | | 36.4 | SB | OFF | (U) |
| 42 | 7 | 5 | LA | | 36.6 | NB | ON | (U) |
| 43 | 7 | 210 | LA | R | 20.4 | WB | ON | (U) |
| 44 | 7 | 210 | LA | R | 20.4 | EB | OFF | (U) |
| 45 | 7 | 210 | LA | R | 21.1 | EB | ON | (U) |
| 46 | 7 | 210 | LA | R | 21.2 | WB | OFF | (U) |
| 47 | 7 | 101 | LA | | 24.7 | NB | OFF | (U) |
| 48 | 7 | 101 | LA | | 24.7 | SB | ON | (U) |
| 49 | 7 | 101 | LA | | 16.7 | NB | OFF | (U) |
| 50 | 7 | 101 | LA | | 16.8 | SB | ON | (U) |

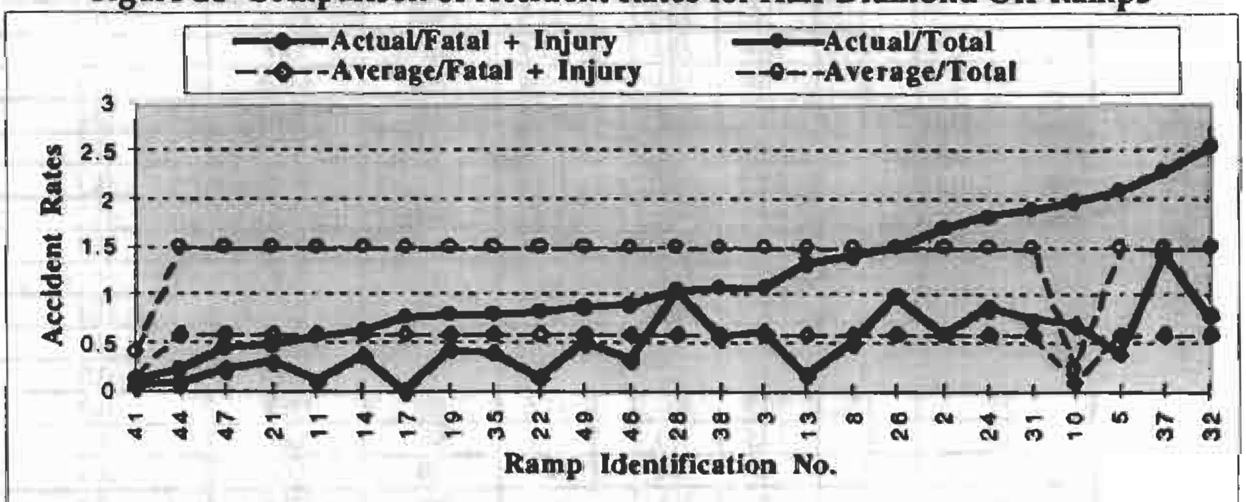
**Figure 20 Comparison of Accident Frequencies for Half Diamond Off-Ramps**




**Descriptive Statistics**

| | Mean | Std. Dev. | Std. Error | Count | Minimum | Maximum | # Missing |
|---|---|---|---|---|---|---|---|
| Total Acc. | 15.640 | 15.599 | 3.120 | 25 | 1.000 | 58.000 | 0 |
| Fat+Inj. Acc. | 5.920 | 5.291 | 1.058 | 25 | 0.000 | 19.000 | 0 |
| Mult Veh Acc. | 13.120 | 13.590 | 2.718 | 25 | 0.000 | 48.000 | 0 |

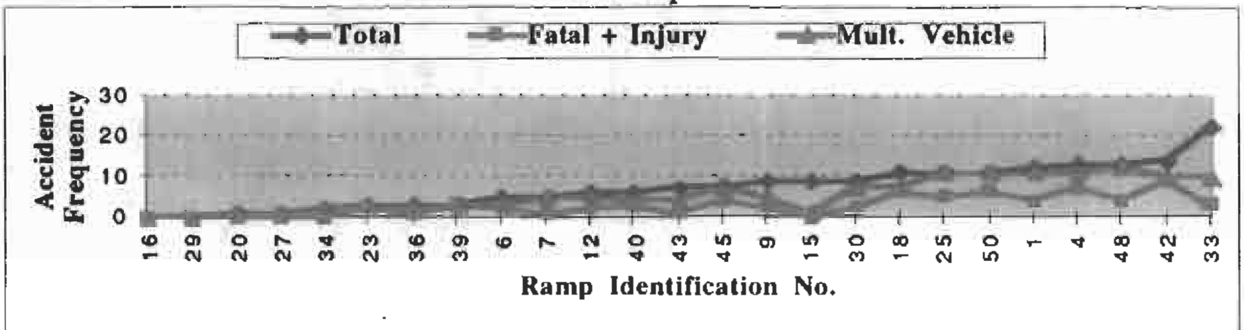
**Figure 21 Comparison of Accident Rates for Half Diamond Off-Ramps**




**Descriptive Statistics**

| | Mean | Std. Dev. | Std. Error | Count | Minimum | Maximum | # Missing |
|---|---|---|---|---|---|---|---|
| Actual F+I Accident Rate | .496 | .356 | .071 | 25 | 0.000 | 1.460 | 0 |
| Actual Total Accident Rate | 1.171 | .662 | .132 | 25 | .130 | 2.560 | 0 |
| Average F+I Accident Rate | .553 | .129 | .026 | 25 | .090 | .590 | 0 |
| Average Total Accident Rate | 1.406 | .326 | .065 | 25 | .250 | 1.500 | 0 |

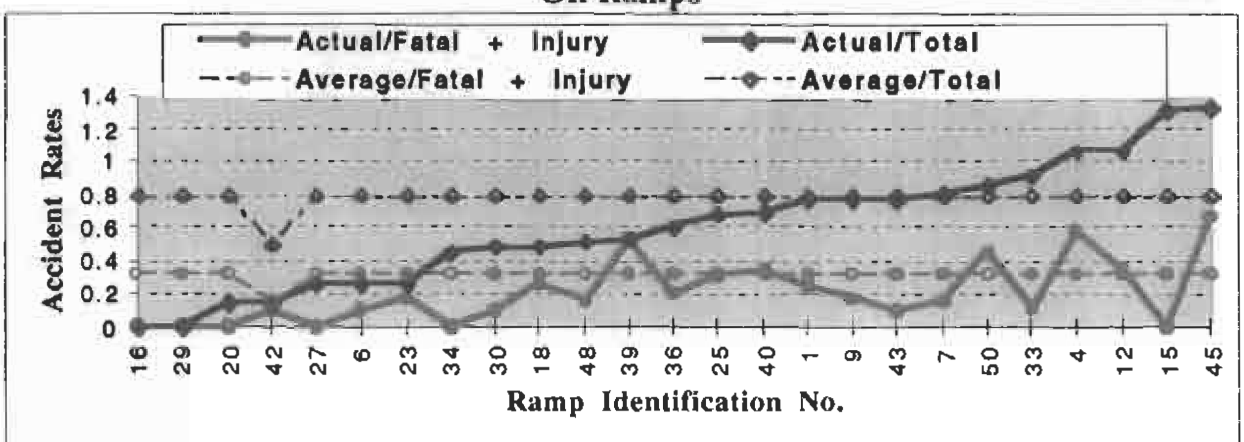
## Figure 22 Comparison of Accident Frequencies for Half Diamond On-Ramps




**Descriptive Statistics**

| | Mean | Std. Dev. | Std. Error | Count | Minimum | Maximum | # Missing |
|---|---|---|---|---|---|---|---|
| Total Accidents | 7.360 | 5.330 | 1.066 | 25 | 0.000 | 22.000 | 0 |
| Fatal Accidents | 2.680 | 2.462 | .492 | 25 | 0.000 | 9.000 | 0 |
| Mult Veh Accidents | 5.480 | 4.001 | .800 | 25 | 0.000 | 12.000 | 0 |

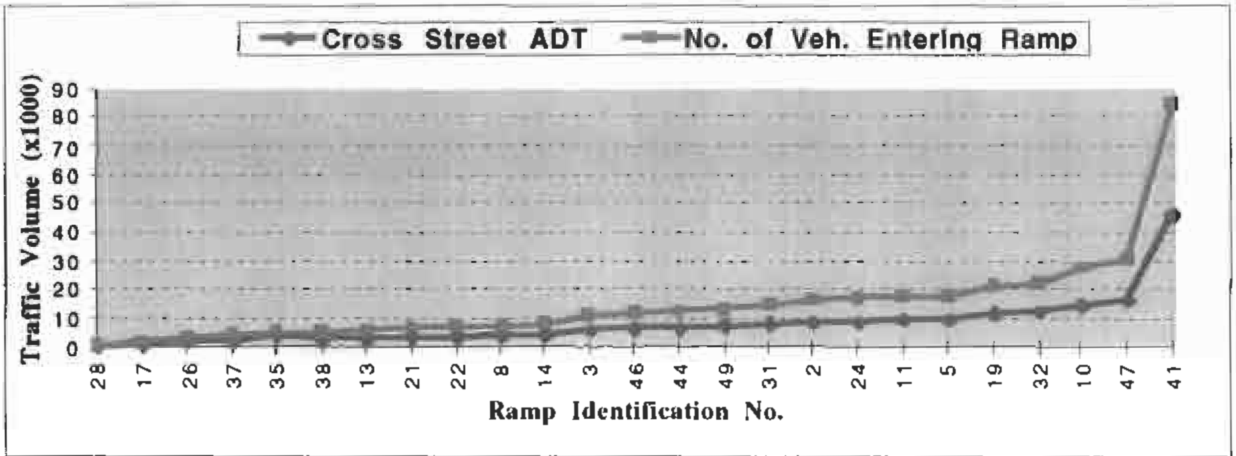
## Figure 23 Comparison of Accident Rates for Half Diamond On-Ramps




**Descriptive Statistics**

| | Mean | Std. Dev. | Std. Error | Count | Minimum | Maximum | # Missing |
|---|---|---|---|---|---|---|---|
| Actual F+I Accident Rate | .207 | .191 | .038 | 25 | 0.000 | .660 | 0 |
| Actual Total Accident Rate | .607 | .370 | .074 | 25 | 0.000 | 1.330 | 0 |
| Average F+I Accident Rate | .314 | .032 | .006 | 25 | .160 | .320 | 0 |
| Average Total Accident Rate | .788 | .060 | .012 | 25 | .500 | .800 | 0 |

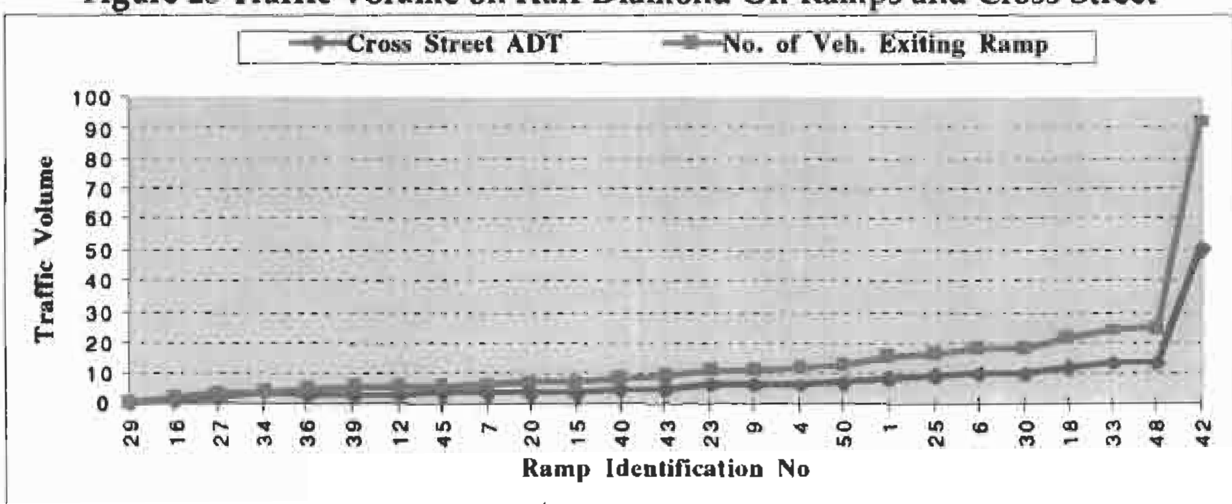
## Figure 24 Traffic Volume on Half Diamond Off-Ramps and Cross Street




**Descriptive Statistics**

| | Mean | Std. Dev. | Std. Error | Count | Minimum | Maximum | # Missing |
|---|---|---|---|---|---|---|---|
| X-Street ADT | 7.878 | 7.324 | 1.036 | 50 | 0.000 | 46.400 | 3 |
| Ramp Traffic Volume | 8.930 | 13.246 | 1.873 | 50 | 0.000 | 84.700 | 3 |

## Figure 25 Traffic Volume on Half Diamond On-Ramps and Cross Street




**Descriptive Statistica**

| | Mean | Std. Dev. | Std. Error | Count | Minimum | Maximum | # Missing |
|---|---|---|---|---|---|---|---|
| X-Street ADT | 7.784 | 9.620 | 1.924 | 25 | .400 | 50.400 | 0 |
| Ramp Traffic Volume | 14.062 | 17.604 | 3.521 | 25 | .780 | 91.900 | 0 |

**Discussion of results on half diamond ramps**

Figure 20 through 25 along with their descriptive statistics are self explanatory. When considering a half diamond ramp safety performance, both accident frequency and accident rate along with the traffic volume on ramp and cross street should be taken into account with engineering judgment. Notice that there is a great deal of variability both in accident frequency and accident rate for the sample of ramps.

As a general rule, a ramp with accident or accident rate greater than mean plus two standard deviation is said to have significantly higher accident or accident rate (with 95 percent confidence level). For example, ramp number 10, and 32 in figure 20 has fatal + injury accident frequencies which are significantly higher than the average half diamond off-ramp accident frequency. The same two ramps show higher than average accident rate in figure 21. However, their accident rates increase above the average is not statistically significant. Therefore, the significant accident frequency on these ramps can be attributed to higher ramp volume as suggested in figure 24.

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