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# ANALYSIS OF SAFETY EFFECTS FOR THE PRESENCE OF ROADWAY LIGHTING

FINAL REPORT

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
of
The National Academies

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June 2009

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The results should not be considered sufficient to change the existing recommendations regarding the accident modification factors that should be used when considering the addition or removal of roadway lighting systems.

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## ABSTRACT

This report includes a summary of a statistical analysis to evaluate the association between the presence of fixed roadway lighting and crashes at intersections, interchanges, and along freeway segments. Electronic roadway inventory data were appended to crash and lighting presence data from several state transportation agencies. The presence of roadway lighting, geometric design, and traffic control features were included in statistical models of nighttime and daytime crash frequency. Night-day crash ratios from negative binomial regression and log-linear models were compared to night-day crash ratios computed only from crash data. The results indicate that the night-day crash ratios are lower at intersections with fixed roadway lighting when compared to intersections without lighting, when controlling for various roadway and traffic control features present at intersections. When computing the night-day ratios at interchanges and along freeway segments, it could not be concluded in the present study that the presence of fixed roadway lighting is associated with a statistically significant reduction in the night-day crash ratio.

# 1. BACKGROUND

When making cost-effective decisions regarding the installation of roadway lighting at intersections, interchanges and on roadway segments, an important consideration for transportation agencies is the expected safety benefit (i.e., reduction in crash frequency and severity) that results from the lighting system. Reductions in crash frequency and severity coincide with economic savings that may or may not outweigh the costs of lighting installation and maintenance.

The objective of the safety analysis in the present report was to estimate the safety effects of roadway lighting at intersections, interchanges and roadway segments by examining expected crash frequencies, severities and night-to-day crash ratios. The literature review for NCHRP Project 5-19 identified other studies with similar goals (see Rea et al., 2009). Findings were mixed; a major shortcoming in previous research was lack of consideration of geometric and traffic control variables potentially associated with crash frequencies and severities. Without control of site-specific geometric design or traffic control variables, safety benefits associated with fixed roadway illumination systems may be over- or underestimated. Addressing this limitation was an important consideration influencing the methodology of this study outlined below.

# 2. METHODOLOGY

Several alternative data analysis techniques were used to evaluate the safety benefit of roadway lighting at intersections, interchanges and freeway segments. These methods included:

- Computation of night-to-day crash ratios;
- Estimation of negative binomial regression models of annual nighttime and daytime crash frequency;
- Estimation of log-linear models of night-to-day crash ratios;
- Estimation of negative binomial regression models of annual nighttime and daytime crash frequency with an instrumental variable for roadway lighting; and
- Computation of crash severity distributions.

While an observational before-after study was considered in the present study, such an analysis method was not used either because a record of installation dates were not readily available for a large sample of locations included in the statistical analysis, or because an assessment of several electronic roadway inventory databases indicated that roadway lighting was not the sole treatment applied to a location included in the study. In the latter, the safety effect of fixed roadway lighting would be difficult to isolate from the effects of other treatments made at the same site.

It is important to note that the methodology used in the present study was based on comparisons of various roadway types with and without fixed roadway illumination systems. While it was desirable to obtain lighting design data (e.g., uniformity, spacing, and luminance), state transportation agencies do not routinely collect this information or do not archive it in electronic records that can be linked to electronic roadway inventory and crash data. As such, a complementary analytical analysis was performed in NCHRP Project 5-19 as a mechanism to address this issue. In the analytical analysis, various lighting quality data were included in computer simulation models to evaluate the effect of lighting design on relative visual performance.

## 2.1 Night-to-Day Crash Ratios

Computing night-to-day crash ratios is historically the most common analytical method used to evaluate the safety effects of roadway lighting. Observed crash data, segregated by time of day are used to compute the ratios. Comparisons can then be made between night-to-day ratios of a specific roadway type with and without roadway lighting. For example, the percent difference in night-to-day ratio between a lighted and unlighted roadway can be expressed as:

$$\frac{\left(\frac{N}{D}\right)_w - \left(\frac{N}{D}\right)_{wo}}{\left(\frac{N}{D}\right)_{wo}} \qquad (1)$$

where: $N$ = number of nighttime crashes, aggregated over a defined time period and roadway type;
$D$ = number of daytime crashes, aggregated over a defined time period and roadway type;
$w$ = subscript to denote the presence of fixed roadway lighting on the respective roadway type;
$wo$ = subscript to denote the absence of fixed roadway lighting on the respective roadway type.

A negative value resulting from equation (1) indicates that night-to-day ratios are lower on roadways with fixed roadway lighting compared to those without lighting.

## 2.2 Negative Binomial Regression Models of Annual Nighttime and Daytime Crash Frequency

The second analysis method consisted of estimating negative binomial regression models of annual nighttime and daytime crash frequency. Models were estimated for three roadway types: intersections, interchanges and freeway segments. A negative binomial regression model relates a crash count as a left-hand-side (LHS) variable to a number of right-hand-side (RHS) variables, coefficients that quantify magnitudes of relationships between LHS and RHS variables and a disturbance term. For this study, the negative binomial regression model was assumed to take the following form:

$$\ln(\lambda) = \omega + X\beta + L\theta + \varepsilon \qquad (2)$$

where: $\lambda$ = expected number of crashes per year at an intersection, interchange or roadway segment;
$\omega$ = $n$ x 1 intercept matrix (all rows are constant)
$X$ = $n$ x $k$ matrix of variables influencing $\lambda$ (e.g., roadway and roadside geometry, type of traffic control, etc.);
$\beta$ = $k$ x 1 matrix of parameters quantifying the relationship between $X$ and $\lambda$ ;
$L$ = a binary (dummy) variable indicating the presence of roadway lighting;
$\theta$ = parameter quantifying the relationship between roadway lighting presence and $\lambda$ ;
$\varepsilon$ = $n$ x 1 disturbance matrix (the distribution of $\varepsilon$ is assumed to be gamma);
$k$ = number of variables in $X$ ; and
$n$ = number of observations.

The mean-variance relationship for the negative binomial distribution is:

$$Var(y_i) = E(y_i)[1 + \alpha E(y_i)] \qquad (3)$$

where: $Var(y_i)$ = variance of observed crashes occurring at location *i*;

$E(y_i)$ = expected crash frequency at location *i*;

$\alpha$ = overdispersion parameter.

The regression parameters (i.e. $\beta$ and $\theta$ ) were estimated using the method of maximum likelihood.

The appropriateness of the negative binomial regression model is based on the significance of the overdispersion parameter ( $\alpha$ ). When $\alpha$ is not significantly different from zero, the negative binomial model reduces to a Poisson model. Previous safety research (e.g., Shankar et al., 1995; Poch and Mannering, 1996; Torbic et al., 2007) has shown that $\alpha$ is nearly always greater than zero (i.e. the variance of crash counts is nearly always greater than the mean).

Regression models were estimated for intersections, interchanges and roadway segments using annual day and night crash frequency as the left hand side variables. The parameter estimates for the presence of roadway lighting ( $\hat{\theta}$ ) were then used to compute the expected percent difference in the night-to-day crash ratios between lighted and unlighted roadways. This computation is as follows:

$$\frac{\exp(\hat{\theta}_N)}{\exp(\hat{\theta}_D)} - 1 \qquad (4)$$

where: $\hat{\theta}_N$ = estimated regression parameter associated with the presence of roadway lighting in the nighttime crash frequency model; and

$\hat{\theta}_D$ = estimated regression parameter associated with the presence of roadway lighting in the daytime crash frequency model;

A negative value resulting from equation (4) indicates that the night-to-day ratios estimated by the regression models are lower on roadways with fixed roadway lighting compared to those without lighting. The advantage of this approach over the approach in the previous section is consideration of variables other than the presence of lighting that may also be associated with the night-to-day crash ratio (e.g. traffic volume, geometrics, etc.).

## 2.3 Log-Linear Models of Night-to-Day Crash Ratios

The third analytical approach used in this study involved computing the observed annual night-to-day crash ratio and modeling the logarithm of this ratio using ordinary least squares (OLS) regression. The objective of this approach was primarily to provide a point of comparison to the negative binomial regression results. OLS is the most commonly used estimator in linear regression modeling and is often used for this purpose. The general form of the log-linear regression model in the present study was:

$$\ln\left(\frac{N}{D}\right) = \omega + X\beta + L\theta + \varepsilon \qquad (5)$$

where: $N$ = number of nighttime crashes, aggregated over a defined time period and roadway type;
$D$ = number of daytime crashes, aggregated over a defined time period and roadway type;
$\omega$ = $n$ x 1 intercept matrix (all rows are constant)
$X$ = $n$ x $k$ matrix of variables influencing $\ln\left(\frac{N}{D}\right)$ (e.g., roadway and roadside geometry, type of traffic control, etc.);
$\beta$ = $k$ x 1 matrix of parameters quantifying the relationship between $X$ and $\lambda$ ;
$L$ = a binary (dummy) variable indicating the presence of roadway lighting;
$\theta$ = parameter quantifying the relationship between roadway lighting presence and $\ln\left(\frac{N}{D}\right)$;
$\varepsilon$ = $n$ x 1 disturbance matrix (the distribution of $\varepsilon$ is assumed to be normal);
$k$ = number of variables in $X$ ; and
$n$ = number of observations.

The following four cases were encountered when modeling the logarithm of night-to-day crash ratios:

- Case I: Night crash frequency > 0; day crash frequency > 0;
- Case II: Night crash frequency = 0; day crash frequency > 0;
- Case III: Night crash frequency = 0; day crash frequency = 0;
- Case IV: Night crash frequency > 0; day crash frequency = 0.

In case I, the night-to-day crash ratios were computed and included in the dataset used to estimate the model as all ratios are greater than zero. In cases II, III and IV, the night-to-day crash ratios are either zero or indeterminate. These observations were not included in the sample of data. The major assumption of this approach is that cases II, III and IV are randomly-distributed in the sample of data. If this assumption is violated, the problem becomes one of selectivity bias; the result being biased and inconsistent parameter estimates. Heckman (1979) developed a method to account for sample selection bias for normally-distributed, continuous data; however, application of the method was not pursued in the present study because of the sensitivity of the model parameters to the assumption of normality (Greene, 2008).

## 2.4 Estimation of Negative Binomial Regression Models of Annual Nighttime and Daytime Crash Frequency with an Instrumental Variable for Roadway Lighting

In the single-equation negative binomial model illustrated in equation (2), the variables in $X$ as well as $L$ were assumed to be exogenous, or independent (i.e., their values vary independently of other variables during a specified time period). However, a review of roadway lighting warrants showed that the likelihood that roadway lighting would be installed on a roadway segment, intersection or interchange (i.e., $L = 1$) may depend on variables including traffic volumes, geometrics, presence of a traffic signal and crash experience. As such, an instrumental variable approach was considered in this research to address this issue. Both day and night crash frequency models with instrumental variables for roadway lighting were estimated using data for Minnesota intersections. Results of the instrumental variable models were uncertain (large changes in parameter magnitude or inconsistent change in signs for various subsets of the Minnesota data) when compared to negative binomial models with the actual lighting dummy variable. The decision not to continue model estimations with lighting instruments was made for several reasons as follows:

1. Intuitively, the relationship between the presence of roadway lighting and crash frequency is not truly endogenous. Although lighting may be installed at locations with a high number of crashes, the lighting installation is not removed if the crash frequency decreases.

2. A right-hand-side instrument that is not highly correlated with the variable for which it is an instrument (i.e., a "weak" instrument) may result in parameter bias that is larger than that introduced by endogeneity. For many subsets of the Minnesota intersection data, the lighting instruments were weak.

3. The econometrics literature regarding the use of instrumental variables in non-linear models is scarce. Although some methods have been proposed (e.g., Windmeijer and Santos Silva, 1997), general consensus on their use does not exist.

## 2.5 Computation of Crash Severity Distributions

In addition to the crash frequency analyses described above, crash severity distributions were computed for all roadway types. The severity distributions were computed based on the KABCO scale as follows:

- Fatality (K);
- Disabling injury (A);
- Evident injury (B);
- Possible injury (C);
- No evident injury or property-damage only (PDO).

Using Minnesota intersection and interchange data, California intersection data and Washington State freeway segment data, severity distributions were developed and stratified by daytime and nighttime crashes with and without fixed roadway lighting. The proportion of crashes occurring within each severity level was compared.

# 3. DATABASE DEVELOPMENT

This section is organized into three subsections. The first describes data acquisition and database development for California and Minnesota intersection analyses. In both instances, the Highway Safety Information System (HSIS) maintained by the Federal Highway Administration (FHWA) was used to acquire roadway inventory and crash data files. An indicator for roadway lighting presence was included in the roadway files from both of these states. The second subsection describes data acquisition and database development for Minnesota interchange analysis. Again, HSIS data files were used with a roadway lighting presence indicator coded in the roadway inventory database. The third subsection includes a summary of the process used to acquire roadway inventory, lighting presence and crash data files from Washington State, Oregon, and Virginia. These data were used to estimate models of nighttime and daytime crash frequency along freeways (Interstates) with and without continuous lighting.

## 3.1 Intersections

### *3.1.1 California*

In order to develop the data files for analysis of California intersections, HSIS data were acquired from the FHWA (HSIS, 2000). These files included crash and roadway inventory and intersection data for the years 1999 through 2002, inclusive. Each observation in the database consists of one intersection for one year. A total of 15,514 intersections were included in the analysis, representing a total of 62,056 annual intersection-level observations. All crash types were included in the analysis. During the analysis period, 46,424 crashes occurred. 8,494 intersection-level observations (13.7 percent) had signal control while the remainder operated under stop control. It was not possible to differentiate between two- and all-way stop-controlled intersections. Three intersection configurations could be distinguished in the California database: four-leg, tee, and wye or offset. Approximately 33.1 percent of the observations were for four-leg intersections; 57.7 percent were tee intersections; and the remaining 9.2 percent of the observations were wye or offset intersections. Although the HSIS roadway inventory data files contained roadway functional classification codes, the rural-urban designation was missing in 64 percent of the cases. As such, the analysis of California data did not differentiate between urban and rural intersection locations. A variety of roadway geometric design data were available for inclusion in the crash frequency models. Table 1 provides definitions and descriptive statistics of variables included in the database.

An analysis taxonomy for California intersections is illustrated in Figure 1. The higher-order models (e.g., all intersections) contained indicator variables for traffic control type (signalized vs. unsignalized) and intersection form (4-leg and 3-leg vs. wye/offset). The methodology progressed through the taxonomy as follows:

- Level 1: all intersections
- Level 2: all signalized intersections; all unsignalized intersections (2 models)
- Level 3: all signalized 4-leg intersections; all signalized 3-leg/tee intersections; all signalized wye/offset intersections; all unsignalized 4-leg intersections; all

unsignalized 3-leg/tee intersections; and, all unsignalized wye/offset intersections (6 models).

**Table 1 Variable Definitions and Descriptive Statistics for the California Intersection Database**

| Variable Description | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|
| Night crash frequency (per year) | 0 | 10 | 0.187 | 0.581 |
| Day crash frequency (per year) | 0 | 21 | 0.561 | 1.241 |
| Night-day crsh ratio | 0 | 6 | 0.243 | 0.487 |
| Log major road average daily traffic (veh/day) | 1.792 | 11.264 | 8.587 | 1.523 |
| Log minor road average daily traffic (veh/day) | 0 | 11.252 | 5.638 | 1.842 |
| Four-leg intersection type indicator<br>(1 = four-leg intersection; 0 otherwise) | 0 | 1 | 0.331 | 0.470 |
| Tee intersection type indicator<br>(1 = tee intersection; 0 otherwise) | 0 | 1 | 0.577 | 0.494 |
| Wye or offset intersection type indicator<br>(1 = wye or offset intersection; 0 otherwise) | 0 | 1 | 0.092 | 0.289 |
| Traffic control indicator<br>(1 = signal; 0 = stop-control) | 0 | 1 | 0.137 | 0.344 |
| Lighting indicator<br>(1 = present; 0 = not present) | 0 | 1 | 0.512 | 0.499 |
| Left-turn channelization on major road indicator<br>(1 = present; 0 otherwise) | 0 | 1 | 0.417 | 0.493 |
| Left-turn restriction indicator<br>(1 = left-turns restricted; 0 otherwise) | 0 | 1 | 0.039 | 0.194 |
| Right-turn channelization on major road indicator<br>1 = present; 0 otherwise) | 0 | 1 | 0.099 | 0.288 |
| Median on major road indicator<br>(1 = present; 0 otherwise) | 0 | 1 | 0.373 | 0.484 |
| Major road number of lanes indicator<br>(1 = major road has two lanes; 0 otherwise) | 0 | 1 | 0.612 | 0.487 |
| Major road number of lanes indicator<br>(1 = major road has three or four lanes; 0 otherwise) | 0 | 1 | 0.326 | 0.469 |
| Major road number of lanes indicator<br>(1 = major road has five or six lanes; 0 otherwise) | 0 | 1 | 0.063 | 0.243 |

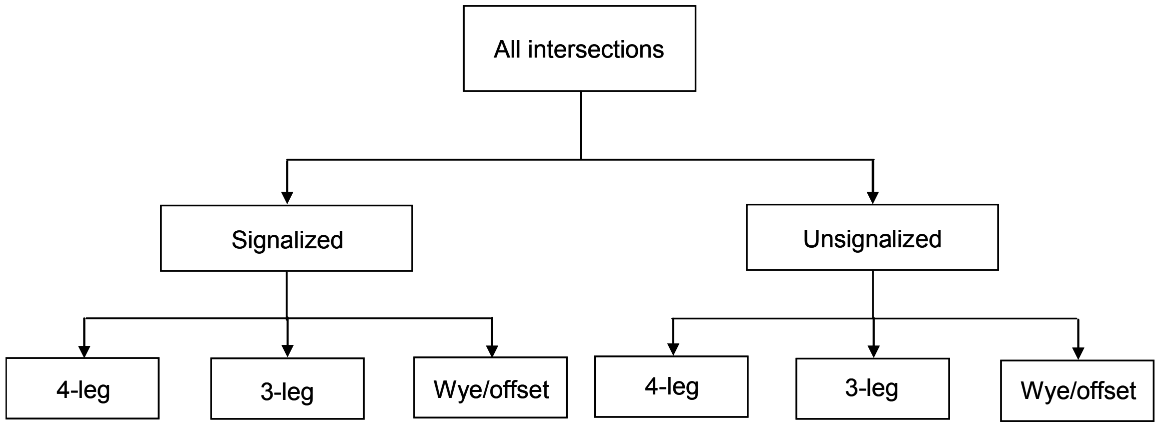


**Figure 1 California Intersection Analysis Taxonomy**

### *3.1.2 Minnesota*

Intersection data contained in the Minnesota HSIS roadway inventory, intersection and crash data files were merged to develop the database (Council and Williams, 2001) used for analysis of Minnesota intersections. Four years (1999 through 2002, inclusive) of crash and corresponding roadway inventory data were included. A total of 25,856 observations (or 6,464 intersections) were available for model estimation. 888 of the 6,464 intersections (13.7 percent) had signal control while the remainder operated under stop control. It was not possible to differentiate two- and all-way stop control. There were three intersection forms coded in the database: cross, tee, and skew. Approximately 49 percent of the intersections (3,181 or 6,464) were four-leg cross intersections. Nearly 40 percent (2,576 of 6,464) were three-leg tee intersections. The remaining 11 percent of the intersections were skew. There were 38,437 reported crashes at the intersections included in the analysis database.

Minnesota is a unique HSIS database in that it contains variables for lighting presence and type (i.e., full, partial, point) for at-grade intersections. Although these data were coded as full, partial or point illumination systems, a majority of the analysis used the lighting presence indicator variable. Table 2 provides a summary of Minnesota intersection data included in the analysis. Only geometric design data for the major roadway were included because of considerable missing data for the minor intersecting roadway. These data include a posted speed indicator, percent heavy vehicles, access control indicator, median indicator and right and left shoulder type indicators. More than 42 percent of the intersections contained some form of roadway lighting.

**Table 2 Descriptive Statistics of Minnesota Intersection Data**

| Variable | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|
| Night crash frequency (per year) | 0 | 28 | 0.3655 | 0.9687 |
| Day crash frequency (per year) | 0 | 55 | 1.1211 | 2.4570 |
| Night-day crash ratio | 0 | 5 | 0.1042 | 0.3175 |
| Log major road average daily traffic | 3.700 | 11.300 | 8.4305 | 1.1451 |
| Percent heavy vehicles on major road | 0 | 61.11 | 8.8880 | 5.1092 |
| Log minor road average daily traffic | 0 | 11.300 | 6.9392 | 1.7331 |
| Area type indicator (1 = urban/suburban; 0 = rural) | 0 | 1 | 0.4456 | 0.4970 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 0 | 1 | 0.1373 | 0.3442 |
| Lighting indicator (1 = present; 0 = not present) | 0 | 1 | 0.4212 | 0.4938 |
| Intersection type indicator (1 = skew; 0 = cross or tee) | 0 | 1 | 0.1095 | 0.3123 |
| Speed indicator* (1 = 50 mph or greater; 0 otherwise) | 0 | 1 | 0.6731 | 0.4691 |
| No access control indicator * (1 = no access; 0 = partial access control) | 0 | 1 | 0.9426 | 0.2326 |
| Depressed median indicator* (1 = depressed median; 0 = barrier or no median) | 0 | 1 | 0.1162 | 0.3204 |
| Paved left-shoulder indicator* (1 = paved shoulder; 0 = unpaved or no shoulder) | 0 | 1 | 0.4577 | 0.4982 |
| Paved right-shoulder indicator* (1 = paved shoulder; 0 = unpaved or no shoulder) | 0 | 1 | 0.5096 | 0.4999 |
| *indicates that data were used for the major intersecting roadway only | | | | |

Like California, an analysis taxonomy was developed for the Minnesota intersection files. The taxonomy is illustrated in Figure 2. Higher-order models (e.g. all intersections) contained indicator variables for traffic control type (signalized vs. unsignalized), area type (urban vs. rural) and intersection form (cross and tee vs. skew). The analysis methodology progressed through the taxonomy as follows:

- Level 1: all intersections
- Level 2: all signalized intersections; all unsignalized intersections; all urban intersections; all rural intersections; all cross intersections; all skewed intersections; and, all tee intersections (7 models)
- Level 3: all urban signalized intersections; all urban unsignalized intersections; all rural signalized intersections; all rural unsignalized intersections (4 models)
- Level 4: all urban signalized cross intersections; all urban signalized skewed intersections; all urban signalized tee intersections; all urban unsignalized cross intersections; all urban unsignalized skewed intersections; all urban unsignalized

tee intersections; all rural signalized cross intersections; all rural signalized skewed intersections; all rural signalized tee intersections; all rural unsignalized cross intersections; all rural unsignalized skewed intersections; all rural unsignalized tee intersections (12 models).

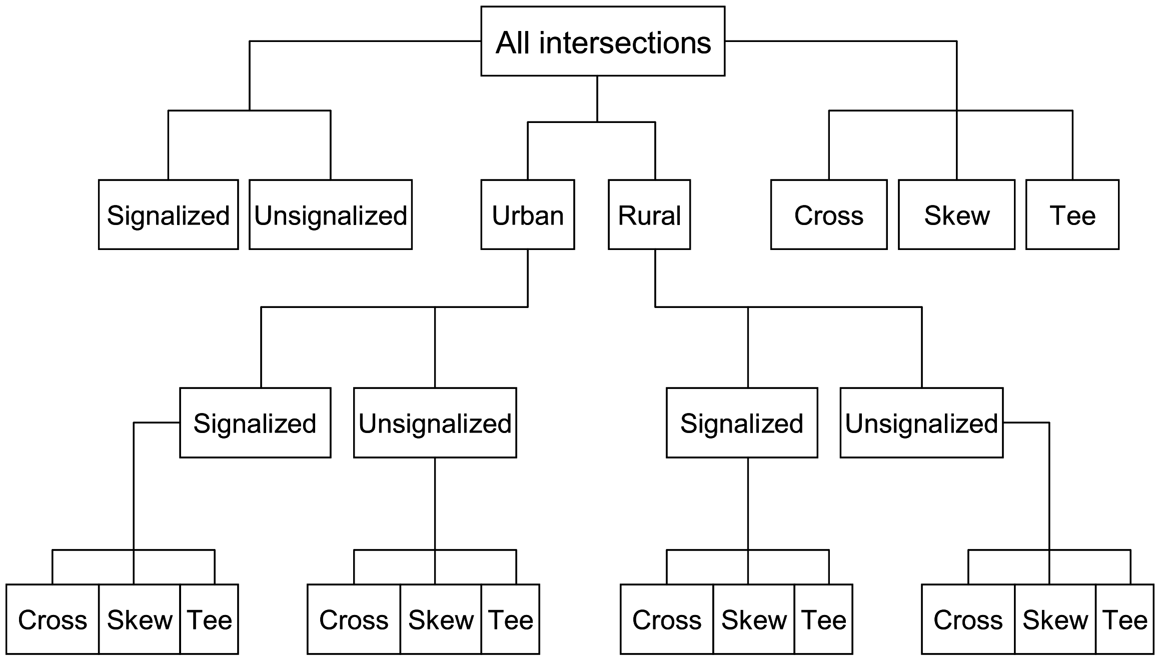


**Figure 2 Minnesota Intersection Analysis Taxonomy**

## 3.2 Interchanges

All data contained in the Minnesota HSIS roadway inventory, intersection/interchange, and crash data files were used to develop the database for analysis of Minnesota interchanges (Council and Williams, 2001). Four years (1999 through 2002, inclusive) of crash and corresponding roadway inventory data were used in the analysis. A total of 2,096 the observations (or 524 interchanges) were available for model estimation, where each observation represented an interchange for one year. Eighty percent of the interchanges were the diamond form while the remainder (i.e. trumpet, semi-direct, cloverleaf, and other) was categorized as non-diamond interchange forms. Nearly 62.1 percent of interchanges in Minnesota were located in an urban or suburban environment while the remainder was classified as rural. There were 36,536 reported crashes in proximity of interchanges included in the database. The crash analysis area was defined as those locations along the mainline through travel lanes between diverge and merge locations plus an additional 1500 feet upstream or downstream of the merge and diverge locations.

Like the intersection data in Minnesota, the interchange data contained lighting presence and type indicators. These data were coded as full, partial or point illumination systems. The lighting variables were analyzed separately and compared to no lighting, as well as combined into a single lighting presence indicator and compared to interchanges with no lighting. Table 3 is a summary of the data included in the Minnesota interchange analysis.

**Table 3 Descriptive Statistics of Minnesota Interchange Data**

| Variable | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|
| Night crash frequency (per year) | 0 | 46 | 5.280 | 6.200 |
| Day crash frequency (per year) | 0 | 89 | 12.151 | 15.026 |
| Night-day crash ratio | 0 | 6 | 0.590 | 0.633 |
| Log total entering vehicles (vehicles/day) | 4.663 | 12.985 | 9.455 | 1.592 |
| Percent heavy vehicles on major road | 0.610 | 45.804 | 8.769 | 5.868 |
| Area type indicator (1 = urban/suburban; 0 = rural) | 0 | 1 | 0.621 | 0.485 |
| Interchange form indicator (1 = diamond; 0 = non-diamond) | 0 | 1 | 0.798 | 0.402 |
| Lighting indicator (1 = present; 0 = not present) | 0 | 1 | 0.798 | 0.402 |
| Posted speed limit on major road (mph) | 25 | 70 | 60.406 | 9.249 |
| Indicator for full-access control on major road (1 = full-access control; 0 = otherwise) | 0 | 1 | 0.781 | 0.413 |
| Indicator for partial-access control on major road (1 = partial access control; 0 = otherwise) | 0 | 1 | 0.094 | 0.291 |
| Indicator for median barrier presence on major road (1 = median barrier present; 0 = no barrier present) | 0 | 1 | 0.256 | 0.436 |
| Pavement surface indicator (1 = concrete pavement; 0 = asphalt pavement) | 0 | 1 | 0.485 | 0.500 |
| Lane width indicator for major road (1 = lane width $\geq$ 13-feet; 0 = otherwise | 0 | 1 | 0.145 | 0.352 |
| Number of lanes on major road indicator 1 = Five or more lanes; 0 = otherwise) | 0 | 1 | 0.250 | 0.433 |

An analysis taxonomy was developed for the Minnesota interchange files. The taxonomy is illustrated in Figure 3. Similar to the intersection models, the higher-order models (e.g., all interchanges) contained indicator variables for area type (urban vs. rural) and interchange form (diamond vs. non-diamond). The analysis methodology progressed through the taxonomy as follows:

- Level 1: all interchanges
- Level 2: all diamond interchanges; all non-diamond interchanges; all urban interchanges; all rural interchanges (4 models)
- Level 3: all urban diamond interchanges; all urban non-diamond interchanges; all rural diamond interchanges; all rural non-diamond interchanges (4 models).

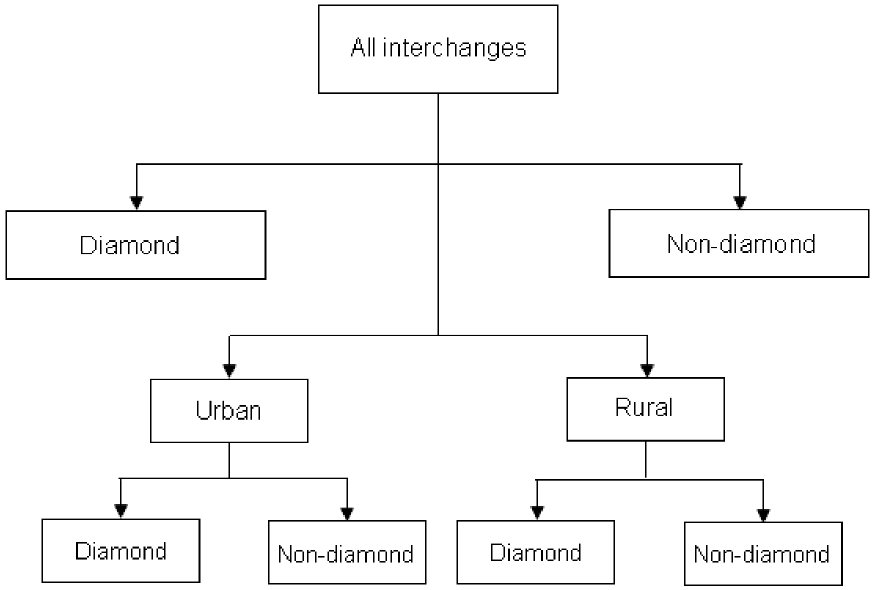


**Figure 3 Minnesota Interchange Analysis Taxonomy**

## 3.3 Freeway Segments

Four freeway segment analyses were undertaken in the present study. The first two were based on Interstate roadway segments in Washington State, and the remaining two were based on roadway segments with continuous freeway lighting in Oregon and Virginia. In the first analysis using the Washington Interstate highway segment data, segments were developed based on the presence of contiguous or point segment-level lighting (i.e., interchange lighting was not considered as part of a continuously-lighted segment); however, the number of interchanges per segment were counted and included in the model specifications and these interchanges generally included either partial or full interchange lighting. A second Washington Interstate analysis was performed excluding interchange and overpass locations as well as point lighting locations. As such, this analysis included only roadway segments with through traffic volumes and therefore did not consider the merge and diverge conflicts at interchange locations, or locations underneath roadway overpasses that were not lighted. The second Washington Interstate analysis contained a subset of segments from the first Washington Interstate analysis. The Oregon and Virginia freeway segment analyses considered continuous freeway lighting as defined by the American Association of State Highway and Transportation Officials' *Roadway Lighting Design Guide* (2005). As described below, locations with continuous freeway lighting, and similar locations without lighting, were identified by the NCHRP Project 5-19 panel.

### *3.3.1 Washington Interstates*

Table 4 shows descriptive statistics for key variables in the lighting segment dataset for Washington State Interstate roadway segments. A total of 1,528 centerline miles of the

Interstate network covering Washington State was scanned using online video photologs to determine many of the variable characteristics included in the analysis. The Interstate network was scanned by direction of travel.

Because the roadway inventory data were coded by direction of travel, a lighting presence indicator was also noted based on travel direction. Fixed roadway lighting in Washington existed either in the median or along the roadside adjacent to the right shoulder location. For the purposes of the analysis, fixed roadway lighting was coded as either continuous or point. If luminaires were present within 0.025 miles of adjacent luminaires, then contiguous luminaires meeting this requirement were combined to form a lighting segment. Point lighting locations were those where a single luminaire was observed along a roadway segment, but not part of a contiguous system. The mean length of lighting segment according to the aforementioned definition was 1.40 miles. The minimum segment length was 0.01 miles, while the maximum segment length was 64.84 miles. The percent of urban segments included in the analysis database was 71 percent, while segments with no lighting constituted 49.77 percent of observations. Continuous lighting segments constituted 32.33 percent of the entire network while point lighting segments constituted 17.90 percent of the network.

The percent of lighted or unlighted segments varied by direction of travel since the Interstate network is a divided highway network. Interchange and overpass data were gathered using the online video photolog system maintained by the Washington State Department of Transportation. The count of interchanges and overpasses was derived on the basis of presence or absence in a segment. The mean number of interchanges per segment was 1.22, with a maximum of 13, while the mean number of overpasses per segment was 0.73 with a maximum of 15. Mean average daily traffic (AADT) per segment was 26,804 with a minimum of 988 vehicles per day and a maximum of 65,109 vehicles per day. Average daily traffic data were obtained in one-mile increments and weighted on the basis of segment lengths.

Using the Washington Interstate segment database, negative binomial regression models were estimated for both daytime and nighttime crashes. Additionally, the night-day crash ratio using only the crash data was also computed. Lastly, a severity distribution for freeway segment with and without fixed roadway lighting is reported, stratified by daytime and nighttime crashes.

### *3.3.2 Supplemental Washington Freeway Segment Analysis*

Revised segment models for evaluating the effect of continuous roadway lighting on crash occurrence were constructed after excluding locations with point lighting. Six models were constructed, including models combining urban and rural segments, models for urban segments only, and models for rural segments only. The effect of interchange and overpass locations on model behavior was also examined. The relative change in daytime crashes, nighttime crashes, and night-day crash ratios were computed from negative binomial regression models for segments including interchanges and overpasses, and for those without interchanges and overpasses.

**Table 4 Descriptive Statistics of Washington Freeway Segment Data**

| Variable | Mean | Minimum | Maximum |
|---|---|---|---|
| Segment length in miles | 1.40 | 0.01 | 64.84 |
| Percent of segments direction of travel (increasing milepost and decreasing milepost respectively) | 0.53/0.47 | 0 | 1 |
| Percent of segments urban | 0.71 | 0 | 1 |
| Percent segments with no lighting presence | 0.50 | 0 | 1 |
| Percent segments with point lighting presence | 0.18 | 0 | 1 |
| Percent segments with continuous lighting presence | 0.32 | 0 | 1 |
| Number of interchanges in segment | 1.22 | 0 | 13 |
| Number of overpasses in segment | 0.73 | 0 | 15 |
| Average daily traffic | 26,804 | 988 | 65,109 |
| Number of vertical curves in segment | 3.25 | 0 | 81 |
| Number of horizontal curves in segment | 1.82 | 0 | 57 |
| Number of lanes in segment | 2.91 | 1 | 6.83 |
| Left shoulder width in feet | 6.85 | 1.28 | 14 |
| Right shoulder width in feet | 6.64 | 0.18 | 24 |
| Number of daytime property damage only crashes in segment | 5.24 | 0 | 107 |
| Number of daytime possible injury crashes in segment | 2.28 | 0 | 55 |
| Number of daytime evident injury crashes in segment | 0.66 | 0 | 22 |
| Number of daytime disabling injury crashes in segment | 0.08 | 0 | 5 |
| Number of daytime fatal crashes in segments | 0.02 | 0 | 5 |
| Number of nighttime property damage only crashes in segment | 1.88 | 0 | 48 |
| Number of nighttime possible injury crashes in segment | 0.69 | 0 | 23 |
| Number of nighttime evident injury crashes in segment | 0.32 | 0 | 12 |
| Number of nighttime disabling injury crashes in segment | 0.05 | 0 | 2 |
| Number of nighttime fatal crashes in segments | 0.02 | 0 | 4 |

### *3.3.3 Oregon Freeways*

To estimate the safety effects of continuous freeway lighting in Oregon, roadway inventory, lighting presence, and traffic crash data were acquired and appended from a variety of sources. Dr. Christopher Monsere from Portland State University provided an electronic database of limited-access roadway segments with and without roadway lighting from a study that was performed while he was employed by the Oregon Department of Transportation (ODOT) Traffic Engineering Services Unit (Monsere and

Grile, 2002). The database included daytime and nighttime crash frequencies, daytime and nighttime traffic volumes, and an indicator for lighting presence on the following roadways during the period 1996 through 2000 (inclusive):

- Interstates 5, 82, 84, 205, and 405;
- U.S. Route 26; and,
- Oregon State Route 217.

Because the database provided by Dr. Monsere did not include any roadway inventory data, the research team requested these data from ODOT staff. Data for the year 2008 were provided to the research team and included roadway cross-section information (number of lanes, lane width, shoulder width, median width), posted speed limit data, and area type (urban vs. rural) information. Additionally, roadway segment information (begin and end milepost and segment length) were also included in the roadway inventory datafiles provided by ODOT.

To verify that the roadway segments identified by Monsere and Grile (2002) contained continuous freeway lighting as defined by AASHTO, the ODOT video photolog system was used. Once this process was completed, the 2008 roadway segment data provided by ODOT and the data provided by Dr. Monsere were appended. The percentage of daytime and nighttime traffic estimates developed by Monsere and Grile (2002) were used in the present analysis to estimate daytime and nighttime traffic volumes. Finally, the daytime and nighttime crash frequency data provided by Dr. Monsere were appended to the roadway inventory and lighting presence data. To develop the final analysis database, ODOT's video photolog system was used to count the number of interchanges, horizontal curves, and vertical curves in each analysis segment. Roadway segments with continuous lighting were defined by the limits of the fixed illumination section.

Table 5 shows the descriptive statistics for all explanatory variables and total daytime and nighttime crashes for each roadway segment included in the analysis database. A total of 680.6 miles of the limited-access highway segments were included in the analysis database. The percentage of urban segments included in the analysis database was 46 percent – approximately 54 percent of the segments were classified as rural. Segments with lighting constituted 11 percent of the observations, while approximately 89 percent of segments did not contain continuous lighting. There were two lanes per direction 77 percent of the roadway segments in the analysis while the remainder had more than two through travel lanes per direction. Approximately 50 percent of segments in the analysis database contained a fixed longitudinal median barrier while the remainder contained an earth-divided, traversable median.

The average roadway segment length was 3.80 miles, ranging from 0.1 to 47.9 miles. The left (median) paved shoulder width in the analysis segments ranged from 0 to 20 feet, while the right (outside) paved shoulder width ranged from 2 to 19 feet. The mean width of the left and right paved shoulders was 7.98 and 7.79 feet, respectively. The average median width of the analysis segments was 50.60 ft, ranging from 0 to 106 feet. The average number of horizontal curves per segment was 4.33, ranging from 0 to 59. The number of vertical curves per segment ranged from 0 to 78. The number of interchanges in an analysis segment ranged from 0 to 17.

The average daytime average daily traffic was 32,817 vehicles per day while the average nighttime daily traffic in the analysis database was 9,292 vehicles per day. Approximately 70 percent of the analysis segments had a posted speed limit of 65 mph or higher.

The average number of daytime crashes along the analysis segments was 61, while the average number of nighttime crashes was 21. Negative binomial regression models were estimated for both daytime and nighttime crashes using the continuous and categorical data shown in Tables 1 and 2. Additionally, the night-day crash ratio was also computed using only the descriptive statistics from the analysis database.

**Table 5 Descriptive Statistics of Variables in Oregon Freeway Segment Database**

| Continuous Variable | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| Number of daytime crashes in segment | 61 | 188.77 | 0 | 2,043 |
| Number of nighttime crashes in segment | 21 | 51.73 | 0 | 537 |
| Left paved shoulder width (feet) | 7.98 | 3.14 | 0 | 20 |
| Right paved shoulder width (feet) | 7.79 | 2.89 | 2 | 19 |
| Average daily daytime traffic (veh/day) | 32,817 | 28,432 | 6,131 | 116,584 |
| Average daily nighttime traffic (veh/day) | 9,292 | 8,572 | 1,669 | 37,700 |
| Segment length (miles) | 3.80 | 7.13 | 0.1 | 47.9 |
| Number of horizontal curves in segment | 4.33 | 8.36 | 0 | 59 |
| Number of vertical curves in segment | 8.24 | 14.32 | 0 | 78 |
| Number of interchanges in segment | 1.34 | 2.50 | 0 | 17 |
| Median width (feet) | 50.60 | 33.30 | 0 | 106 |

| Categorical Variable | Definition | Proportion |
|---|---|---|
| Area type | 1 if the segment is in an urban area | 0.46 |
| | 0 if the segment is in a rural area (baseline) | 0.54 |
| Lighting presence | 1 if lighting is present | 0.11 |
| | 0 if lighting is not present (baseline) | 0.89 |
| Number of lanes | 1 if number of through lanes per direction = 2 | 0.77 |
| | 0 if number of through lanes per direction > 2 (baseline) | 0.23 |
| Median barrier presence | 1 if median barrier is present | 0.50 |
| | 0 if no median barrier is present (baseline) | 0.50 |
| Posted speed limit | 1 if posted speed limit = 65mph | 0.70 |
| | 0 if posted speed limit < 65mph (baseline) | 0.30 |

### *3.3.4 Virginia Freeway Segments*

Freeway segments with and without roadway lighting were identified by Virginia Department of Transportation (VDOT) staff. The roadways included in the analysis database included segments with and without continuous freeway lighting on Interstates 66, 95, 395, and 495. Electronic roadway inventory and crash data were also obtained from VDOT staff for the segments with and without roadway lighting. In all, approximately 113 miles were included in the analysis database.

Table 6 shows descriptive statistics for the continuous and categorical variables included in the analysis dataset. All of the roadway segments included in the analysis database were in an urban area. Segments with continuous freeway lighting constituted 15.5 percent of the observations. Approximately 19.8 percent of the roadway segments had two through travel lanes per direction, while 37.0 percent of the segments had three through lanes per direction, and 43.3 percent of the segments had four or more through travel lanes per direction. Approximately 65.9 percent of the roadway segments in the analysis database contained a longitudinal median barrier.

The average roadway segment length was 0.33 miles, ranging from 0.01 to 2.45 miles. The mean width of the left shoulder was 2.35 feet, while the mean width of the right shoulder was 9.34 feet. The left shoulder width ranged from 0 to 12 feet, while the right shoulder ranged from 0 to 14 feet. The average median width was 48.11 feet, ranging from 2 to 285.5 feet. Interchange locations within each roadway segment were identified by VDOT staff. The number of interchanges per analysis segment ranged from 0 to 1.

The mean average daily traffic was 68,519 vehicles per day, ranging from 18,945 to 133,528 vehicles per day. The posted speed limit ranged from 45 to 65 mph; however, posted speed limit data were missing for approximately one-half of the analysis segments. The average percentage of truck traffic was 4.56 percent, ranging from 0.29 to 10.19 percent.

The average number of daytime crashes in the analysis database was 6.0, ranging from 0 to 100. Among all the daytime crashes, 65.9 percent were property-damage-only crashes, 34.0 percent were injury crashes, and 0.2 percent was fatal crashes. The average number of nighttime crashes in the analysis database was 2.0, ranging from 0 to 29 per segment. Among all nighttime crashes, 65.2 percent were property-damage-only crashes, 34.2 percent were injury crashes, and 0.6 percent was fatal crashes.

Using the Virginia Interstate segment database, negative binomial regression models were estimated for both daytime and nighttime crashes. Additionally, the night-day crash ratio using only the observed crash data was also computed.

**Table 6 Descriptive Statistics of Variables in Virginia Freeway Segment Database**

| Continuous Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Segment length (miles) | 0.33 | 0.39 | 0.01 | 2.45 |
| Number of interchanges in segment | 0.18 | 0.38 | 0 | 1 |
| Average daily traffic (veh/day) | 68,519 | 24418.23 | 18945 | 133,528 |
| Number of lanes per direction | 3.29 | 0.85 | 2 | 6 |
| Travel way surface width (feet) | 39.43 | 10.20 | 22 | 72 |
| Right shoulder width (feet) | 9.34 | 3.35 | 0 | 14 |
| Left shoulder width (feet) | 2.35 | 3.65 | 0 | 12 |
| Percentage of truck traffic | 4.56 | 2.84 | 0.29 | 10.19 |
| Speed limit (mph) | 57.48 | 3.91 | 45 | 65 |
| Median width (feet) | 48.11 | 49.41 | 2 | 285.5 |
| Daytime crash count | 6.17 | 8.97 | 0 | 100 |
| Nighttime crash count | 2.47 | 3.43 | 0 | 29 |
| Daytime property-damage-only crash count | 4.07 | 6.00 | 0 | 61 |
| Daytime injury crash count | 2.10 | 3.35 | 0 | 39 |
| Daytime fatal crash count | 0.01 | 0.11 | 0 | 1 |
| Nighttime property-damage-only crash count | 1.61 | 2.37 | 0 | 18 |
| Nighttime injury crash count | 0.84 | 1.38 | 0 | 12 |
| Nighttime fatal crash count | 0.02 | 0.12 | 0 | 1 |

| Categorical Variable | Definition | Proportion |
|---|---|---|
| Lighting presence | 1: if lighting is present | 0.79 |
| | 0: if lighting is not present (baseline) | 0.21 |
| Median barrier | 1: if median barrier is present | 0.66 |
| | 0: if no median barrier is present (baseline) | 0.34 |
| Two lanes indicator | 1: if number of through lanes per direction = 2 | 0.20 |
| | 0: otherwise | 0.80 |
| Three lanes indicator | 1: if number of through lanes per direction = 3 | 0.37 |
| | 0: otherwise | 0.63 |
| Four or more lanes indicator (baseline) | 1: if number of through lanes per direction ≥ 4 | 0.43 |
| | 0: otherwise | 0.57 |

# 4. ANALYSIS RESULTS

This section is divided into two subsections. The first contains results of the crash frequency modeling efforts. Included are the higher-order daytime and nighttime crash frequency models estimated using the Minnesota and California intersection databases, the Minnesota interchange database and the Oregon, Virginia, and Washington State freeway segment database. The higher order models are those shown at the top of each analysis taxonomy (see Figures 1, 2, and 3). Estimation results of the lower-order nighttime and daytime crash frequency models results are also briefly summarized with statistical output contained in Appendixes A, B, and C for the California intersection, Minnesota intersection, and Minnesota interchanges, respectively. The first subsection also includes estimation results of the log-linear models of night-to-day crash ratios for the higher-order taxonomy levels. The second subsection describes the severity analysis. Results are presented in tabular form for the Minnesota and California intersections, Minnesota interchanges and Washington State freeway segment databases.

## 4.1 Crash Frequency Models

### *4.1.1 Intersections*

Included in this section are night-to-day crash ratios, nighttime and daytime crash frequency negative binomial regression models, and log-linear night-day crash ratio models for the California and Minnesota intersection models. The instrumental variable model for all Minnesota intersections is also presented.

#### 4.1.1.1 California

Per the methodological process described previously, both daytime and nighttime crash frequency models were estimated using negative binomial regression. The results of these models are shown in Tables 7 and 8. Because a small proportion of the geometric data were missing from the analysis database, a total of 62,027 observations were included in the analysis. The variables included in Table 7 all contain a reasonable level of statistical significance. Those positively correlated with the expected number of daytime crashes are: major and minor road traffic volumes, four-leg intersection type, indicator for signal control, indicator for roadway lighting presence, indicators for left- and right-turn channelization on the major road, and number of lanes indicators on the major road approach. The variables negatively correlated with the expected number of daytime crashes are: tee intersection type indicator, left-turn restriction indicator, and the median presence indicator.

**Table 7 California Intersection Daytime Crash Frequency Model**

| Variable | Parameter Estimate | Standard Error | z-statistic | p-value |
|---|---|---|---|---|
| Constant | -4.518 | 0.068 | -66.85 | <0.001 |
| Log major road average daily traffic (veh/day) | 0.115 | 0.007 | 17.66 | <0.001 |
| Log minor road average daily traffic (veh/day) | 0.374 | 0.006 | 60.38 | <0.001 |
| Four-leg intersection type indicator (1 = four-leg intersection; 0 otherwise) | 0.397 | 0.029 | 13.52 | <0.001 |
| Tee intersection type indicator (1 = tee intersection; 0 otherwise) | -0.183 | 0.029 | -6.23 | <0.001 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 0.058 | 0.022 | 2.60 | 0.009 |
| Lighting indicator (1 = present; 0 = not present) | 0.169 | 0.020 | 8.36 | <0.001 |
| Left-turn channelization on major road indicator (1 = present; 0 otherwise) | 0.345 | 0.021 | 16.75 | <0.001 |
| Left-turn restriction on major road indicator (1 = left-turn restrictions present; 0 otherwise) | -0.467 | 0.048 | -9.75 | <0.001 |
| Right-turn channelization on major road indicator 1 = present; 0 otherwise) | 0.158 | 0.022 | 7.07 | <0.001 |
| Median on major road indicator (1 = present; 0 otherwise) | -0.102 | 0.023 | -4.44 | <0.001 |
| Major road number of lanes indicator (1 = major road has three or four lanes; 0 otherwise) | 0.138 | 0.022 | 6.17 | <0.001 |
| Major road number of lanes indicator (1 = major road has five or six lanes; 0 otherwise) | 0.151 | 0.035 | 4.34 | <0.001 |
| Dispersion Parameter ($\alpha$) | 0.994 | 0.020 | 49.70 | <0.001 |
| Number of observations = 62,027<br>Log-likelihood (constant only) = -60732.833<br>Log-likelihood of the fitted model = -52061.488<br>Pseudo $R^2$ = 0.1428 | | | | |

The variables included in Table 8 (total nighttime crashes) all contain a reasonable level of statistical significance, except the median indicator. Those positively correlated with the expected number of nighttime crashes are: major and minor road traffic volumes, four-leg intersection type, indicator for signal control, indicators for left- and right-turn channelization on the major road, and number of lanes indicators on the major road approach. The variables negatively correlated with the expected number of nighttime crashes are: tee intersection type indicator, lighting indicator, and the left-turn restriction indicator.

**Table 8 California Intersection Nighttime Crash Frequency Model**

| Variable | Parameter Estimate | Standard Error | z-statistic | p-value |
|---|---|---|---|---|
| Constant | -5.430 | 0.102 | -53.06 | <0.001 |
| Log major road average daily traffic (veh/day) | 0.092 | 0.010 | 9.39 | <0.001 |
| Log minor road average daily traffic (veh/day) | 0.369 | 0.009 | 39.39 | <0.001 |
| Four-leg intersection type indicator (1 = four-leg intersection; 0 otherwise) | 0.442 | 0.047 | 9.51 | <0.001 |
| Tee intersection type indicator (1 = tee intersection; 0 otherwise) | -0.103 | 0.047 | -2.20 | 0.028 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 0.379 | 0.032 | 11.67 | <0.001 |
| Lighting indicator (1 = present; 0 = not present) | -0.086 | 0.032 | -2.68 | 0.007 |
| Left-turn channelization on major road indicator (1 = present; 0 otherwise) | 0.345 | 0.032 | 10.84 | <0.001 |
| Left-turn restriction on major road indicator (1 = left-turn restrictions present; 0 otherwise) | -0.397 | .074 | 5.37 | <0.001 |
| Right-turn channelization on major road indicator 1 = present; 0 otherwise) | 0.198 | 0.030 | 6.50 | <0.001 |
| Median on major road indicator (1 = present; 0 otherwise) | 0.014 | 0.034 | 0.42 | 0.674 |
| Major road number of lanes indicator (1 = major road has three or four lanes; 0 otherwise) | 0.062 | 0.034 | 1.82 | 0.070 |
| Major road number of lanes indicator (1 = major road has five or six lanes; 0 otherwise) | 0.146 | 0.050 | 2.95 | 0.003 |
| Dispersion Parameter ($\alpha$) | 1.002 | 0.040 | 25.05 | <0.001 |
| Number of observations = 62,027<br>Log-likelihood (constant only) = -31129.769<br>Log-likelihood of the fitted model = -26401.153<br>Pseudo $R^2$ = 0.1519 | | | | |

The relative effects of each indicator variable were computed as $e^{\beta k} - 1$. The data shown in Table 9 are relative effects for the daytime and nighttime crash frequencies. Assuming all other explanatory variables are held constant, the relative effects of a four-leg intersection are a 48.7 percent increase in the expected daytime crash frequency when compared to wye or offset intersections. The relative effects of a tee intersection are a 16.7 percent reduction in the expected daytime crash frequency when compared to wye or offset intersections. The relative effect of a signalized intersection is a 6 percent increase in the expected daytime crash frequency when compared to a stop-controlled intersection. The relative predicted effect of fixed roadway lighting is an 18.4 percent increase in the expected daytime crash frequency when compared to intersections with no fixed roadway lighting. Left-turn and right-turn channelization on the major road increases the expected daytime crash frequency at California intersections increases the expected daytime crash frequency by 41.2 and 17.1 percent, respectively, when compared to intersections without left- and right-turn channelization. Left-turn restrictions on the major road decreases the expected daytime crash frequency by 37.3 percent when compared to intersections without left-turn restrictions. The presence of a median on the major road decreases the expected daytime crash frequency by 9.7 percent when compared to intersections without a median on the major road. Major roads with more than two-lanes increases the expected crash frequency when compared to major roads with two approach lanes.

Assuming all other explanatory variables are held constant, the relative effects of a four-leg intersection are a 55.6 percent increase in the expected nighttime crash frequency when compared to wye or offset intersections. The relative effects of tee intersection are a 9.8 percent reduction in the expected nighttime crash frequency when compared to wye or offset intersections. The relative effect of a signalized intersection is a 46.1 percent increase in the expected nighttime crash frequency when compared to a stop-controlled intersection. The relative predicted effect of fixed roadway lighting is an 8.2 percent decrease in the expected nighttime crash frequency when compared to intersections with no fixed roadway lighting. Left-turn and right-turn channelization on the major road increases the expected daytime crash frequency at California intersections increases the expected daytime crash frequency by 41.2 and 21.9 percent, respectively, when compared to intersections without left- and right-turn channelization. Left-turn restrictions on the major road decreases the expected daytime crash frequency by 32.8 percent when compared to intersections without left-turn restrictions. Major roads with more than two-lanes increases the expected crash frequency when compared to major roads with two approach lanes.

Using equation (4), the percent difference in the night-day crash ratio for California intersections with and without lighting is -22.51 percent. This was computed using the lighting parameter estimate from the nighttime and daytime crash frequency negative binomial regression analysis results presented in Tables 7 and 8. As such, the negative binomial regression modeling approach indicates that fixed roadway lighting at California intersections is associated with a positive safety effect when compared to intersections without fixed roadway lighting.

### Table 9 Relative Effects for Indicator Variables in California Crash Frequency Models

| Variable | Daytime Relative Effects[a] | Nighttime Relative Effects[a] |
|---|---|---|
| Four-leg intersection type indicator (1 = four-leg intersection; 0 otherwise) | 0.487 | 0.556 |
| Tee intersection type indicator (1 = tee intersection; 0 otherwise) | -0.167 | -0.098 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 0.060 | 0.461 |
| Lighting indicator (1 = present; 0 = not present) | 0.184 | -0.082 |
| Left-turn channelization on major road indicator (1 = present; 0 otherwise) | 0.412 | 0.412 |
| Left-turn restriction on major road indicator (1 = left-turn restrictions present; 0 otherwise) | -0.373 | -0.328 |
| Right-turn channelization on major road indicator 1 = present; 0 otherwise) | 0.171 | 0.219 |
| Median on major road indicator (1 = present; 0 otherwise) | -0.097 | N/A |
| Major road number of lanes indicator (1 = major road has three or four lanes; 0 otherwise) | 0.148 | 0.064 |
| Major road number of lanes indicator (1 = major road has five or six lanes; 0 otherwise) | 0.163 | 0.157 |
| [a] Relative effects are computed for each indicator variable. Relative effects are computed as [exp(β) – 1]. | | |

The overdispersion parameter, α, was statistically different than zero in both the daytime and nighttime crash frequency models, indicating that the crash frequency variance exceeds the mean. The pseudo-$R^2$ is computed as follows:

$$R^2 = 1 - \frac{LL(\beta)}{LL(0)} \tag{6}$$

where: $LL(\beta)$ = log-likelihood for the full model
$LL(0)$ = log-likelihood for the constant only model

The low value of the pseudo-$R^2$ statistic (0.1428) in the daytime crash frequency model indicates a relatively poor fit for the daytime crash frequency model. Likewise, the pseudo-$R^2$ statistic in the nighttime crash frequency (0.1519) model indicates a relatively poor fit to the data.

The log-linear night-day ratio linear regression model for all California intersections was estimated and the model results are shown in Table 10. A significant amount of data attrition resulted from the night-day crash ratio log-linear models (5,296 observations). As such, these models are not recommended for interpretation. The presence of lighting decreases the natural logarithm of the night-day crash ratio by 0.054.

**Table 10 Log-linear Regression Model of Night-Day Crash Ratio for California Intersections**

| Variable | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| Constant | -0.215 | 0.099 | -2.17 | 0.030 |
| Log major road average daily traffic (veh/day) | 0.005 | 0.009 | 0.60 | 0.549 |
| Log minor road average daily traffic (veh/day) | -0.033 | 0.008 | -4.09 | <0.001 |
| Four-leg intersection type indicator (1 = four-leg intersection; 0 otherwise) | -0.025 | 0.045 | -0.57 | 0.570 |
| Tee intersection type indicator (1 = tee intersection; 0 otherwise) | 0.130 | 0.046 | 2.81 | 0.005 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 0.026 | 0.027 | 0.96 | 0.335 |
| Lighting indicator (1 = present; 0 = not present) | -0.054 | 0.030 | -1.80 | 0.072 |
| Left-turn channelization on major road indicator (1 = present; 0 otherwise) | -0.032 | 0.028 | -1.18 | 0.229 |
| Left-turn restriction on major road indicator (1 = left-turn restrictions present; 0 otherwise) | 0.003 | 0.070 | 0.04 | 0.969 |
| Right-turn channelization on major road indicator 1 = present; 0 otherwise) | -0.053 | 0.024 | -2.24 | 0.025 |
| Median on major road indicator (1 = present; 0 otherwise) | 0.045 | 0.028 | 1.61 | 0.109 |
| Major road number of lanes indicator (1 = major road has three or four lanes; 0 otherwise) | -0.015 | 0.029 | -0.50 | 0.615 |
| Major road number of lanes indicator (1 = major road has five or six lanes; 0 otherwise) | -0.057 | 0.040 | -1.41 | 0.158 |
| Number of observations = 5,296<br>$R^2 = 0.0235$<br>$R_{adj}^2 = 0.0213$ | | | | |

The third approach to evaluate the safety effects of roadway lighting at California intersections was to use the observed data and compute the night-day crash ratio. To compute the percent difference between the lighted and unlighted intersections, equation (1) was used. From all of the observed data, the night-day crash ratio at intersections with lighting was 0.3313 (9235 night crashes and 27,878 day crashes) while the night-day crash ratio at intersections without lighting was 0.3420 (2373 night crashes and 6938 day crashes). As such the percent difference per equation (1) is -3.1 percent. Alternatively stated, the night-day crash ratio is 3.1 percent lower with fixed roadway lighting at intersections in California when compared to intersections without lighting. When comparing this measure to those obtained in the regression model estimations described previously, it is clear that using the night-day ratio as a measure of safety underestimates the effects of roadway lighting at intersections in California. One possible explanation for this underestimation is the lack of control given to the geometric features and traffic volume present at the intersections.

Rather than show all of the negative binomial regression, log-linear regression, and descriptive statistics analysis results in this section, a summary of these results is provided in Table 10. All of the statistical modeling results for California intersections are shown in Appendix A.

**Table 11 Summary of California Intersection Analysis Results**

| Roadway Type | NB Model | Descriptive Statistics | NB Model Sample Size | Night-Day Ratio Model | Night-Day Ratio Sample Size |
|---|---|---|---|---|---|
| All Intersections | -22.51 | -3.15 | 62,055 | -5.40 | 17,349 |
| All Signalized | -24.54 | -15.40 | 8494 | -16.9 | 2862 |
| All Stop-control | -23.15 | -21.86 | 53,561 | -3.97 | 2434 |
| All Four-leg | -26.60 | 1.40 | 20,514 | -10.1 | 9347 |
| All Tee | -20.02 | -11.68 | 35,828 | 1.2 | 6696 |
| All Wye/Offset | -30.58 | -15.36 | 5713 | -10.1 | 1301 |
| Signalized Four-leg | -22.40 | -18.93 | 6290 | -16.3 | 4589 |
| Stop Four-leg | -24.45 | -23.43 | 14,224 | -6.9 | 4758 |
| Signalized Tee | -1.18 | 12.98 | 1830 | -33.0 | 966 |
| Stop Tee | -20.52 | -19.55 | 33,998 | 0.1 | 5735 |
| Signalized Wye/Offset | -95.77 | N/A | 374 | N/A | 190 |
| Stop Wye/Offset | -24.37 | -22.16 | 5339 | -10.1 | 1111 |

Based on the negative binomial regression analysis results shown in Table 11, intersections with fixed roadway lighting have fewer expected total crashes than intersections without fixed roadway lighting at all levels of the analysis taxonomy. The percent difference between intersections with lighting and those without lighting in California ranges from -1.18 to -95.77 percent. When excluding the lower-order negative binomial regression models (i.e., signalized and stop-controlled four-leg, signalized and stop-controlled tee, and signalized and stop-controlled wye/offset intersections), the percent difference in the expected crash frequency between lighted and unlighted intersection in California is -20.02 to -30.58 percent. The descriptive statistics and night-day ratio model results generally coincide with the negative binomial regression models with respect to the sign, but are lower in magnitude.

4.1.1.2 Minnesota

Per the methodological process described previously, both daytime and nighttime crash frequency models were estimated using negative binomial regression. Because some geometric design data were missing from the analysis database, the number of observations included in the analysis was 22,058. The variables included in Table 12 (total daytime crashes) all contain a reasonable level of statistical significance. Those positively correlated with the expected number of daytime crashes are: major and minor road traffic volumes, indicator for signal control, indicator for lighting presence, skewed intersection form indicator, depressed median indicator, and paved right shoulder indicator. The explanatory variables that are negatively correlated with the expected daytime crash frequency are: percent heavy vehicles on the major road, urban area indicator, posted speed limit indicator, no access control indicator, and the paved left shoulder indicator. Assuming all other explanatory variables are held constant, the relative effects of an urban/suburban intersection are a 9.45 percent decrease in the expected daytime crash frequency when compared to rural intersection locations. High-speed on the major road decreases the expected daytime crash frequency by 15.79 percent compared to low-speed operations. No access control and a paved left-shoulder also decrease the expected daytime crash frequency when compared to their baseline levels (i.e., partial access control and no or unpaved left shoulders).

Traffic signal control, the presence of lighting, skewed crossing, depressed median, and paved right shoulder all increase the expected daytime crash frequency, holding all other explanatory variables constant. Signal control increases the expected daytime crash frequency by 90.49 percent when compared to stop control. The presence of roadway lighting is associated with an increased expected daytime crash frequency by nearly 5 percent when compared to no lighting. Skewed intersections increase the expected daytime crash frequency by 62.62 percent when compared to cross or tee intersections. This finding was expected because of the limited intersection sight distance often associated with skewed intersections when compared to right-angle intersections. Depressed medians and paved right shoulders increase the expected by approximately 8 to 9 percent when compared to barrier or no medians and unpaved or no shoulders, respectively.

The overdispersion parameter, $\alpha$, was statistically different than zero. The low value of the pseudo-$R^2$ statistic (0.1355) in the daytime crash frequency model indicates a relatively poor fit for the daytime crash frequency model.

The nighttime crash frequency model estimation results are shown in Table 13. The relative effects for each indicator variable are shown in Table 14. When comparing the relative effects of the daytime crash frequency model to those from the nighttime frequency model, the signs are all the same except for the lighting indicator. It was expected that roadway lighting would decrease the nighttime crash frequency as a result of improved visibility. During the daytime, one would expect either no change or a slight increase in crash frequency with lighting when compared to intersections without lighting. This may be due to the addition of fixed objects near the travel lane. In the model estimation of nighttime crashes, the overdispersion parameter, $\alpha$, was again statistically different than zero. The psedo-$R^2$ was low (0.1259) indicating a relatively poor model fit.

## Table 12 Total Daytime Crash Frequency Estimation Results for Minnesota Intersections

| Variable | Parameter Estimate | z-statistic | p-value |
|---|---|---|---|
| Constant | -6.5373 | -43.37 | <0.001 |
| Log major road average daily traffic | 0.6011 | 38.88 | <0.001 |
| Percent heavy vehicles on major road | -0.0092 | -3.30 | 0.001 |
| Log minor road average daily traffic | 0.1603 | 21.79 | <0.001 |
| Area type indicator (1 = urban/suburban; 0 = rural) | -0.0992 | -3.39 | 0.001 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 0.6445 | 21.07 | <0.001 |
| Lighting indicator (1 = present; 0 = not present) | 0.0477 | 1.56 | 0.119 |
| Intersection type indicator (1 = skew; 0 = cross or tee) | 0.4862 | 15.86 | <0.001 |
| Speed indicator* (1 = 50 mph or greater; 0 otherwise) | -0.1601 | -7.36 | <0.001 |
| No access control indicator * (1 = no access; 0 = partial access control) | -0.0416 | -1.09 | 0.276 |
| Depressed median indicator* (1 = depressed median; 0 = barrier or no median) | 0.0851 | 2.53 | 0.011 |
| Paved left-shoulder indicator* (1 = paved shoulder; 0 = unpaved or no shoulder) | -0.1163 | -2.75 | 0.006 |
| Paved right-shoulder indicator* (1 = paved shoulder; 0 = unpaved or no shoulder) | 0.0798 | 1.93 | 0.054 |
| Dispersion parameter ($\alpha$) | 0.9487 | 40.31 | <0.001 |
| Number of observations = 22,058<br>Log-likelihood (constant only) = -28,954.27<br>Log-likelihood (full model) = -27,084.31<br>Pseudo $R^2$ = 0.1355 | | | |

## Table 13 Total Nighttime Crash Frequency Estimation Results for Minnesota Intersections

| Variable | Parameter Estimate | z-statistic | p-value |
|---|---|---|---|
| Constant | -6.8986 | -33.53 | <0.001 |
| Log major road average daily traffic | 0.5737 | 26.85 | <0.001 |
| Percent heavy vehicles on major road | -0.0168 | -4.37 | <0.001 |
| Log minor road average daily traffic | 0.1262 | 12.29 | <0.001 |
| Area type indicator<br>(1 = urban/suburban; 0 = rural) | -0.4212 | -10.52 | <0.001 |
| Traffic control indicator<br>(1 = signal; 0 = stop-control) | 0.7120 | 17.20 | <0.001 |
| Lighting indicator<br>(1 = present; 0 = not present) | -0.0791 | -1.86 | 0.062 |
| Intersection type indicator<br>(1 = skew; 0 = cross or tee) | 0.4845 | 12.17 | <0.001 |
| Speed indicator<br>(1 = 50 mph or greater; 0 otherwise) | -0.1131 | -3.88 | <0.001 |
| No access control indicator<br>(1 = no access; 0 = partial access control) | -0.0148 | -0.31 | 0.754 |
| Depressed median indicator<br>(1 = depressed median; 0 = barrier or no median) | 0.1712 | 3.99 | <0.001 |
| Paved left-shoulder indicator<br>(1 = paved shoulder; 0 = unpaved or no shoulder) | -0.2907 | -5.44 | <0.001 |
| Paved right-shoulder indicator<br>(1 = paved shoulder; 0 = unpaved or no shoulder) | 0.2153 | 4.11 | <0.001 |
| Dispersion parameter ($\alpha$) | 0.8948 | 21.99 | <0.001 |
| Number of observations = 22,058<br>Log-likelihood (constant only) = -17,842.15<br>Log-likelihood (full model) = -15,165.85<br>Pseudo $R^2$ = 0.1259 | | | |

**Table 14 Relative Effects for Indicator Variables in the Minnesota Crash Frequency Models**

| Variable | Daytime Relative Effects[a] | Nighttime Relative Effects[a] |
|---|---|---|
| Area type indicator (1 = urban/suburban; 0 = rural) | -9.45 | -34.30 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 90.49 | 103.80 |
| Lighting indicator (1 = present; 0 = not present) | 4.89 | -7.61 |
| Intersection type indicator (1 = skew; 0 = cross or tee) | 62.62 | 62.34 |
| Speed indicator (1 = 50 mph or greater; 0 otherwise) | -15.79 | -12.29 |
| No access control indicator (1 = no access; 0 = partial access control) | -4.07 | -1.47 |
| Depressed median indicator (1 = depressed median; 0 = barrier or no median) | 8.88 | 18.67 |
| Paved left-shoulder indicator (1 = paved shoulder; 0 = unpaved or no shoulder) | -10.98 | -25.23 |
| Paved right-shoulder indicator (1 = paved shoulder; 0 = unpaved or no shoulder) | 8.30 | 24.02 |

[a] Relative effects are computed for each indicator variable. Relative effects are computed as [exp(β) – 1].

The night-day ratio linear regression model was estimated and the model results are shown in Table 15. The signs of all of the parameter estimates from linear regression model are the same as those for the nighttime crash frequency model shown in Table 14. Interpretation of the model parameters is straight-forward. For example, the presence of lighting decreases the natural logarithm of the night-day crash ratio by 0.1277. Alternatively stated, the presence of lighting decreases the expected night-day crash ratio by 12.8 percent.

Using the data from the negative binomial regression models, equation (4) is -11.9, or an 11.9 percent reduction in the expected night-day crash ratio at intersections in Minnesota with lighting. This closely matches the results of the linear regression model and suggests that the parameter estimates obtained from the model estimation process are consistent with those obtained from the negative binomial regression modeling process.

**Table 15 Log-linear Night-Day Ratio Crash Estimation Results for Minnesota Intersections**

| Variable | Parameter Estimate | t-statistic | p-value |
|---|---|---|---|
| Constant | -10.7040 | -23.79 | <0.001 |
| Log major road average daily traffic | 0.6008 | 12.98 | <0.001 |
| Percent heavy vehicles on major road | -0.0303 | -3.68 | <0.001 |
| Log minor road average daily traffic | 0.1391 | 6.63 | <0.001 |
| Area type indicator (1 = urban/suburban; 0 = rural) | -0.6132 | -7.12 | <0.001 |
| Traffic control indicator (1 = signal; 0 = stop-control) | 1.1086 | 12.82 | <0.001 |
| Lighting indicator (1 = present; 0 = not present) | -0.1277 | -1.41 | 0.159 |
| Intersection type indicator (1 = skew; 0 = cross or tee) | 0.5781 | 6.47 | <0.001 |
| Speed indicator (1 = 50 mph or greater; 0 otherwise) | -0.1800 | -2.83 | 0.005 |
| No access control indicator (1 = no access; 0 = partial access control) | -0.0509 | -0.48 | 0.633 |
| Depressed median indicator (1 = depressed median; 0 = barrier or no median) | 0.3470 | 3.60 | <0.001 |
| Paved left-shoulder indicator (1 = paved shoulder; 0 = unpaved or no shoulder) | -0.5034 | -4.21 | <0.001 |
| Paved right-shoulder indicator (1 = paved shoulder; 0 = unpaved or no shoulder) | 0.4714 | 4.03 | <0.001 |
| Number of observations = 9,053<br>$R^2$ = 0.1324<br>Adjusted $R^2$ = 0.1312<br>Root MSE = 2.8814 | | | |

The third approach to evaluate the safety effects of roadway lighting at Minnesota intersections is to use the observed data and compute the night-day ratio. To compute the percent difference between the lighted and unlighted intersections, equation (1) was used. From all of the observed data, the night-day crash ratio at intersections with lighting was 0.2933 (6109 night crashes and 20,831 day crashes) while the night-day crash ratio at intersections without lighting was 0.4096 (3341 night crashes and 8156 day crashes). As such, the percent difference per equation (1) is -28.4 percent. Alternatively stated, the night-day crash ratio is 28.4 percent lower with fixed roadway lighting at intersections in Minnesota when compared to intersections without lighting. When comparing this measure to those obtained in the regression model estimations described previously, it is clear that using the night-day ratio as a measure of safety overestimates the effects of roadway lighting at intersections in Minnesota. One possible explanation for this overestimation is the lack of control given to the geometric features and traffic volumes present at the intersections.

Rather than show all of the negative binomial regression, log-linear regression, and descriptive statistics analysis results in this section, a summary of these results is provided in Table 16. All of the statistical modeling results are shown in Appendix A.

**Table 16 Summary of Minnesota Intersection Analysis Results**

| Intersection Type | NB Model | Descriptive Statistics (N/D) | NB Sample Size | N/D Log-linear Model | N/D Log-linear Sample Size |
|---|---|---|---|---|---|
| All intersections | -11.91% | -28.00% | 22,058 | -12.77% | 9,053 |
| All signalized | -5.19% | 5.04% | 3,227 | -40.58% | 2,834 |
| All unsignalized | -7.45% | -30.91% | 18,831 | -4.25% | 6,219 |
| Cross | -14.66% | -24.26% | 10,593 | -28.44% | 4,955 |
| Skew | -11.09% | -22.49% | 2,502 | 9.96% | 1,284 |
| Tee | -8.85% | -30.62% | 8,963 | -17.14% | 2,814 |
| All urban | -14.37% | -8.84% | 10,605 | -29.91% | 5,445 |
| Urban signalized | -6.51% | 13.46% | 2,875 | -39.69% | 2,521 |
| Urban unsignalized | -13.27% | -18.96% | 7,730 | -27.92% | 2,924 |
| Urban signalized cross | -26.46% | -7.90% | 2,158 | -107.70% | 1,900 |
| Urban signalized skew | 64.62% | 98.95% | 514 | 88.38% | 450 |
| Urban signalized tee | 117.81% | 162.93% | 203 | 150.57% | 171 |
| Urban unsignalized cross | 12.47% | 3.47% | 3,547 | -8.33% | 1,475 |
| Urban unsignalized skew | -1.65% | -2.96% | 663 | 40.68% | 293 |
| Urban unsignalized tee | -25.33% | -30.98% | 3,520 | -54.63% | 1,156 |
| All rural | -1.44% | -16.87% | 11,453 | 18.56% | 3,608 |
| Rural signalized | 0.33% | -8.69% | 352 | -38.23% | 313 |
| Rural unsignalized | -1.55% | -7.55% | 11,101 | 19.37% | 3,295 |
| Rural signalized cross | -2.58% | -7.99% | 248 | 6.64% | 223 |
| Rural signalized skew | -10.23% | -15.06% | 48 | -136.01% | 44 |
| Rural signalized tee | n/a | n/a | 0 | n/a | 0 |
| Rural unsignalized cross | -12.23% | -20.45% | 4,640 | 15.75% | 1,357 |
| Rural unsignalized skew | -19.31% | -18.71% | 1,277 | 20.52% | 497 |
| Rural unsignalized tee | 13.37% | 6.07% | 5,184 | 21.41% | 1,441 |

### *4.1.2 Minnesota Interchanges*

Per the methodological process described previously, both daytime and nighttime crash frequency models were estimated using negative binomial regression. Because some geometric design data were missing for some intersections, the number of observations included in the analysis was 2,021. The negative binomial regression model for the expected number of daytime crashes on Minnesota interchanges is shown in Table 17. Those explanatory variables positively correlated with the expected number of daytime crashes are: total entering vehicles, urban/suburban area type, diamond interchange form, lighting presence indicator, indicators for full- and partial-access control on the major road, indicator for median barrier presence on the major road, concrete pavement surface type indicator, and the indicator for major roadways with five or more through lanes (in both directions). The explanatory variables that are negatively correlated with the expected daytime crash frequency are: percent heavy vehicle on the major road, posted speed limit on the major road, and lane width indicator. The relative effects for each indicator variable in the daytime and nighttime models are shown in Table 18. Assuming all other explanatory variables are held constant, the relative effects of an urban/suburban interchange are a 44.84 percent increase in the expected daytime crash frequency when compared to rural interchange locations in Minnesota. Diamond interchange forms have a higher daytime expected crash frequency than non-diamond interchange forms by 30.47 percent. Interchanges with access control on the major road have a higher expected daytime crash frequency than those with no access control. Interchange locations with a median barrier have a 22.51 percent higher expected daytime crash frequency than interchange locations without longitudinal median barrier. Interchange locations with five or more lanes have a 27.51 percent higher expected daytime crash frequency than interchange locations with fewer travel lanes.

The percent heavy vehicles, posted speed limit, and wide travel lanes on the major roadway all decrease the expected daytime crash frequency at Minnesota interchange locations, holding all other explanatory variables constant. The relative effects of lane widths 13-feet or wider is -20.63 percent when compared to narrower lanes. This suggests that the expected daytime crash frequency is higher for narrower lanes at Minnesota interchange locations.

The overdispersion parameter, $\alpha$, was statistically different than zero. The low value of the pseudo-$R^2$ statistic (0.0994) in the daytime crash frequency model indicates are relatively poor fit for the daytime crash frequency model.

## Table 17 Total Daytime Crash Frequency Estimation Results for Interchanges

| Variable | Parameter Estimate | Standard Error | z-statistic | p-value |
|---|---|---|---|---|
| Constant | -0.145 | 0.274 | -0.528 | 0.598 |
| Log total entering vehicles (vehicles/day) | 0.219 | 0.019 | 11.735 | <0.001 |
| Percent heavy vehicles on major road | -0.050 | 0.005 | -9.246 | <0.001 |
| Area type indicator (1 = urban/suburban; 0 = rural) | 0.368 | 0.060 | 6.094 | <0.001 |
| Interchange form indicator (1 = diamond; 0 = non-diamond) | 0.266 | 0.060 | 4.436 | <0.001 |
| Lighting indicator (1 = present; 0 = not present) | 0.217 | 0.067 | 3.219 | 0.001 |
| Posted speed limit on major road (mph) | -0.009 | 0.003 | -3.299 | 0.001 |
| Indicator for full-access control on major road (1 = full-access control; 0 = otherwise) | 0.638 | 0.064 | 9.906 | <0.001 |
| Indicator for partial-access control on major road (1 = partial access control; 0 = otherwise) | 0.204 | 0.084 | 2.417 | 0.016 |
| Indicator for median barrier presence on major road (1 = median barrier present; 0 = no barrier present) | 0.203 | 0.045 | 4.474 | <0.001 |
| Pavement surface indicator (1 = concrete pavement; 0 = asphalt pavement) | 0.051 | 0.040 | 1.281 | 0.200 |
| Lane width indicator for major road (1 = lane width $\geq$ 13-feet; 0 = otherwise | -0.231 | 0.063 | -3.652 | <0.001 |
| Number of lanes on major road indicator 1 = Five or more lanes; 0 = otherwise) | 0.243 | 0.047 | 5.142 | <0.001 |
| Dispersion parameter ($\alpha$) | 0.554 | 0.021 | 25.851 | <0.001 |
| Number of observations = 2,021<br>Log-likelihood (constant only) = -7134.6036<br>Log-likelihood (full model) = -6425.7234<br>Pseudo $R^2$ = 0.0994 | | | | |

**Table 18 Relative Effects for Indicator Variables in Interchange Crash Frequency Models**

| Variable | Daytime Relative Effects[a] | Nighttime Relative Effects[a] |
|---|---|---|
| Area type indicator (1 = urban/suburban; 0 = rural) | 44.48 | 27.51 |
| Interchange form indicator (1 = diamond; 0 = non-diamond) | 30.47 | 14.57 |
| Lighting indicator (1 = present; 0 = not present) | 31.00 | 14.57 |
| Indicator for full-access control on major road (1 = full-access control; 0 = otherwise) | 89.27 | 80.22 |
| Indicator for partial-access control on major road (1 = partial access control; 0 = otherwise) | 22.63 | 11.18 |
| Indicator for median barrier presence on major road (1 = median barrier present; 0 = no barrier present) | 22.51 | 18.77 |
| Pavement surface indicator (1 = concrete pavement; 0 = asphalt pavement) | 5.23 | -3.54 |
| Lane width indicator for major road (1 = lane width $\geq$ 13-feet; 0 = otherwise | -20.63 | -6.20 |
| Number of lanes on major road indicator 1 = Five or more lanes; 0 = otherwise) | 27.51 | 33.38 |

[a] Relative effects are computed for each indicator variable. Relative effects are computed as [exp(β) – 1].

The nighttime crash frequency model estimation results are shown in Table 19. The relative effects for each indicator variable are shown in Table 18. When comparing the relative effects of the daytime crash frequency model to those from the nighttime frequency model, the signs are all the same except for the pavement surface indicator. In the model estimation of nighttime crashes, the overdispersion parameter, $\alpha$, was again statistically different than zero, indicating that the variance exceeds the mean of the crash frequency distribution. The psedo-$R^2$ was low (0.0838) indicating a relatively poor model fit.

Using the parameter estimates from the negative binomial regression models, a 7.78 percent reduction in night-to-day crash ratio is expected at interchanges in Minnesota with lighting.

**Table 19 Total Nighttime Crash Frequency Estimation Results for Interchanges**

| Variable | Parameter Estimate | Standard Error | z-statistic | p-value |
|---|---|---|---|---|
| Constant | -0.685 | 0.048 | -2.29 | 0.022 |
| Log total entering vehicles (vehicles/day) | 0.176 | 0.020 | 8.96 | <0.001 |
| Percent heavy vehicles on major road | -0.034 | 0.006 | -6.12 | <0.001 |
| Area type indicator (1 = urban/suburban; 0 = rural) | 0.243 | 0.065 | 3.77 | <0.001 |
| Interchange form indicator (1 = diamond; 0 = non-diamond) | 0.136 | 0.062 | 2.20 | 0.028 |
| Lighting indicator (1 = present; 0 = not present) | 0.136 | 0.072 | 1.90 | 0.058 |
| Posted speed limit on major road (mph) | -0.004 | 0.003 | -1.22 | 0.222 |
| Indicator for full-access control on major road (1 = full-access control; 0 = otherwise) | 0.589 | 0.069 | 8.56 | <0.001 |
| Indicator for partial-access control on major road (1 = partial access control; 0 = otherwise) | 0.106 | 0.091 | 1.16 | 0.247 |
| Indicator for median barrier presence on major road (1 = median barrier present; 0 = no barrier present) | 0.172 | 0.047 | 3.68 | <0.001 |
| Pavement surface indicator (1 = concrete pavement; 0 = asphalt pavement) | -0.036 | 0.041 | -0.87 | 0.385 |
| Lane width indicator for major road (1 = lane width ≥ 13-feet; 0 = otherwise | -0.064 | 0.066 | -0.97 | 0.332 |
| Number of lanes on major road indicator 1 = Five or more lanes; 0 = otherwise) | 0.288 | 0.049 | 5.88 | <0.001 |
| Dispersion parameter ($\alpha$) | 0.504 | 0.024 | 21.00 | <0.001 |
| Number of observations = 2,021<br>Log-likelihood (constant only) = -5559.251<br>Log-likelihood (full model) = -5093.5436<br>Pseudo $R^2$ = 0.0838 | | | | |

In addition to the lighting presence models shown above, lighting type models were also run using the Minnesota interchange data. Of particular interest in these models is the influence of partial and full lighting on daytime and nighttime crash frequency. The results of these models are shown in Tables 20 and 21. Based on the daytime crash frequency model, the indicator variables for full and partial interchange lighting are statistically significant and the relative effects are 31.9 and 20.4 percent, respectively. This indicates that the expected daytime crash frequency at Minnesota interchanges is higher with full and partial lighting when compared to no lighting. The nighttime crash frequency model suggests the same. The relative effects from the nighttime crash frequency model for full and partial interchange lighting are 18.5 and 12.9 percent, respectively. Using the data from the negative binomial regression models, equation (4) is -10.15 and -6.29 percent, or a 10.15 and 6.29 percent reduction, respectively, in the expected night-day crash ratio at interchanges in Minnesota with full and partial lighting.

### Table 20 Total Daytime Crash Frequency Estimation Results for Interchange Lighting Type

| Variable | Parameter Estimate | Standard Error | z-statistic | p-value |
|---|---|---|---|---|
| Constant | -0.069 | 0.274 | -0.25 | 0.803 |
| Log total entering vehicles (vehicles/day) | 0.290 | 0.019 | 11.08 | <0.001 |
| Percent heavy vehicles on major road | -0.051 | 0.005 | -9.39 | <0.001 |
| Area type indicator<br>(1 = urban/suburban; 0 = rural) | 0.334 | 0.062 | 5.43 | <0.001 |
| Interchange form indicator<br>(1 = diamond; 0 = non-diamond) | 0.255 | 0.060 | 4.25 | <0.001 |
| Full interchange lighting indicator<br>(1 = present; 0 = otherwise) | 0.277 | 0.073 | 3.78 | <0.001 |
| Partial interchange lighting indicator<br>(1 = present; 0 = otherwise) | 0.186 | 0.069 | 2.69 | 0.007 |
| Continuous interchange lighting indicator<br>(1 = present; 0 = otherwise) | 0.435 | 0.092 | 4.73 | <0.001 |
| Posted speed limit on major road (mph) | -0.009 | 0.003 | -3.19 | 0.001 |
| Indicator for full-access control on major road<br>(1 = full-access control; 0 = otherwise) | 0.664 | 0.065 | 10.26 | <0.001 |
| Indicator for partial-access control on major road<br>(1 = partial access control; 0 = otherwise) | 0.229 | 0.084 | 2.72 | 0.007 |
| Indicator for median barrier presence on major road<br>(1 = median barrier present; 0 = no barrier present) | 0.172 | 0.046 | 3.74 | <0.001 |
| Pavement surface indicator<br>(1 = concrete pavement; 0 = asphalt pavement) | 0.045 | 0.040 | 1.12 | 0.262 |
| Lane width indicator for major road<br>(1 = lane width ≥ 13-feet; 0 = otherwise | -0.231 | 0.063 | -3.65 | <0.001 |
| Number of lanes on major road indicator<br>1 = Five or more lanes; 0 = otherwise) | 0.235 | 0.047 | 4.99 | <0.001 |
| Dispersion parameter ($\alpha$) | 0.550 | 0.021 | 25.80 | <0.001 |
| Number of observations = 2,021<br>Log-likelihood (constant only) = -7134.6036<br>Log-likelihood (full model) = -6418.4594<br>Pseudo $R^2$ = 0.1004 | | | | |

### Table 21 Total Nighttime Crash Frequency Estimation Results for Interchange Lighting Type

| Variable | Parameter Estimate | Standard Error | z-statistic | p-value |
|---|---|---|---|---|
| Constant | -0.566 | 0.281 | -2.01 | 0.044 |
| Log total entering vehicles (vehicles/day) | 0.165 | 0.020 | 8.34 | <0.001 |
| Percent heavy vehicles on major road | -0.034 | 0.006 | -6.12 | <0.001 |
| Area type indicator (1 = urban/suburban; 0 = rural) | 0.222 | 0.065 | 3.39 | 0.001 |
| Interchange form indicator (1 = diamond; 0 = non-diamond) | 0.115 | 0.062 | 1.86 | 0.062 |
| Full interchange lighting indicator (1 = present; 0 = otherwise) | 0.170 | 0.078 | 2.19 | 0.029 |
| Partial interchange lighting indicator (1 = present; 0 = otherwise) | 0.121 | 0.073 | 1.65 | 0.100 |
| Continuous interchange lighting indicator (1 = present; 0 = otherwise) | 0.378 | 0.096 | 3.93 | <0.001 |
| Posted speed limit on major road (mph) | -0.003 | 0.003 | -1.12 | 0.261 |
| Indicator for full-access control on major road (1 = full-access control; 0 = otherwise) | 0.614 | 0.069 | 8.88 | <0.001 |
| Indicator for partial-access control on major road (1 = partial access control; 0 = otherwise) | 0.132 | 0.091 | 1.44 | 0.149 |
| Indicator for median barrier presence on major road (1 = median barrier present; 0 = no barrier present) | 0.136 | 0.048 | 2.86 | 0.004 |
| Pavement surface indicator (1 = concrete pavement; 0 = asphalt pavement) | -0.045 | 0.042 | -1.09 | 0.278 |
| Lane width indicator for major road (1 = lane width ≥ 13-feet; 0 = otherwise | -0.064 | 0.066 | -0.957 | 0.339 |
| Number of lanes on major road indicator 1 = Five or more lanes; 0 = otherwise) | 0.278 | 0.049 | 5.69 | <0.001 |
| Dispersion parameter ($\alpha$) | 0.499 | 0.024 | 20.78 | <0.001 |
| Number of observations = 2,021<br>Log-likelihood (constant only) = -5559.251<br>Log-likelihood (full model) = -5086.2512<br>Pseudo $R^2$ = 0.0851 | | | | |

The night-day ratio linear regression models for lighting presence and lighting type were estimated and the model results are shown in Tables 22 and 23. From the lighting presence model, the lighting presence parameter estimate is -0.006 which indicates that the presence of fixed roadway lighting decreases the natural logarithm of the night-day crash ratio by -0.6 percent. From the lighting type log-linear model results shown in Table 21, the full and partial interchange lighting presence dummies are -0.033 and 0.010, respectively. This suggests that full interchange lighting decreases the natural logarithm of the night-day crash ratio by 3.3 percent. The presence of partial interchange lighting increases the natural logarithm of the night-day crash ratio by 1.0 percent when compared to no lighting. In both log-linear models, the lighting indicator variables are not statistically significant. Data attrition appears to be significant as the number of observations is 1,679 – nearly 17 percent of the available data were not used to estimate the log-linear model.

## Table 22 Log-linear Night-Day Ratio Crash Estimation Results for Minnesota Interchanges (Lighting Presence)

| Variable | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| Constant | 0.029 | 0.239 | 0.123 | 0.902 |
| Log total entering vehicles (vehicles/day) | -0.076 | 0.017 | -4.366 | <0.001 |
| Percent heavy vehicles on major road | 0.020 | 0.005 | 4.328 | <0.001 |
| Area type indicator<br>(1 = urban/suburban; 0 = rural) | -0.209 | 0.054 | -3.865 | <0.001 |
| Interchange form indicator<br>(1 = diamond; 0 = non-diamond) | -0.191 | 0.053 | -3.599 | <0.001 |
| Lighting indicator<br>(1 = present; 0 = not present) | -0.006 | 0.060 | -0.106 | 0.915 |
| Posted speed limit on major road (mph) | 0.004 | 0.002 | 1.541 | 0.123 |
| Indicator for full-access control on major road<br>(1 = full-access control; 0 = otherwise) | -0.076 | 0.059 | -1.301 | 0.193 |
| Indicator for partial-access control on major road<br>(1 = partial access control; 0 = otherwise) | -0.074 | 0.077 | -0.961 | 0.337 |
| Indicator for median barrier presence on major road<br>(1 = median barrier present; 0 = no barrier present) | 0.004 | 0.042 | 0.093 | 0.926 |
| Pavement surface indicator<br>(1 = concrete pavement; 0 = asphalt pavement) | -0.082 | 0.036 | -2.288 | 0.022 |
| Lane width indicator for major road<br>(1 = lane width $\geq$ 13-feet; 0 = otherwise | 0.121 | 0.056 | 2.179 | 0.029 |
| Number of lanes on major road indicator<br>1 = Five or more lanes; 0 = otherwise) | 0.002 | 0.043 | 0.047 | 0.963 |
| Number of observations = 1,679<br>$R^2$ = 0. 1496<br>Adjusted $R^2$ = 0.1434<br>Root MSE = 0.6874 | | | | |

### Table 23 Log-linear Night-Day Ratio Crash Estimation Results for Minnesota Interchanges (Lighting Type)

| Variable | Parameter Estimate | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| Constant | 0.036 | 0.2239 | 0.152 | 0.879 |
| Log total entering vehicles (vehicles/day) | -0.076 | 0.017 | -4.375 | <0.001 |
| Percent heavy vehicles on major road | 0.021 | 0.005 | 4.467 | <0.001 |
| Area type indicator (1 = urban/suburban; 0 = rural) | -0.200 | 0.055 | -3.629 | <0.001 |
| Interchange form indicator (1 = diamond; 0 = non-diamond) | -0.197 | 0.053 | -3.706 | <0.001 |
| Full interchange lighting indicator (1 = present; 0 = otherwise) | -0.033 | 0.065 | -0.503 | 0.615 |
| Partial interchange lighting indicator (1 = present; 0 = otherwise) | 0.010 | 0.062 | 0.169 | 0.866 |
| Continuous interchange lighting indicator (1 = present; 0 = otherwise) | 0.038 | 0.083 | 0.456 | 0.648 |
| Posted speed limit on major road (mph) | 0.004 | 0.002 | 1.491 | 0.136 |
| Indicator for full-access control on major road (1 = full-access control; 0 = otherwise) | -0.078 | 0.059 | -1.327 | 0.185 |
| Indicator for partial-access control on major road (1 = partial access control; 0 = otherwise) | -0.074 | 0.077 | -0.962 | 0.336 |
| Indicator for median barrier presence on major road (1 = median barrier present; 0 = no barrier present) | 0.002 | 0.043 | 0.035 | 0.972 |
| Pavement surface indicator (1 = concrete pavement; 0 = asphalt pavement) | -0.087 | 0.036 | -2.405 | 0.016 |
| Lane width indicator for major road (1 = lane width ≥ 13-feet; 0 = otherwise) | 0.125 | 0.056 | 2.246 | 0.025 |
| Number of lanes on major road indicator 1 = Five or more lanes; 0 = otherwise) | -0.001 | 0.043 | -0.018 | 0.985 |
| Number of observations = 1,679<br>$R^2$ = 0.1505<br>Adjusted $R^2$ = 0.1434<br>Root MSE = 0.68746 | | | | |

The third approach to evaluate the safety effects of roadway lighting at Minnesota interchanges is to use the observed data and compute the night-day ratio. To compute the percent difference between the lighted and unlighted intersections, equation (1) was used. From all of the observed data, the night-day crash ratio at interchanges with lighting was 0.4242 (10,304 night crashes and 24,293 day crashes) while the night-day crash ratio at interchanges without lighting was 0.6488 (763 night crashes and 1,176 day crashes). As such the percent difference per equation (1) is -34.6 percent. Alternatively stated, the night-day crash ratio is 34.6 percent lower with fixed roadway lighting at interchanges in Minnesota when compared to interchanges without lighting. When comparing this measure to those obtained in the regression model estimations described previously, it is clear that using the night-day ratio as a measure of safety overestimates the effects of roadway lighting at interchanges in Minnesota. One possible explanation for this overestimation is the lack of control given to the geometric features present at the intersections.

Using equation (4), the percent difference in the night-day crash ratio with and without full interchange lighting is -7.1 percent. The percent difference in the night-day crash ratio with and without partial interchange lighting is 0.8 percent.

Rather than show all of the negative binomial, log-linear regression, and descriptive statistics analysis results in this section, a summary of these results is provided in Table 24. All of the statistical modeling results is shown in Appendix C.

**Table 24 Summary of Minnesota Interchange Analysis Results**

| Facility Type | Negative Binomial Model | | N/D Ratio Linear Model | | Descriptive Statistics |
|---|---|---|---|---|---|
| | Model | Sample Size | Model | Sample Size | |
| All Interchanges | -7.77% | 2021 | -0.64% | 1679 | -34.59% |
| Diamond | -12.80% | 1615 | -3.25% | 1315 | -38.80% |
| Non-diamond | 19.60% | 406 | 10.86% | 364 | 11.90% |
| Rural Interchanges | -1.79% | 776 | 12.24% | 540 | -26.25% |
| Urban Interchanges | 7.89% | 1245 | -23.07% | 1139 | 5.39% |
| Rural - Diamond | -8.81% | 644 | 8.18% | 441 | -33.19% |
| Rural - Nondiamond | 36.83% | 132 | 30.94% | 99 | 13.52% |
| Urban - Diamond | 11.12% | 971 | -22.51% | 874 | 4.34% |
| Urban - Nondiamond | -29.05% | 274 | -37.23% | 265 | -3.93% |

From the data summary shown in Table 24, the negative binomial regression model and descriptive statistics produce lighting safety effect estimates that have the same sign but are different in magnitude. This was expected as the negative binomial regression models control for many geometric variables and traffic volumes while the descriptive statistics do not control for any explanatory variables. It can generally be concluded that interchanges with fixed roadway lighting have a lower night-day crash ratio than interchanges without fixed roadway lighting. Likewise, the night-day crash ratio for diamond interchange is lower with fixed roadway lighting than without lighting.

### *4.1.3 Freeway Segments*

#### 4.1.3.1 Washington

For the Washington freeway segments, negative binomial regression models were estimated for both nighttime and daytime crashes. The results of these models are shown in Tables 25 and 26 below. The continuous lighting parameter estimate in the nighttime crash frequency model is 0.221 while the nighttime parameter estimate is 0.179. Using equation (4) above, the percent difference in the night-day crash ratio for segments with and without lighting is 4.29 percent. This indicates that freeway segments in Washington have a higher mean crash frequency with lighting than without lighting. Using the standard error of the nighttime and daytime crash frequency parameter estimates suggests that the confidence interval around the mean value ranges from -1.69 to 10.63 percent.

Using equation (1) above, the percent difference in the night-day crash ratios along roadway segments with and without roadway was computed. The night-day crash at segments with lighting was 0.331 (5080 night crashes and 16,333 day crashes) while the night-day crash ratio at segments without lighting was 0.391 (11,528 day crashes and

29,469 night crashes). As such, the percent difference in the night-day crash ratio was -15.35 percent. This indicates that using only the descriptive statistics, without controlling for traffic volume and geometric design variables, overestimates the safety effects of fixed roadway lighting on freeway segments in Washington.

**Table 25 Daytime Crash Frequency Model for Washington Freeway Segments**

| Variable | Coefficient | Standard Error | t-statistic |
|---|---|---|---|
| Constant | -10.847 | 0.403 | -26.944 |
| Northwest region indicator* (1 if segment is located in the northwest region; 0 otherwise) | -0.245 | 0.148 | -1.650 |
| Olympic region indicator (1 if segment is located in the olympic region; 0 otherwise) | -0.487 | 0.147 | -3.304 |
| Southwest region indicator (1 if segment is located in the southwest region; 0 otherwise) | -0.664 | 0.142 | -4.675 |
| Eastern region indicator (1 if segment is located in the eastern region; 0 otherwise) | -0.431 | 0.145 | -2.981 |
| South central region indicator (1 if segment is located in the south central region; 0 otherwise) | -0.252 | 0.141 | -1.783 |
| Logarithm of segment length (miles) | 0.890 | 0.013 | 69.719 |
| Direction indicator (1 if increasing milepost of travel; 0 otherwise) | 0.133 | 0.045 | 2.929 |
| Rural segment indicator (1 if segment was in rural location; 0 otherwise) | -0.170 | 0.052 | -3.247 |
| Point lighting indicator (1 if segment had point lighting; 0 otherwise) | 0.108 | 0.055 | 1.970 |
| Continuous lighting indicator ( 1 if segment had continuous lighting; 0 otherwise) | 0.179 | 0.028 | 6.411 |
| Number of interchanges in segment | -0.094 | 0.019 | -4.828 |
| Number of overpasses in segment | 0.056 | 0.011 | 5.135 |
| Logarithm of average annual daily traffic | 1.310 | 0.041 | 31.604 |
| Number of vertical curves in segment | -0.003 | 0.004 | -0.780 |
| Number of horizontal curves in segment | 0.023 | 0.004 | 5.098 |
| Number of lanes in segment | -0.013 | 0.021 | -0.592 |
| Left shoulder width in feet | -0.043 | 0.006 | -7.563 |
| Right shoulder width in feet | -0.030 | 0.005 | -6.392 |
| Overdispersion parameter | 0.450 | 0.015 | 30.508 |
| Log-likelihood at convergence | -12,537.76 | | |
| Log-likelihood at zero | -17,806.96 | | |
| Number of observations | 5,475 | | |
| Adjusted $\rho^2$ | 0.29 | | |
| * North central region is the base region, and set to zero. Region effects in the table should be interpreted using the north central region as a baseline. Since all region effects have a negative sign, north central region segments are expected to have higher crash counts. | | | |

## Table 26 Nighttime Crash Frequency Model for Washington Freeway Segments

| Variable | Coefficient | Standard Error | t-statistic |
|---|---|---|---|
| Constant | -11.452 | 0.433 | -26.450 |
| Northwest region indicator* (1 if segment is located in the northwest region; 0 otherwise) | -0.143 | 0.148 | -0.963 |
| Olympic region indicator (1 if segment is located in the Olympic region; 0 otherwise) | -0.379 | 0.147 | -2.572 |
| Southwest region indicator (1 if segment is located in the southwest region; 0 otherwise) | -0.317 | 0.141 | -2.248 |
| Eastern region indicator (1 if segment is located in the eastern region; 0 otherwise) | -0.170 | 0.143 | -1.189 |
| South central region indicator (1 if segment is located in the south central region; 0 otherwise) | -0.040 | 0.139 | -0.289 |
| Logarithm of segment length (miles) | 0.885 | 0.014 | 62.240 |
| Direction indicator (1 if increasing milepost of travel; 0 otherwise) | 0.052 | 0.048 | 1.082 |
| Rural segment indicator (1 if segment was in rural location; 0 otherwise) | 0.188 | 0.0520 | 3.616 |
| Point lighting indicator (1 if segment had point lighting; 0 otherwise) | 0.170 | 0.076 | 2.229 |
| Continuous lighting indicator ( 1 if segment had continuous lighting; 0 otherwise) | 0.221 | 0.031 | 7.149 |
| Number of interchanges in segment | -0.048 | 0.018 | -2.654 |
| Number of overpasses in segment | 0.025 | 0.010 | 2.417 |
| Logarithm of average annual daily traffic | 1.205 | 0.045 | 26.830 |
| Number of vertical curves in segment | 0.003 | 0.003 | 0.756 |
| Number of horizontal curves in segment | 0.016 | 0.004 | 4.058 |
| Number of lanes in segment | 0.111 | 0.023 | 4.844 |
| Left shoulder width in feet | -0.038 | 0.006 | -6.380 |
| Right shoulder width in feet | -0.023 | 0.005 | -4.416 |
| Overdispersion parameter | 0.266 | 0.015 | 17.346 |
| Log-likelihood at convergence | -8,349.58 | | |
| Log-likelihood at zero | -8,968.72 | | |
| Number of observations | 5,475 | | |
| Adjusted $\rho^2$ | 0.067 | | |

* North central region is the base region, and set to zero. Region effects in the table should be interpreted using the north central region as a baseline. Since all region effects have a negative sign, north central region segments are expected to have higher crash counts.

The findings from the negative binomial models for daytime and nighttime crash occurrence indicate that lighting variables such as the presence of point lighting and continuous lighting are associated with increases in nighttime crashes. When controlling for geometric and traffic volume factors, as well as segment length, lighting presence appears to indicate a greater than expected number of crashes compared to no lighting. In particular, the presence of continuous lighting is associated with a stronger positive effect compared to point lighting. This might suggest that the lighting effect occurs in two possible ways – where non-interchange/non-decision points are lighted, drivers are afforded greater visibility resulting in behavior conducive to increased crash occurrence. For example, more frequent lane changing can be expected to occur in lighted segments. At decision points, especially at interchanges, merge-weave effects contribute to increased crash likelihoods. While this counter-productive finding may argue for removal of roadway lighting, one should view the finding in a broader context – the tradeoff between decision related conflict points and resulting severities from absence of lighting versus energy gains from removal of lighting.

In terms of other significant findings from Tables 23 and 24, geometric effects with the exception of vertical curves in the roadway segment were found to be significant. The greater the number of interchanges in a segment, the fewer daytime and nighttime crashes were expected to be. This can be attributed to the fact that increased interchange density creates the effect of cautious driving to the extent that it offsets the merge-weave effect that occurs in an isolated manner at interchange areas. On the contrary, as the number of overpasses increase, crash frequency is expected to increase both during the day and night. This might be attributed to the potential visibility and roadside encroachment issues arising from increasing overpass density. Shoulder widths are expected to decrease crash occurrence. With wider roadway lane cross sections, nighttime crashes are expected to increase, while daytime crashes are expected to remain unchanged from a significance standpoint. The magnitude of the variable is marginally negative for daytime effects, and marginally positive for nighttime effects. Horizontal curve frequency in a segment is expected to increase crash occurrence during both daytime and nighttime periods. Vertical curve frequency is expected to have an insignificant impact. Furthermore, the magnitude of vertical curve frequency is less than horizontal curve frequency for both daytime and nighttime periods.

Urban Interstate segments were expected to increase crash occurrence during daytime periods and decrease frequency during nighttime periods, compared to rural locations. The overdispersion parameter is of lesser magnitude for nighttime crash occurrence, while remaining significant in both periods. As expected, traffic volume and segment length (both in logarithm form) contribute the greatest to the variance explained by the models and increase crash frequency during both daytime and nighttime periods.

#### 4.1.3.2 Supplemental Washington Freeway Segments

Several variations of the models shown in Tables 25 and 26 were specified to determine if excluding point lighting only, excluding interchange and overpass locations, or stratifying the sample into urban and rural segments produced different results from the full Washington Interstate segment models described in the previous section. For brevity, the statistical output is not provided in this section of the report. Only the overall assessment of the safety effects of lighting are provided in summary tables below.

As Tables 27a, 27b and 27c show, a total of 4,495 observations were used in the estimation of the combined urban-rural models to estimate the safety effects of continuous roadway lighting, excluding point lighting locations. Continuous lighting was differentiated in terms of whether the location was on the median side only, on the right side only, or on both sides of the freeway. The baseline lighting scenario included segments without any lighting installation. Table 27a shows the mean parameter estimates from the model estimations, while tables 27b and 27c show the estimated changes due to lighting type with associated confidence intervals of one standard error.

Combined Urban and Rural Segments Excluding Point Lighting (with Interchange and Overpasses)

When interchanges and overpasses are included in the assessment, all 4,495 observations remained in the analysis. It is estimated that the presence of median-only continuous lighting is associated with a 10.36 percent reduction in night-day ratios of crash frequencies with respect to the no-lighting baseline. Comparatively, the observed change in night-day ratios was significantly higher, a decrease of 32.58 percent. A right-side only lighting installation was estimated to be associated with a marginal 0.32 percent increase in night-day ratios, while the observed change was a decrease of 40.15 percent. Lighting installations on both sides of a freeway are estimated to be associated with a 15.07 percent decrease in night-day ratios while the observed change was a decrease of 56.82 percent.

Combined Urban and Rural Segments Excluding Point Lighting, Interchanges and Overpasses

When interchanges and overpasses are excluded from the analysis, 495 observations remained in the data analysis file. This indicates that eliminating interchange and overpass locations from the freeway segment database resulted in the exclusion of nearly 90 percent of the sample. As such, continuous freeway lighting is nearly always present in locations that include interchange and overpass locations. The presence of median-only continuous lighting is associated with a 9.69 percent reduction in night-day ratios of crash frequencies with respect to the no-lighting baseline. Comparatively, the observed change in night-day ratios for this scenario was an increase of 17.74 percent. A right-side only lighting installation was associated with a 9.95 percent decrease in night-day ratios, while the observed change was a decrease of 45.16 percent. Lighting installations on both sides of the freeway were associated with a 40.57 percent increase in night-day ratios while the observed change was a decrease of 29.03 percent.

**Table 27a Comparisons of Predicted versus Observed Change in Night-Day Ratios for all Interstate Segments for Median-Side Only, Right-Side Only, and Both-Sides Continuous Lighting**

| Overall Model Summary | | | | |
|---|---|---|---|---|
| Lighting Location | With interchanges and overpasses | | Without interchanges and overpasses | |
| | 4,495 observations | | 495 observations | |
| | Observed Change[1] | Predicted Change[2] | Observed Change[1] | Predicted Change[2] |
| Median only | -32.58% | -10.36% | 17.74% | -9.69% |
| Right only | -40.15% | 0.32% | -45.16% | -9.95% |
| Both | -56.82% | -15.07% | -29.03% | 40.57% |

[1] Values computed based on equation (1)
[2] Values computed based on equation (4)

**Table 27b Comparisons of Predicted versus Observed Change in Night-Day Ratios for all Interstate Segments with Interchanges and Overpasses for Median-side only, Right-side only, and Both-sides continuous lighting**

| Continuous Lighting type (count, %) | Model | | | Descriptive data: change in night/day ratio |
|---|---|---|---|---|
| | Change in night/day ratio with lighting (based on ±1 standard error) | Change in day crashes with lighting (±1 standard error) | Change in night crashes with lighting (±1 standard error) | |
| Median Only (n=1030, 22.91%) | -10.36% (-1.21% to -16.97%) | +16.05% (+11.33% to +20.78%) | +5.11% (+0.07% to +10.16%) | -32.58% |
| Right Only (n=630, 14.02%) | +0.32% (-15.89% to 18.89%) | -33.10% (-39.06% to -27.15%) | -32.79% (-39.36% to -26.21%) | -40.15% |
| Both (n=55, 1.22%) | -15.07% (-34.69% to 15.03%) | +22.26% (+5.63% to +38.88%) | +5.92% (-11.96% to +23.81%) | -56.82% |

**Table 27c Comparisons of Predicted versus Observed Change in Night-Day Ratios for all Interstate Segments without Interchanges and Overpasses for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| Continuous Lighting type (count, %) | Model | | | Descriptive data: change in night/day ratio |
|---|---|---|---|---|
| | Change in night/day ratio with lighting (based on ±1 standard error) | Change in day crashes with lighting (±1 standard error) | Change in night crashes with lighting (±1 standard error) | |
| Median Only (n=75, 15.15%) | -9.69% (-20.15% to 11.96%) | +85.41% (+71.14% to +99.68%) | +75.22% (+57.64% to +92.80%) | 17.74% |
| Right Only (n=145, 29.29%) | -9.95% (-31.68% to 19.36%) | +8.50% (-4.66% to +21.66%) | -1.98% (-19.56% to +15.61%) | -45.16% |
| Both (n=15, 3.03%) | +40.57% (-11.22% to 78.07%) | +32.27% (+6.03% to +58.52%) | +66.33% (+36.05% to +96.60%) | -29.03% |

*Urban Segments*

As tables 28a, 28b and 28c show, a total of 3,720 observations were used in the estimation of urban-only models with interchange and overpass locations present. When excluding interchange and overpass locations from the analysis, 405 observations were included in the safety assessment. Table 28a shows the mean parameter effects, while Tables 28b and 28c show the estimated day, night, and nigh-day ratio relative effects of continuous roadway lighting. Confidence intervals, computed using the standard error of the parameter estimate, are also shown.

Urban Segments Excluding Point Lighting (with Interchanges and Overpasses)

When interchanges and overpasses are included in the assessment, all 3,720 observations remained in the analysis. It is estimated that the presence of median-only continuous lighting is associated with a 5.45 percent reduction in night-day ratios of crash frequencies when compared to the no-lighting baseline. Comparatively, the observed change in night-day ratios was a marginal increase of 0.99 percent. A right-side only lighting installation was estimated to be associated with a 4.47 percent increase in night-day ratios, while the observed change was a decrease of 28.60 percent. Lighting installations on both sides were estimated to be associated with an 8.57 percent decrease in night-day ratios while the observed change was a decrease of 7.50 percent.

Urban Segments Excluding Point Lighting, Interchanges, and Overpasses

When interchanges and overpasses are excluded from the assessment, 405 observations remained in the analysis data file. It is estimated that the presence of median-only continuous lighting is associated with a 5.87 percent reduction in night-day ratios of crash frequencies when compared to the no-lighting baseline. Comparatively, the observed change in the night-day ratio was a decrease of 6.12 percent. A right-side only lighting installation was associated with a 1.92 percent increase in the night-day ratio, while the observed change was a decrease of 2.04 percent. Lighting installations on both sides were estimated to be associated with a 40.18 percent increase in night-day ratios while the observed change was a decrease of 10.20 percent.

**Table 28a Comparisons of Predicted versus Observed Change in Night-Day Ratios for Urban Interstate Segments for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| Urban Model Summary | | | | |
|---|---|---|---|---|
| Lighting Location | With interchanges and overpasses | | Without interchanging and overpasses | |
| | 3,675 observations | | 405 observations | |
| | Observed Change[1] | Predicted Change[2] | Observed Change[1] | Predicted Change[2] |
| Median only | 0.99% | -5.10 | -6.12% | -5.87% |
| Right only | -28.60% | 4.47% | -2.04% | 1.92% |
| Both | -7.50% | -8.57% | -10.20% | 40.18% |

[1] Values computed based on equation (1)
[2] Values computed based on equation (4)

**Table 28b Comparisons of Predicted versus Observed Change in Night-day Ratios for Urban Interstate Segments <u>with Interchanges and Overpasses</u> for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| **Continuous Lighting type (count, %)** | **Model** | | | **Descriptive data: change in night/day ratio** |
|---|---|---|---|---|
| | **Change in night/day ratio with lighting (based on ±1 standard error)** | **Change in day crashes with lighting (±1 standard error)** | **Change in night crashes with lighting (±1 standard error)** | |
| Median Only (n=995, 26.75%) | -5.10% (-10.77% to 3.05%) | +37.10% (+32.39% to +41.80%) | +31.50% (+26.43% to +36.56%) | 0.99% |
| Right Only (n=500, 13.44%) | +4.47% (-7.13% to 16.88%) | +4.48% (-1.87% to +10.08%) | +8.85% (+1.75% to +15.96%) | -28.60% |
| Both (n=55, 1.48%) | -8.57% (-26.21% to 18.53%) | +39.20% (+23.00% to +55.39%) | +30.24% (+12.66% to +47.82%) | -7.50% |

**Table 28c Comparisons of Predicted versus Observed Change in Night-day Ratios for Urban Interstate Segments without Interchanges and Overpasses for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| Continuous Lighting type (count, %) | Model | | | Descriptive data: change in night/day ratio |
|---|---|---|---|---|
| | Change in night/day ratio with lighting (based on ±1 standard error) | Change in day crashes with lighting (±1 standard error) | Change in night crashes with lighting (±1 standard error) | |
| Median Only (n=70, 16.41%) | -5.87% (-17.88% to 14.22%) | +88.96% (+74.80% to +103.12%) | +82.91% (+65.00% to +100.83%) | -6.12% |
| Right Only (n=100, 24.10%) | +1.92% (-23.73% to +35.66%) | +12.27% (-1.70% to +28.27%) | +14.17% (-5.04% to +33.38%) | -2.04% |
| Both (n=15,3.15%) | +40.18% (-10.77% to 73.33%) | +38.98% (+13.24% to +64.72%) | +72.75% (+42.36% to +103.14%) | -10.20% |

*Rural Segments*

As Tables 29a, 29b and 29c shows, a total of 775 observations were used in the model estimation of rural-only models with interchange and overpass locations present. When excluding interchange and overpass locations, 80 observations were used in the analysis. Table 29a shows the mean effects from the regression models, while tables 29b and 29c show the estimated day, night, and night-day ratio changes due to continuous roadway lighting. The confidence intervals for each mean estimate are also provided.

Rural Segments Excluding Point Lighting (with Interchanges and Overpasses)

When interchanges and overpasses are included in the assessment, all 775 observations remained in the analysis. It is estimated that the presence of median-only continuous lighting is associated with a 16.71 percent reduction in night-day ratios of crash frequencies when compared to the no-lighting baseline. Comparatively, the observed change in the night-day ratios was a decrease of 85.16 percent. A right-side only lighting installation was associated with a 22.16 percent increase in the night-day ratios, while the observed change was a decrease of 50.97 percent. Lighting installations on both sides of a rural freeway were not observed.

Rural Segments Excluding Point Lighting, Interchanges, and Overpasses

When interchanges and overpasses were excluded from the assessment, only 80 observations remained. It is estimated that the presence of median-only continuous lighting is estimated to be associated with a 100 percent reduction in night-day ratios of crash frequencies when compared to the no-lighting baseline. Comparatively, the observed change in night-day ratios was a decrease of 100 percent. A right-side only lighting installation was estimated to be associated with a 17.86 percent decrease in night-day ratios, while the observed change was a decrease of 54.55 percent. Lighting installations on both sides were not observed. Due to small sample sizes in the rural only database the results of the analysis excluding point lighting, interchanges, and overpasses should be interpreted with caution.

**Table 29a Comparisons of Predicted versus Observed Change in Night-day Ratios for Rural Interstate Segments for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| Rural Model Summary | | | | |
|---|---|---|---|---|
| Lighting Location | With interchanges and overpasses | | Without interchanging and overpasses | |
| | 775 observations | | 80 observations | |
| | Observed Change[1] | Predicted Change[2] | Observed Change[1] | Predicted Change[2] |
| Median only | -85.16% | -16.71% | -100% | -100.00% |
| Right only | -50.97% | 22.16% | -54.55% | -17.86% |
| Both | No data | No data | No data | No data |

[1] Values computed based on equation (1)
[2] Values computed based on equation (4)

**Table 29b Comparisons of Predicted versus Observed Change in Night-day Ratios for Rural Interstate Segments <u>with Interchanges and Overpasses</u> for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| **Continuous Lighting type (count, %)** | **Model** | | | **Descriptive data: change in night/day ratio** |
|---|---|---|---|---|
| | **Change in night/day ratio with lighting (based on ±1 standard error)** | **Change in day crashes with lighting (±1 standard error)** | **Change in night crashes with lighting (±1 standard error)** | |
| Median Only (n=35, 4.52%) | -16.71% (-37% to 0%) | -72.84% (-98.84% to -46.83%) | -91.12% (-100% to -55.57%) | -85.16% |
| Right Only (n=130, 16.77%) | +22.16% (-30% to +30%) | -100% (-100% to -89.80%) | -80.65% (-92.71% to -68.59%) | -50.97% |
| Both (n=0, 0%) | No data | No data | No data | No data |

**Table 29c Comparisons of Predicted versus Observed Change in Night-day Ratios for Rural Interstate Segments <u>without Interchanges and Overpasses</u> for Median-side only, Right-side only, and Both-sides Continuous Lighting**

| **Continuous Lighting type (count, %)** | **Model** | | | **Descriptive data: change in night/day ratio** |
|---|---|---|---|---|
| | **Change in night/day ratio with lighting (based on ±1 standard error)** | **Change in day crashes with lighting (±1 standard error)** | **Change in night crashes with lighting (±1 standard error)** | |
| Median Only (n=5, 6.25%) | N/A (Very high s.e.) | -40.45% (-148.37% to +68.46%) | -100% (very high s.e.) | -100.0% |
| Right Only (n=45, 56.25%) | -17.86% (-67% to 77%) | +18.98% (-16.20% to +54.16%) | -0.70% (-49.35% to +47.96%) | -54.55% |
| Both (n=0,0%) | No data | No data | No data | No data |

4.1.3.2 Oregon Segments

For the Oregon freeway segments, negative binomial regression models were estimated for both nighttime and daytime crashes. The results of these models are shown in Tables 30 and 31 below. The lighting parameter estimate in the daytime crash frequency model is 0.740 while the nighttime parameter estimate is 0.670 in the nighttime crash frequency model. The mean percent difference in the night-day crash ratio for segments with and without lighting is - 6.76 percent. This indicates that freeway segments in Oregon have a lower night-day crash ratio with continuous lighting when compared to segments without continuous lighting. When using the standard error of the mean estimate for daytime and nighttime crashes, the range of the night-day crash ratio is -34.4 to +32.6 percent. Using the descriptive statistics, the night-day crash ratio along freeway segments with lighting was 0.278 (1972 night crashes and 7101 day crashes) while the night-day crash ratio at segments without lighting was 0.468 (1808 day crashes and 3867 night crashes). As such, the percent difference in the night-day crash ratio was -18.98 percent. This indicates that using only the descriptive statistics, without controlling for traffic volume and geometric design variables, the safety effects of roadway lighting on freeway segments in Oregon might be overestimated. Table 32 shows a summary of the safety analysis results.

The findings from the negative binomial models for daytime and nighttime crash occurrence indicate that lighting has a slight positive effect (i.e., lower crash frequency). When controlling for geometric and traffic volume factors, as well as segment length, lighting presence appears to indicate a greater than expected number of crashes when compared to no lighting.

In terms of other significant findings from Tables 30 and 31, an urban area does not have a statistically significant effect on either daytime or nighttime crash occurrence when compared to the baseline of a rural area. A wider paved right shoulder increases the expected daytime crash frequency, but the right paved shoulder width is not statistically significant in the nighttime crash frequency model. The paved left shoulder width was not statistically significant in either the daytime or nighttime crash frequency models. Higher ADTs tend to increase both daytime and nighttime crash occurrence. Freeways segments with two through lanes in each direction are associated with fewer expected daytime and nighttime crashes when compared to freeways with more than two through lanes in each direction. The presence of a median barrier increases daytime crash occurrence, while it has no statistically significant effect on nighttime crash frequency. More horizontal curves along the road segment tend to increase both daytime and nighttime crash occurrence, while the effects of vertical curves are not statistically significant. More interchanges along a road segment tend to increase the expected crash frequencies.

### Table 30  Daytime Crash Frequency Model for Oregon Freeway Segments

| Variable | Coefficient | Standard Error | z | P>\|z\| | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Higher |
| Constant | -8.313 | 1.181 | -7.04 | <0.001 | -10.627 | -5.999 |
| Urban indicator | -0.032 | 0.147 | -0.22 | 0.830 | -0.320 | 0.257 |
| Left shoulder pavement width (feet) | 0.002 | 0.019 | 0.09 | 0.928 | -0.035 | 0.038 |
| Right shoulder pavement width (feet) | 0.057 | 0.023 | 2.45 | 0.014 | 0.011 | 0.102 |
| Logarithm of average daytime daily traffic (veh/day) | 0.998 | 0.098 | 10.15 | <0.001 | 0.806 | 1.191 |
| Presence of lighting indicator | 0.740 | 0.184 | 4.03 | <0.001 | 0.380 | 1.100 |
| Two-lanes per direction indicator | -0.444 | 0.169 | -2.62 | 0.009 | -0.776 | -0.112 |
| Logarithm of segment length (miles) | 0.842 | 0.059 | 14.16 | <0.001 | 0.725 | 0.958 |
| Median barrier presence indicator | 0.271 | 0.141 | 1.92 | 0.054 | -0.005 | 0.548 |
| Number of horizontal curves in segment | 0.016 | 0.011 | 1.46 | 0.143 | -0.006 | 0.038 |
| Number of vertical curves in segment | -0.001 | 0.008 | -0.19 | 0.853 | -0.016 | 0.014 |
| Number of interchanges in segment | 0.056 | 0.037 | 1.52 | 0.128 | -0.016 | 0.129 |
| Median width (feet) | 0.0009 | 0.002 | 0.43 | 0.666 | -0.003 | 0.005 |
| Overdispersion parameter | 0.257 | 0.040 | | | 0.190 | 0.347 |
| Number of observations = 179 | | | | | | |
| Log likelihood at convergence = -599.45457 | | | | | | |
| Pseudo $R^2$=0.2598 | | | | | | |

**Table 31 Nighttime Crash Frequency Model for Oregon Freeway Segments**

| Variable | Coefficient | Standard Error | z | P>\|z\| | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Higher |
| Constant | -4.888 | 1.005 | -4.86 | <0.001 | -6.859 | -2.918 |
| Urban indicator | -0.036 | 0.147 | -0.25 | 0.805 | -0.324 | 0.251 |
| Left shoulder pavement width (feet) | -0.003 | 0.017 | -0.19 | 0.847 | -0.036 | 0.030 |
| Right shoulder pavement width (feet) | 0.032 | 0.022 | 1.43 | 0.153 | -0.012 | 0.075 |
| Logarithm of average nighttime daily traffic (veh/day) | 0.709 | 0.093 | 7.66 | <0.001 | 0.528 | 0.890 |
| Lighting presence indicator | 0.670 | 0.168 | 3.98 | <0.001 | 0.340 | 1.000 |
| Two-lanes per direction indicator | -0.321 | 0.163 | -1.97 | 0.049 | -0.640 | -0.002 |
| Logarithm of segment length (miles) | 0.859 | 0.058 | 14.7 | <0.001 | 0.745 | 0.974 |
| Median barrier presence indicator | 0.140 | 0.135 | 1.04 | 0.300 | -0.125 | 0.404 |
| Number of horizontal curves in segment | 0.013 | 0.008 | 1.51 | 0.130 | -0.004 | 0.029 |
| Number of vertical curves in segment | -0.002 | 0.006 | -0.36 | 0.722 | -0.015 | 0.010 |
| Number of interchanges in segment | 0.043 | 0.031 | 1.39 | 0.165 | -0.018 | 0.103 |
| Median width (feet) | -0.0004 | 0.002 | -0.18 | 0.859 | -0.004 | 0.004 |
| Overdispersion parameter | 0.158 | 0.032 | | | 0.107 | 0.2347 |
| Number of observations = 179 | | | | | | |
| Log likelihood at convergence = -474.549 | | | | | | |
| Pseudo $R^2$=0.2861 | | | | | | |

**Table 32 Summary of statistical modeling and descriptive statistics for N/D crash ratios, nighttime crashes, and daytime crashes associated with lighting for OR highway segments**

| Number of segments with lighting | Model | | | Descriptive data: change in night/day ratio |
|---|---|---|---|---|
| | Change in night/day ratio with lighting | Change in day crashes with lighting | Change in night crashes with lighting | |
| 19 (10.6%) | -6.76% | +109.6% | +95.4% | -18.98% |

4.1.3.3 Virginia Segments

For the Virginia freeway segments, negative binomial regression models were estimated for both nighttime and daytime crashes. The results of these models are shown in Tables 33 and 34 below. The overdispersion parameter was statistically significant in both models. The lighting parameter estimate in the daytime crash frequency model is -0.027, but is not statistically significant. The nighttime parameter estimate is -0.095. The percent difference in the night-day crash ratio for segments with and without lighting is -

6.64 percent. Using the standard error of this estimate, the range in the night-day crash ratio is +6.29 to -17.5 percent. Using the observed crash count data, the night-day crash on segments with lighting was 0.390 (4966 night crashes and 12,730 day crashes) while the night-day crash ratio on segments without lighting was 0.446 (1173 day crashes and 2632 night crashes). As such, the percent difference in the night-day crash ratio was -5.6 percent. This indicates that using only the observed crash count data, without controlling for traffic volume and geometric design variables, the safety effects of roadway lighting on freeway segments in Virginia may be slightly underestimated. Table 35 shows a summary of the statistical modeling and descriptive statistics analysis for night-day crash ratios, nighttime crashes, and daytime crashes associated with continuous freeway lighting on Virginia freeway segments.

Other findings from the statistical models for daytime and nighttime crashes shown in Tables 33 and 34 are as follows:

- A unit increase in the right shoulder width is associated with an increase in the expected daytime and nighttime crash frequencies.
- The left shoulder width has no statistically significant association with daytime crash frequencies, while a unit increase in the left shoulder width is associated with a decrease in the expected nighttime crash frequency.
- The median width has no statistically significant effect on daytime crashes, but a unit increase in the median width is associated with an increase in the expected number of nighttime crashes.
- Higher truck traffic percentages is associated with an increase in the expected number of daytime crashes, but the effect of truck traffic percentage on nighttime crash occurrence is not statistically significant.
- Increased traffic volumes are associated with an increase in the expected number of daytime and nighttime crashes.
- Two through travel lanes per direction are associated with an increase in the expected number of daytime crashes when compared to the baseline of four or more through travel lanes per direction. However, the opposite effect was found in the nighttime crash frequency model. Three through travel lanes per direction are associated with an increase in the expected number of daytime and nighttime crashes when compared to the baseline of four or more through travel lanes per direction.
- The presence of a median barrier increases the expected nighttime crash frequency, while it has no statistically significant effect on daytime crash frequency.
- The presence of interchanges along a road segment tends to increase both daytime and nighttime crash frequencies, but the effect on daytime crash frequency is not statistically significant.

**Table 33  Daytime Crash Frequency Model for Virginia Freeway Segments**

| Variable | Coefficient | Standard Error | z | P>\|z\| | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Higher |
| Constant | -7.334 | 0.775 | -9.460 | <0.001 | -8.854 | -5.815 |
| Lighting presence indicator | -0.027 | 0.059 | -0.450 | 0.652 | -0.143 | 0.089 |
| Number of interchanges in segment | 0.076 | 0.055 | 1.380 | 0.168 | -0.032 | 0.185 |
| Two-lanes per direction indicator | 0.238 | 0.076 | 3.150 | 0.002 | 0.090 | 0.386 |
| Three-lanes per direction indicator | 0.431 | 0.049 | 8.810 | <0.001 | 0.335 | 0.527 |
| Right shoulder width (feet) | 0.024 | 0.007 | 3.620 | <0.001 | 0.011 | 0.036 |
| Left shoulder width (feet) | 0.001 | 0.006 | 0.240 | 0.814 | -0.010 | 0.012 |
| Percentage of truck traffic | 0.016 | 0.009 | 1.840 | 0.066 | -0.001 | 0.033 |
| Median width (feet) | 0.00006 | 0.001 | 0.120 | 0.906 | -0.001 | 0.001 |
| Logarithm of segment length (miles) | 0.570 | 0.020 | 27.880 | <0.001 | 0.530 | 0.610 |
| Logarithm of average daily traffic (veh/day) | 0.838 | 0.067 | 12.440 | <0.001 | 0.706 | 0.970 |
| Median Barrier presence indicator | 0.045 | 0.046 | 0.980 | 0.326 | -0.045 | 0.136 |
| Overdispersion parameter | 0.627 | 0.027 | | | 0.575 | 0.683 |
| Number of observations = 2276 | | | | | | |
| Log likelihood at convergence =  -5990.355 | | | | | | |
| Pseudo $R^2$=0.0892 | | | | | | |

**Table 34 Nighttime Crash Frequency Model for Virginia Freeway Segments**

| Variable | Coefficient | Standard Error | z | P>\|z\| | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Higher |
| Constant | -6.750 | 0.863 | -7.820 | <0.001 | -8.441 | -5.059 |
| Lighting presence indicator | -0.095 | 0.065 | -1.470 | 0.143 | -0.223 | 0.032 |
| Number of interchanges in segment | 0.157 | 0.057 | 2.740 | 0.006 | 0.045 | 0.269 |
| Two-lanes per direction indicator | -0.125 | 0.085 | -1.480 | 0.139 | -0.291 | 0.041 |
| Three-lanes per direction indicator | 0.111 | 0.053 | 2.090 | 0.037 | 0.007 | 0.215 |
| Right shoulder width (feet) | 0.042 | 0.008 | 5.530 | <0.001 | 0.027 | 0.057 |
| Left shoulder width (feet) | -0.022 | 0.006 | -3.660 | <0.001 | -0.033 | -0.010 |
| Percentage of truck traffic | 0.004 | 0.009 | 0.470 | 0.637 | -0.014 | 0.023 |
| Median width (feet) | 0.002 | 0.001 | 3.270 | 0.001 | 0.001 | 0.003 |
| Logarithm of segment length (miles) | 0.594 | 0.023 | 25.380 | <0.001 | 0.548 | 0.640 |
| Logarithm of average daily traffic (veh/day) | 0.701 | 0.075 | 9.320 | <0.001 | 0.554 | 0.849 |
| Median Barrier presence indicator | 0.217 | 0.051 | 4.240 | <0.001 | 0.117 | 0.318 |
| Overdispersion parameter | 0.485 | 0.033 | | | 0.426 | 0.553 |
| Number of observations = 2276 | | | | | | |
| Log likelihood at convergence = -4201.6594 | | | | | | |
| Pseudo $R^2$=0.1103 | | | | | | |

**Table 35 Summary of statistical modeling and descriptive statistics for N/D crash ratios, nighttime crashes, and daytime crashes associated with lighting for VA highway segments**

| Number of segments with lighting | Model | | | Descriptive data: change in night/day ratio |
|---|---|---|---|---|
| | Change in night/day ratio with lighting | Change in day crashes with lighting | Change in night crashes with lighting | |
| 1968 (79%) | -6.64% | -2.6% | -9.1% | -5.6% |

## 4.2 Crash Severity Results

This section contains crash severity distributions for the California and Minnesota intersection databases, Minnesota interchange database, and Washington freeway segment database. The severity distributions are based on the KABCO scale as described previously. Additionally, the crash severity distributions are stratified by sections with and without lighting, and during daytime and nighttime conditions.

### *4.2.1 Intersections*

#### 4.2.1.1 Minnesota

Table 36 shows the fatal crash frequency and proportion of total crashes for Minnesota intersections. Table 37 shows the incapacitating crash frequency and proportion of total crashes for Minnesota intersections. Table 38 shows the non-incapacitating crash frequency and proportion of total crashes for Minnesota intersections. Table 39 shows the possible injury crash frequency and proportion of total crashes for Minnesota intersections. Table 40 shows the property-damage only crash frequency and proportion of total crashes for Minnesota intersections. Table 41 shows the unknown crash frequency and proportion of total crashes for Minnesota intersections. When considering all intersection forms, the crash severity distribution is as follows, irrespective of time of day and with or without lighting:

- Fatals: 0.77 percent
- Incapacitating injury: 2.35 percent
- Non-incapacitating injury: 12.45 percent
- Possible injury: 21.82 percent
- Property-damage only: 14.78 percent
- Unknown injury severity: 47.82 percent

When considering nighttime crashes with and without fixed roadway lighting, the proportion of the fatal crashes is higher without lighting than with lighting; the proportion of incapacity injury crashes is higher without lighting than with lighting; the proportion of non-incapacitating injury crashes without lighting is higher than with lighting; the proportion of possible injury crashes without lighting is lower than with lighting; and, the proportion of property-damage only crashes is lower without lighting than with lighting. As such, the severity distribution suggests that the nighttime crash severity is generally lower at intersections with lighting than at those without lighting. Similar changes in the crash severity distribution were also observed during the daytime at intersections with and without fixed roadway lighting, which may indicate that other roadway and traffic control factors that are often associated with lighting are also influencing crash severity. Furthermore, it is worth noting that nearly 50 percent of Minnesota intersection crashes were recorded as unknown injury severity. As such, a conclusion related to the effect of roadway lighting on crash severity is difficult to quantify.

# Table 36 Minnesota Intersection Fatal Crash Severity

| Intersection Type | # fatal | | | | | % fatal | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| All intersections | 93 | 44 | 115 | 47 | 299 | 0.45% | 0.72% | 1.41% | 1.41% | 0.77% |
| All signalized | 48 | 26 | 1 | 1 | 76 | 0.34% | 0.63% | 0.34% | 1.22% | 0.41% |
| All unsignalized | 45 | 18 | 114 | 46 | 223 | 0.65% | 0.92% | 1.45% | 1.41% | 1.11% |
| Cross | 63 | 22 | 71 | 23 | 179 | 0.45% | 0.55% | 1.96% | 1.69% | 0.77% |
| Skew | 14 | 9 | 12 | 9 | 44 | 0.39% | 0.81% | 0.95% | 1.78% | 0.67% |
| Tee | 16 | 13 | 32 | 15 | 76 | 0.48% | 1.27% | 0.98% | 1.02% | 0.82% |
| All urban | 63 | 33 | 9 | 6 | 111 | 0.34% | 0.64% | 0.54% | 1.11% | 0.43% |
| Urban signalized | 37 | 21 | 1 | 1 | 60 | 0.29% | 0.56% | 0.45% | 1.75% | 0.36% |
| Urban unsignalized | 26 | 12 | 8 | 5 | 51 | 0.46% | 0.82% | 0.56% | 1.03% | 0.56% |
| Urban signalized cross | 26 | 12 | 0 | 0 | 43 | 0.46% | 0.82% | 0.00% | 0.00% | 0.34% |
| Urban signalized skew | 6 | 3 | 1 | 1 | 11 | 0.25% | 0.41% | 1.89% | 12.50% | 0.34% |
| Urban signalized tee | 3 | 3 | 0 | 0 | 6 | 0.47% | 1.49% | 0.00% | 0.00% | 0.68% |
| Urban unsignalized cross | 17 | 3 | 3 | 1 | 24 | 0.59% | 0.42% | 0.62% | 0.88% | 0.56% |
| Urban unsignalized skew | 3 | 2 | 2 | 1 | 8 | 0.43% | 0.90% | 1.74% | 2.50% | 0.74% |
| Urban unsignalized tee | 6 | 7 | 3 | 3 | 19 | 0.30% | 1.34% | 0.36% | 0.91% | 0.51% |
| All rural | 30 | 11 | 106 | 41 | 188 | 1.17% | 1.19% | 1.63% | 1.46% | 1.45% |
| Rural signalized | 11 | 5 | 0 | 0 | 16 | 0.83% | 1.14% | 0.00% | 0.00% | 0.85% |
| Rural unsignalized | 19 | 6 | 106 | 41 | 172 | 1.52% | 1.24% | 1.65% | 1.48% | 1.55% |
| Rural signalized cross | 10 | 4 | 0 | 0 | 14 | 1.00% | 1.22% | 0.00% | 0.00% | 0.97% |
| Rural signalized skew | 1 | 1 | 0 | 0 | 2 | 0.64% | 1.89% | 0.00% | 0.00% | 0.93% |
| Rural signalized tee | 0 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | #DIV/0! | #DIV/0! | 0.00% |
| Rural unsignalized cross | 8 | 0 | 68 | 22 | 98 | 1.98% | 0.00% | 2.32% | 1.87% | 2.09% |
| Rural unsignalized skew | 4 | 3 | 9 | 7 | 23 | 1.16% | 2.59% | 0.82% | 1.54% | 1.14% |
| Rural unsignalized tee | 7 | 3 | 29 | 12 | 51 | 1.40% | 1.23% | 1.20% | 1.05% | 1.17% |

# Table 37 Minnesota Intersection Incapacitating Injury Crash Severity

| Intersection Type | #incapacitating injury( severe injury) | | | | | % incapacitating injury( severe injury) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| All intersections | 376 | 139 | 279 | 106 | 916 | 1.80% | 2.27% | 3.42% | 3.17% | 2.35% |
| All signalized | 245 | 89 | 6 | 3 | 352 | 1.75% | 2.14% | 2.05% | 3.66% | 1.88% |
| All unsignalized | 131 | 50 | 273 | 103 | 564 | 1.91% | 2.56% | 3.47% | 3.16% | 2.80% |
| Cross | 266 | 92 | 158 | 50 | 575 | 1.91% | 2.32% | 4.35% | 3.67% | 2.48% |
| Skew | 55 | 23 | 46 | 18 | 143 | 1.54% | 2.06% | 3.63% | 3.56% | 2.19% |
| Tee | 55 | 24 | 75 | 38 | 198 | 1.64% | 2.34% | 2.30% | 2.58% | 2.15% |
| All urban | 323 | 117 | 31 | 13 | 493 | 1.77% | 2.25% | 1.88% | 2.40% | 1.90% |
| Urban signalized | 229 | 81 | 4 | 3 | 324 | 1.81% | 2.18% | 1.81% | 5.26% | 1.92% |
| Urban unsignalized | 94 | 36 | 27 | 10 | 169 | 1.67% | 2.45% | 1.89% | 2.06% | 1.85% |
| Urban signalized cross | 94 | 36 | 2 | 2 | 261 | 1.67% | 2.45% | 1.32% | 4.26% | 2.04% |
| Urban signalized skew | 30 | 16 | 2 | 1 | 50 | 1.26% | 2.21% | 3.77% | 12.50% | 1.56% |
| Urban signalized tee | 6 | 5 | 0 | 0 | 13 | 0.93% | 2.49% | 0.00% | 0.00% | 1.48% |
| Urban unsignalized cross | 42 | 22 | 14 | 1 | 81 | 1.45% | 3.05% | 2.87% | 0.88% | 1.90% |
| Urban unsignalized skew | 13 | 7 | 1 | 2 | 23 | 1.86% | 3.14% | 0.87% | 5.00% | 2.12% |
| Urban unsignalized tee | 39 | 7 | 12 | 7 | 65 | 1.92% | 1.34% | 1.45% | 2.11% | 1.73% |
| All rural | 53 | 22 | 248 | 93 | 423 | 2.06% | 2.39% | 3.81% | 3.32% | 3.27% |
| Rural signalized | 16 | 8 | 2 | 0 | 28 | 1.21% | 1.83% | 2.82% | 0.00% | 1.49% |
| Rural unsignalized | 37 | 14 | 246 | 93 | 395 | 2.96% | 2.89% | 3.82% | 3.35% | 3.57% |
| Rural signalized cross | 15 | 7 | 2 | 0 | 26 | 1.51% | 2.14% | 3.03% | 0.00% | 1.81% |
| Rural signalized skew | 1 | 0 | 0 | 0 | 1 | 0.64% | 0.00% | 0.00% | 0.00% | 0.46% |
| Rural signalized tee | 0 | 1 | 0 | 0 | 1 | 0.00% | 1.75% | #DIV/0! | #DIV/0! | 0.44% |
| Rural unsignalized cross | 16 | 3 | 140 | 47 | 207 | 3.95% | 2.40% | 4.79% | 3.99% | 4.41% |
| Rural unsignalized skew | 11 | 0 | 43 | 15 | 69 | 3.20% | 0.00% | 3.93% | 3.29% | 3.41% |
| Rural unsignalized tee | 10 | 11 | 63 | 31 | 119 | 2.00% | 4.53% | 2.61% | 2.72% | 2.74% |

# Table 38 Minnesota Intersection Non-Incapacitating Injury Crash Severity

| Intersection Type | # non-incapacitating injury (visible injury) | | | | | % non-incapacitating injury (visible injury) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| All intersections | 2344 | 736 | 1270 | 433 | 4847 | 11.25% | 12.05% | 15.57% | 12.96% | 12.45% |
| All signalized | 1547 | 498 | 52 | 11 | 2138 | 11.08% | 11.98% | 17.81% | 13.41% | 11.40% |
| All unsignalized | 797 | 238 | 1218 | 422 | 2709 | 11.59% | 12.19% | 15.49% | 12.95% | 13.43% |
| Cross | 1576 | 502 | 608 | 188 | 2914 | 11.32% | 12.64% | 16.75% | 13.79% | 12.57% |
| Skew | 398 | 121 | 199 | 58 | 781 | 11.13% | 10.84% | 15.71% | 11.46% | 11.97% |
| Tee | 370 | 113 | 463 | 187 | 1152 | 11.06% | 11.04% | 14.20% | 12.70% | 12.50% |
| All urban | 1999 | 605 | 238 | 51 | 2934 | 10.94% | 11.66% | 14.41% | 9.41% | 11.29% |
| Urban signalized | 1398 | 428 | 41 | 7 | 1901 | 11.06% | 11.50% | 18.55% | 12.28% | 11.27% |
| Urban unsignalized | 601 | 177 | 197 | 44 | 1033 | 10.68% | 12.06% | 13.77% | 9.07% | 11.34% |
| Urban signalized cross | 601 | 177 | 21 | 5 | 1450 | 10.68% | 12.06% | 13.91% | 10.64% | 11.34% |
| Urban signalized skew | 257 | 78 | 14 | 1 | 352 | 10.81% | 10.77% | 26.42% | 12.50% | 11.01% |
| Urban signalized tee | 70 | 21 | 6 | 1 | 99 | 10.89% | 10.45% | 35.29% | 50.00% | 11.24% |
| Urban unsignalized cross | 312 | 94 | 71 | 8 | 490 | 10.77% | 13.02% | 14.58% | 7.02% | 11.48% |
| Urban unsignalized skew | 73 | 22 | 14 | 3 | 115 | 10.44% | 9.87% | 12.17% | 7.50% | 10.59% |
| Urban unsignalized tee | 216 | 61 | 112 | 33 | 428 | 10.64% | 11.66% | 13.51% | 9.97% | 11.39% |
| All rural | 345 | 131 | 1032 | 382 | 1913 | 13.41% | 14.22% | 15.87% | 13.65% | 14.78% |
| Rural signalized | 149 | 70 | 11 | 4 | 237 | 11.26% | 16.02% | 15.49% | 16.00% | 12.59% |
| Rural unsignalized | 196 | 61 | 1021 | 378 | 1676 | 15.69% | 12.60% | 15.87% | 13.63% | 15.15% |
| Rural signalized cross | 116 | 58 | 11 | 3 | 191 | 11.65% | 17.74% | 16.67% | 13.04% | 13.29% |
| Rural signalized skew | 19 | 9 | 0 | 1 | 28 | 12.18% | 16.98% | 0.00% | 50.00% | 12.96% |
| Rural signalized tee | 14 | 4 | 0 | 0 | 18 | 8.19% | 7.02% | #DIV/0! | #DIV/0! | 7.86% |
| Rural unsignalized cross | 77 | 21 | 505 | 172 | 783 | 19.01% | 16.80% | 17.26% | 14.59% | 16.70% |
| Rural unsignalized skew | 49 | 13 | 171 | 53 | 286 | 14.24% | 11.21% | 15.63% | 11.62% | 14.12% |
| Rural unsignalized tee | 70 | 27 | 345 | 153 | 607 | 14.00% | 11.11% | 14.29% | 13.43% | 13.95% |

# Table 39 Minnesota Intersection Possible Injury Crash Severity

| Intersection Type | # possible injury (pain/complaint) | | | | | % possible injury (pain/complaint) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| All intersections | 4701 | 1248 | 1867 | 593 | 8495 | 22.56% | 20.43% | 22.89% | 17.75% | 21.82% |
| All signalized | 3263 | 882 | 75 | 20 | 4292 | 23.37% | 21.21% | 25.68% | 24.39% | 22.89% |
| All unsignalized | 1438 | 366 | 1792 | 573 | 4203 | 20.91% | 18.75% | 22.79% | 17.58% | 20.83% |
| Cross | 3121 | 815 | 810 | 241 | 5043 | 22.42% | 20.53% | 22.32% | 17.68% | 21.75% |
| Skew | 855 | 242 | 310 | 95 | 1512 | 23.91% | 21.68% | 24.47% | 18.77% | 23.18% |
| Tee | 725 | 191 | 747 | 257 | 1940 | 21.68% | 18.65% | 22.91% | 17.46% | 21.05% |
| All urban | 4111 | 1086 | 395 | 107 | 5765 | 22.50% | 20.93% | 23.91% | 19.74% | 22.19% |
| Urban signalized | 2968 | 794 | 56 | 17 | 3884 | 23.48% | 21.34% | 25.34% | 29.82% | 23.02% |
| Urban unsignalized | 1143 | 292 | 339 | 90 | 1881 | 20.31% | 19.89% | 23.69% | 18.56% | 20.65% |
| Urban signalized cross | 1143 | 292 | 40 | 15 | 2906 | 20.31% | 19.89% | 26.49% | 31.91% | 22.72% |
| Urban signalized skew | 587 | 165 | 13 | 2 | 773 | 24.69% | 22.79% | 24.53% | 25.00% | 24.18% |
| Urban signalized tee | 164 | 35 | 3 | 0 | 205 | 25.51% | 17.41% | 17.65% | 0.00% | 23.27% |
| Urban unsignalized cross | 590 | 137 | 109 | 23 | 865 | 20.36% | 18.98% | 22.38% | 20.18% | 20.27% |
| Urban unsignalized skew | 150 | 44 | 29 | 6 | 230 | 21.46% | 19.73% | 25.22% | 15.00% | 21.18% |
| Urban unsignalized tee | 403 | 111 | 201 | 61 | 786 | 19.85% | 21.22% | 24.25% | 18.43% | 20.92% |
| All rural | 590 | 162 | 1472 | 486 | 2730 | 22.94% | 17.59% | 22.63% | 17.36% | 21.09% |
| Rural signalized | 295 | 88 | 19 | 3 | 408 | 22.30% | 20.14% | 26.76% | 12.00% | 21.68% |
| Rural unsignalized | 295 | 74 | 1453 | 483 | 2322 | 23.62% | 15.29% | 22.59% | 17.41% | 20.99% |
| Rural signalized cross | 225 | 66 | 17 | 3 | 313 | 22.59% | 20.18% | 25.76% | 13.04% | 21.78% |
| Rural signalized skew | 35 | 10 | 2 | 0 | 47 | 22.44% | 18.87% | 40.00% | 0.00% | 21.76% |
| Rural signalized tee | 35 | 12 | 0 | 0 | 48 | 20.47% | 21.05% | #DIV/0! | #DIV/0! | 20.96% |
| Rural unsignalized cross | 89 | 18 | 644 | 200 | 959 | 21.98% | 14.40% | 22.02% | 16.96% | 20.45% |
| Rural unsignalized skew | 83 | 23 | 266 | 87 | 462 | 24.13% | 19.83% | 24.31% | 19.08% | 22.81% |
| Rural unsignalized tee | 123 | 33 | 543 | 196 | 901 | 24.60% | 13.58% | 22.49% | 17.21% | 20.71% |

# Table 40 Minnesota Intersection Property-damage Only Crash Severity

| Intersection Type | # pdo | | | | | % pdo | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| All intersections | 3219 | 904 | 1005 | 479 | 5754 | 15.45% | 14.80% | 12.32% | 14.34% | 14.78% |
| All signalized | 2134 | 605 | 39 | 18 | 2884 | 15.28% | 14.55% | 13.36% | 21.95% | 15.38% |
| All unsignalized | 1085 | 299 | 966 | 461 | 2870 | 15.78% | 15.32% | 12.28% | 14.15% | 14.22% |
| Cross | 2190 | 613 | 429 | 203 | 3531 | 15.73% | 15.44% | 11.82% | 14.89% | 15.23% |
| Skew | 517 | 143 | 144 | 59 | 886 | 14.46% | 12.81% | 11.37% | 11.66% | 13.58% |
| Tee | 512 | 148 | 432 | 217 | 1337 | 15.31% | 14.45% | 13.25% | 14.74% | 14.50% |
| All urban | 2890 | 770 | 220 | 76 | 4065 | 15.82% | 14.84% | 13.32% | 14.02% | 15.65% |
| Urban signalized | 1963 | 549 | 28 | 9 | 2630 | 15.53% | 14.75% | 12.67% | 15.79% | 15.59% |
| Urban unsignalized | 927 | 221 | 192 | 67 | 1435 | 16.47% | 15.05% | 13.42% | 13.81% | 15.75% |
| Urban signalized cross | 927 | 221 | 20 | 8 | 2026 | 16.47% | 15.05% | 13.25% | 17.02% | 15.84% |
| Urban signalized skew | 359 | 96 | 7 | 1 | 478 | 15.10% | 13.26% | 13.21% | 12.50% | 14.95% |
| Urban signalized tee | 92 | 27 | 1 | 0 | 126 | 14.31% | 13.43% | 5.88% | 0.00% | 14.30% |
| Urban unsignalized cross | 500 | 121 | 76 | 22 | 733 | 17.25% | 16.76% | 15.61% | 19.30% | 17.17% |
| Urban unsignalized skew | 100 | 27 | 14 | 5 | 150 | 14.31% | 12.11% | 12.17% | 12.50% | 13.81% |
| Urban unsignalized tee | 327 | 73 | 102 | 40 | 552 | 16.11% | 13.96% | 12.30% | 12.08% | 14.69% |
| All rural | 329 | 134 | 785 | 403 | 1689 | 12.79% | 14.55% | 12.07% | 14.40% | 13.05% |
| Rural signalized | 171 | 56 | 11 | 9 | 254 | 12.93% | 12.81% | 15.49% | 36.00% | 13.50% |
| Rural unsignalized | 158 | 78 | 774 | 394 | 1435 | 12.65% | 16.12% | 12.03% | 14.20% | 12.97% |
| Rural signalized cross | 126 | 42 | 11 | 8 | 194 | 12.65% | 12.84% | 16.67% | 34.78% | 13.50% |
| Rural signalized skew | 20 | 5 | 0 | 1 | 26 | 12.82% | 9.43% | 0.00% | 50.00% | 12.04% |
| Rural signalized tee | 25 | 9 | 0 | 0 | 34 | 14.62% | 15.79% | #DIV/0! | #DIV/0! | 14.85% |
| Rural unsignalized cross | 52 | 24 | 322 | 165 | 578 | 12.84% | 19.20% | 11.01% | 13.99% | 12.33% |
| Rural unsignalized skew | 38 | 15 | 123 | 52 | 232 | 11.05% | 12.93% | 11.24% | 11.40% | 11.46% |
| Rural unsignalized tee | 68 | 39 | 329 | 177 | 625 | 13.60% | 16.05% | 13.63% | 15.54% | 14.36% |

# Table 41 Minnesota Intersection Unknown Injury Crash Severity

| Intersection Type | # severity unknown | | | | | % severity unknown | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| All intersections | 10107 | 3039 | 3620 | 1683 | 18616 | 48.50% | 49.74% | 44.38% | 50.37% | 47.82% |
| All signalized | 6727 | 2058 | 119 | 29 | 9009 | 48.17% | 49.49% | 40.75% | 35.37% | 48.05% |
| All unsignalized | 3380 | 981 | 3501 | 1654 | 9607 | 49.16% | 50.26% | 44.52% | 50.75% | 47.62% |
| Cross | 6704 | 1926 | 1553 | 658 | 10943 | 48.16% | 48.51% | 42.79% | 48.28% | 47.20% |
| Skew | 1737 | 578 | 556 | 267 | 3158 | 48.57% | 51.79% | 43.88% | 52.77% | 48.41% |
| Tee | 1666 | 535 | 1511 | 758 | 4515 | 49.82% | 52.25% | 46.35% | 51.49% | 48.98% |
| All urban | 8882 | 2578 | 759 | 289 | 12612 | 48.62% | 49.68% | 45.94% | 53.32% | 48.54% |
| Urban signalized | 6046 | 1848 | 91 | 20 | 8070 | 47.83% | 49.66% | 41.18% | 35.09% | 47.84% |
| Urban unsignalized | 2836 | 730 | 668 | 269 | 4542 | 50.40% | 49.73% | 46.68% | 55.46% | 49.85% |
| Urban signalized cross | 2836 | 730 | 68 | 17 | 6105 | 50.40% | 49.73% | 45.03% | 36.17% | 47.73% |
| Urban signalized skew | 1138 | 366 | 16 | 2 | 1533 | 47.88% | 50.55% | 30.19% | 25.00% | 47.95% |
| Urban signalized tee | 308 | 110 | 7 | 1 | 432 | 47.90% | 54.73% | 41.18% | 50.00% | 49.04% |
| Urban unsignalized cross | 1437 | 345 | 214 | 59 | 2075 | 49.59% | 47.78% | 43.94% | 51.75% | 48.62% |
| Urban unsignalized skew | 360 | 121 | 55 | 23 | 560 | 51.50% | 54.26% | 47.83% | 57.50% | 51.57% |
| Urban unsignalized tee | 1039 | 264 | 399 | 187 | 1907 | 51.18% | 50.48% | 48.13% | 56.50% | 50.76% |
| All rural | 1225 | 461 | 2861 | 1394 | 6004 | 47.63% | 50.05% | 43.99% | 49.80% | 46.37% |
| Rural signalized | 681 | 210 | 28 | 9 | 939 | 51.47% | 48.05% | 39.44% | 36.00% | 49.89% |
| Rural unsignalized | 544 | 251 | 2833 | 1385 | 5065 | 43.56% | 51.86% | 44.04% | 49.93% | 45.77% |
| Rural signalized cross | 504 | 150 | 25 | 9 | 699 | 50.60% | 45.87% | 37.88% | 39.13% | 48.64% |
| Rural signalized skew | 80 | 29 | 3 | 0 | 112 | 51.28% | 54.72% | 60.00% | 0.00% | 51.85% |
| Rural signalized tee | 97 | 31 | 0 | 0 | 128 | 56.73% | 54.39% | #DIV/0! | #DIV/0! | 55.90% |
| Rural unsignalized cross | 163 | 59 | 1246 | 573 | 2064 | 40.25% | 47.20% | 42.60% | 48.60% | 44.02% |
| Rural unsignalized skew | 159 | 62 | 482 | 242 | 953 | 46.22% | 53.45% | 44.06% | 53.07% | 47.06% |
| Rural unsignalized tee | 222 | 130 | 1105 | 570 | 2048 | 44.40% | 53.50% | 45.77% | 50.04% | 47.07% |

#### 4.2.1.2 California

Table 42 shows the fatal crash frequency and proportion of total crashes for California intersections. Table 43 shows the incapacitating crash frequency and proportion of total crashes for California intersections. Table 44 shows the non-incapacitating crash frequency and proportion of total crashes for California intersections. Table 45 shows the possible injury crash frequency and proportion of total crashes for California intersections. Table 46 shows the property-damage only crash frequency and proportion of total crashes for California intersections. When considering all intersection forms, the crash severity distribution is as follows, irrespective of time of day and with or without lighting:

- Fatals: 0.85 percent
- Incapacitating injury: 2.47 percent
- Non-incapacitating injury: 14.33 percent
- Possible injury: 25.46 percent
- Property-damage only: 56.69 percent

When considering nighttime crashes with and without fixed roadway lighting, the proportion of the fatal crashes is higher without lighting than with lighting; the proportion of incapacity injury crashes is higher without lighting than with lighting; the proportion of non-incapacitating injury crashes without lighting is higher than with lighting; the proportion of possible injury crashes without lighting is lower than with lighting; and, the proportion of property-damage only crashes is lower without lighting than with lighting. As such, the severity distribution suggests that the nighttime crash severity is generally lower at California intersections with lighting than at those without lighting. Similar trends were observed in the daytime crash severity data, which suggests that others roadway and traffic control features, in addition to lighting, are influencing the crash severity at California intersections.

## Table 42 California Intersection Fatal Crash Severity

| Intersections | # fatal | | | | | % fatal | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| all | 120 | 84 | 132 | 58 | 395 | 0.43% | 0.91% | 1.90% | 2.44% | 0.85% |
| all 4leg | 66 | 57 | 84 | 39 | 246 | 0.35% | 0.86% | 2.84% | 3.87% | 0.83% |
| all T | 46 | 19 | 39 | 10 | 115 | 0.64% | 0.87% | 1.14% | 0.85% | 0.82% |
| all stop | 83 | 50 | 131 | 58 | 323 | 0.66% | 1.50% | 1.91% | 2.48% | 1.28% |
| all signal | 37 | 34 | 1 | 0 | 72 | 0.24% | 0.58% | 1.30% | 0.00% | 0.34% |
| all Y/offset | 8 | 8 | 9 | 9 | 34 | 0.48% | 1.72% | 1.57% | 4.79% | 1.17% |
| signal 4leg | 31 | 32 | 1 | 0 | 631 | 0.24% | 0.64% | 1.54% | 0.00% | 3.49% |
| stop 4leg | 35 | 25 | 83 | 39 | 182 | 0.57% | 1.59% | 2.87% | 4.00% | 1.57% |
| signal T | 6 | 1 | 0 | 0 | 7 | 0.31% | 0.14% | 0.00% | 0.00% | 0.26% |
| stop T | 40 | 18 | 39 | 10 | 108 | 0.77% | 1.25% | 1.15% | 0.85% | 0.96% |
| signal Y/offset | 0 | 1 | 0 | 0 | 1 | 0.00% | 0.74% | #DIV/0! | #DIV/0! | 0.19% |
| stop Y/offset | 8 | 7 | 9 | 9 | 33 | 0.62% | 2.13% | 1.57% | 4.79% | 1.38% |

## Table 43 California Intersection Incapacitating Injury Crash Severity

| Intersections | # severe injury | | | | | % severe injury | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| all | 464 | 252 | 286 | 148 | 1151 | 1.66% | 2.73% | 4.12% | 6.24% | 2.47% |
| all 4leg | 283 | 171 | 135 | 81 | 671 | 1.48% | 2.59% | 4.57% | 8.04% | 2.26% |
| all T | 141 | 74 | 128 | 53 | 396 | 1.98% | 3.40% | 3.75% | 4.50% | 2.83% |
| all stop | 255 | 114 | 283 | 148 | 800 | 2.03% | 3.41% | 4.12% | 6.33% | 3.17% |
| all signal | 209 | 138 | 3 | 0 | 351 | 1.36% | 2.34% | 3.90% | 0.00% | 1.64% |
| all Y/offset | 40 | 7 | 23 | 14 | 84 | 2.40% | 1.51% | 4.02% | 7.45% | 2.88% |
| signal 4leg | 164 | 113 | 2 | 0 | 1364 | 1.26% | 2.25% | 3.08% | 0.00% | 7.54% |
| stop 4leg | 119 | 58 | 133 | 81 | 391 | 1.95% | 3.68% | 4.61% | 8.30% | 3.38% |
| signal T | 35 | 23 | 1 | 0 | 59 | 1.79% | 3.12% | 8.33% | 0.00% | 2.17% |
| stop T | 106 | 51 | 127 | 53 | 337 | 2.05% | 3.55% | 3.73% | 4.51% | 2.99% |
| signal Y/offset | 10 | 2 | 0 | 0 | 12 | 2.62% | 1.48% | #DIV/0! | #DIV/0! | 2.31% |
| stop Y/offset | 30 | 5 | 23 | 14 | 72 | 2.33% | 1.52% | 4.02% | 7.45% | 3.01% |

## Table 44 California Intersection Non-incapacitating Crash Severity

| Intersections | # visible injury | | | | | % visible injury | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| all | 3600 | 1326 | 1314 | 433 | 6677 | 12.91% | 14.36% | 18.94% | 18.25% | 14.33% |
| all 4leg | 2453 | 916 | 633 | 213 | 4216 | 12.86% | 13.89% | 21.44% | 21.15% | 14.19% |
| all T | 946 | 350 | 584 | 187 | 2070 | 13.26% | 16.09% | 17.11% | 15.87% | 14.82% |
| all stop | 1752 | 541 | 1298 | 427 | 4021 | 13.95% | 16.18% | 18.92% | 18.26% | 15.95% |
| all signal | 1848 | 785 | 16 | 6 | 2656 | 12.06% | 13.33% | 20.78% | 17.14% | 12.43% |
| all Y/offset | 201 | 60 | 97 | 33 | 391 | 12.05% | 12.93% | 16.96% | 17.55% | 13.42% |
| signal 4leg | 1600 | 651 | 13 | 5 | 4250 | 12.33% | 12.97% | 20.00% | 16.13% | 23.50% |
| stop 4leg | 853 | 265 | 620 | 208 | 1946 | 14.00% | 16.80% | 21.47% | 21.31% | 16.83% |
| signal T | 211 | 113 | 3 | 1 | 328 | 10.78% | 15.33% | 25.00% | 25.00% | 12.08% |
| stop T | 735 | 237 | 581 | 186 | 1742 | 14.19% | 16.48% | 17.08% | 15.84% | 15.48% |
| signal Y/offset | 37 | 21 | 0 | 0 | 58 | 9.69% | 15.56% | #DIV/0! | #DIV/0! | 11.15% |
| stop Y/offset | 164 | 39 | 97 | 33 | 333 | 12.75% | 11.85% | 16.96% | 17.55% | 13.91% |

## Table 45 California Intersection Possible Injury Crash Severity

| Intersections | # pain/complaint | | | | | % pain/complaint | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| all | 7478 | 2424 | 1490 | 452 | 11862 | 26.82% | 26.25% | 21.48% | 19.05% | 25.46% |
| all 4leg | 5229 | 1822 | 625 | 180 | 7862 | 27.41% | 27.62% | 21.16% | 17.87% | 26.47% |
| all T | 1834 | 488 | 730 | 235 | 3299 | 25.70% | 22.44% | 21.39% | 19.95% | 23.62% |
| all stop | 3173 | 743 | 1473 | 447 | 5849 | 25.27% | 22.22% | 21.47% | 19.12% | 23.20% |
| all signal | 4305 | 1681 | 17 | 5 | 6013 | 28.10% | 28.53% | 22.08% | 14.29% | 28.13% |
| all Y/offset | 415 | 114 | 135 | 37 | 701 | 24.88% | 24.57% | 23.60% | 19.68% | 24.06% |
| signal 4leg | 3662 | 1470 | 14 | 5 | 7133 | 28.21% | 29.29% | 21.54% | 16.13% | 39.44% |
| stop 4leg | 1567 | 352 | 611 | 175 | 2706 | 25.71% | 22.32% | 21.16% | 17.93% | 23.40% |
| signal T | 540 | 179 | 3 | 0 | 722 | 27.59% | 24.29% | 25.00% | 0.00% | 26.58% |
| stop T | 1294 | 309 | 727 | 235 | 2577 | 24.99% | 21.49% | 21.38% | 20.02% | 22.90% |
| signal Y/offset | 103 | 32 | 0 | 0 | 135 | 26.96% | 23.70% | #DIV/0! | #DIV/0! | 25.96% |
| stop Y/offset | 312 | 82 | 135 | 37 | 566 | 24.26% | 24.92% | 23.60% | 19.68% | 23.64% |

## Table 46 California Intersection Property Damage Only Crash Severity

| Intersections | # pdo | | | | | % pdo | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | with lighting day | with lighting night | without lighting day | without lighting night | total | with lighting day | with lighting night | without lighting day | without lighting night | total |
| all | 16159 | 5130 | 3705 | 1277 | 26409 | 57.96% | 55.55% | 53.40% | 53.81% | 56.69% |
| all 4leg | 11005 | 3618 | 1475 | 491 | 16653 | 57.69% | 54.85% | 49.95% | 48.76% | 56.06% |
| all T | 4156 | 1237 | 1925 | 692 | 8062 | 58.25% | 56.87% | 56.40% | 58.74% | 57.71% |
| all stop | 7268 | 1890 | 3665 | 1253 | 14169 | 57.88% | 56.52% | 53.42% | 53.59% | 56.20% |
| all signal | 8891 | 3240 | 40 | 24 | 12240 | 58.04% | 55.00% | 51.95% | 68.57% | 57.26% |
| all Y/offset | 998 | 275 | 305 | 94 | 1694 | 59.83% | 59.27% | 53.32% | 50.00% | 58.13% |
| signal 4leg | 7497 | 2743 | 35 | 21 | 12575 | 57.75% | 54.65% | 53.85% | 67.74% | 69.52% |
| stop 4leg | 3508 | 875 | 1440 | 470 | 6321 | 57.56% | 55.49% | 49.86% | 48.16% | 54.66% |
| signal T | 1162 | 418 | 5 | 3 | 1594 | 59.38% | 56.72% | 41.67% | 75.00% | 58.69% |
| stop T | 2994 | 819 | 1920 | 689 | 6468 | 57.82% | 56.95% | 56.45% | 58.69% | 57.48% |
| signal Y/offset | 232 | 79 | 0 | 0 | 314 | 60.73% | 58.52% | #DIV/0! | #DIV/0! | 60.38% |
| stop Y/offset | 766 | 196 | 305 | 94 | 1380 | 59.56% | 59.57% | 53.32% | 50.00% | 57.64% |

### *4.2.2 Minnesota Interchanges*

Table 47 shows severity distributions for Minnesota interchanges. When considering all interchange forms, the crash severity distribution is as follows, irrespective of time of day and with or without lighting:

- Fatals: 0.42 percent
- Incapacitating injury: 0.81 percent
- Non-incapacitating injury: 6.95 percent
- Possible injury: 18.78 percent
- Property-damage only: 21.40 percent
- Unknown severity: 52.09 percent

When considering nighttime crashes with and without fixed roadway lighting, the proportion of the fatal crashes is higher without lighting than with lighting; the proportion of incapacitating injury crashes is higher without lighting than with lighting; the proportion of non-incapacitating injury crashes without lighting is higher than with lighting; the proportion of possible injury crashes without lighting is lower than with lighting; and, the proportion of property-damage only crashes is higher without lighting than with lighting. As such, the severity distribution suggests that the nighttime crash severity is generally lower at Minnesota interchanges with lighting than at those without lighting. Again, similar trends were observed in the daytime crash frequency data, suggesting that other roadway and traffic control features, in addition to lighting, may be influencing the crash severity distribution.

## Table 47 Minnesota Interchange Fatal Crash Severity

| All Interchange Data | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | With Lighting | | | | | Without Lighting | | | | | | |
| Crash Severity | Day | Percent | Night | Percent | Total | Day | Percent | Night | Percent | Total | Percent | Total |
| Total Crashes | 24293 | 70.22% | 10304 | 29.78% | 34597 | 1176 | 60.65% | 763 | 39.35% | 1939 | 100.00% | 36536 |
| PDO | 5253 | 21.62% | 2136 | 20.73% | 7389 | 248 | 21.09% | 183 | 23.98% | 431 | 21.40% | 7820 |
| Severity Unknown | 12652 | 52.08% | 5299 | 51.43% | 17951 | 539 | 45.83% | 380 | 49.80% | 919 | 51.65% | 18870 |
| Possible Injury | 4688 | 19.30% | 1853 | 17.98% | 6541 | 213 | 18.11% | 107 | 14.02% | 320 | 18.78% | 6861 |
| Minor Injury | 1469 | 6.05% | 848 | 8.23% | 2317 | 143 | 12.16% | 78 | 10.22% | 221 | 6.95% | 2538 |
| Major Injury | 162 | 0.67% | 103 | 1.00% | 265 | 20 | 1.70% | 10 | 1.31% | 30 | 0.81% | 295 |
| Fatal | 69 | 0.28% | 65 | 0.63% | 134 | 13 | 1.11% | 5 | 0.66% | 18 | 0.42% | 152 |
| | | | | | | | | | | | | |
| Urban Interchanges | | | | | | | | | | | | |
| | With Lighting | | | | | Without Lighting | | | | | | |
| Crash Severity | Day | Percent | Night | Percent | Total | Day | Percent | Night | Percent | Total | Percent | Total |
| Total Crashes | 21872 | 70.11% | 9060 | 29.04% | 31292 | 189 | 0.61% | 74 | 0.24% | 265 | 100.00% | 31195 |
| PDO | 4775 | 21.83% | 1898 | 20.95% | 6794 | 43 | 22.75% | 17 | 22.97% | 61 | 21.97% | 6733 |
| Severity Unknown | 11399 | 52.12% | 4621 | 51.00% | 16161 | 83 | 43.92% | 33 | 44.59% | 116 | 52.18% | 16277 |
| Possible Injury | 4247 | 19.42% | 1662 | 18.34% | 5973 | 37 | 19.58% | 11 | 14.86% | 49 | 19.30% | 5957 |
| Minor Injury | 1260 | 5.76% | 735 | 8.11% | 2022 | 19 | 10.05% | 12 | 16.22% | 31 | 6.58% | 2026 |
| Major Injury | 134 | 0.61% | 94 | 1.04% | 234 | 5 | 2.65% | 1 | 1.35% | 6 | 0.77% | 234 |
| Fatal | 57 | 0.26% | 50 | 0.55% | 108 | 2 | 1.06% | 0 | 0.00% | 2 | 0.35% | 109 |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| Rural Interchanges | | | | | | | | | | | | |
| | With Lighting | | | | | Without Lighting | | | | | | |
| Crash Severity | Day | Percent | Night | Percent | Total | Day | Percent | Night | Percent | Total | Percent | Total |
| Total Crashes | 2421 | 44.88% | 1244 | 23.06% | 3699 | 987 | 18.30% | 689 | 12.77% | 1695 | 100.00% | 5394 |
| PDO | 478 | 19.74% | 238 | 19.13% | 728 | 205 | 20.77% | 166 | 24.09% | 378 | 20.50% | 1106 |
| Severity Unknown | 1253 | 51.76% | 678 | 54.50% | 1942 | 456 | 46.20% | 347 | 50.36% | 812 | 51.06% | 2754 |
| Possible Injury | 441 | 18.22% | 191 | 15.35% | 638 | 176 | 17.83% | 96 | 13.93% | 275 | 16.93% | 913 |
| Minor Injury | 209 | 8.63% | 113 | 9.08% | 325 | 124 | 12.56% | 66 | 9.58% | 190 | 9.55% | 515 |
| Major Injury | 28 | 1.16% | 9 | 0.72% | 39 | 15 | 1.52% | 9 | 1.31% | 24 | 1.17% | 63 |
| Fatal | 12 | 0.50% | 15 | 1.21% | 27 | 11 | 1.11% | 5 | 0.73% | 16 | 0.80% | 43 |
| | | | | | | | | | | | | |
| All Diamond Interchanges | | | | | | | | | | | | |
| | With Lighting | | | | | Without Lighting | | | | | | |
| Crash Severity | Day | Percent | Night | Percent | Total | Day | Percent | Night | Percent | Total | Percent | Total |
| Total Crashes | 18190 | 66.46% | 7537 | 27.54% | 25727 | 979 | 3.58% | 662 | 2.42% | 1641 | 100.00% | 27368 |
| PDO | 3891 | 21.39% | 1590 | 21.10% | 5481 | 210 | 21.45% | 165 | 24.92% | 375 | 21.40% | 5856 |
| Severity Unknown | 9528 | 52.38% | 3861 | 51.23% | 13389 | 453 | 46.27% | 325 | 49.09% | 778 | 51.76% | 14167 |
| Possible Injury | 3492 | 19.20% | 1352 | 17.94% | 4844 | 169 | 17.26% | 94 | 14.20% | 263 | 18.66% | 5107 |
| Minor Injury | 1106 | 6.08% | 614 | 8.15% | 1720 | 119 | 12.16% | 67 | 10.12% | 186 | 6.96% | 1906 |
| Major Injury | 123 | 0.68% | 72 | 0.96% | 195 | 18 | 1.84% | 8 | 1.21% | 26 | 0.81% | 221 |
| Fatal | 50 | 0.27% | 48 | 0.64% | 98 | 10 | 1.02% | 3 | 0.45% | 13 | 0.41% | 111 |
| | | | | | | | | | | | | |
| All Non-diamond Interchanges | | | | | | | | | | | | |
| | With Lighting | | | | | Without Lighting | | | | | | |
| Crash Severity | Day | Percent | Night | Percent | Total | Day | Percent | Night | Percent | Total | Percent | Total |
| Total Crashes | 6103 | 66.55% | 2767 | 30.17% | 8870 | 199 | 2.17% | 101 | 1.10% | 300 | 100.00% | 9170 |
| PDO | 1362 | 22.32% | 546 | 19.73% | 1908 | 38 | 19.10% | 18 | 17.82% | 56 | 21.42% | 1964 |
| Severity Unknown | 3124 | 51.19% | 1438 | 51.97% | 4562 | 88 | 44.22% | 55 | 54.46% | 143 | 51.31% | 4705 |
| Possible Injury | 1196 | 19.60% | 501 | 18.11% | 1697 | 44 | 22.11% | 13 | 12.87% | 57 | 19.13% | 1754 |
| Minor Injury | 363 | 5.95% | 234 | 8.46% | 597 | 24 | 12.06% | 11 | 10.89% | 35 | 6.89% | 632 |
| Major Injury | 39 | 0.64% | 31 | 1.12% | 70 | 2 | 1.01% | 2 | 1.98% | 4 | 0.81% | 74 |
| Fatal | 19 | 0.31% | 17 | 0.61% | 36 | 3 | 1.51% | 2 | 1.98% | 5 | 0.45% | 41 |

### *4.2.3 Freeway Segments*

#### 4.2.3.1 Washington

Table 48 shows severity distribution for Washington roadway segments with and without continuous freeway lighting. The crash severity distribution indicates the following:

- The proportion of fatal crashes is higher along roadway sections without lighting when compared to roadway sections with lighting, both during the day and at night;
- The proportion of disabling injury crashes is higher along roadway sections without lighting when compared to roadway sections with lighting, both during the day and at night;
- The proportion of evident injury crashes is higher along roadway sections without lighting when compared to roadway sections with lighting, both during the day and at night;

- The proportion of possible injury crashes is lower along roadway sections without lighting when compared to roadway sections with lighting, both during the day and at night;
- The proportion of property damage only (PDO) crashes is lower along roadway sections without lighting when compared to roadway sections with lighting, both during the day and at night.

**Table 48 Severity Distribution for Washington Freeway Segments**

| Day/Night | Total Length (miles) | Lighting Indicator | Severity Level | COUNTS | Mean Count Per Mile Per Year | Severity Proportion |
|---|---|---|---|---|---|---|
| Day | 760.93 | With Lighting | PDO | 10430 | 2.74 | 63.86% |
| | | | Possible injury | 4816 | 1.27 | 29.49% |
| | | | Evident injury | 954 | 0.25 | 5.84% |
| | | | Disabling injury | 112 | 0.03 | 0.69% |
| | | | Fatal | 21 | 0.01 | 0.13% |
| | | | Total Crashes | 16333 | 4.29 | 100.00% |
| | 767.92 | Without Lighting | PDO | 18689 | 4.87 | 63.42% |
| | | | Possible injury | 7685 | 2.00 | 26.08% |
| | | | Evident injury | 2666 | 0.69 | 9.05% |
| | | | Disabling injury | 325 | 0.08 | 1.10% |
| | | | Fatal | 104 | 0.03 | 0.35% |
| | | | Total Crashes | 29469 | 7.68 | 100.00% |
| Night | 760.93 | With Lighting | PDO | 3193 | 0.84 | 62.85% |
| | | | Possible injury | 1341 | 0.35 | 26.40% |
| | | | Evident injury | 466 | 0.12 | 9.17% |
| | | | Disabling injury | 59 | 0.02 | 1.16% |
| | | | Fatal | 21 | 0.01 | 0.41% |
| | | | Total Crashes | 5080 | 1.34 | 100.00% |
| | 767.92 | Without Lighting | PDO | 7506 | 1.95 | 65.11% |
| | | | Possible injury | 2414 | 0.63 | 20.94% |
| | | | Evident injury | 1308 | 0.34 | 11.35% |
| | | | Disabling injury | 203 | 0.05 | 1.76% |
| | | | Fatal | 97 | 0.03 | 0.84% |
| | | | Total Crashes | 11528 | 3.00 | 100.00% |

4.2.3.2 Oregon and Virginia Freeway Segments

The database acquired from Monsere and Grile (2002) contained only crash frequency data, so a severity distribution for freeway segments with and without lighting in Oregon was not developed for the present study. The freeway segment crash data from Virginia contained severity information at three levels: fatal, injury, and PDO. The severity distributions for locations with and without continuous freeway lighting, stratified by daytime and nighttime periods, are shown in Table 49.

**Table 49 Crash Severity Distribution for Virginia Freeway Segments**

| Lighting Presence | Fatal Crashes (%) | | Injury Crashes (%) | | PDO Crashes (%) | |
|---|---|---|---|---|---|---|
| | Daytime | Nighttime | Daytime | Nighttime | Daytime | Nighttime |
| Without Lighting | 0.1 | 0.1 | 23.3 | 11.0 | 45.8 | 19.8 |
| With Lighting | 0.1 | 0.2 | 24.4 | 9.6 | 47.2 | 18.5 |

Based on the results provided in Table 49, it appears that locations with lighting experience fewer nighttime injury and PDO crashes than segments without lighting, but the proportion of fatal crashes is higher at night with lighting than without lighting. During the day, locations with continuous freeway lighting experience more PDO and injury crashes than locations without lighting; the proportion of fatal crashes with and without lighting is equal during the daytime.

# 5. SUMMARY AND CONCLUSIONS

The results of the negative binomial regression models indicate that the presence of fixed roadway lighting appears to be associated with a safety benefit at intersections included in the present analysis. Using the nighttime and daytime negative binomial crash frequency models for all intersections in California, the difference in the night-day ratios between intersections with lighting and those without lighting is a 22.51 percent lower expected total crash frequency (range is 18 to 26 percent reduction based on $95^{th}$-percentile confidence interval). This suggests that the presence of lighting is associated with a net safety benefit. At nearly all levels of the analysis taxonomy for California intersections, the difference in the night-day crash ratios between lighted and unlighted intersections, computed using the negative binomial regression models, indicated a mean 20 to 30 percent reduction in the night-day crash ratio with lighting. The only exceptions were at signalized tee-intersections and signalized wye- or offset-intersections. The log-linear night-day ratio models, and the night-day descriptive statistics, both produced results that showed a less favorable safety benefit attributed to roadway lighting at intersections. As noted earlier in this report, computing night-day ratios using only crash data does not control for differences in the roadway geometry or traffic control features across intersections. Use of the night-day ratio log-linear models resulted in a significant reduction in the sample size used to estimate the safety effects of roadway lighting. As such, results obtained from the negative binomial regression models appear most suitable in the present study.

For Minnesota intersections, an expected 11.9 percent reduction (5 to 18 percent reduction based on $95^{th}$-percentile confidence interval) in the night-day total crash ratio was computed using the negative binomial regression models for all intersections. At most levels of the analysis taxonomy, the models predict a reduction in the night-day total crash ratio of between 5 and 26 percent. For urban signalized skew intersections, urban signalized t-intersections, urban unsignalized cross-intersections, rural signalized intersections, and rural unsignalized t-intersections, the change in the night-day crash ratio was positive, indicating that the presence of roadway lighting is associated with a crash increase. At most levels of the analysis taxonomy, the night-day ratios computed using only the crash data showed a more favorable safety benefit from the presence of roadway lighting when compared to the negative binomial regression models. The log-linear models exhibited inconsistent results when compared to the negative binomial regression models. Again, the sample size used to estimate the log-linear models was significantly lower than the sample used to estimate the negative binomial models. As such, results from the negative binomial regression models appear more suitable to compute the change in the night-day ratios for Minnesota intersections with and without lighting.

At Minnesota interchange locations, a mean 7.77 percent decrease (6 percent increase to 20 percent reduction based on $95^{th}$-percentile confidence interval) in the night-day ratio at locations with lighting was computed using the negative binomial regression parameter estimates. Similar results were obtained when considering the effects of full or partial interchange lighting. At lower levels of the analysis taxonomy, the safety effects of lighting interchange areas were inconsistent. Computing the night-day ratios using only the crash data showed more favorable safety effects attributed to roadway lighting when compared to the negative binomial regression models, but do not control for the various roadway features present at the analysis locations. As such, the safety effects from roadway lighting at interchange locations that were computed using the negative binomial regression models appear more suitable in the present analysis. Based on the confidence interval around the point estimate of the night-day ratio computed from the negative binomial regression model, the presence of interchange lighting does not appear to have a significant benefit on total crashes.

The freeway segment analysis in Washington indicated that continuous freeway lighting was associated with an expected 4.3 percent increase (2 percent reduction to 11 percent increase based on 95$^{th}$-percentile confidence interval) in the night-day total crash ratio along segments with lighting when compared to segments without lighting. This result was obtained when accounting for interchange and overpass locations, as well as segments with only point lighting. When excluding point lighting locations from the analysis, the models were used to predict an expected 10.4 percent decrease in the night-day ratio for continuous lighting in the median only. If lighting was located only on the right-side of the freeway segment, the models predicted an expected 0.3 percent increase in the night-day ratio on segments with lighting relative to segments without lighting. If continuous lighting was located along both sides of the freeway segment, the negative binomial models predicted an expected 15.0 percent decrease in the night-day crash ratio when comparing lighted segments to those that were not lighted. Similar trends were observed when stratifying the sample into urban and rural segments, where an expected safety benefit was computed for segments with lighting on the median- or on both sides, but an expected increase in the night-day ratio was computed when lighting was present only on the right-side of the freeway segment. When excluding freeway segments with point lighting, interchanges, and overpasses, the sample size was reduced by nearly 90 percent, resulting in large standard errors for the lighting presence parameter estimates. The night-day ratios computed using the crash data generally showed a significant safety benefit for fixed roadway lighting; however, these ratios do not account for the roadway geometrics present along roadway segments.

The freeway segment analyses using data from Oregon and Virginia produced consistent results. In Oregon, a mean 6.7 percent decrease (34.4 percent decrease to 32.6 increase based on 95$^{th}$-percentile confidence interval) in the night-day ratio was computed from the negative binomial regression models, indicating a net safety benefit on roadway segments with continuous freeway lighting. Similarly, the negative binomial regression models estimated using data from Virginia indicated a mean 6.6 percent decrease (5.6 percent increase to 17.5 reduction based on 95$^{th}$-percentile confidence interval) in the night-day ratio for segments with continuous lighting relative to segments without lighting. The night-day ratios computed using only the crash data from Oregon and Virginia indicated that the night-day ratios were lower on segments with continuous lighting when compared to segments without lighting by 19.0 and 5.6 percent, respectively. Based on the continuous freeway lighting analysis using data from Oregon, Virginia, and Washington, the confidence intervals around the mean safety estimates do not suggest that continuous freeway lighting reduces total crash frequency.

In the present analysis, it was assumed that fixed roadway lighting would not be associated with daytime crash frequencies. In many of the models, however, the expected number of daytime crashes was higher at locations with lighting when compared to locations without lighting. This suggests that there are other factors associated with the presence of lighting that were not included in the statistical models. Separate nighttime crash frequency models were estimated to address this issue, assuming that these same unobserved factors would be captured in the lighting presence indicator. The night-day crash ratios were then computed as the metric to determine the association with lighting presence and safety. Future research should attempt to include additional factors in statistical models that may be associated with roadway lighting to address the issue of daytime crash frequencies being associated with the presence of fixed roadway lighting.

The severity distributions computed for intersections, interchanges, and freeway segments generally indicated that the presence of lighting reduced the proportion of the most severe crashes at night; however, this effect was offset by similar reductions at the same locations during the daytime. As such, future research is recommended to determine the change in the severity distributions at locations with and without lighting. This may include estimation of statistical models that not only include the presence of lighting, but also include driver-related factors as well as various geometric and traffic control features present at locations with and without lighting.

As shown in the literature review for NCHRP Project 5-19 (Rea et al. [2009]), past research appears to agree that the presence of roadway lighting is a safety benefit. Generally, published research appears to converge on a 20 to 30 percent reduction in nighttime crashes. This nighttime crash reduction was confirmed by Elvik (1995) in a meta-analysis on the safety effects of roadway lighting. Based on 37 published studies, conducted over a 40-year period, in 11 different countries, the author found that total nighttime crashes are reduced by approximately 23 percent on roadways with lighting. The safety benefits of roadway lighting appeared to be more favorable at junctions (30 percent reduction in nighttime crashes) than on motorways (23 percent reduction in nighttime crashes). The same trends were found in the present study where the safety benefits of lighting presence was greater at intersections than at interchanges or along freeway segments.

Harwood et al. (2007) developed an accident modification factor (AMF) for total crashes using the meta-analysis by Elvik (1995). The AMF is proposed for inclusion in the first edition of the Highway Safety Manual to predict the expected crash frequency along roadway segments, and at-grade intersections, on urban and suburban arterials. Using combined data from Michigan and Minnesota as an example, and adjusting for the proportion of crashes that occur at night, Harwood et al. (2007) illustrated that an appropriate AMF for total crashes on roadway segments with lighting would be approximately 0.96 (i.e., 4 percent reduction in total crashes after installing roadway lighting). Similarly, an AMF for at-grade intersections was estimated using combined data from Minnesota and North Carolina. A 4 percent reduction in total crashes was shown to be an appropriate safety effect estimate for intersection lighting (AMF = 0.96). Assuming that approximately 25 percent of the average daily traffic travels during nighttime periods (which is consistent with Hallmark et al. [2004] and Box [1970]), similar safety effects for roadway lighting at intersections would be obtained from the present study; however, the association between continuous lighting presence and safety on freeway segments is not as apparent in the present study.

In addition to estimating statistical models to determine the effects of lighting on crash severity, additional research is recommended based on the results of the present study. These include:

- Only one state transportation agency was identified that maintained lighting presence data in electronic roadway inventory files for interchanges. Future research should consider estimating statistical models of crash frequency to evaluate the safety effects of full and partial interchange lighting.
- The statistical analyses in the present study considered the presence of roadway lighting. Lighting design parameters (e.g., illuminance, uniformity, and spacing) were either not included in state transportation agency roadway inventory files or were not linkable to electronic roadway data. As such, future research should consider the effects of lighting design on safety. The visibility analyses included in a separate report for NCHRP Project 5-19 addressed the effects of lighting design using relative visual performance (see Bullough et al. [2009]).
- Consider an observational before-after study to determine the effects of roadway lighting presence and lighting-quality at intersections, interchanges, and along roadway segments.

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# APPENDIX A

# CALIFORNIA INTERSECTION MODELING RESULTS

### Table A.1 Nighttime Crash Frequency at Signalized Intersections

```
Negative binomial regression                      Number of obs   =       8494
                                                  LR chi2(11)     =     694.26
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -9418.158                        Pseudo R2       =     0.0355
```

| total_n | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| fourleg | .6554975 | .0992076 | 6.61 | 0.000 | .4610541 | .8499408 |
| tee | .1436888 | .1063655 | 1.35 | 0.177 | -.0647837 | .3521614 |
| lght_typ | -.1613575 | .2036699 | -0.79 | 0.428 | -.5605432 | .2378281 |
| mlltncha | -.0742938 | .060697 | -1.22 | 0.221 | -.1932577 | .0446701 |
| ml_right | .1335361 | .0369311 | 3.62 | 0.000 | .0611524 | .2059197 |
| ltres | -.3252026 | .1159291 | -2.81 | 0.005 | -.5524194 | -.0979857 |
| mllan34 | -.0474021 | .0573136 | -0.83 | 0.408 | -.1597347 | .0649304 |
| mllan56 | .0724366 | .0695266 | 1.04 | 0.297 | -.0638331 | .2087062 |
| med_ind | .1412432 | .0474102 | 2.98 | 0.003 | .0483209 | .2341655 |
| lnmladt | -.0010204 | .0150798 | -0.07 | 0.946 | -.0305764 | .0285355 |
| lnxsadt | .2631832 | .0147547 | 17.84 | 0.000 | .2342646 | .2921019 |
| _cons | -3.007431 | .2833551 | -10.61 | 0.000 | -3.562797 | -2.452066 |
| /lnalpha | -.3339442 | .0551903 | | | -.4421153 | -.2257731 |
| alpha | .7160937 | .0395215 | | | .6426755 | .7978991 |

Likelihood-ratio test of alpha=0: chibar2(01) = 754.16 Prob>=chibar2 = 0.000

### Table A.2 Daytime Crash Frequency at Signalized Intersections

```
Negative binomial regression                      Number of obs   =       8494
                                                  LR chi2(11)     =     947.80
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -15030.774                       Pseudo R2       =     0.0306
```

| total_d | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| fourleg | .5981006 | .0668191 | 8.95 | 0.000 | .4671376 | .7290636 |
| tee | .0803543 | .0716736 | 1.12 | 0.262 | -.0601235 | .220832 |
| lght_typ | .1201818 | .1502131 | 0.80 | 0.424 | -.1742305 | .4145941 |
| mlltncha | -.1416663 | .0430823 | -3.29 | 0.001 | -.226106 | -.0572266 |
| ml_right | .1198676 | .026973 | 4.44 | 0.000 | .0670014 | .1727338 |
| ltres | -.3284141 | .0816943 | -4.02 | 0.000 | -.488532 | -.1682963 |
| mllan34 | .0946837 | .0410342 | 2.31 | 0.021 | .0142581 | .1751093 |
| mllan56 | .1987008 | .0501077 | 3.97 | 0.000 | .1004916 | .29691 |
| med_ind | .0238777 | .0336804 | 0.71 | 0.478 | -.0421347 | .0898901 |
| lnmladt | .0001506 | .0109886 | 0.01 | 0.989 | -.0213868 | .0216879 |
| lnxsadt | .1903048 | .0101652 | 18.72 | 0.000 | .1703814 | .2102282 |
| _cons | -1.62843 | .2043929 | -7.97 | 0.000 | -2.029033 | -1.227827 |
| /lnalpha | -.5327527 | .0343557 | | | -.6000886 | -.4654167 |
| alpha | .586987 | .0201664 | | | .548763 | .6278734 |

Likelihood-ratio test of alpha=0: chibar2(01) = 2514.64 Prob>=chibar2 = 0.000

Table A.3 Nighttime Crash Frequency at Stop-controlled Intersections

Negative binomial regression — Number of obs = 53533; LR chi2(11) = 3277.66; Dispersion = mean; Prob > chi2 = 0.0000; Log likelihood = -16816.184; Pseudo R2 = 0.0888

| total_n | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| fourleg | .401659 | .0547377 | 7.34 | 0.000 | .294375 | .5089429 |
| tee | -.1550745 | .0539808 | -2.87 | 0.004 | -.2608748 | -.0492741 |
| lght_typ | -.1621588 | .0350366 | -4.63 | 0.000 | -.2308292 | -.0934883 |
| mlltncha | .3992548 | .0390965 | 10.21 | 0.000 | .3226272 | .4758825 |
| ml_right | .3322819 | .0488217 | 6.81 | 0.000 | .2365931 | .4279707 |
| ltres | -.6373171 | .1022618 | -6.23 | 0.000 | -.8377466 | -.4368876 |
| mllan34 | .1005901 | .0443774 | 2.27 | 0.023 | .013612 | .1875682 |
| mllan56 | .2214548 | .0799682 | 2.77 | 0.006 | .06472 | .3781897 |
| med_ind | -.0704971 | .0476471 | -1.48 | 0.139 | -.1638836 | .0228894 |
| lnmladt | .1412268 | .0129257 | 10.93 | 0.000 | .1158928 | .1665607 |
| lnxsadt | .4181169 | .0121408 | 34.44 | 0.000 | .3943214 | .4419123 |
| _cons | -6.105697 | .1313854 | -46.47 | 0.000 | -6.363207 | -5.848186 |
| /lnalpha | .4618308 | .0552108 | | | .3536196 | .5700419 |
| alpha | 1.586977 | .0876182 | | | 1.424213 | 1.768341 |

Likelihood-ratio test of alpha=0: chibar2(01) = 788.24 Prob>=chibar2 = 0.000

Table A.4 Daytime Crash Frequency at Stop-controlled Intersections

Negative binomial regression — Number of obs = 53533; LR chi2(11) = 8902.22; Dispersion = mean; Prob > chi2 = 0.0000; Log likelihood = -36501.459; Pseudo R2 = 0.1087

| total_d | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| fourleg | .3894287 | .0341533 | 11.40 | 0.000 | .3224895 | .4563679 |
| tee | -.2067008 | .0333834 | -6.19 | 0.000 | -.2721312 | -.1412705 |
| lght_typ | .1011913 | .0220822 | 4.58 | 0.000 | .0579111 | .1444716 |
| mlltncha | .3799336 | .0246128 | 15.44 | 0.000 | .3316935 | .4281738 |
| ml_right | .2539307 | .033018 | 7.69 | 0.000 | .1892165 | .3186448 |
| ltres | -.6805289 | .0621382 | -10.95 | 0.000 | -.8023174 | -.5587403 |
| mllan34 | .1448535 | .027588 | 5.25 | 0.000 | .0907821 | .198925 |
| mllan56 | .1285369 | .0516046 | 2.49 | 0.013 | .0273937 | .2296801 |
| med_ind | -.1485493 | .0300572 | -4.94 | 0.000 | -.2074604 | -.0896382 |
| lnmladt | .1540217 | .0080697 | 19.09 | 0.000 | .1382054 | .169838 |
| lnxsadt | .433753 | .0077028 | 56.31 | 0.000 | .4186557 | .4488502 |
| _cons | -5.17563 | .0827528 | -62.54 | 0.000 | -5.337823 | -5.013438 |
| /lnalpha | .2834054 | .0250182 | | | .2343707 | .3324402 |
| alpha | 1.327643 | .0332153 | | | 1.264113 | 1.394367 |

Likelihood-ratio test of alpha=0: chibar2(01) = 5099.01 Prob>=chibar2 = 0.000

## Table A.5 Nighttime Crash Frequency at Four-leg Intersections

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 20510 |
| | | LR chi2(10) = | 3704.42 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -14350.041 | | Pseudo R2 = | 0.1143 |

| total_n | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .5288767 | .0415668 | 12.72 | 0.000 | .4474074 | .6103461 |
| lght_typ | -.1138911 | .0470836 | -2.42 | 0.016 | -.2061733 | -.021609 |
| mlltncha | .3125752 | .0419108 | 7.46 | 0.000 | .2304316 | .3947188 |
| ml_right | .1111264 | .0357633 | 3.11 | 0.002 | .0410317 | .1812211 |
| ltres | -.7742412 | .1415403 | -5.47 | 0.000 | -1.051655 | -.4968274 |
| mllan34 | -.0234593 | .0439194 | -0.53 | 0.593 | -.1095398 | .0626212 |
| mllan56 | .0221758 | .06187 | 0.36 | 0.720 | -.099087 | .1434387 |
| med_ind | .0508374 | .0414549 | 1.23 | 0.220 | -.0304127 | .1320874 |
| lnmladt | .05566 | .0126223 | 4.41 | 0.000 | .0309207 | .0803992 |
| lnxsadt | .3325413 | .0123962 | 26.83 | 0.000 | .3082452 | .3568374 |
| _cons | -4.341071 | .1248567 | -34.77 | 0.000 | -4.585786 | -4.096357 |
| /lnalpha | -.1734326 | .0489634 | | | -.2693991 | -.0774661 |
| alpha | .8407738 | .0411671 | | | .7638384 | .9254584 |

Likelihood-ratio test of alpha=0: chibar2(01) = 984.73 Prob>=chibar2 = 0.000

.

## Table A.6 Daytime Crash Frequency at Four-leg Intersections

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 20510 |
| | | LR chi2(10) = | 5799.96 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -26249.872 | | Pseudo R2 = | 0.0995 |

| total_d | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .187809 | .027907 | 6.73 | 0.000 | .1331123 | .2425057 |
| lght_typ | .1752955 | .030076 | 5.83 | 0.000 | .1163476 | .2342434 |
| mlltncha | .2491665 | .0274265 | 9.08 | 0.000 | .1954115 | .3029215 |
| ml_right | .0633353 | .0265985 | 2.38 | 0.017 | .0112033 | .1154674 |
| ltres | -.897536 | .095591 | -9.39 | 0.000 | -1.084891 | -.7101811 |
| mllan34 | .0417367 | .029421 | 1.42 | 0.156 | -.0159273 | .0994007 |
| mllan56 | .0143057 | .0444446 | 0.32 | 0.748 | -.0728042 | .1014156 |
| med_ind | -.0430422 | .0289342 | -1.49 | 0.137 | -.0997523 | .0136679 |
| lnmladt | .0704389 | .0087204 | 8.08 | 0.000 | .0533472 | .0875306 |
| lnxsadt | .3380876 | .0084302 | 40.10 | 0.000 | .3215647 | .3546106 |
| _cons | -3.393503 | .0857402 | -39.58 | 0.000 | -3.56155 | -3.225455 |
| /lnalpha | -.2179179 | .0264014 | | | -.2696637 | -.1661722 |
| alpha | .8041915 | .0212318 | | | .7636363 | .8469004 |

Likelihood-ratio test of alpha=0: chibar2(01) = 4661.13 Prob>=chibar2 = 0.000

.

## Table A.7 Nighttime Crash Frequency at Tee Intersections

Negative binomial regression — Number of obs = 35804; LR chi2(10) = 2316.20

Dispersion = mean — Prob > chi2 = 0.0000

Log likelihood = -10073.871 — Pseudo R2 = 0.1031

| total_n | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .3146287 | .0629599 | 5.00 | 0.000 | .1912295 | .4380279 |
| lght_typ | -.1239344 | .0484833 | -2.56 | 0.011 | -.2189598 | -.028909 |
| mlltncha | .3382613 | .0538702 | 6.28 | 0.000 | .2326776 | .4438449 |
| ml_right | .3461815 | .0590751 | 5.86 | 0.000 | .2303963 | .4619666 |
| ltres | -.3495211 | .1027186 | -3.40 | 0.001 | -.5508458 | -.1481964 |
| mllan34 | .147679 | .0615274 | 2.40 | 0.016 | .0270876 | .2682704 |
| mllan56 | .3503216 | .0903172 | 3.88 | 0.000 | .1733031 | .5273401 |
| med_ind | -.0832786 | .0640409 | -1.30 | 0.193 | -.2087964 | .0422393 |
| lnmladt | .128157 | .0168282 | 7.62 | 0.000 | .0951743 | .1611397 |
| lnxsadt | .4266044 | .0155883 | 27.37 | 0.000 | .3960519 | .4571569 |
| _cons | -6.216904 | .1571157 | -39.57 | 0.000 | -6.524845 | -5.908963 |
| /lnalpha | .3882756 | .0755745 | | | .2401523 | .5363989 |
| alpha | 1.474436 | .1114298 | | | 1.271443 | 1.709838 |

Likelihood-ratio test of alpha=0: chibar2(01) = 429.94 Prob>=chibar2 = 0.000

## Table A.8 Daytime Crash Frequency at Tee Intersections

Negative binomial regression — Number of obs = 35804; LR chi2(10) = 5277.13

Dispersion = mean — Prob > chi2 = 0.0000

Log likelihood = -21476.462 — Pseudo R2 = 0.1094

| total_d | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .0781033 | .0443835 | 1.76 | 0.078 | -.0088868 | .1650934 |
| lght_typ | .0995101 | .030219 | 3.29 | 0.001 | .040282 | .1587382 |
| mlltncha | .3949195 | .0337583 | 11.70 | 0.000 | .3287545 | .4610844 |
| ml_right | .3122609 | .0406806 | 7.68 | 0.000 | .2325284 | .3919934 |
| ltres | -.3895633 | .0645438 | -6.04 | 0.000 | -.5160667 | -.2630598 |
| mllan34 | .2855989 | .0383835 | 7.44 | 0.000 | .2103687 | .3608291 |
| mllan56 | .4102358 | .0591423 | 6.94 | 0.000 | .294319 | .5261525 |
| med_ind | -.1923247 | .0403944 | -4.76 | 0.000 | -.2714963 | -.113153 |
| lnmladt | .1484817 | .0106329 | 13.96 | 0.000 | .1276416 | .1693219 |
| lnxsadt | .4055048 | .0099145 | 40.90 | 0.000 | .3860727 | .4249369 |
| _cons | -5.244946 | .0998629 | -52.52 | 0.000 | -5.440673 | -5.049218 |
| /lnalpha | .2721221 | .0355222 | | | .2024999 | .3417443 |
| alpha | 1.312747 | .0466316 | | | 1.22446 | 1.4074 |

Likelihood-ratio test of alpha=0: chibar2(01) = 2347.15 Prob>=chibar2 = 0.000

## Table A.9 Nighttime Crash Frequency at Wye/Offset Intersections

```
Negative binomial regression                      Number of obs   =       5713
                                                  LR chi2(10)     =     375.84
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1889.0062                       Pseudo R2       =     0.0905

------------------------------------------------------------------------------
     total_n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    sig_cntl |   .1382316   .1394519     0.99   0.322     -.135089    .4115523
    lght_typ |  -.0387059   .1186723    -0.33   0.744    -.2712994    .1938876
    mlltncha |   .1813172   .1363355     1.33   0.184    -.0858954    .4485298
    ml_right |   .4834917   .1485161     3.26   0.001     .1924056    .7745778
       ltres |  -.5252292   .2335949    -2.25   0.025    -.9830669   -.0673916
     mllan34 |   .3755989   .1329871     2.82   0.005     .1149489    .6362489
     mllan56 |   .3966216   .2023704     1.96   0.050    -.0000171    .7932603
     med_ind |    .174923   .1479011     1.18   0.237    -.1149579    .4648039
     lnmladt |    .172588   .0395285     4.37   0.000     .0951135    .2500625
     lnxsadt |    .294424   .0375335     7.84   0.000     .2208597    .3679883
       _cons |  -5.841688   .3679982   -15.87   0.000    -6.562952   -5.120425
-------------+----------------------------------------------------------------
    /lnalpha |   .4034995   .1643047                      .0814681    .7255308
-------------+----------------------------------------------------------------
       alpha |   1.497054   .2459731                      1.084879    2.065827
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =   87.04 Prob>=chibar2 = 0.000
```

## Table A.10 Daytime Crash Frequency at Wye/Offset Intersections

```
Negative binomial regression                      Number of obs   =       5713
                                                  LR chi2(10)     =     925.92
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -4115.6751                       Pseudo R2       =     0.1011

------------------------------------------------------------------------------
     total_d |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    sig_cntl |   -.099207   .0998925    -0.99   0.321    -.2949927    .0965787
    lght_typ |   .3263588   .0738495     4.42   0.000     .1816164    .4711012
    mlltncha |   .4383632   .0864683     5.07   0.000     .2688885    .6078379
    ml_right |    .278881   .1033665     2.70   0.007     .0762864    .4814756
       ltres |  -.4981119    .162377    -3.07   0.002    -.8163649   -.1798589
     mllan34 |   .0165101   .0812287     0.20   0.839    -.1426953    .1757156
     mllan56 |    -.11168   .1399532    -0.80   0.425    -.3859832    .1626231
     med_ind |  -.1365893   .0967888    -1.41   0.158    -.3262918    .0531132
     lnmladt |   .1927221   .0249097     7.74   0.000     .1438999    .2415442
     lnxsadt |   .3699301   .0239308    15.46   0.000     .3230265    .4168337
       _cons |   -5.24207   .2358371   -22.23   0.000    -5.704303   -4.779838
-------------+----------------------------------------------------------------
    /lnalpha |   .4031829   .0688749                      .2681905    .5381752
-------------+----------------------------------------------------------------
       alpha |   1.496581   .1030768                      1.307596    1.712878
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  706.78 Prob>=chibar2 = 0.000
```

.

Table A.11 Nighttime Crash Frequency at Signalized, Four-leg Intersections

```
Negative binomial regression                      Number of obs   =       6290
                                                  LR chi2(9)      =     306.47
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -7633.9591                       Pseudo R2       =     0.0197

------------------------------------------------------------------------------
     total_n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |  -.5049901   .2375554    -2.13   0.034    -.9705902    -.03939
    mlltncha |   -.068523   .0671141    -1.02   0.307    -.2000641   .0630181
    ml_right |   .1262114   .0403309     3.13   0.002     .0471644   .2052585
       ltres |  -.7417399   .1628686    -4.55   0.000    -1.060956  -.4225234
     mllan34 |  -.0763841   .0639554    -1.19   0.232    -.2017344   .0489662
     mllan56 |   .0109408   .0780011     0.14   0.888    -.1419385   .1638201
     med_ind |   .1434854   .0517888     2.77   0.006     .0419813   .2449896
     lnmladt |  -.0005751   .0165033    -0.03   0.972    -.0329209   .0317707
     lnxsadt |   .2475643   .0164267    15.07   0.000     .2153685   .2797601
       _cons |  -1.846162   .3090309    -5.97   0.000    -2.451852  -1.240473
-------------+----------------------------------------------------------------
    /lnalpha |  -.3641492   .0595617                     -.4808881  -.2474104
-------------+----------------------------------------------------------------
       alpha |   .6947875   .0413827                      .6182341   .7808202
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  647.24 Prob>=chibar2 = 0.000
```

.

Table A.12 Daytime Crash Frequency at Signalized, Four-leg Intersections

```
Negative binomial regression                      Number of obs   =       6290
                                                  LR chi2(9)      =     356.05
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -11927.461                       Pseudo R2       =     0.0147

------------------------------------------------------------------------------
     total_d |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |  -.2513577   .1855702    -1.35   0.176    -.6150686   .1123532
    mlltncha |  -.1666395   .0478218    -3.48   0.000    -.2603685  -.0729104
    ml_right |   .1150011   .0295832     3.89   0.000     .0570191   .1729831
       ltres |  -.8812696   .1164033    -7.57   0.000    -1.109416  -.6531234
     mllan34 |   .0569525   .0460816     1.24   0.216    -.0333657   .1472708
     mllan56 |   .1069438   .0565362     1.89   0.059    -.0038651   .2177527
     med_ind |   .0679526   .0370869     1.83   0.067    -.0047364   .1406416
     lnmladt |  -.0086112   .0120889    -0.71   0.476     -.032305   .0150827
     lnxsadt |   .1803001    .011464    15.73   0.000     .1578311   .2027691
       _cons |  -.4489477   .2341807    -1.92   0.055    -.9079335   .0100381
-------------+----------------------------------------------------------------
    /lnalpha |  -.5839137    .037697                     -.6577984  -.5100289
-------------+----------------------------------------------------------------
       alpha |   .5577114    .021024                      .5179905   .6004782
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 2105.80 Prob>=chibar2 = 0.000
```

.

Table A.13 Nighttime Crash Frequency at Signalized, Tee Intersections

```
Negative binomial regression                      Number of obs   =       1830
                                                  LR chi2(9)      =     135.54
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1473.8499                       Pseudo R2       =     0.0440

------------------------------------------------------------------------------
     total_n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |   .7275625   .5351088     1.36   0.174    -.3212315    1.776357
    mlltncha |  -.2259463   .1682567    -1.34   0.179    -.5557234    .1038308
    ml_right |   .2266572   .0979418     2.31   0.021     .0346948    .4186197
       ltres |  -.0823061   .2198585    -0.37   0.708    -.5132208    .3486085
     mllan34 |   .1397559   .1488895     0.94   0.348    -.1520623     .431574
     mllan56 |   .5019131   .1713783     2.93   0.003     .1660179    .8378084
     med_ind |   .0082778   .1386999     0.06   0.952    -.2635691    .2801246
     lnmladt |   .0068662   .0409892     0.17   0.867    -.0734711    .0872035
     lnxsadt |   .3242814   .0363365     8.92   0.000     .2530632    .3954996
       _cons |  -4.341065   .7015611    -6.19   0.000      -5.7161   -2.966031
-------------+----------------------------------------------------------------
    /lnalpha |  -.1355293   .1567485                     -.4427508    .1716922
-------------+----------------------------------------------------------------
       alpha |   .8732536   .1368812                      .6422673    1.187312
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =   93.32 Prob>=chibar2 = 0.000
```

.

Table A.14 Daytime Crash Frequency at Signalized, Tee Intersections

```
Negative binomial regression                      Number of obs   =       1830
                                                  LR chi2(9)      =     223.74
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -2517.4135                       Pseudo R2       =     0.0425

------------------------------------------------------------------------------
     total_d |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |   .7394551   .3236864     2.28   0.022     .1050415    1.373869
    mlltncha |  -.0270067   .1182443    -0.23   0.819    -.2587613    .2047479
    ml_right |   .2046344   .0660745     3.10   0.002     .0751308    .3341381
       ltres |   .1452398   .1524908     0.95   0.341    -.1536367    .4441163
     mllan34 |   .3306574   .1011209     3.27   0.001     .1324641    .5288508
     mllan56 |   .7193201   .1175442     6.12   0.000     .4889377    .9497024
     med_ind |  -.2202703   .0898425    -2.45   0.014    -.3963583   -.0441824
     lnmladt |   .0427851   .0278128     1.54   0.124    -.0117269    .0972972
     lnxsadt |   .2560985   .0231037    11.08   0.000     .2108161     .301381
       _cons |   -3.33104    .445962    -7.47   0.000    -4.205109   -2.456971
-------------+----------------------------------------------------------------
    /lnalpha |  -.5270193     .10119                     -.7253481   -.3286906
-------------+----------------------------------------------------------------
       alpha |    .590362   .0597387                       .484156    .7198657
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  235.80 Prob>=chibar2 = 0.000
```

.

Table A.15 Nighttime Crash Frequency at Signalized, Wye/Offset Intersections

```
Negative binomial regression                      Number of obs   =        374
                                                  LR chi2(9)      =      14.41
Dispersion     = mean                             Prob > chi2     =     0.1086
Log likelihood = -285.40374                       Pseudo R2       =     0.0246

------------------------------------------------------------------------------
     total_n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |   13.81879   1925.948     0.01   0.994    -3760.969    3788.607
    mlltncha |   .2204247   .2880579     0.77   0.444    -.3441585    .7850079
    ml_right |  -.1203247   .2831407    -0.42   0.671    -.6752701    .4346208
       ltres |   .3096953   .4256384     0.73   0.467    -.5245407    1.143931
     mllan34 |  -.1751865   .3149083    -0.56   0.578    -.7923954    .4420224
     mllan56 |  -.2313904    .389041    -0.59   0.552    -.9938968    .5311159
     med_ind |   .2738449   .2408188     1.14   0.255    -.1981514    .7458411
     lnmladt |   .0195551   .0863385     0.23   0.821    -.1496653    .1887755
     lnxsadt |   .3350836   .1196279     2.80   0.005     .1006173    .5695499
       _cons |  -17.96947   1925.948    -0.01   0.993    -3792.757    3756.818
-------------+----------------------------------------------------------------
    /lnalpha |  -1.229114   .7676671                     -2.733714    .2754857
-------------+----------------------------------------------------------------
       alpha |   .2925516   .2245822                      .0649775     1.31717
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =    2.40 Prob>=chibar2 = 0.061
```

Table A.16 Daytime Crash Frequency at Signalized, Wye/Offset Intersections

```
Negative binomial regression                      Number of obs   =        374
                                                  LR chi2(9)      =       9.57
Dispersion     = mean                             Prob > chi2     =     0.3864
Log likelihood = -519.1899                        Pseudo R2       =     0.0091

------------------------------------------------------------------------------
     total_d |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |    17.2033   2137.189     0.01   0.994     -4171.61    4206.016
    mlltncha |   -.172803   .2113692    -0.82   0.414    -.5870791     .241473
    ml_right |    .086472   .2292985     0.38   0.706    -.3629449    .5358888
       ltres |   .0585445   .3208794     0.18   0.855    -.5703676    .6874565
     mllan34 |  -.1181909   .2312985    -0.51   0.609    -.5715276    .3351458
     mllan56 |   -.082538   .2929073    -0.28   0.778    -.6566257    .4915497
     med_ind |  -.1603016   .1900674    -0.84   0.399    -.5328269    .2122237
     lnmladt |   .0325573   .0693752     0.47   0.639    -.1034155    .1685301
     lnxsadt |  -.0512632   .0845659    -0.61   0.544    -.2170093     .114483
       _cons |  -16.75143   2137.189    -0.01   0.994    -4205.564    4172.062
-------------+----------------------------------------------------------------
    /lnalpha |  -.0692543   .1818956                     -.4257631    .2872545
-------------+----------------------------------------------------------------
       alpha |   .9330894   .1697248                      .6532711    1.332763
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =   89.10 Prob>=chibar2 = 0.000
```

## Table A.17 Nighttime Crash Frequency at Stop-controlled, Four-leg Intersections

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 14220 |
| | | LR chi2(9) = | 945.76 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -6627.6334 | | Pseudo R2 = | 0.0666 |

| total_n | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | -.2105725 | .0531903 | -3.96 | 0.000 | -.3148236 | -.1063214 |
| mlltncha | .4510264 | .0564552 | 7.99 | 0.000 | .3403763 | .5616765 |
| ml_right | .1918961 | .0721481 | 2.66 | 0.008 | .0504885 | .3333037 |
| ltres | -1.592226 | .3506561 | -4.54 | 0.000 | -2.2795 | -.904953 |
| mllan34 | -.004084 | .0635918 | -0.06 | 0.949 | -.1287216 | .1205537 |
| mllan56 | -.0161918 | .1362645 | -0.12 | 0.905 | -.2832654 | .2508817 |
| med_ind | -.0720557 | .068174 | -1.06 | 0.291 | -.2056743 | .0615628 |
| lnmladt | .1135378 | .0198063 | 5.73 | 0.000 | .0747183 | .1523574 |
| lnxsadt | .4223719 | .0191829 | 22.02 | 0.000 | .3847742 | .4599696 |
| _cons | -5.409494 | .1926972 | -28.07 | 0.000 | -5.787174 | -5.031814 |
| /lnalpha | .2864056 | .0810798 | | | .1274921 | .4453192 |
| alpha | 1.331632 | .1079686 | | | 1.135976 | 1.560988 |

Likelihood-ratio test of alpha=0: chibar2(01) = 348.32 Prob>=chibar2 = 0.000

## Table A.18 Daytime Crash Frequency at Stop-controlled, Four-leg Intersections

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 14220 |
| | | LR chi2(9) = | 2477.00 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -14012.257 | | Pseudo R2 = | 0.0812 |

| total_d | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | .0698004 | .0342752 | 2.04 | 0.042 | .0026222 | .1369785 |
| mlltncha | .3410019 | .0360695 | 9.45 | 0.000 | .270307 | .4116968 |
| ml_right | .1145468 | .0489348 | 2.34 | 0.019 | .0186364 | .2104572 |
| ltres | -1.348291 | .1756806 | -7.67 | 0.000 | -1.692619 | -1.003963 |
| mllan34 | .0178318 | .0403769 | 0.44 | 0.659 | -.0613054 | .0969691 |
| mllan56 | -.0964315 | .0897491 | -1.07 | 0.283 | -.2723364 | .0794734 |
| med_ind | -.1423488 | .0439456 | -3.24 | 0.001 | -.2284805 | -.056217 |
| lnmladt | .12549 | .0125462 | 10.00 | 0.000 | .1008999 | .1500802 |
| lnxsadt | .4551796 | .0123439 | 36.87 | 0.000 | .430986 | .4793732 |
| _cons | -4.555415 | .1233449 | -36.93 | 0.000 | -4.797166 | -4.313663 |
| /lnalpha | .1264685 | .0365949 | | | .0547438 | .1981933 |
| alpha | 1.134814 | .0415284 | | | 1.05627 | 1.219198 |

Likelihood-ratio test of alpha=0: chibar2(01) = 2416.02 Prob>=chibar2 = 0.000

.

Table A.19 Nighttime Crash Frequency at Stop-controlled, Tee Intersections

```
Negative binomial regression                      Number of obs   =      33974
                                                  LR chi2(9)      =    1452.15
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -8561.7788                       Pseudo R2       =     0.0782

------------------------------------------------------------------------------
     total_n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |  -.1379249   .0500687    -2.75   0.006    -.2360577    -.039792
    mlltncha |   .3628024   .0577889     6.28   0.000     .2495382    .4760667
    ml_right |    .437131   .0714038     6.12   0.000     .2971822    .5770797
       ltres |  -.5735366   .1237676    -4.63   0.000    -.8161167   -.3309566
     mllan34 |   .1529334   .0675056     2.27   0.023     .0206248    .2852419
     mllan56 |    .308699    .109907     2.81   0.005     .0932851    .5241128
     med_ind |  -.0969483   .0714655    -1.36   0.175    -.2370182    .0431215
     lnmladt |   .1479407   .0185004     8.00   0.000     .1116807    .1842008
     lnxsadt |   .4333521   .0171742    25.23   0.000     .3996912     .467013
       _cons |  -6.433075   .1719839   -37.41   0.000    -6.770157   -6.095993
-------------+----------------------------------------------------------------
    /lnalpha |   .5629813   .0863542                      .3937301    .7322325
-------------+----------------------------------------------------------------
       alpha |     1.7559   .1516294                        1.4825    2.079718
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  326.49 Prob>=chibar2 = 0.000
```

Table A.20 Daytime Crash Frequency at Stop-controlled, Tee Intersections

```
Negative binomial regression                      Number of obs   =      33974
                                                  LR chi2(9)      =    3929.44
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -18845.79                        Pseudo R2       =     0.0944

------------------------------------------------------------------------------
     total_d |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |   .0917047    .031311     2.93   0.003     .0303362    .1530733
    mlltncha |   .3992568   .0359823    11.10   0.000     .3287328    .4697807
    ml_right |   .3762739   .0481978     7.81   0.000     .2818079    .4707399
       ltres |  -.5917986   .0746105    -7.93   0.000    -.7380325   -.4455648
     mllan34 |   .2881039   .0414825     6.95   0.000     .2067996    .3694082
     mllan56 |   .3185721   .0694732     4.59   0.000     .1824072    .4547371
     med_ind |  -.1829326   .0444345    -4.12   0.000    -.2700226   -.0958425
     lnmladt |   .1615991   .0114958    14.06   0.000     .1390677    .1841304
     lnxsadt |   .4189914   .0108194    38.73   0.000     .3977857    .4401971
       _cons |  -5.434232   .1078528   -50.39   0.000    -5.645619   -5.222844
-------------+----------------------------------------------------------------
    /lnalpha |   .4060604   .0381587                      .3312707      .48085
-------------+----------------------------------------------------------------
       alpha |   1.500893   .0572721                      1.392737    1.617449
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 2049.71 Prob>=chibar2 = 0.000
```

.

## Table A.21 Nighttime Crash Frequency at Stop-controlled, Wye/Offset Intersections

Negative binomial regression — Number of obs = 5339; LR chi2(9) = 263.29

Dispersion = mean — Prob > chi2 = 0.0000

Log likelihood = -1588.087 — Pseudo R2 = 0.0765

| total_n | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | -.0660367 | .1240162 | -0.53 | 0.594 | -.3091041 | .1770307 |
| mlltncha | .1481959 | .1601022 | 0.93 | 0.355 | -.1655986 | .4619904 |
| ml_right | .6147544 | .1734669 | 3.54 | 0.000 | .2747656 | .9547433 |
| ltres | -.80907 | .2823511 | -2.87 | 0.004 | -1.362468 | -.2556721 |
| mllan34 | .41918 | .1498961 | 2.80 | 0.005 | .1253889 | .712971 |
| mllan56 | .5454333 | .2449523 | 2.23 | 0.026 | .0653357 | 1.025531 |
| med_ind | .1716879 | .1827129 | 0.94 | 0.347 | -.1864228 | .5297986 |
| lnmladt | .202322 | .04431 | 4.57 | 0.000 | .115476 | .2891679 |
| lnxsadt | .2969429 | .0409108 | 7.26 | 0.000 | .2167592 | .3771267 |
| _cons | -6.120546 | .4100147 | -14.93 | 0.000 | -6.92416 | -5.316932 |
| /lnalpha | .7480604 | .1660624 | | | .422584 | 1.073537 |
| alpha | 2.112898 | .3508729 | | | 1.525899 | 2.925709 |

Likelihood-ratio test of alpha=0: chibar2(01) = 96.66 Prob>=chibar2 = 0.000

## Table A.22 Daytime Crash Frequency at Stop-controlled, Wye/Offset Intersections

Negative binomial regression — Number of obs = 62027; LR chi2(9) = 16139.25

Dispersion = mean — Prob > chi2 = 0.0000

Log likelihood = -52663.208 — Pseudo R2 = 0.1329

| total_d | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | .2132609 | .0202835 | 10.51 | 0.000 | .1735059 | .2530159 |
| mlltncha | .3462093 | .0207068 | 16.72 | 0.000 | .3056247 | .3867939 |
| ml_right | .1835214 | .0225001 | 8.16 | 0.000 | .1394219 | .2276208 |
| ltres | -.6691504 | .0479764 | -13.95 | 0.000 | -.7631824 | -.5751184 |
| mllan34 | .1862352 | .0224141 | 8.31 | 0.000 | .1423042 | .2301661 |
| mllan56 | .2010967 | .0345704 | 5.82 | 0.000 | .13334 | .2688534 |
| med_ind | -.1212837 | .0232834 | -5.21 | 0.000 | -.1669183 | -.0756491 |
| lnmladt | .1087546 | .0065631 | 16.57 | 0.000 | .0958912 | .1216181 |
| lnxsadt | .4369189 | .0056419 | 77.44 | 0.000 | .425861 | .4479769 |
| _cons | -4.793478 | .0609838 | -78.60 | 0.000 | -4.913004 | -4.673952 |
| /lnalpha | .0841143 | .0196956 | | | .0455116 | .122717 |
| alpha | 1.087753 | .021424 | | | 1.046563 | 1.130564 |

Likelihood-ratio test of alpha=0: chibar2(01) = 8767.45 Prob>=chibar2 = 0.000

..

## Table A.23 Log-linear Regression Model for Signalized Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 16.9726993 | 11 | 1.54297267 |
| Residual | 1521.87591 | 2850 | .533991546 |
| Total | 1538.84861 | 2861 | .537870886 |

| | |
|---|---|
| Number of obs = | 2862 |
| F( 11, 2850) = | 2.89 |
| Prob > F = | 0.0009 |
| R-squared = | 0.0110 |
| Adj R-squared = | 0.0072 |
| Root MSE = | .73075 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| fourleg | -.0248632 | .091186 | -0.27 | 0.785 | -.2036603 | .1539339 |
| tee | .1184383 | .097799 | 1.21 | 0.226 | -.0733258 | .3102023 |
| lght_typ | -.1692033 | .1838822 | -0.92 | 0.358 | -.529759 | .1913523 |
| mlltncha | .1376608 | .050519 | 2.72 | 0.006 | .0386032 | .2367183 |
| ml_right | -.0338712 | .0308321 | -1.10 | 0.272 | -.0943267 | .0265843 |
| ltres | .1856594 | .0973058 | 1.91 | 0.056 | -.0051375 | .3764563 |
| mllan34 | -.0288585 | .0489818 | -0.59 | 0.556 | -.1249018 | .0671848 |
| mllan56 | -.1192405 | .0596474 | -2.00 | 0.046 | -.2361969 | -.0022841 |
| med_ind | .0038051 | .0398946 | 0.10 | 0.924 | -.0744202 | .0820303 |
| lnmladt | .0168799 | .0128388 | 1.31 | 0.189 | -.0082943 | .0420542 |
| lnxsadt | -.0068811 | .0120363 | -0.57 | 0.568 | -.0304818 | .0167197 |
| _cons | -.5153513 | .2541477 | -2.03 | 0.043 | -1.013683 | -.0170193 |

## Table A.24 Log-linear Regression Model for Stop-controlled Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 47.1188764 | 11 | 4.28353422 |
| Residual | 949.96769 | 2422 | .39222448 |
| Total | 997.086566 | 2433 | .409817742 |

| | |
|---|---|
| Number of obs = | 2434 |
| F( 11, 2422) = | 10.92 |
| Prob > F = | 0.0000 |
| R-squared = | 0.0473 |
| Adj R-squared = | 0.0429 |
| Root MSE = | .62628 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| fourleg | -.027735 | .0482123 | -0.58 | 0.565 | -.1222767 | .0668067 |
| tee | .1366073 | .0491061 | 2.78 | 0.005 | .0403131 | .2329015 |
| lght_typ | -.0397144 | .0286861 | -1.38 | 0.166 | -.0959662 | .0165374 |
| mlltncha | -.1036154 | .0310491 | -3.34 | 0.001 | -.164501 | -.0427299 |
| ml_right | -.1113747 | .0376771 | -2.96 | 0.003 | -.1852572 | -.0374921 |
| ltres | -.099561 | .1031391 | -0.97 | 0.334 | -.3018111 | .1026891 |
| mllan34 | -.0198821 | .0366091 | -0.54 | 0.587 | -.0916704 | .0519062 |
| mllan56 | .0658324 | .0618016 | 1.07 | 0.287 | -.0553572 | .1870219 |
| med_ind | .0824447 | .0383825 | 2.15 | 0.032 | .0071787 | .1577106 |
| lnmladt | -.0080601 | .0109749 | -0.73 | 0.463 | -.0295812 | .013461 |
| lnxsadt | -.053084 | .0105822 | -5.02 | 0.000 | -.073835 | -.032333 |
| _cons | .0593277 | .1233526 | 0.48 | 0.631 | -.1825598 | .3012152 |

.

Table A.25 Log-linear Regression Model for Four-leg Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 18.0103642 | 10 | 1.80103642 |
| Residual | 1897.54582 | 3674 | .516479537 |
| Total | 1915.55618 | 3684 | .519966391 |

| | |
|---|---|
| Number of obs = | 3685 |
| F( 10, 3674) = | 3.49 |
| Prob > F = | 0.0001 |
| R-squared = | 0.0094 |
| Adj R-squared = | 0.0067 |
| Root MSE = | .71867 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .0160636 | .0348445 | 0.46 | 0.645 | -.0522529 | .0843801 |
| lght_typ | -.1013809 | .0437119 | -2.32 | 0.020 | -.1870829 | -.0156788 |
| mlltncha | .0025133 | .035542 | 0.07 | 0.944 | -.0671707 | .0721972 |
| ml_right | -.0272455 | .028883 | -0.94 | 0.346 | -.0838739 | .0293829 |
| ltres | .3896218 | .1230157 | 3.17 | 0.002 | .1484359 | .6308076 |
| mllan34 | .0047167 | .0376054 | 0.13 | 0.900 | -.0690129 | .0784462 |
| mllan56 | -.0680349 | .0515628 | -1.32 | 0.187 | -.1691295 | .0330596 |
| med_ind | .0419774 | .0343829 | 1.22 | 0.222 | -.0254341 | .1093888 |
| lnmladt | .0083342 | .0107623 | 0.77 | 0.439 | -.0127665 | .029435 |
| lnxsadt | -.0266843 | .0105334 | -2.53 | 0.011 | -.0473361 | -.0060325 |
| _cons | -.3179901 | .1179695 | -2.70 | 0.007 | -.5492823 | -.0866979 |

Table A.26 Log-linear Regression Model for Tee Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 15.1518978 | 10 | 1.51518978 |
| Residual | 465.623755 | 1335 | .348781839 |
| Total | 480.775653 | 1345 | .357454017 |

| | |
|---|---|
| Number of obs = | 1346 |
| F( 10, 1335) = | 4.34 |
| Prob > F = | 0.0000 |
| R-squared = | 0.0315 |
| Adj R-squared = | 0.0243 |
| Root MSE = | .59058 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .0330864 | .0453837 | 0.73 | 0.466 | -.0559447 | .1221175 |
| lght_typ | .0121986 | .0408293 | 0.30 | 0.765 | -.067898 | .0922952 |
| mlltncha | -.0966428 | .0436406 | -2.21 | 0.027 | -.1822544 | -.0110312 |
| ml_right | -.1039917 | .0423755 | -2.45 | 0.014 | -.1871216 | -.0208619 |
| ltres | -.226885 | .0830885 | -2.73 | 0.006 | -.3898833 | -.0638867 |
| mllan34 | -.0629741 | .0502112 | -1.25 | 0.210 | -.1614756 | .0355274 |
| mllan56 | -.0428029 | .068051 | -0.63 | 0.529 | -.1763013 | .0906956 |
| med_ind | .0358372 | .0502453 | 0.71 | 0.476 | -.0627311 | .1344054 |
| lnmladt | -.0081721 | .0142625 | -0.57 | 0.567 | -.0361515 | .0198073 |
| lnxsadt | -.0356675 | .0125423 | -2.84 | 0.005 | -.0602723 | -.0110627 |
| _cons | .1036945 | .1401085 | 0.74 | 0.459 | -.1711624 | .3785513 |

Table A.27 Log-linear Regression Model for Wye/Offset Intersections

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| Model | 8.89087976 | 10 | .889087976 | Number of obs = | 265 |
| Residual | 110.569707 | 254 | .435313807 | F( 10, 254) = | 2.04 |
| Total | 119.460587 | 264 | .452502222 | Prob > F = | 0.0297 |
| | | | | R-squared = | 0.0744 |
| | | | | Adj R-squared = | 0.0380 |
| | | | | Root MSE = | .65978 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sig_cntl | .0149772 | .1204366 | 0.12 | 0.901 | -.2222044 | .2521588 |
| lght_typ | -.1013449 | .1068806 | -0.95 | 0.344 | -.31183 | .1091402 |
| mlltncha | -.136959 | .1197977 | -1.14 | 0.254 | -.3728822 | .0989642 |
| ml_right | -.2157577 | .1238242 | -1.74 | 0.083 | -.4596107 | .0280952 |
| ltres | -.1788878 | .2434754 | -0.73 | 0.463 | -.6583756 | .3005999 |
| mllan34 | .0616837 | .1160478 | 0.53 | 0.596 | -.1668548 | .2902222 |
| mllan56 | -.0092139 | .1765997 | -0.05 | 0.958 | -.357 | .3385723 |
| med_ind | .244236 | .1304688 | 1.87 | 0.062 | -.0127024 | .5011743 |
| lnmladt | .0321734 | .0379101 | 0.85 | 0.397 | -.0424847 | .1068316 |
| lnxsadt | -.0597779 | .038963 | -1.53 | 0.126 | -.1365095 | .0169537 |
| _cons | -.3012334 | .3977018 | -0.76 | 0.449 | -1.084447 | .4819797 |

Table A.28 Log-linear Regression Model for Signalized, Four-leg Intersections

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| Model | 12.9393148 | 9 | 1.43770164 | Number of obs = | 2440 |
| Residual | 1343.28828 | 2430 | .552793531 | F( 9, 2430) = | 2.60 |
| Total | 1356.22759 | 2439 | .556058874 | Prob > F = | 0.0055 |
| | | | | R-squared = | 0.0095 |
| | | | | Adj R-squared = | 0.0059 |
| | | | | Root MSE = | .7435 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | -.1632917 | .1933548 | -0.84 | 0.398 | -.542449 | .2158657 |
| mlltncha | .1362408 | .0562272 | 2.42 | 0.015 | .0259826 | .2464991 |
| ml_right | -.0295993 | .033879 | -0.87 | 0.382 | -.0960341 | .0368354 |
| ltres | .5124301 | .1363291 | 3.76 | 0.000 | .2450968 | .7797633 |
| mllan34 | -.0082609 | .0547896 | -0.15 | 0.880 | -.1157001 | .0991782 |
| mllan56 | -.0881594 | .0674173 | -1.31 | 0.191 | -.2203607 | .0440418 |
| med_ind | .0032415 | .0441165 | 0.07 | 0.941 | -.0832684 | .0897514 |
| lnmladt | .0217055 | .0141249 | 1.54 | 0.124 | -.0059925 | .0494035 |
| lnxsadt | -.0083862 | .0132726 | -0.63 | 0.528 | -.0344129 | .0176406 |
| _cons | -.6043408 | .2553279 | -2.37 | 0.018 | -1.105024 | -.1036579 |

Table A.29 Log-linear Regression Model for Signalized, Tee Intersections

```
   Source |       SS       df       MS              Number of obs =     355
-------------+------------------------------           F(  9,   345) =    1.80
       Model |  6.52279844     9  .724755382           Prob > F      =  0.0665
    Residual |   138.65555   345  .401900145           R-squared     =  0.0449
-------------+------------------------------           Adj R-squared =  0.0200
       Total |  145.178349   354  .410108329           Root MSE      =  .63396

------------------------------------------------------------------------------
     lnntday |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |   -.330324   .6368789    -0.52   0.604    -1.582978    .9223301
    mlltncha |   .1668343   .1256287     1.33   0.185    -.0802603    .4139289
    ml_right |  -.1061384   .0749063    -1.42   0.157     -.253469    .0411921
       ltres |  -.0682121   .1617449    -0.42   0.673    -.3863424    .2499182
     mllan34 |  -.1408728   .1124026    -1.25   0.211    -.3619535    .0802078
     mllan56 |    -.29711   .1288979    -2.31   0.022    -.5506347   -.0435853
     med_ind |   .0191749   .1010198     0.19   0.850    -.1795174    .2178671
     lnmladt |  -.0392368   .0320805    -1.22   0.222    -.1023347    .0238612
     lnxsadt |   .0014542   .0288016     0.05   0.960    -.0551946    .0581029
       _cons |   .3647468   .7485085     0.49   0.626    -1.107468    1.836961
------------------------------------------------------------------------------
```

Table A.30 Log-linear Regression Model for Signalized, Wye/Offset Intersections

```
      Source |       SS       df       MS              Number of obs =      67
-------------+------------------------------           F(  8,    58) =    0.76
       Model |  2.91249828     8  .364062285           Prob > F      =  0.6357
    Residual |  27.6489861    58  .476706657           R-squared     =  0.0953
-------------+------------------------------           Adj R-squared = -0.0295
       Total |  30.5614844    66  .463052794           Root MSE      =  .69044

------------------------------------------------------------------------------
     lnntday |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lght_typ |  (dropped)
    mlltncha |   .1265767     .27745     0.46   0.650    -.4287999    .6819532
    ml_right |    .226762   .2897694     0.78   0.437    -.3532745    .8067986
       ltres |  -.2447303   .3586895    -0.68   0.498    -.9627253    .4732647
     mllan34 |   .0720703   .3760762     0.19   0.849    -.6807279    .8248685
     mllan56 |  -.3251513   .4459435    -0.73   0.469    -1.217804    .5675015
     med_ind |   .1595017   .2480575     0.64   0.523    -.3370393    .6560426
     lnmladt |   .1029183   .0882738     1.17   0.248     -.073781    .2796176
     lnxsadt |  -.1066517   .1158036    -0.92   0.361    -.3384577    .1251544
       _cons |  -.8388531   1.178598    -0.71   0.479    -3.198074    1.520368
------------------------------------------------------------------------------
```

Table A.31 Log-linear Regression Model for Stop-controlled, Four-leg Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 13.7265927 | 9 | 1.52517697 |
| Residual | 542.943217 | 1235 | .439630135 |
| Total | 556.66981 | 1244 | .44748377 |

| | |
|---|---|
| Number of obs | = 1245 |
| F( 9, 1235) | = 3.47 |
| Prob > F | = 0.0003 |
| R-squared | = 0.0247 |
| Adj R-squared | = 0.0176 |
| Root MSE | = .66305 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | -.0685009 | .0433443 | -1.58 | 0.114 | -.1535375 | .0165357 |
| mlltncha | -.0899448 | .0443243 | -2.03 | 0.043 | -.1769041 | -.0029856 |
| ml_right | -.0561153 | .0582001 | -0.96 | 0.335 | -.1702973 | .0580668 |
| ltres | .0594111 | .3906558 | 0.15 | 0.879 | -.7070114 | .8258335 |
| mllan34 | .0074574 | .0520551 | 0.14 | 0.886 | -.0946689 | .1095837 |
| mllan56 | -.0475031 | .1006917 | -0.47 | 0.637 | -.2450489 | .1500427 |
| med_ind | .1042379 | .0544429 | 1.91 | 0.056 | -.0025728 | .2110487 |
| lnmladt | -.01566 | .0161861 | -0.97 | 0.333 | -.0474152 | .0160953 |
| lnxsadt | -.0647212 | .0173652 | -3.73 | 0.000 | -.0987898 | -.0306526 |
| _cons | .1652048 | .1815345 | 0.91 | 0.363 | -.1909453 | .5213549 |

Table A.32 Log-linear Regression Model for Stop-controlled, Tee Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 15.4030131 | 9 | 1.7114459 |
| Residual | 318.180234 | 981 | .324342746 |
| Total | 333.583247 | 990 | .336952774 |

| | |
|---|---|
| Number of obs | = 991 |
| F( 9, 981) | = 5.28 |
| Prob > F | = 0.0000 |
| R-squared | = 0.0462 |
| Adj R-squared | = 0.0374 |
| Root MSE | = .56951 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | .0012878 | .040256 | 0.03 | 0.974 | -.07771 | .0802856 |
| mlltncha | -.1333039 | .0459362 | -2.90 | 0.004 | -.2234485 | -.0431593 |
| ml_right | -.118027 | .0521548 | -2.26 | 0.024 | -.2203748 | -.0156791 |
| ltres | -.1492342 | .1054754 | -1.41 | 0.157 | -.3562175 | .0577492 |
| mllan34 | -.0643944 | .0564923 | -1.14 | 0.255 | -.1752541 | .0464653 |
| mllan56 | .1170564 | .0836932 | 1.40 | 0.162 | -.047182 | .2812947 |
| med_ind | .0363149 | .0576537 | 0.63 | 0.529 | -.0768238 | .1494537 |
| lnmladt | -.0039525 | .0157358 | -0.25 | 0.802 | -.0348321 | .0269271 |
| lnxsadt | -.0410495 | .0137836 | -2.98 | 0.003 | -.0680982 | -.0140008 |
| _cons | .1160649 | .1526169 | 0.76 | 0.447 | -.1834281 | .415558 |

Table A.33 Log-linear Regression Model for Stop-controlled, Wye/Offset Intersections

| Source | SS | df | MS |
|---|---|---|---|
| Model | 9.45788023 | 9 | 1.05087558 |
| Residual | 79.2371569 | 188 | .421474239 |
| Total | 88.6950371 | 197 | .450228615 |

| | |
|---|---|
| Number of obs = | 198 |
| F( 9, 188) = | 2.49 |
| Prob > F = | 0.0103 |
| R-squared = | 0.1066 |
| Adj R-squared = | 0.0639 |
| Root MSE = | .64921 |

| lnntday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lght_typ | -.1011074 | .1060858 | -0.95 | 0.342 | -.3103789 | .108164 |
| mlltncha | -.128923 | .137109 | -0.94 | 0.348 | -.3993928 | .1415468 |
| ml_right | -.3186755 | .1428198 | -2.23 | 0.027 | -.6004109 | -.0369402 |
| ltres | .203484 | .3901212 | 0.52 | 0.603 | -.5660935 | .9730616 |
| mllan34 | .0705385 | .127736 | 0.55 | 0.581 | -.1814415 | .3225184 |
| mllan56 | .1699066 | .2074821 | 0.82 | 0.414 | -.2393855 | .5791987 |
| med_ind | .1914675 | .1625482 | 1.18 | 0.240 | -.1291853 | .5121204 |
| lnmladt | .0176642 | .0421658 | 0.42 | 0.676 | -.0655148 | .1008431 |
| lnxsadt | -.0545003 | .0411127 | -1.33 | 0.187 | -.1356018 | .0266012 |
| _cons | -.1899423 | .4336625 | -0.44 | 0.662 | -1.045412 | .6655275 |

# APPENDIX B

# MINNESOTA INTERSECTION MODELING RESULTS

Table B1. Day Crash Frequency Model for All Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:10:04AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 22058 |
| Iterations completed | 20 |
| Log likelihood function | -27087.49 |
| Restricted log likelihood | -30979.15 |
| Chi squared | 7783.324 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.53264106 | .15084148 | -43.308 | .0000 | |
| LNADTMAJ | .60061020 | .01546967 | 38.825 | .0000 | 8.52246180 |
| LNADTMN | .16030383 | .00735881 | 21.784 | .0000 | 6.98494400 |
| LIGHTING | .04758165 | .03059577 | 1.555 | .1199 | .45752108 |
| SKEW | .48770956 | .03066339 | 15.905 | .0000 | .11342823 |
| URBSUB | -.09952432 | .02931312 | -3.395 | .0007 | .48077795 |
| SIGNALIZ | .64559033 | .03058379 | 21.109 | .0000 | .14629613 |
| HIGHSP50 | -.15982583 | .02174191 | -7.351 | .0000 | .67014235 |
| PER | -.00926586 | .00278935 | -3.322 | .0009 | 8.59552611 |
| DEPRESS | .08544284 | .03359337 | 2.543 | .0110 | .12911415 |
| NOACCON | -.04216732 | .03818598 | -1.104 | .2695 | .93634962 |
| LSHPAV | -.11804647 | .04224130 | -2.795 | .0052 | .46559072 |
| RSHPAV | .08085443 | .04143621 | 1.951 | .0510 | .51287515 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .94974485 | .02361081 | 40.225 | .0000 | |

Table B2. Night Crash Frequency Model for All Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:10:47AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 22058 |
| Iterations completed | 18 |
| Log likelihood function | -15168.45 |
| Restricted log likelihood | -15887.89 |
| Chi squared | 1438.897 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.88625456 | .20593927 | -33.438 | .0000 | |
| LNADTMAJ | .57217224 | .02138705 | 26.753 | .0000 | 8.52246180 |
| LNADTMN | .12658194 | .01027589 | 12.318 | .0000 | 6.98494400 |
| LIGHTING | -.07917456 | .04244971 | -1.865 | .0622 | .45752108 |
| SKEW | .48549137 | .03980885 | 12.196 | .0000 | .11342823 |
| URBSUB | -.42133795 | .04005058 | -10.520 | .0000 | .48077795 |
| SIGNALIZ | .71287769 | .04140312 | 17.218 | .0000 | .14629613 |
| HIGHSP50 | -.11296275 | .02915918 | -3.874 | .0001 | .67014235 |
| PER | -.01699813 | .00385689 | -4.407 | .0000 | 8.59552611 |
| DEPRESS | .17152343 | .04295123 | 3.993 | .0001 | .12911415 |
| NOACCON | -.01600660 | .04711328 | -.340 | .7340 | .93634962 |
| LSHPAV | -.29194832 | .05344464 | -5.463 | .0000 | .46559072 |
| RSHPAV | .21655019 | .05242544 | 4.131 | .0000 | .51287515 |
| | Dispersion parameter for count data model | | | | |
| Alpha | .89631324 | .04077399 | 21.982 | .0000 | |

Table B3. Day Crash Frequency Model for All Signalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:14:42AM.|
| Dependent variable             TOTAL_D      |
| Weighting variable                None      |
| Number of observations            3227      |
| Iterations completed                17      |
| Log likelihood function      -7420.663      |
| Restricted log likelihood    -8202.862      |
| Chi squared                   1564.398      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .0000000      |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.74859828 | .30509550 | -22.120 | .0000 | |
| LNADTMAJ | .67589263 | .03217919 | 21.004 | .0000 | 9.70895835 |
| LNADTMN | .16882637 | .01929906 | 8.748 | .0000 | 9.02913538 |
| LIGHTING | -.00314848 | .08748358 | -.036 | .9713 | .96870158 |
| SKEW | .22739053 | .03958161 | 5.745 | .0000 | .17415556 |
| URBSUB | .04366528 | .04690217 | .931 | .3519 | .89092036 |
| HIGHSP50 | -.03657944 | .02842000 | -1.287 | .1981 | .61140378 |
| PER | -.00449086 | .00465688 | -.964 | .3349 | 5.55126106 |
| DEPRESS | .10611267 | .04337423 | 2.446 | .0144 | .26216300 |
| NOACCON | -.12100355 | .03829957 | -3.159 | .0016 | .83885962 |
| LSHPAV | -.08452831 | .04831751 | -1.749 | .0802 | .39727301 |
| RSHPAV | .00404509 | .04111404 | .098 | .9216 | .54942671 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .32707037 | .01558563 | 20.985 | .0000 | |

Table B4. Night Crash Frequency Model for All Signalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:15:09AM.|
| Dependent variable            TOTAL_N       |
| Weighting variable               None       |
| Number of observations           3227       |
| Iterations completed               17       |
| Log likelihood function     -4459.628       |
| Restricted log likelihood   -4578.791       |
| Chi squared                  238.3262       |
| Degrees of freedom                  1       |
| Prob[ChiSqd > value] =       .0000000       |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -8.93674705 | .44658154 | -20.011 | .0000 | |
| LNADTMAJ | .72543708 | .04801223 | 15.109 | .0000 | 9.70895835 |
| LNADTMN | .23698629 | .03131641 | 7.567 | .0000 | 9.02913538 |
| LIGHTING | -.05647396 | .13346751 | -.423 | .6722 | .96870158 |
| SKEW | .33593750 | .05731117 | 5.862 | .0000 | .17415556 |
| URBSUB | -.10493485 | .06597372 | -1.591 | .1117 | .89092036 |
| HIGHSP50 | -.03639427 | .04071996 | -.894 | .3714 | .61140378 |
| PER | -.02507615 | .00698033 | -3.592 | .0003 | 5.55126106 |
| DEPRESS | .00822407 | .06067522 | .136 | .8922 | .26216300 |
| NOACCON | -.08038171 | .05271473 | -1.525 | .1273 | .83885962 |
| LSHPAV | -.08380479 | .06779798 | -1.236 | .2164 | .39727301 |
| RSHPAV | .15855726 | .05798045 | 2.735 | .0062 | .54942671 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .33765043 | .03166679 | 10.663 | .0000 | |

Table B5. Day Crash Frequency Model for All Unsignalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:15:52AM.|
| Dependent variable             TOTAL_D      |
| Weighting variable                None      |
| Number of observations           18831      |
| Iterations completed                17      |
| Log likelihood function      -19163.23      |
| Restricted log likelihood    -22656.42      |
| Chi squared                   6986.380      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .0000000      |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant    -6.45883774      .18977032   -34.035   .0000
 LNADTMAJ      .58971787      .01897214    31.083   .0000    8.31913620
 LNADTMN       .15788576      .00854233    18.483   .0000    6.63463836
 LIGHTING      .06392618      .03746466     1.706   .0880     .36992194
 SKEW          .59747159      .04198203    14.232   .0000     .10302161
 URBSUB      -.12247154      .03739590    -3.275   .0011     .41049334
 HIGHSP50    -.21469146      .02916637    -7.361   .0000     .68020817
 PER         -.00950971      .00344301    -2.762   .0057    9.11721074
 DEPRESS       .09720011      .04849047     2.005   .0450     .10631406
 NOACCON       .00935651      .06182603      .151   .8797     .95305613
 LSHPAV      -.18944322      .06808325    -2.783   .0054     .47729807
 RSHPAV        .17108417      .06876060     2.488   .0128     .50661144
          Dispersion parameter for count data model
 Alpha        1.58900005      .04289051    37.048   .0000
```

Table B6. Night Crash Frequency Model for All Unsignalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:16:18AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations            18831     |
| Iterations completed                 18     |
| Log likelihood function       -10515.34     |
| Restricted log likelihood     -11208.37     |
| Chi squared                    1386.060     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant     -6.49687303      .25532202   -25.446   .0000
 LNADTMAJ       .53760734      .02598646    20.688   .0000    8.31913620
 LNADTMN        .10851344      .01158771     9.365   .0000    6.63463836
 LIGHTING     -.01348695      .05076050     -.266   .7905     .36992194
 SKEW           .60107219      .05464859    10.999   .0000     .10302161
 URBSUB       -.49207514      .05099836    -9.649   .0000     .41049334
 HIGHSP50     -.15329308      .03954312    -3.877   .0001     .68020817
 PER          -.01402336      .00466530    -3.006   .0026    9.11721074
 DEPRESS        .22888717      .06250214     3.662   .0003     .10631406
 NOACCON        .01821295      .07827623      .233   .8160     .95305613
 LSHPAV       -.34988871      .08885618    -3.938   .0001     .47729807
 RSHPAV         .24753759      .09032665     2.740   .0061     .50661144
          Dispersion parameter for count data model
 Alpha         1.68204391      .08420331    19.976   .0000
```

Table B7. Day Crash Frequency Model for All Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:18:09AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 10593 |
| Iterations completed | 18 |
| Log likelihood function | -14147.74 |
| Restricted log likelihood | -15753.35 |
| Chi squared | 3211.219 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.84660749 | .19295887 | -35.482 | .0000 | |
| LNADTMAJ | .16994546 | .05403770 | 3.145 | .0017 | 8.48707935 |
| LNADTMN | .65880736 | .05706381 | 11.545 | .0000 | 8.00819948 |
| LIGHTING | -.02453100 | .04419007 | -.555 | .5788 | .53129425 |
| URBSUB | -.06277456 | .04123673 | -1.522 | .1279 | .53856320 |
| SIGNALIZ | .61660836 | .03559440 | 17.323 | .0000 | .22713112 |
| HIGHSP50 | -.09131889 | .02733207 | -3.341 | .0008 | .68129897 |
| PER | -.00675841 | .00353626 | -1.911 | .0560 | 8.81875288 |
| DEPRESS | -.01364508 | .04266265 | -.320 | .7491 | .12640423 |
| NOACCON | -.09042185 | .04643478 | -1.947 | .0515 | .94043236 |
| LSHPAV | .03645914 | .05189697 | .703 | .4823 | .37609742 |
| RSHPAV | -.03532071 | .04839407 | -.730 | .4655 | .42934013 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .64669086 | .02360382 | 27.398 | .0000 | |

Table B8. Night Crash Frequency Model for All Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:18:29AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 10593 |
| Iterations completed | 18 |
| Log likelihood function | -7703.160 |
| Restricted log likelihood | -7985.448 |
| Chi squared | 564.5753 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.24568341 | .27843559 | -26.023 | .0000 | |
| LNADTMAJ | .11395738 | .07582519 | 1.503 | .1329 | 8.48707935 |
| LNADTMN | .65289618 | .07966015 | 8.196 | .0000 | 8.00819948 |
| LIGHTING | -.18302131 | .06449057 | -2.838 | .0045 | .53129425 |
| URBSUB | -.34594228 | .05809517 | -5.955 | .0000 | .53856320 |
| SIGNALIZ | .71005197 | .05252644 | 13.518 | .0000 | .22713112 |
| HIGHSP50 | -.08502325 | .03846411 | -2.210 | .0271 | .68129897 |
| PER | -.02113041 | .00521960 | -4.048 | .0001 | 8.81875288 |
| DEPRESS | .09992351 | .05737490 | 1.742 | .0816 | .12640423 |
| NOACCON | -.02821129 | .05978772 | -.472 | .6370 | .94043236 |
| LSHPAV | -.17006592 | .06867861 | -2.476 | .0133 | .37609742 |
| RSHPAV | .19918602 | .06338407 | 3.143 | .0017 | .42934013 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .62873297 | .04340109 | 14.487 | .0000 | |

Table B9. Day Crash Frequency Model for All Skew Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:19:02AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 2502 |
| Iterations completed | 17 |
| Log likelihood function | -3816.239 |
| Restricted log likelihood | -4562.848 |
| Chi squared | 1493.219 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.83649774 | .45373582 | -15.067 | .0000 | |
| LNADTMAJ | .62852968 | .04620484 | 13.603 | .0000 | 8.63901733 |
| LNADTMN | .25091759 | .02794492 | 8.979 | .0000 | 6.52253795 |
| LIGHTING | .33100045 | .08240136 | 4.017 | .0001 | .47681855 |
| URBSUB | -.36559402 | .07955706 | -4.595 | .0000 | .47042366 |
| SIGNALIZ | .13335235 | .08686258 | 1.535 | .1247 | .22462030 |
| HIGHSP50 | -.14109421 | .05796415 | -2.434 | .0149 | .69104716 |
| PER | -.01621833 | .00772590 | -2.099 | .0358 | 8.82625316 |
| DEPRESS | .03971078 | .08528086 | .466 | .6415 | .16626699 |
| NOACCON | .07057007 | .09177739 | .769 | .4419 | .90487610 |
| LSHPAV | .04129539 | .11311582 | .365 | .7151 | .58193445 |
| RSHPAV | -.06074305 | .11482333 | -.529 | .5968 | .62949640 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .91175073 | .05517813 | 16.524 | .0000 | |

Table B10. Night Crash Frequency Model for All Skew Minnesota Intersections

| Negative Binomial Regression | |
|---|---|
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:19:37AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 2502 |
| Iterations completed | 17 |
| Log likelihood function | -2260.145 |
| Restricted log likelihood | -2415.651 |
| Chi squared | 311.0136 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -8.64315652 | .60046505 | -14.394 | .0000 | |
| LNADTMAJ | .72688505 | .06082010 | 11.951 | .0000 | 8.63901733 |
| LNADTMN | .23867633 | .03715944 | 6.423 | .0000 | 6.52253795 |
| LIGHTING | .21341119 | .11152736 | 1.914 | .0557 | .47681855 |
| URBSUB | -.53355608 | .10646864 | -5.011 | .0000 | .47042366 |
| SIGNALIZ | .05182383 | .11302149 | .459 | .6466 | .22462030 |
| HIGHSP50 | -.09968322 | .07443079 | -1.339 | .1805 | .69104716 |
| PER | -.255397D-04 | .01023172 | -.002 | .9980 | 8.82625316 |
| DEPRESS | .02583016 | .10725705 | .241 | .8097 | .16626699 |
| NOACCON | .14425747 | .11221534 | 1.286 | .1986 | .90487610 |
| LSHPAV | -.01076510 | .14291811 | -.075 | .9400 | .58193445 |
| RSHPAV | -.14177913 | .14402146 | -.984 | .3249 | .62949640 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .89670311 | .09199663 | 9.747 | .0000 | |

Table B11. Day Crash Frequency Model for All Tee Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:20:14AM.|
| Dependent variable              TOTAL_D     |
| Weighting variable                 None     |
| Number of observations             8963     |
| Iterations completed                 18     |
| Log likelihood function       -8856.289     |
| Restricted log likelihood     -10436.66     |
| Chi squared                    3160.736     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -5.89662928 | .28233264 | -20.885 | .0000 | |
| LNADTMAJ | .57770886 | .02790069 | 20.706 | .0000 | 8.53174266 |
| LNADTMN | .10433486 | .01156675 | 9.020 | .0000 | 5.90468010 |
| LIGHTING | -.03399687 | .05279564 | -.644 | .5196 | .36494477 |
| URBSUB | -.05615028 | .05122836 | -1.096 | .2730 | .41537432 |
| SIGNALIZ | .69798419 | .09886746 | 7.060 | .0000 | .02889657 |
| HIGHSP50 | -.27931572 | .04241123 | -6.586 | .0000 | .65112128 |
| PER | -.01186188 | .00547851 | -2.165 | .0304 | 8.26729669 |
| DEPRESS | .20407093 | .06828495 | 2.989 | .0028 | .12194578 |
| NOACCON | -.09750650 | .08260494 | -1.180 | .2378 | .94031016 |
| LSHPAV | -.33448715 | .08634722 | -3.874 | .0001 | .53888207 |
| RSHPAV | .26191216 | .08886684 | 2.947 | .0032 | .57904719 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.67478497 | .06718893 | 24.927 | .0000 | |

Table B12. Night Crash Frequency Model for All Tee Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:20:42AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 8963 |
| Iterations completed | 18 |
| Log likelihood function | -5100.943 |
| Restricted log likelihood | -5375.175 |
| Chi squared | 548.4651 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -5.87672215 | .36212310 | -16.229 | .0000 | |
| LNADTMAJ | .51108537 | .03622867 | 14.107 | .0000 | 8.53174266 |
| LNADTMN | .08707337 | .01546013 | 5.632 | .0000 | 5.90468010 |
| LIGHTING | -.12666815 | .06776424 | -1.869 | .0616 | .36494477 |
| URBSUB | -.45192824 | .06585855 | -6.862 | .0000 | .41537432 |
| SIGNALIZ | .72151034 | .11721069 | 6.156 | .0000 | .02889657 |
| HIGHSP50 | -.15950331 | .05446852 | -2.928 | .0034 | .65112128 |
| PER | -.01490102 | .00695475 | -2.143 | .0321 | 8.26729669 |
| DEPRESS | .24233719 | .08515263 | 2.846 | .0044 | .12194578 |
| NOACCON | -.15893467 | .09954235 | -1.597 | .1103 | .94031016 |
| LSHPAV | -.48266614 | .10584825 | -4.560 | .0000 | .53888207 |
| RSHPAV | .29432170 | .11009581 | 2.673 | .0075 | .57904719 |
| Dispersion parameter for count data model | | | | | |
| Alpha | 1.49154430 | .11217198 | 13.297 | .0000 | |

Table B13. Day Crash Frequency Model for All Urban Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:22:23AM.|
| Dependent variable              TOTAL_D     |
| Weighting variable                 None     |
| Number of observations            10605     |
| Iterations completed                 18     |
| Log likelihood function       -15723.07     |
| Restricted log likelihood     -17820.19     |
| Chi squared                    4194.242     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.39542636 | .20758396 | -35.626 | .0000 | |
| LNADTMAJ | .69312728 | .02056588 | 33.703 | .0000 | 8.93925369 |
| LNADTMN | .14325722 | .00970060 | 14.768 | .0000 | 7.61005548 |
| LIGHTING | .06982479 | .03982644 | 1.753 | .0796 | .81423857 |
| SIGNALIZ | .66417158 | .03270074 | 20.311 | .0000 | .27109854 |
| SKEW | .37309117 | .03769015 | 9.899 | .0000 | .11098538 |
| HIGHSP50 | -.13978397 | .02581154 | -5.416 | .0000 | .62083923 |
| PER | .00102902 | .00379190 | .271 | .7861 | 7.10717803 |
| DEPRESS | .04740628 | .04278226 | 1.108 | .2678 | .11824611 |
| NOACCON | -.06493810 | .04220183 | -1.539 | .1239 | .92267798 |
| LSHPAV | -.00317613 | .04654401 | -.068 | .9456 | .36115040 |
| RSHPAV | -.05894422 | .04258546 | -1.384 | .1663 | .44045262 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .70453938 | .02319544 | 30.374 | .0000 | |

Table B14. Night Crash Frequency Model for All Urban Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:22:43AM.|
| Dependent variable               TOTAL_N    |
| Weighting variable                  None    |
| Number of observations             10605    |
| Iterations completed                  16    |
| Log likelihood function        -8209.186    |
| Restricted log likelihood      -8582.260    |
| Chi squared                     746.1476    |
| Degrees of freedom                     1    |
| Prob[ChiSqd > value] =          .0000000    |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -8.23025802 | .31133226 | -26.436 | .0000 | |
| LNADTMAJ | .67200159 | .03128921 | 21.477 | .0000 | 8.93925369 |
| LNADTMN | .12630883 | .01511418 | 8.357 | .0000 | 7.61005548 |
| LIGHTING | -.08536231 | .06168714 | -1.384 | .1664 | .81423857 |
| SIGNALIZ | .73030069 | .04831000 | 15.117 | .0000 | .27109854 |
| SKEW | .42580674 | .05194166 | 8.198 | .0000 | .11098538 |
| HIGHSP50 | -.13593034 | .03703963 | -3.670 | .0002 | .62083923 |
| PER | -.01550855 | .00578751 | -2.680 | .0074 | 7.10717803 |
| DEPRESS | .11928686 | .05881800 | 2.028 | .0426 | .11824611 |
| NOACCON | -.03933892 | .05523693 | -.712 | .4764 | .92267798 |
| LSHPAV | -.18731501 | .06384067 | -2.934 | .0033 | .36115040 |
| RSHPAV | .16427662 | .05734069 | 2.865 | .0042 | .44045262 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .73427708 | .04541467 | 16.168 | .0000 | |

Table B15. Day Crash Frequency Model for Urban Signalized Minnesota Intersections

| Negative Binomial Regression | |
| --- | --- |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:23:31AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 2875 |
| Iterations completed | 16 |
| Log likelihood function | -6637.240 |
| Restricted log likelihood | -7379.624 |
| Chi squared | 1484.768 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
| --- | --- | --- | --- | --- | --- |
| Constant | -6.50267849 | .32500633 | -20.008 | .0000 | |
| LNADTMAJ | .66106742 | .03415663 | 19.354 | .0000 | 9.70266139 |
| LNADTMN | .16219915 | .02048459 | 7.918 | .0000 | 9.03185966 |
| LIGHTING | .03379945 | .09961396 | .339 | .7344 | .97217391 |
| SKEW | .21591982 | .04142157 | 5.213 | .0000 | .17878261 |
| HIGHSP50 | -.04826888 | .03018526 | -1.599 | .1098 | .60104348 |
| PER | -.00833491 | .00516090 | -1.615 | .1063 | 5.44667753 |
| DEPRESS | .06069128 | .04793850 | 1.266 | .2055 | .23826087 |
| NOACCON | -.13303869 | .04093847 | -3.250 | .0012 | .84069565 |
| LSHPAV | -.02072160 | .05242216 | -.395 | .6926 | .34400000 |
| RSHPAV | -.00431818 | .04304374 | -.100 | .9201 | .50365217 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .33835619 | .01680866 | 20.130 | .0000 | |

Table B16. Night Crash Frequency Model for Urban Signalized Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:23:58AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 2875 |
| Iterations completed | 16 |
| Log likelihood function | -3940.872 |
| Restricted log likelihood | -4045.988 |
| Chi squared | 210.2315 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -9.18517422 | .47852489 | -19.195 | .0000 | |
| LNADTMAJ | .73062436 | .05092417 | 14.347 | .0000 | 9.70266139 |
| LNADTMN | .24845524 | .03386847 | 7.336 | .0000 | 9.03185966 |
| LIGHTING | -.03356483 | .15685097 | -.214 | .8306 | .97217391 |
| SKEW | .33931968 | .05987103 | 5.668 | .0000 | .17878261 |
| HIGHSP50 | -.04208159 | .04315055 | -.975 | .3294 | .60104348 |
| PER | -.02916415 | .00775545 | -3.760 | .0002 | 5.44667753 |
| DEPRESS | -.01416974 | .06682751 | -.212 | .8321 | .23826087 |
| NOACCON | -.09266252 | .05562517 | -1.666 | .0957 | .84069565 |
| LSHPAV | -.06965974 | .07288797 | -.956 | .3392 | .34400000 |
| RSHPAV | .15157643 | .05994703 | 2.529 | .0115 | .50365217 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .33672865 | .03376810 | 9.972 | .0000 | |

Table B17. Day Crash Frequency Model for Urban Unsignalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:24:37AM.|
| Dependent variable             TOTAL_D      |
| Weighting variable                None      |
| Number of observations            7730      |
| Iterations completed                18      |
| Log likelihood function      -8800.517      |
| Restricted log likelihood    -10369.59      |
| Chi squared                   3138.137      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .0000000      |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.71145461 | .30158210 | -25.570 | .0000 | |
| LNADTMAJ | .72162967 | .02859220 | 25.239 | .0000 | 8.65532133 |
| LNADTMN | .13717364 | .01226967 | 11.180 | .0000 | 7.08124733 |
| LIGHTING | .05263560 | .04942478 | 1.065 | .2869 | .75549806 |
| SKEW | .57186186 | .06630215 | 8.625 | .0000 | .08576973 |
| HIGHSP50 | -.22195787 | .04153669 | -5.344 | .0000 | .62820181 |
| PER | .00934229 | .00546058 | 1.711 | .0871 | 7.72476393 |
| DEPRESS | .04552367 | .07979708 | .570 | .5683 | .07360931 |
| NOACCON | .03800811 | .08814559 | .431 | .6663 | .95316947 |
| LSHPAV | .02326850 | .08715170 | .267 | .7895 | .36752911 |
| RSHPAV | -.10580662 | .08527286 | -1.241 | .2147 | .41694696 |
| Dispersion parameter for count data model | | | | | |
| Alpha | 1.42086894 | .05607419 | 25.339 | .0000 | |

Table B18. Night Crash Frequency Model for Urban Unsignalized Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:25:02AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 7730 |
| Iterations completed | 17 |
| Log likelihood function | -4109.605 |
| Restricted log likelihood | -4470.158 |
| Chi squared | 721.1056 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.54554919 | .46635251 | -16.180 | .0000 | |
| LNADTMAJ | .62725022 | .04512582 | 13.900 | .0000 | 8.65532133 |
| LNADTMN | .08367199 | .01873851 | 4.465 | .0000 | 7.08124733 |
| LIGHTING | -.08978536 | .07624689 | -1.178 | .2390 | .75549806 |
| SKEW | .71642034 | .09834180 | 7.285 | .0000 | .08576973 |
| HIGHSP50 | -.26603315 | .06449416 | -4.125 | .0000 | .62820181 |
| PER | .00075714 | .00862544 | .088 | .9301 | 7.72476393 |
| DEPRESS | .25341418 | .11807388 | 2.146 | .0319 | .07360931 |
| NOACCON | -.02830633 | .12920289 | -.219 | .8266 | .95316947 |
| LSHPAV | -.23635619 | .13088295 | -1.806 | .0709 | .36752911 |
| RSHPAV | .08886383 | .12786671 | .695 | .4871 | .41694696 |
| Dispersion parameter for count data model | | | | | |
| Alpha | 2.19140748 | .16254618 | 13.482 | .0000 | |

Table B19. Day Crash Frequency Model for Urban Signalized Cross Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:26:12AM.|
| Dependent variable              TOTAL_D     |
| Weighting variable                 None     |
| Number of observations             2158     |
| Iterations completed                 16     |
| Log likelihood function       -4960.373     |
| Restricted log likelihood     -5507.643     |
| Chi squared                    1094.540     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.44969909 | .38057610 | -16.947 | .0000 | |
| LNADTMAJ | .58062561 | .06703993 | 8.661 | .0000 | 9.67838374 |
| LNADTMN | .25656355 | .07041171 | 3.644 | .0003 | 9.27893123 |
| LIGHTING | -.04806528 | .12355390 | -.389 | .6973 | .97775718 |
| HIGHSP50 | -.04289559 | .03470146 | -1.236 | .2164 | .59592215 |
| PER | -.00788670 | .00570494 | -1.382 | .1668 | 5.51110903 |
| DEPRESS | .00486484 | .05966777 | .082 | .9350 | .21362373 |
| NOACCON | -.18624869 | .04982562 | -3.738 | .0002 | .87303058 |
| LSHPAV | .02539302 | .06439989 | .394 | .6934 | .29101019 |
| RSHPAV | -.03887524 | .04963291 | -.783 | .4335 | .45690454 |
| | Dispersion parameter for count data model | | | | |
| Alpha | .32811667 | .01887348 | 17.385 | .0000 | |

Table B20. Night Crash Frequency Model for Urban Signalized Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:26:35AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 2158 |
| Iterations completed | 16 |
| Log likelihood function | -2924.645 |
| Restricted log likelihood | -3014.327 |
| Chi squared | 179.3628 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -9.29486754 | .57048626 | -16.293 | .0000 | |
| LNADTMAJ | .30626355 | .09968152 | 3.072 | .0021 | 9.67838374 |
| LNADTMN | .74031602 | .10598999 | 6.985 | .0000 | 9.27893123 |
| LIGHTING | -.35545333 | .18123783 | -1.961 | .0498 | .97775718 |
| HIGHSP50 | -.04755818 | .05083089 | -.936 | .3495 | .59592215 |
| PER | -.03335134 | .00882949 | -3.777 | .0002 | 5.51110903 |
| DEPRESS | -.14103047 | .08470581 | -1.665 | .0959 | .21362373 |
| NOACCON | -.10180859 | .06914530 | -1.472 | .1409 | .87303058 |
| LSHPAV | .04354556 | .09049061 | .481 | .6304 | .29101019 |
| RSHPAV | .13520413 | .07014626 | 1.927 | .0539 | .45690454 |
| | Dispersion parameter for count data model | | | | |
| Alpha | .35518044 | .03954782 | 8.981 | .0000 | |

Table B21. Day Crash Frequency Model for Urban Signalized Skew Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:27:06AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 514 |
| Iterations completed | 15 |
| Log likelihood function | -1224.874 |
| Restricted log likelihood | -1359.843 |
| Chi squared | 269.9394 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.18404375 | .79828811 | -8.999 | .0000 | |
| LNADTMAJ | .71008733 | .07781102 | 9.126 | .0000 | 9.73023153 |
| LNADTMN | .17317375 | .03964990 | 4.368 | .0000 | 8.41171648 |
| LIGHTING | .14601602 | .20497700 | .712 | .4762 | .96108949 |
| HIGHSP50 | -.11968312 | .07032882 | -1.702 | .0888 | .60700389 |
| PER | -.02332911 | .01450267 | -1.609 | .1077 | 5.44478066 |
| DEPRESS | .21303203 | .09608516 | 2.217 | .0266 | .30350195 |
| NOACCON | .09313155 | .08503799 | 1.095 | .2734 | .73540856 |
| LSHPAV | .01035587 | .11078216 | .093 | .9255 | .46303502 |
| RSHPAV | .15207441 | .10479715 | 1.451 | .1467 | .61478599 |
| | Dispersion parameter for count data model | | | | |
| Alpha | .32817502 | .03883258 | 8.451 | .0000 | |

Table B22. Night Crash Frequency Model for Urban Signalized Skew Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:27:31AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations              514     |
| Iterations completed                 16     |
| Log likelihood function       -739.3866     |
| Restricted log likelihood     -747.3102     |
| Chi squared                    15.84714     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .6866965E-04 |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -10.1534095 | 1.07882432 | -9.412 | .0000 | |
| LNADTMAJ | .75636468 | .10152848 | 7.450 | .0000 | 9.73023153 |
| LNADTMN | .27250115 | .05616434 | 4.852 | .0000 | 8.41171648 |
| LIGHTING | .64447459 | .38080210 | 1.692 | .0906 | .96108949 |
| HIGHSP50 | -.07536585 | .09155159 | -.823 | .4104 | .60700389 |
| PER | -.01755791 | .01919180 | -.915 | .3603 | 5.44478066 |
| DEPRESS | .22305835 | .12419271 | 1.796 | .0725 | .30350195 |
| NOACCON | .08583094 | .10754402 | .798 | .4248 | .73540856 |
| LSHPAV | -.12621377 | .14835948 | -.851 | .3949 | .46303502 |
| RSHPAV | .08986331 | .13650432 | .658 | .5103 | .61478599 |
| | Dispersion parameter for count data model | | | | |
| Alpha | .19942882 | .06325688 | 3.153 | .0016 | |

Table B23. Day Crash Frequency Model for Urban Signalized Tee Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:28:05AM.|
| Dependent variable             TOTAL_D      |
| Weighting variable                None      |
| Number of observations             203      |
| Iterations completed                17      |
| Log likelihood function      -428.0800      |
| Restricted log likelihood    -453.0799      |
| Chi squared                   49.99974      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .0000000      |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant     -7.25332434     1.30951275    -5.539   .0000
 LNADTMAJ       .78387081      .12898612     6.077   .0000    9.89093783
 LNADTMN        .06448167      .03335774     1.933   .0532    7.97556980
 LIGHTING       .26040133      .34248326      .760   .4471     .94088670
 HIGHSP50       .07023095      .13196672      .532   .5946     .64039409
 PER            .01435673      .02341399      .613   .5398    4.76653865
 DEPRESS      -.20700625      .15974400    -1.296   .1950     .33497537
 NOACCON      -.16657606      .14786075    -1.127   .2599     .76354680
 LSHPAV       -.01572775      .19226360     -.082   .9348     .60591133
 RSHPAV       -.19631326      .20129528     -.975   .3294     .71921182
         Dispersion parameter for count data model
 Alpha          .31798312      .07176408     4.431   .0000
```

Table B24. Night Crash Frequency Model for Urban Signalized Tee Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:28:23AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations              203     |
| Iterations completed                 16     |
| Log likelihood function       -243.7161     |
| Restricted log likelihood     -245.5207     |
| Chi squared                    3.609148     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =        .5746256E-01 |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -11.9205466 | 1.94157347 | -6.140 | .0000 | |
| LNADTMAJ | 1.03301420 | .18254639 | 5.659 | .0000 | 9.89093783 |
| LNADTMN | .08435517 | .05018253 | 1.681 | .0928 | 7.97556980 |
| LIGHTING | 1.03884190 | .76349966 | 1.361 | .1736 | .94088670 |
| HIGHSP50 | -.20323702 | .18297047 | -1.111 | .2667 | .64039409 |
| PER | .04831234 | .03410108 | 1.417 | .1566 | 4.76653865 |
| DEPRESS | -.19810430 | .21078902 | -.940 | .3473 | .33497537 |
| NOACCON | -.46271715 | .19254630 | -2.403 | .0163 | .76354680 |
| LSHPAV | -.11070715 | .26603310 | -.416 | .6773 | .60591133 |
| RSHPAV | .19031634 | .29162080 | .653 | .5140 | .71921182 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .20316904 | .13106400 | 1.550 | .1211 | |

Table B25. Day Crash Frequency Model for Urban Unsignalized Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:28:55AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 3547 |
| Iterations completed | 18 |
| Log likelihood function | -4181.529 |
| Restricted log likelihood | -4732.424 |
| Chi squared | 1101.790 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.54302056 | .40148894 | -18.788 | .0000 | |
| LNADTMAJ | -.06538544 | .11802237 | -.554 | .5796 | 8.53089692 |
| LNADTMN | .97978375 | .12860594 | 7.618 | .0000 | 8.05411635 |
| LIGHTING | -.00698841 | .07649024 | -.091 | .9272 | .83281646 |
| HIGHSP50 | -.14389276 | .05667146 | -2.539 | .0111 | .64899915 |
| PER | .00972247 | .00721525 | 1.347 | .1778 | 8.22710724 |
| DEPRESS | -.15908581 | .12081232 | -1.317 | .1879 | .05497604 |
| NOACCON | -.13255378 | .12982661 | -1.021 | .3073 | .96306738 |
| LSHPAV | .15231216 | .12930552 | 1.178 | .2388 | .26332112 |
| RSHPAV | -.24822667 | .12381024 | -2.005 | .0450 | .30279109 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.05153302 | .06481192 | 16.224 | .0000 | |

Table B26. Night Crash Frequency Model for Urban Unsignalized Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:29:16AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 3547 |
| Iterations completed | 16 |
| Log likelihood function | -1853.269 |
| Restricted log likelihood | -1998.719 |
| Chi squared | 290.9000 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.36088717 | .66574812 | -11.057 | .0000 | |
| LNADTMAJ | -.04585723 | .19548428 | -.235 | .8145 | 8.53089692 |
| LNADTMN | .74772243 | .21175257 | 3.531 | .0004 | 8.05411635 |
| LIGHTING | .11051074 | .13249772 | .834 | .4042 | .83281646 |
| HIGHSP50 | -.21996286 | .09581461 | -2.296 | .0217 | .64899915 |
| PER | .00438711 | .01228307 | .357 | .7210 | 8.22710724 |
| DEPRESS | .36362566 | .18742754 | 1.940 | .0524 | .05497604 |
| NOACCON | -.00757681 | .20373475 | -.037 | .9703 | .96306738 |
| LSHPAV | -.20142316 | .21335464 | -.944 | .3451 | .26332112 |
| RSHPAV | .08414423 | .20126214 | .418 | .6759 | .30279109 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.90329841 | .22337783 | 8.521 | .0000 | |

Table B27. Day Crash Frequency Model for Urban Unsignalized Skew Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:29:51AM.|
| Dependent variable             TOTAL_D      |
| Weighting variable                None      |
| Number of observations             663      |
| Iterations completed                16      |
| Log likelihood function      -887.8690      |
| Restricted log likelihood    -1141.163      |
| Chi squared                   506.5888      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .0000000      |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant     -10.1976122     1.27004971    -8.029   .0000
 LNADTMAJ        .88156889      .11597121     7.602   .0000    8.56885854
 LNADTMN         .34056441      .08985278     3.790   .0002    6.63587915
 LIGHTING        .19840180      .17093126     1.161   .2458     .76168929
 HIGHSP50      -.32425031      .13607264    -2.383   .0172     .64404223
 PER             .01875522      .01610747     1.164   .2443    8.30046711
 DEPRESS       -.49740742      .26752603    -1.859   .0630     .09049774
 NOACCON         .44268378      .31387008     1.410   .1584     .95173454
 LSHPAV          .41714994      .36659641     1.138   .2552     .56862745
 RSHPAV        -.77382708      .38043904    -2.034   .0419     .59577677
          Dispersion parameter for count data model
 Alpha          1.56274287      .17265184     9.051   .0000
```

Table B28. Night Crash Frequency Model for Urban Unsignalized Skew Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:30:13AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 663 |
| Iterations completed | 15 |
| Log likelihood function | -469.4456 |
| Restricted log likelihood | -527.6173 |
| Chi squared | 116.3435 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -10.9697863 | 1.77523734 | -6.179 | .0000 | |
| LNADTMAJ | .91089107 | .16795301 | 5.423 | .0000 | 8.56885854 |
| LNADTMN | .23781710 | .12561139 | 1.893 | .0583 | 6.63587915 |
| LIGHTING | .18172103 | .25222761 | .720 | .4712 | .76168929 |
| HIGHSP50 | -.39783347 | .19216212 | -2.070 | .0384 | .64404223 |
| PER | .00687253 | .02447717 | .281 | .7789 | 8.30046711 |
| DEPRESS | -.07993178 | .36338252 | -.220 | .8259 | .09049774 |
| NOACCON | .57727975 | .42857315 | 1.347 | .1780 | .95173454 |
| LSHPAV | .16934022 | .50863810 | .333 | .7392 | .56862745 |
| RSHPAV | -.51250937 | .52846794 | -.970 | .3321 | .59577677 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 2.24503482 | .42285363 | 5.309 | .0000 | |

Table B29. Day Crash Frequency Model for Urban Unsignalized Tee Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:30:48AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 3520 |
| Iterations completed | 16 |
| Log likelihood function | -3664.442 |
| Restricted log likelihood | -4394.254 |
| Chi squared | 1459.625 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -8.11748929 | .50811182 | -15.976 | .0000 | |
| LNADTMAJ | .77514647 | .04737337 | 16.362 | .0000 | 8.79698559 |
| LNADTMN | .10351712 | .01765468 | 5.863 | .0000 | 6.18480207 |
| LIGHTING | .00095101 | .07297060 | .013 | .9896 | .67642045 |
| HIGHSP50 | -.27458969 | .06763977 | -4.060 | .0000 | .60426136 |
| PER | .00465754 | .00974253 | .478 | .6326 | 7.11013241 |
| DEPRESS | .18562348 | .11812058 | 1.571 | .1161 | .08920455 |
| NOACCON | .13333108 | .13190690 | 1.011 | .3121 | .94346591 |
| LSHPAV | -.04014493 | .12732018 | -.315 | .7525 | .43465909 |
| RSHPAV | .03409080 | .12636802 | .270 | .7873 | .49829545 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.77937114 | .10651888 | 16.705 | .0000 | |

Table B30. Night Crash Frequency Model for Urban Unsignalized Tee Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:31:09AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 3520 |
| Iterations completed | 16 |
| Log likelihood function | -1769.817 |
| Restricted log likelihood | -1917.070 |
| Chi squared | 294.5061 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.84980525 | .73383303 | -10.697 | .0000 | |
| LNADTMAJ | .69396264 | .06986064 | 9.934 | .0000 | 8.79698559 |
| LNADTMN | .06486353 | .02619710 | 2.476 | .0133 | 6.18480207 |
| LIGHTING | -.29108155 | .10476662 | -2.778 | .0055 | .67642045 |
| HIGHSP50 | -.25693191 | .09951956 | -2.582 | .0098 | .60426136 |
| PER | -.00288410 | .01422343 | -.203 | .8393 | 7.11013241 |
| DEPRESS | .19070119 | .17078640 | 1.117 | .2642 | .08920455 |
| NOACCON | -.10011623 | .18251178 | -.549 | .5833 | .94346591 |
| LSHPAV | -.23209588 | .17855342 | -1.300 | .1936 | .43465909 |
| RSHPAV | .07774294 | .17832641 | .436 | .6629 | .49829545 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 2.34476706 | .26664834 | 8.793 | .0000 | |

Table B31. Day Crash Frequency Model for All Rural Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:32:21AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 11453 |
| Iterations completed | 18 |
| Log likelihood function | -11212.01 |
| Restricted log likelihood | -13069.52 |
| Chi squared | 3715.023 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -5.71938980 | .24131593 | -23.701 | .0000 | |
| LNADTMAJ | .49003472 | .02530969 | 19.362 | .0000 | 8.13652991 |
| LNADTMN | .17600631 | .01163627 | 15.126 | .0000 | 6.40611686 |
| LIGHTING | .08099104 | .05419972 | 1.494 | .1351 | .12721558 |
| SIGNALIZ | .53061480 | .08906274 | 5.958 | .0000 | .03073431 |
| SKEW | .61374783 | .05116125 | 11.996 | .0000 | .11569021 |
| HIGHSP50 | -.19233836 | .03855016 | -4.989 | .0000 | .71579499 |
| PER | -.01857325 | .00423725 | -4.383 | .0000 | 9.97367430 |
| DEPRESS | .14677759 | .05729583 | 2.562 | .0104 | .13917751 |
| NOACCON | -.02866851 | .07660452 | -.374 | .7082 | .94900899 |
| LSHPAV | -.40934445 | .09520447 | -4.300 | .0000 | .56229809 |
| RSHPAV | .49221367 | .09954111 | 4.945 | .0000 | .57993539 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.48136036 | .05469210 | 27.085 | .0000 | |

Table B32. Night Crash Frequency Model for All Rural Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:32:40AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations            11453     |
| Iterations completed                 18     |
| Log likelihood function       -6923.386     |
| Restricted log likelihood     -7254.762     |
| Chi squared                    662.7519     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.38641240 | .29777282 | -21.447 | .0000 | |
| LNADTMAJ | .49806004 | .03155036 | 15.786 | .0000 | 8.13652991 |
| LNADTMN | .12874238 | .01425443 | 9.032 | .0000 | 6.40611686 |
| LIGHTING | .06649521 | .06478107 | 1.026 | .3047 | .12721558 |
| SIGNALIZ | .40601802 | .09869032 | 4.114 | .0000 | .03073431 |
| SKEW | .52887716 | .06144509 | 8.607 | .0000 | .11569021 |
| HIGHSP50 | -.07360354 | .04721259 | -1.559 | .1190 | .71579499 |
| PER | -.01669873 | .00523706 | -3.189 | .0014 | 9.97367430 |
| DEPRESS | .23950317 | .06720261 | 3.564 | .0004 | .13917751 |
| NOACCON | .06424996 | .08707751 | .738 | .4606 | .94900899 |
| LSHPAV | -.39116905 | .11176443 | -3.500 | .0005 | .56229809 |
| RSHPAV | .31663153 | .11772242 | 2.690 | .0072 | .57993539 |
| Dispersion parameter for count data model | | | | | |
| Alpha | 1.15272098 | .07804117 | 14.771 | .0000 | |

Table B33. Day Crash Frequency Model for Rural Signalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:33:43AM.|
| Dependent variable            TOTAL_D       |
| Weighting variable               None       |
| Number of observations            352       |
| Iterations completed               17       |
| Log likelihood function     -768.0485       |
| Restricted log likelihood   -801.0677       |
| Chi squared                  66.03830       |
| Degrees of freedom                  1       |
| Prob[ChiSqd > value] =       .0000000       |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -8.01364708 | .88961769 | -9.008 | .0000 | |
| LNADTMAJ | .82079675 | .10272841 | 7.990 | .0000 | 9.76038946 |
| LNADTMN | .16113140 | .05886343 | 2.737 | .0062 | 9.00688449 |
| LIGHTING | -.02269614 | .17562526 | -.129 | .8972 | .94034091 |
| SKEW | .28676303 | .13799980 | 2.078 | .0377 | .13636364 |
| HIGHSP50 | .07490567 | .08469415 | .884 | .3765 | .69602273 |
| PER | .01198076 | .01084772 | 1.104 | .2694 | 6.40545893 |
| DEPRESS | .28132899 | .10810390 | 2.602 | .0093 | .45738636 |
| NOACCON | -.02718821 | .11576018 | -.235 | .8143 | .82386364 |
| LSHPAV | -.49147864 | .12738042 | -3.858 | .0001 | .83238636 |
| RSHPAV | -.10409652 | .16762387 | -.621 | .5346 | .92329545 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .19579909 | .03711637 | 5.275 | .0000 | |

Table B34. Night Crash Frequency Model for Rural Signalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:34:01AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations              352     |
| Iterations completed                 16     |
| Log likelihood function       -513.0686     |
| Restricted log likelihood     -524.1446     |
| Chi squared                    22.15208     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =        .2518105E-05 |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.63090007 | 1.33976587 | -4.949 | .0000 | |
| LNADTMAJ | .53890908 | .15599110 | 3.455 | .0006 | 9.76038946 |
| LNADTMN | .12619884 | .08976953 | 1.406 | .1598 | 9.00688449 |
| LIGHTING | -.01941672 | .26114538 | -.074 | .9407 | .94034091 |
| SKEW | .16314281 | .20968611 | .778 | .4365 | .13636364 |
| HIGHSP50 | -.02086682 | .12797851 | -.163 | .8705 | .69602273 |
| PER | .00760209 | .01642101 | .463 | .6434 | 6.40545893 |
| DEPRESS | .26574904 | .16282422 | 1.632 | .1027 | .45738636 |
| NOACCON | .21146771 | .17993077 | 1.175 | .2399 | .82386364 |
| LSHPAV | -.10275865 | .20400244 | -.504 | .6145 | .83238636 |
| RSHPAV | .13496020 | .28223091 | .478 | .6325 | .92329545 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .29894644 | .08654760 | 3.454 | .0006 | |

Table B35. Day Crash Frequency Model for Rural Unsignalized Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:34:45AM.|
| Dependent variable              TOTAL_D     |
| Weighting variable                 None     |
| Number of observations            11101     |
| Iterations completed                 16     |
| Log likelihood function       -10327.05     |
| Restricted log likelihood     -12204.60     |
| Chi squared                    3755.088     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -5.57755210 | .25705642 | -21.698 | .0000 | |
| LNADTMAJ | .47733852 | .02666446 | 17.902 | .0000 | 8.08503918 |
| LNADTMN | .17294355 | .01211675 | 14.273 | .0000 | 6.32364950 |
| LIGHTING | .08562994 | .05748770 | 1.490 | .1363 | .10143230 |
| SKEW | .63150862 | .05464261 | 11.557 | .0000 | .11503468 |
| HIGHSP50 | -.21231279 | .04123193 | -5.149 | .0000 | .71642194 |
| PER | -.02023336 | .00450066 | -4.496 | .0000 | 10.0868183 |
| DEPRESS | .13608483 | .06314549 | 2.155 | .0312 | .12908747 |
| NOACCON | -.03301721 | .08664957 | -.381 | .7032 | .95297721 |
| LSHPAV | -.44065252 | .11083740 | -3.976 | .0001 | .55373390 |
| RSHPAV | .54823226 | .11482370 | 4.775 | .0000 | .56904783 |
| Dispersion parameter for count data model | | | | | |
| Alpha | 1.72417976 | .06428254 | 26.822 | .0000 | |

Table B36. Night Crash Frequency Model for Rural Unsignalized Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:35:06AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 11101 |
| Iterations completed | 18 |
| Log likelihood function | -6383.613 |
| Restricted log likelihood | -6722.546 |
| Chi squared | 677.8660 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.26837611 | .31571662 | -19.854 | .0000 | |
| LNADTMAJ | .48977277 | .03310012 | 14.797 | .0000 | 8.08503918 |
| LNADTMN | .12666425 | .01475011 | 8.587 | .0000 | 6.32364950 |
| LIGHTING | .06996648 | .06812609 | 1.027 | .3044 | .10143230 |
| SKEW | .55383025 | .06529190 | 8.482 | .0000 | .11503468 |
| HIGHSP50 | -.08174527 | .05060805 | -1.615 | .1063 | .71642194 |
| PER | -.01813068 | .00554350 | -3.271 | .0011 | 10.0868183 |
| DEPRESS | .23539251 | .07436200 | 3.165 | .0015 | .12908747 |
| NOACCON | .03994523 | .09814610 | .407 | .6840 | .95297721 |
| LSHPAV | -.46209866 | .12834189 | -3.601 | .0003 | .55373390 |
| RSHPAV | .39037411 | .13344562 | 2.925 | .0034 | .56904783 |
| Dispersion parameter for count data model | | | | | |
| Alpha | 1.38431915 | .09462971 | 14.629 | .0000 | |

Table B37. Day Crash Frequency Model for Rural Signalized Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:36:30AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 248 |
| Iterations completed | 16 |
| Log likelihood function | -548.9494 |
| Restricted log likelihood | -572.3853 |
| Chi squared | 46.87185 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -7.62480421 | .99757239 | -7.643 | .0000 | |
| LNADTMAJ | .66140687 | .20467109 | 3.232 | .0012 | 9.76727850 |
| LNADTMN | .28661495 | .20044155 | 1.430 | .1527 | 9.37634801 |
| LIGHTING | -.06067051 | .19241721 | -.315 | .7525 | .93145161 |
| HIGHSP50 | .05768318 | .09924496 | .581 | .5611 | .73790323 |
| PER | .00929815 | .01222893 | .760 | .4471 | 6.67048714 |
| DEPRESS | .40214614 | .12241355 | 3.285 | .0010 | .40725806 |
| NOACCON | .04074145 | .15218830 | .268 | .7889 | .88709677 |
| LSHPAV | -.54743803 | .15229779 | -3.595 | .0003 | .79435484 |
| RSHPAV | -.08088256 | .18122379 | -.446 | .6554 | .89112903 |
| | Dispersion parameter for count data model | | | | |
| Alpha | .17730429 | .03997379 | 4.436 | .0000 | |

Table B38. Night Crash Frequency Model for Rural Signalized Cross Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:36:50AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations              248     |
| Iterations completed                 15     |
| Log likelihood function       -368.1396     |
| Restricted log likelihood     -375.1231     |
| Chi squared                    13.96693     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =        .1860540E-03 |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.74207458 | 1.53458372 | -4.393 | .0000 | |
| LNADTMAJ | .45948960 | .31045571 | 1.480 | .1389 | 9.76727850 |
| LNADTMN | .22637592 | .30759109 | .736 | .4618 | 9.37634801 |
| LIGHTING | -.08677737 | .28744927 | -.302 | .7627 | .93145161 |
| HIGHSP50 | .01866381 | .15090402 | .124 | .9016 | .73790323 |
| PER | -.00141686 | .01846008 | -.077 | .9388 | 6.67048714 |
| DEPRESS | .38511447 | .18411271 | 2.092 | .0365 | .40725806 |
| NOACCON | .25516276 | .23730393 | 1.075 | .2823 | .88709677 |
| LSHPAV | -.14008851 | .24528095 | -.571 | .5679 | .79435484 |
| RSHPAV | .14160699 | .30223699 | .469 | .6394 | .89112903 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .25703950 | .09200732 | 2.794 | .0052 | |

Table B39. Day Crash Frequency Model for Rural Signalized Skew Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:37:56AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 48 |
| Iterations completed | 58 |
| Log likelihood function | -91.98571 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.81242764 | 2.10636151 | -3.234 | .0012 | |
| LNADTMAJ | .53089020 | .28868242 | 1.839 | .0659 | 9.56124093 |
| LNADTMN | .40405124 | .14366429 | 2.812 | .0049 | 7.68419388 |
| LIGHTING | .36156880 | .50826781 | .711 | .4769 | .91666667 |
| HIGHSP50 | .19688635 | .17821716 | 1.105 | .2693 | .66666667 |
| PER | .00216616 | .02494018 | .087 | .9308 | 6.82521195 |
| DEPRESS | -.86211819 | .30369535 | -2.839 | .0045 | .66666667 |
| NOACCON | -.52077277 | .20659650 | -2.521 | .0117 | .79166667 |
| LSHPAV | .19674821 | .38646517 | .509 | .6107 | .91666667 |
| Dispersion parameter for count data model | | | | | |
| Alpha | .957824D-05 | .00116501 | .008 | .9934 | |

Table B40. Night Crash Frequency Model for Rural Signalized Skew Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:38:20AM.|
| Dependent variable             TOTAL_N      |
| Weighting variable                None      |
| Number of observations              48      |
| Iterations completed                15      |
| Log likelihood function      -66.25534      |
| Restricted log likelihood    -67.39952      |
| Chi squared                   2.288361      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .1303475      |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant     -6.86331278     4.06838030    -1.687   .0916
 LNADTMAJ       .61492770      .57544274     1.069   .2852    9.56124093
 LNADTMN        .21531288      .30821080      .699   .4848    7.68419388
 LIGHTING       .25362187      .88992681      .285   .7757     .91666667
 HIGHSP50     -.09266726      .35871052     -.258   .7961     .66666667
 PER            .02368904      .04899638      .483   .6288    6.82521195
 DEPRESS      -.26443916      .72726991     -.364   .7162     .66666667
 NOACCON      -.49741939      .43666351    -1.139   .2546     .79166667
 LSHPAV       -.47224220      .81676366     -.578   .5631     .91666667
         Dispersion parameter for count data model
 Alpha          .31077963      .27172140     1.144   .2527
```

Table B41. Day Crash Frequency Model for Rural Signalized Tee Minnesota Intersections

No model

Table B42. Night Crash Frequency Model for Rural Signalized Tee Minnesota Intersections

No model

Table B43. Day Crash Frequency Model for Rural Unsignalized Cross Minnesota Intersections

| Negative Binomial Regression | |
|---|---|
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:40:02AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 4640 |
| Iterations completed | 16 |
| Log likelihood function | -4188.279 |
| Restricted log likelihood | -4804.002 |
| Chi squared | 1231.447 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.33419380 | .38768677 | -16.338 | .0000 | |
| LNADTMAJ | -.47219334 | .12821262 | -3.683 | .0002 | 7.83109979 |
| LNADTMN | 1.24959608 | .13444778 | 9.294 | .0000 | 7.30897383 |
| LIGHTING | .00928775 | .09825683 | .095 | .9247 | .07176724 |
| HIGHSP50 | -.16276341 | .06394054 | -2.546 | .0109 | .74267241 |
| PER | -.01549035 | .00661182 | -2.343 | .0191 | 10.9241909 |
| DEPRESS | .06027837 | .09428972 | .639 | .5226 | .12543103 |
| NOACCON | .14984212 | .13097998 | 1.144 | .2526 | .95732759 |
| LSHPAV | -.18333464 | .21398635 | -.857 | .3916 | .47952586 |
| RSHPAV | .37485760 | .22081840 | 1.698 | .0896 | .48857759 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.46843123 | .09001232 | 16.314 | .0000 | |

Table B44. Night Crash Frequency Model for Rural Unsignalized Cross Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:40:37AM. | |
| Dependent variable | TOTAL_N |
| Weighting variable | None |
| Number of observations | 4640 |
| Iterations completed | 15 |
| Log likelihood function | -2456.970 |
| Restricted log likelihood | -2529.646 |
| Chi squared | 145.3523 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.68225789 | .47946661 | -13.937 | .0000 | |
| LNADTMAJ | -.13907453 | .16000452 | -.869 | .3847 | 7.83109979 |
| LNADTMN | .83552464 | .16516825 | 5.059 | .0000 | 7.30897383 |
| LIGHTING | -.12120814 | .12309445 | -.985 | .3248 | .07176724 |
| HIGHSP50 | -.08533633 | .08054468 | -1.059 | .2894 | .74267241 |
| PER | -.01984652 | .00850246 | -2.334 | .0196 | 10.9241909 |
| DEPRESS | .18146563 | .11333876 | 1.601 | .1094 | .12543103 |
| NOACCON | .10257895 | .14697005 | .698 | .4852 | .95732759 |
| LSHPAV | -.18559236 | .24897449 | -.745 | .4560 | .47952586 |
| RSHPAV | .23337866 | .25894821 | .901 | .3675 | .48857759 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.05570986 | .13665772 | 7.725 | .0000 | |

Table B45. Day Crash Frequency Model for Rural Unsignalized Skew Minnesota Intersections

| | |
|---|---|
| Negative Binomial Regression | |
| Maximum Likelihood Estimates | |
| Model estimated: Jul 05, 2007 at 07:41:11AM. | |
| Dependent variable | TOTAL_D |
| Weighting variable | None |
| Number of observations | 1277 |
| Iterations completed | 17 |
| Log likelihood function | -1502.168 |
| Restricted log likelihood | -1884.253 |
| Chi squared | 764.1711 |
| Degrees of freedom | 1 |
| Prob[ChiSqd > value] = | .0000000 |

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -6.59815229 | .77408387 | -8.524 | .0000 | |
| LNADTMAJ | .55931979 | .07693986 | 7.270 | .0000 | 8.20155802 |
| LNADTMN | .25842861 | .04492172 | 5.753 | .0000 | 5.65962294 |
| LIGHTING | .53653769 | .14461428 | 3.710 | .0002 | .11746280 |
| HIGHSP50 | -.05305462 | .11421983 | -.464 | .6423 | .75019577 |
| PER | -.02666613 | .01266776 | -2.105 | .0353 | 10.5355116 |
| DEPRESS | .13497720 | .17435722 | .774 | .4388 | .13155834 |
| NOACCON | .31169837 | .23754535 | 1.312 | .1895 | .95301488 |
| LSHPAV | .18766935 | .33143748 | .566 | .5712 | .62411903 |
| RSHPAV | -.08867902 | .33625060 | -.264 | .7920 | .63899765 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.49483788 | .13484490 | 11.086 | .0000 | |

Table B46. Night Crash Frequency Model for Rural Unsignalized Skew Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:41:37AM.|
| Dependent variable              TOTAL_N     |
| Weighting variable                 None     |
| Number of observations             1277     |
| Iterations completed                 15     |
| Log likelihood function       -925.2663     |
| Restricted log likelihood     -1045.876     |
| Chi squared                    241.2185     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -8.94407170 | 1.02727083 | -8.707 | .0000 | |
| LNADTMAJ | .72895668 | .10527847 | 6.924 | .0000 | 8.20155802 |
| LNADTMN | .21649734 | .05875543 | 3.685 | .0002 | 5.65962294 |
| LIGHTING | .32193137 | .18724289 | 1.719 | .0856 | .11746280 |
| HIGHSP50 | -.04093812 | .14902861 | -.275 | .7835 | .75019577 |
| PER | .00834383 | .01649473 | .506 | .6130 | 10.5355116 |
| DEPRESS | -.08602163 | .23026975 | -.374 | .7087 | .13155834 |
| NOACCON | .50574385 | .30219738 | 1.674 | .0942 | .95301488 |
| LSHPAV | .76284838 | .47636736 | 1.601 | .1093 | .62411903 |
| RSHPAV | -.92120788 | .47987242 | -1.920 | .0549 | .63899765 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.74433334 | .24555074 | 7.104 | .0000 | |

Table B47. Day Crash Frequency Model for Rural Unsignalized Tee Minnesota Intersections

```
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 05, 2007 at 07:42:24AM.|
| Dependent variable              TOTAL_D     |
| Weighting variable                 None     |
| Number of observations             5184     |
| Iterations completed                 15     |
| Log likelihood function       -4563.699     |
| Restricted log likelihood     -5378.243     |
| Chi squared                    1629.089     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant     -4.71104839      .38497045   -12.237   .0000
 LNADTMAJ       .44716633      .03908163    11.442   .0000    8.28362796
 LNADTMN        .11827903      .01747617     6.768   .0000    5.60529630
 LIGHTING     -.06484848      .08533172     -.760   .4473     .12403549
 HIGHSP50     -.29378132      .06083001    -4.830   .0000     .68460648
 PER          -.01702919      .00711901    -2.392   .0168    9.22678939
 DEPRESS        .20669476      .09739275     2.122   .0338     .13175154
 NOACCON      -.24410149      .12949943    -1.885   .0594     .94907407
 LSHPAV       -.59759870      .14283099    -4.184   .0000     .60281636
 RSHPAV         .59114813      .15016730     3.937   .0001     .62384259
         Dispersion parameter for count data model
 Alpha         1.91177203      .10750994    17.782   .0000
```

Table B48. Night Crash Frequency Model for Rural Unsignalized Tee Minnesota Intersections

```
+----------------------------------------------+
| Negative Binomial Regression                 |
| Maximum Likelihood Estimates                 |
| Model estimated: Jul 05, 2007 at 07:42:51AM.|
| Dependent variable              TOTAL_N      |
| Weighting variable                 None      |
| Number of observations             5184      |
| Iterations completed                 16      |
| Log likelihood function       -2965.580      |
| Restricted log likelihood     -3098.281      |
| Chi squared                    265.4032      |
| Degrees of freedom                    1      |
| Prob[ChiSqd > value] =         .0000000      |
+----------------------------------------------+
```

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] | Mean of X |
|---|---|---|---|---|---|
| Constant | -5.19290697 | .45757004 | -11.349 | .0000 | |
| LNADTMAJ | .40115218 | .04641249 | 8.643 | .0000 | 8.28362796 |
| LNADTMN | .10958480 | .02099918 | 5.219 | .0000 | 5.60529630 |
| LIGHTING | .06060979 | .09565357 | .634 | .5263 | .12403549 |
| HIGHSP50 | -.09336677 | .07192160 | -1.298 | .1942 | .68460648 |
| PER | -.01653396 | .00829095 | -1.994 | .0461 | 9.22678939 |
| DEPRESS | .33934040 | .11063072 | 3.067 | .0022 | .13175154 |
| NOACCON | -.11120055 | .14197695 | -.783 | .4335 | .94907407 |
| LSHPAV | -.69540747 | .15693949 | -4.431 | .0000 | .60281636 |
| RSHPAV | .53103600 | .16546869 | 3.209 | .0013 | .62384259 |
| | Dispersion parameter for count data model | | | | |
| Alpha | 1.35965761 | .14225196 | 9.558 | .0000 | |

# APPENDIX C

# MINNESOTA INTERCHANGE MODELING RESULTS

## Table C.1 Nighttime Crash Frequency at Urban Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 586 |
| | | LR chi2(10) = | 350.76 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -1623.5861 | | Pseudo R2 = | 0.0975 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .5867927 | .2124439 | 2.76 | 0.006 | .1704104 | 1.003175 |
| speed | .0039009 | .0046664 | 0.84 | 0.403 | -.005245 | .0130468 |
| lntotent | .1868157 | .0288608 | 6.47 | 0.000 | .1302495 | .2433818 |
| perhv | -.0951145 | .0121908 | -7.80 | 0.000 | -.1190081 | -.071221 |
| fullacc | .5041879 | .1464644 | 3.44 | 0.001 | .217123 | .7912529 |
| paracc | .0680255 | .1777824 | 0.38 | 0.702 | -.2804216 | .4164725 |
| barrier | .2726549 | .0822509 | 3.31 | 0.001 | .1114461 | .4338638 |
| surf_typ | -.1441283 | .0769424 | -1.87 | 0.061 | -.2949326 | .006676 |
| lnwdt13 | -.0418096 | .122657 | -0.34 | 0.733 | -.2822128 | .1985936 |
| nolanes5 | .4270882 | .0875003 | 4.88 | 0.000 | .2555907 | .5985857 |
| _cons | -.8351119 | .4304406 | -1.94 | 0.052 | -1.67876 | .0085362 |
| /lnalpha | -.6100133 | .0816371 | | | -.7700192 | -.4500075 |
| alpha | .5433436 | .044357 | | | .4630042 | .6376234 |

Likelihood-ratio test of alpha=0: chibar2(01) = 1218.24 Prob>=chibar2 = 0.000

.

## Table C.2 Daytime Crash Frequency at Urban Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 586 |
| | | LR chi2(10) = | 397.27 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -2061.7647 | | Pseudo R2 = | 0.0879 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .6944077 | .1878684 | 3.70 | 0.000 | .3261923 | 1.062623 |
| speed | .0016317 | .0045698 | 0.36 | 0.721 | -.007325 | .0105884 |
| lntotent | .164903 | .0281489 | 5.86 | 0.000 | .1097322 | .2200739 |
| perhv | -.1073809 | .0110951 | -9.68 | 0.000 | -.1291269 | -.0856348 |
| fullacc | .4176206 | .1376832 | 3.03 | 0.002 | .1477665 | .6874748 |
| paracc | .1275491 | .1633842 | 0.78 | 0.435 | -.1926781 | .4477762 |
| barrier | .4349037 | .0805808 | 5.40 | 0.000 | .2769682 | .5928392 |
| surf_typ | -.1020716 | .0753399 | -1.35 | 0.175 | -.2497351 | .0455919 |
| lnwdt13 | -.2477663 | .1169114 | -2.12 | 0.034 | -.4769084 | -.0186242 |
| nolanes5 | .3413149 | .0865674 | 3.94 | 0.000 | .1716459 | .510984 |
| _cons | .331869 | .4069203 | 0.82 | 0.415 | -.4656802 | 1.129418 |
| /lnalpha | -.5264352 | .0669861 | | | -.6577256 | -.3951449 |
| alpha | .590707 | .0395692 | | | .5180282 | .6735825 |

Likelihood-ratio test of alpha=0: chibar2(01) = 3978.51 Prob>=chibar2 = 0.000

.

## Table C.3 Nighttime Crash Frequency at Rural Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 1435 |
| | | LR chi2(10) = | 524.37 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -3429.1553 | | Pseudo R2 = | 0.0710 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .2886575 | .0738712 | 3.91 | 0.000 | .1438726 | .4334424 |
| speed | -.0089544 | .003536 | -2.53 | 0.011 | -.0158848 | -.0020239 |
| lntotent | .1464587 | .017816 | 8.22 | 0.000 | .1115399 | .1813775 |
| perhv | -.0277927 | .0056278 | -4.94 | 0.000 | -.038823 | -.0167624 |
| fullacc | .5747832 | .0754821 | 7.61 | 0.000 | .426841 | .7227255 |
| paracc | .0525896 | .1059195 | 0.50 | 0.620 | -.1550088 | .260188 |
| barrier | .0000767 | .0578331 | 0.00 | 0.999 | -.113274 | .1134275 |
| surf_typ | .0005942 | .0471759 | 0.01 | 0.990 | -.0918688 | .0930572 |
| lnwdt13 | -.1680718 | .0798577 | -2.10 | 0.035 | -.32459 | -.0115536 |
| nolanes5 | .181286 | .058061 | 3.12 | 0.002 | .0674886 | .2950834 |
| _cons | .0984901 | .2959619 | 0.33 | 0.739 | -.4815846 | .6785648 |
| /lnalpha | -.8310014 | .0627141 | | | -.9539188 | -.708084 |
| alpha | .4356128 | .0273191 | | | .3852284 | .4925871 |

Likelihood-ratio test of alpha=0: chibar2(01) = 1163.26 Prob>=chibar2 = 0.000

## Table C.4 Daytime Crash Frequency at Rural Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 1435 |
| | | LR chi2(10) = | 933.07 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -4359.6032 | | Pseudo R2 = | 0.0967 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .3721704 | .0722535 | 5.15 | 0.000 | .2305561 | .5137846 |
| speed | -.0227364 | .0035974 | -6.32 | 0.000 | -.0297872 | -.0156857 |
| lntotent | .1854693 | .0174591 | 10.62 | 0.000 | .1512501 | .2196884 |
| perhv | -.0499698 | .0057152 | -8.74 | 0.000 | -.0611715 | -.0387681 |
| fullacc | .7551505 | .0726938 | 10.39 | 0.000 | .6126732 | .8976277 |
| paracc | .1997086 | .1016152 | 1.97 | 0.049 | .0005465 | .3988706 |
| barrier | .0307676 | .0571023 | 0.54 | 0.590 | -.0811508 | .1426861 |
| surf_typ | .0608123 | .0467234 | 1.30 | 0.193 | -.0307639 | .1523886 |
| lnwdt13 | -.2894733 | .0775884 | -3.73 | 0.000 | -.4415438 | -.1374028 |
| nolanes5 | .2094159 | .0567987 | 3.69 | 0.000 | .0980926 | .3207393 |
| _cons | 1.264104 | .2934896 | 4.31 | 0.000 | .6888751 | 1.839333 |
| /lnalpha | -.62515 | .0474863 | | | -.7182214 | -.5320786 |
| alpha | .5351811 | .0254138 | | | .4876187 | .5873828 |

Likelihood-ratio test of alpha=0: chibar2(01) = 5331.08 Prob>=chibar2 = 0.000

.

## Table C.5 Nighttime Crash Frequency at Diamond Interchanges

Negative binomial regression

| | | | |
|---|---|---|---|
| Dispersion = mean | | Number of obs = | 1615 |
| Log likelihood = -3975.4573 | | LR chi2(11) = | 719.88 |
| | | Prob > chi2 = | 0.0000 |
| | | Pseudo R2 = | 0.0830 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | .2193731 | .0721004 | 3.04 | 0.002 | .0780588 | .3606873 |
| light | .1454341 | .0788446 | 1.84 | 0.065 | -.0090986 | .2999668 |
| speed | -.003962 | .0032708 | -1.21 | 0.226 | -.0103726 | .0024486 |
| lntotent | .1404026 | .0204554 | 6.86 | 0.000 | .1003108 | .1804945 |
| perhv | -.0349947 | .0060323 | -5.80 | 0.000 | -.0468179 | -.0231716 |
| fullacc | .6143975 | .0830741 | 7.40 | 0.000 | .4515752 | .7772198 |
| paracc | .220536 | .1081712 | 2.04 | 0.041 | .0085244 | .4325476 |
| barrier | .0411261 | .0539615 | 0.76 | 0.446 | -.0646366 | .1468888 |
| surf_typ | -.0657381 | .0473778 | -1.39 | 0.165 | -.1585969 | .0271208 |
| lnwdt13 | -.1453685 | .0737372 | -1.97 | 0.049 | -.2898908 | -.0008461 |
| nolanes5 | .4460293 | .0569015 | 7.84 | 0.000 | .3345044 | .5575542 |
| _cons | -.1528953 | .2778334 | -0.55 | 0.582 | -.6974387 | .3916481 |
| /lnalpha | -.695254 | .0556197 | | | -.8042667 | -.5862413 |
| alpha | .4989477 | .0277513 | | | .4474159 | .5564148 |

Likelihood-ratio test of alpha=0: chibar2(01) = 1834.70 Prob>=chibar2 = 0.000

## Table C.6 Daytime Crash Frequency at Diamond Interchanges

Negative binomial regression

| | | | |
|---|---|---|---|
| Dispersion = mean | | Number of obs = | 1615 |
| Log likelihood = -5024.2953 | | LR chi2(11) = | 1162.18 |
| | | Prob > chi2 = | 0.0000 |
| | | Pseudo R2 = | 0.1037 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | .3210806 | .0671678 | 4.78 | 0.000 | .1894342 | .4527271 |
| light | .2820434 | .0744099 | 3.79 | 0.000 | .1362028 | .427884 |
| speed | -.012723 | .0032039 | -3.97 | 0.000 | -.0190025 | -.0064434 |
| lntotent | .1793995 | .0195007 | 9.20 | 0.000 | .1411788 | .2176202 |
| perhv | -.0505427 | .0058873 | -8.59 | 0.000 | -.0620816 | -.0390038 |
| fullacc | .7037749 | .0776261 | 9.07 | 0.000 | .5516306 | .8559193 |
| paracc | .3089696 | .10007 | 3.09 | 0.002 | .1128361 | .5051032 |
| barrier | .0955495 | .0518679 | 1.84 | 0.065 | -.0061097 | .1972087 |
| surf_typ | .03421 | .0460213 | 0.74 | 0.457 | -.0559902 | .1244101 |
| lnwdt13 | -.3374671 | .0704481 | -4.79 | 0.000 | -.4755428 | -.1993915 |
| nolanes5 | .3882963 | .0546769 | 7.10 | 0.000 | .2811315 | .495461 |
| _cons | .6124136 | .2689089 | 2.28 | 0.023 | .0853618 | 1.139465 |
| /lnalpha | -.5945438 | .0441946 | | | -.6811635 | -.507924 |
| alpha | .5518143 | .0243872 | | | .5060279 | .6017435 |

Likelihood-ratio test of alpha=0: chibar2(01) = 6852.38 Prob>=chibar2 = 0.000

.

## Table C.7 Nighttime Crash Frequency at Non-diamond Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 406 |
| | | LR chi2(11) = | 270.78 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -1072.8337 | | Pseudo R2 = | 0.1121 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | .1296607 | .1406268 | 0.92 | 0.357 | -.1459628 | .4052843 |
| light | .1954161 | .1725065 | 1.13 | 0.257 | -.1426903 | .5335226 |
| speed | -.0085987 | .0057192 | -1.50 | 0.133 | -.0198082 | .0026107 |
| lntotent | .6838169 | .0802445 | 8.52 | 0.000 | .5265406 | .8410932 |
| perhv | .0208956 | .0143831 | 1.45 | 0.146 | -.0072947 | .0490859 |
| fullacc | .3820624 | .1247409 | 3.06 | 0.002 | .1375748 | .6265501 |
| paracc | .1440984 | .1676587 | 0.86 | 0.390 | -.1845066 | .4727034 |
| barrier | .3636504 | .0890573 | 4.08 | 0.000 | .1891013 | .5381994 |
| surf_typ | -.0149644 | .0813596 | -0.18 | 0.854 | -.1744263 | .1444975 |
| lnwdt13 | .3068953 | .1502972 | 2.04 | 0.041 | .0123181 | .6014725 |
| nolanes5 | -.1601787 | .095884 | -1.67 | 0.095 | -.3481079 | .0277504 |
| _cons | -6.267433 | .9545055 | -6.57 | 0.000 | -8.13823 | -4.396637 |
| /lnalpha | -.9883788 | .1079593 | | | -1.199975 | -.7767825 |
| alpha | .3721796 | .0401802 | | | .3012017 | .4598833 |

Likelihood-ratio test of alpha=0: chibar2(01) = 477.42 Prob>=chibar2 = 0.000

## Table C.8 Daytime Crash Frequency at Non-diamond Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 406 |
| | | LR chi2(11) = | 346.51 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -1343.382 | | Pseudo R2 = | 0.1142 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | .3829578 | .1289768 | 2.97 | 0.003 | .1301679 | .6357476 |
| light | .0158911 | .1550926 | 0.10 | 0.918 | -.2880848 | .3198671 |
| speed | -.0004376 | .005595 | -0.08 | 0.938 | -.0114035 | .0105283 |
| lntotent | .7428129 | .0722225 | 10.29 | 0.000 | .6012595 | .8843663 |
| perhv | .0025853 | .0130436 | 0.20 | 0.843 | -.0229797 | .0281504 |
| fullacc | .2443714 | .1171482 | 2.09 | 0.037 | .0147651 | .4739777 |
| paracc | .1958816 | .1483634 | 1.32 | 0.187 | -.0949053 | .4866686 |
| barrier | .3921486 | .084833 | 4.62 | 0.000 | .225879 | .5584182 |
| surf_typ | -.018593 | .0760622 | -0.24 | 0.807 | -.1676722 | .1304862 |
| lnwdt13 | .2938539 | .1364177 | 2.15 | 0.031 | .0264802 | .5612277 |
| nolanes5 | -.2159345 | .0904153 | -2.39 | 0.017 | -.3931452 | -.0387239 |
| _cons | -6.43579 | .8703579 | -7.39 | 0.000 | -8.14166 | -4.72992 |
| /lnalpha | -.9179204 | .0879265 | | | -1.090253 | -.7455875 |
| alpha | .3993487 | .0351133 | | | .3361314 | .4744555 |

Likelihood-ratio test of alpha=0: chibar2(01) = 1438.60 Prob>=chibar2 = 0.000

## Table C.9 Nighttime Crash Frequency at Urban Diamond Interchanges

```
Negative binomial regression                      Number of obs   =        466
                                                  LR chi2(10)     =     288.84
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1233.4546                       Pseudo R2       =     0.1048

------------------------------------------------------------------------------
    nighttim |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       light |   .6456998   .2133101     3.03   0.002     .2276197     1.06378
       speed |   .0049785   .0051087     0.97   0.330    -.0050343    .0149913
    lntotent |   .1761292   .0380121     4.63   0.000     .1016269    .2506315
       perhv |  -.0919834   .0128823    -7.14   0.000    -.1172322   -.0667346
     fullacc |   .4313385   .1564595     2.76   0.006     .1246835    .7379935
      paracc |   .1088033   .1948686     0.56   0.577    -.2731322    .4907388
     barrier |   .1331015   .0940993     1.41   0.157    -.0513298    .3175328
    surf_typ |  -.1218866   .0892679    -1.37   0.172    -.2968485    .0530752
     lnwdt13 |  -.2065809   .1356517    -1.52   0.128    -.4724533    .0592914
    nolanes5 |    .592187   .1073697     5.52   0.000     .3817462    .8026278
       _cons |  -.8120932   .4888005    -1.66   0.097    -1.770125    .1459381
-------------+----------------------------------------------------------------
    /lnalpha |    -.64899   .0982818                     -.8416187   -.4563613
-------------+----------------------------------------------------------------
       alpha |   .5225733   .0513594                      .4310123    .6335849
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  725.71 Prob>=chibar2 = 0.000
```

## Table C.10 Daytime Crash Frequency at Urban Diamond Interchanges

```
Negative binomial regression                      Number of obs   =        466
                                                  LR chi2(10)     =     326.35
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1589.6379                       Pseudo R2       =     0.0931

------------------------------------------------------------------------------
     daytime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       light |   .7382279   .1933234     3.82   0.000     .3593209    1.117135
       speed |   .0001808   .0050418     0.04   0.971    -.0097009    .0100624
    lntotent |   .1964347   .0376528     5.22   0.000     .1226366    .2702327
       perhv |  -.1050144   .0120387    -8.72   0.000    -.1286099    -.081419
     fullacc |   .3856521   .1516194     2.54   0.011     .0884836    .6828206
      paracc |   .1429716   .1841316     0.78   0.437    -.2179196    .5038628
     barrier |   .2841804     .09299     3.06   0.002     .1019233    .4664374
    surf_typ |  -.0085291   .0888369    -0.10   0.924    -.1826462    .1655881
     lnwdt13 |  -.4735559   .1306141    -3.63   0.000    -.7295548    -.217557
    nolanes5 |    .430548   .1081458     3.98   0.000     .2185862    .6425098
       _cons |   .1179226   .4775779     0.25   0.805    -.8181128    1.053958
-------------+----------------------------------------------------------------
    /lnalpha |    -.49451   .0768578                     -.6451486   -.3438714
-------------+----------------------------------------------------------------
       alpha |   .6098697   .0468733                      .5245846    .7090201
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 2863.90 Prob>=chibar2 = 0.000
```

.

## Table C.11 Nighttime Crash Frequency at Urban Non-diamond Interchanges

```
Negative binomial regression                      Number of obs   =        120
                                                  LR chi2(9)      =      73.09
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -372.19094                       Pseudo R2       =     0.0894

------------------------------------------------------------------------------
    nighttim |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       speed |  -.0146038   .0103482    -1.41   0.158    -.0348858    .0056783
    lntotent |   .5450068   .2193566     2.48   0.013     .1150758    .9749377
       perhv |   .0651549   .0569456     1.14   0.253    -.0464564    .1767662
     fullacc |   1.095213   .3750625     2.92   0.003     .3601035    1.830321
      paracc |   .6010731   .4383883     1.37   0.170    -.2581521    1.460298
     barrier |   .4965469   .2125319     2.34   0.019      .079992    .9131018
    surf_typ |  -.2870485   .1516555    -1.89   0.058    -.5842878    .0101909
     lnwdt13 |   .7384109   .2982454     2.48   0.013     .1538606    1.322961
    nolanes5 |   .0379337   .1622413     0.23   0.815    -.2800534    .3559209
       _cons |  -4.781607   2.509786    -1.91   0.057    -9.700698    .1374833
-------------+----------------------------------------------------------------
    /lnalpha |  -.8992467   .1700664                     -1.232571   -.5659228
-------------+----------------------------------------------------------------
       alpha |    .406876   .0691959                      .2915422    .5678359
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  239.05 Prob>=chibar2 = 0.000
```

## Table C.12 Daytime Crash Frequency at Urban Non-diamond Interchanges

```
Negative binomial regression                      Number of obs   =        120
                                                  LR chi2(9)      =     117.80
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -437.18035                       Pseudo R2       =     0.1187

------------------------------------------------------------------------------
     daytime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       speed |  -.0025469   .0086126    -0.30   0.767    -.0194273    .0143335
    lntotent |   .7311727   .1717078     4.26   0.000     .3946317    1.067714
       perhv |   .0714641   .0450384     1.59   0.113    -.0168094    .1597377
     fullacc |   .6860883   .2703619     2.54   0.011     .1561888    1.215988
      paracc |   .6542017   .3312799     1.97   0.048      .004905    1.303498
     barrier |   .6453552   .1702445     3.79   0.000      .311682    .9790283
    surf_typ |  -.4257531   .1213291    -3.51   0.000    -.6635539   -.1879524
     lnwdt13 |   .7783586   .2412997     3.23   0.001     .3054198    1.251297
    nolanes5 |  -.0893806    .132583    -0.67   0.500    -.3492386    .1704774
       _cons |  -6.508942   1.971371    -3.30   0.001    -10.37276   -2.645125
-------------+----------------------------------------------------------------
    /lnalpha |  -1.265993   .1581327                     -1.575927   -.9560586
-------------+----------------------------------------------------------------
       alpha |   .2819592    .044587                      .2068156     .384405
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  404.71 Prob>=chibar2 = 0.000
```

.

Table C.13 Nighttime Crash Frequency at Rural Diamond Interchanges

```
Negative binomial regression                      Number of obs   =       1149
                                                  LR chi2(10)     =     415.40
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -2705.8768                       Pseudo R2       =     0.0713

------------------------------------------------------------------------------
    nighttim |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       light |   .2736851   .0829569     3.30   0.001     .1110926    .4362775
       speed |  -.0108622   .0040795    -2.66   0.008    -.0188578   -.0028665
    lntotent |   .1531824   .0231243     6.62   0.000     .1078596    .1985051
       perhv |   -.025076    .006343    -3.95   0.000    -.0375081    -.012644
     fullacc |   .6000502    .096618     6.21   0.000     .4106825     .789418
      paracc |   .1782219   .1303735     1.37   0.172    -.0773055    .4337494
     barrier |  -.0722396    .066293    -1.09   0.276    -.2021715    .0576922
    surf_typ |  -.0638489   .0534455    -1.19   0.232    -.1686002    .0409024
     lnwdt13 |  -.1649462   .0882052    -1.87   0.061    -.3378251    .0079328
    nolanes5 |   .2719922   .0665963     4.08   0.000     .1414658    .4025186
       _cons |   .1720876   .3445188     0.50   0.617    -.5031569    .8473321
-------------+----------------------------------------------------------------
    /lnalpha |   -.832743   .0711814                      -.972256   -.6932301
-------------+----------------------------------------------------------------
       alpha |   .4348548   .0309536                      .3782288    .4999585
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  880.52 Prob>=chibar2 = 0.000
```

.

Table C.14 Daytime Crash Frequency at Rural Diamond Interchanges

```
Negative binomial regression                      Number of obs   =       1149
                                                  LR chi2(10)     =     818.95
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -3413.2482                       Pseudo R2       =     0.1071

------------------------------------------------------------------------------
     daytime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       light |   .3834003   .0795557     4.82   0.000      .227474    .5393267
       speed |  -.0264689   .0040002    -6.62   0.000    -.0343091   -.0186287
    lntotent |   .2086921   .0222109     9.40   0.000     .1651595    .2522247
       perhv |  -.0424414   .0063088    -6.73   0.000    -.0548065   -.0300764
     fullacc |   .8223061   .0910953     9.03   0.000     .6437626     1.00085
      paracc |   .3464857   .1227203     2.82   0.005     .1059583    .5870132
     barrier |  -.0148906   .0634801    -0.23   0.815    -.1393093     .109528
    surf_typ |  -.0169043   .0519131    -0.33   0.745    -.1186522    .0848435
     lnwdt13 |  -.3073003   .0851967    -3.61   0.000    -.4742827   -.1403179
    nolanes5 |   .3423453   .0640221     5.35   0.000     .2168644    .4678262
       _cons |   1.206262   .3318764     3.63   0.000     .5557959    1.856727
-------------+----------------------------------------------------------------
    /lnalpha |  -.6876814   .0547565                     -.7950021   -.5803607
-------------+----------------------------------------------------------------
       alpha |   .5027404   .0275283                      .4515803    .5596965
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 3752.65 Prob>=chibar2 = 0.000
```

## Table C.15 Nighttime Crash Frequency at Rural Non-diamond Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 286 |
| | | LR chi2(10) = | 180.21 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -683.2217 | | Pseudo R2 = | 0.1165 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .2288388 | .1655554 | 1.38 | 0.167 | -.0956437 | .5533214 |
| speed | -.0017687 | .0064223 | -0.28 | 0.783 | -.0143561 | .0108188 |
| lntotent | .769023 | .0821775 | 9.36 | 0.000 | .607958 | .9300881 |
| perhv | .0310834 | .0137215 | 2.27 | 0.023 | .0041898 | .057977 |
| fullacc | .1484467 | .1370569 | 1.08 | 0.279 | -.1201798 | .4170732 |
| paracc | .0806542 | .1791332 | 0.45 | 0.653 | -.2704404 | .4317488 |
| barrier | .2003693 | .1058127 | 1.89 | 0.058 | -.0070198 | .4077585 |
| surf_typ | .0425087 | .0952066 | 0.45 | 0.655 | -.1440928 | .2291102 |
| lnwdt13 | .1240215 | .1776796 | 0.70 | 0.485 | -.2242242 | .4722671 |
| nolanes5 | -.141564 | .1158089 | -1.22 | 0.222 | -.3685453 | .0854173 |
| _cons | -7.549688 | 1.07958 | -6.99 | 0.000 | -9.665625 | -5.43375 |
| /lnalpha | -1.332882 | .1650967 | | | -1.656466 | -1.009298 |
| alpha | .2637161 | .0435387 | | | .1908122 | .3644746 |

Likelihood-ratio test of alpha=0: chibar2(01) = 126.28 Prob>=chibar2 = 0.000

.

## Table C.16 Daytime Crash Frequency at Rural Non-diamond Interchanges

| | | | |
|---|---|---|---|
| Negative binomial regression | | Number of obs = | 286 |
| | | LR chi2(10) = | 207.44 |
| Dispersion = mean | | Prob > chi2 = | 0.0000 |
| Log likelihood = -895.49615 | | Pseudo R2 = | 0.1038 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .0810993 | .1669421 | 0.49 | 0.627 | -.2461011 | .4082998 |
| speed | -.0054637 | .0072166 | -0.76 | 0.449 | -.0196079 | .0086805 |
| lntotent | .7810165 | .0815988 | 9.57 | 0.000 | .6210858 | .9409472 |
| perhv | -.0080572 | .0140716 | -0.57 | 0.567 | -.035637 | .0195225 |
| fullacc | .1948116 | .144446 | 1.35 | 0.177 | -.0882975 | .4779206 |
| paracc | .1250202 | .178962 | 0.70 | 0.485 | -.2257389 | .4757792 |
| barrier | .1763627 | .1144553 | 1.54 | 0.123 | -.0479657 | .400691 |
| surf_typ | .1242483 | .1001298 | 1.24 | 0.215 | -.0720024 | .320499 |
| lnwdt13 | .0959326 | .169422 | 0.57 | 0.571 | -.2361284 | .4279936 |
| nolanes5 | -.2055231 | .12197 | -1.69 | 0.092 | -.4445799 | .0335337 |
| _cons | -6.278309 | 1.096109 | -5.73 | 0.000 | -8.426643 | -4.129975 |
| /lnalpha | -.8522279 | .1088904 | | | -1.065649 | -.6388067 |
| alpha | .4264638 | .0464378 | | | .3445042 | .527922 |

Likelihood-ratio test of alpha=0: chibar2(01) = 849.34 Prob>=chibar2 = 0.000

.

Table C.17 Nighttime Crash Frequency at Urban Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =       1245
                                                  LR chi2(13)     =     420.75
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -3529.7978                       Pseudo R2       =     0.0562

------------------------------------------------------------------------------
    nighttim |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     diamond |   .1299719   .0729257     1.78   0.075    -.0129599    .2729037
        full |   .4977644   .1720527     2.89   0.004     .1605473    .8349815
     partial |   .4644382   .1721442     2.70   0.007     .1270417    .8018348
    continuo |   .6367349   .1801518     3.53   0.000     .2836438     .989826
       speed |   .0002781   .0031525     0.09   0.930    -.0059006    .0064569
    lntotent |   .1697101   .0245944     6.90   0.000     .1215059    .2179143
       perhv |  -.0651578   .0094855    -6.87   0.000    -.0837491   -.0465666
     fullacc |   .6152043   .0844129     7.29   0.000     .4497581    .7806505
      paracc |   .1852011   .1131457     1.64   0.102    -.0365604    .4069627
     barrier |   .2640473   .0553848     4.77   0.000     .1554952    .3725994
    surf_typ |  -.1095608   .0500379    -2.19   0.029    -.2076334   -.0114883
     lnwdt13 |  -.2678678   .0941922    -2.84   0.004    -.4524811   -.0832544
    nolanes5 |   .1827489   .0539085     3.39   0.001     .0770901    .2884076
       _cons |   -.713106   .3553065    -2.01   0.045    -1.409494   -.0167181
-------------+----------------------------------------------------------------
    /lnalpha |   -.699693   .0542203                     -.8059628   -.5934232
-------------+----------------------------------------------------------------
       alpha |   .4967378   .0269333                      .4466577    .5524329
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 2361.70 Prob>=chibar2 = 0.000
```

Table C.18 Daytime Crash Frequency at Urban Interchanges (Lighting Presence)

```
Negative binomial regression                      Number of obs   =       1245
                                                  LR chi2(13)     =     485.01
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -4551.1874                       Pseudo R2       =     0.0506

------------------------------------------------------------------------------
     daytime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     diamond |   .2377835   .0699023     3.40   0.001     .1007775    .3747894
        full |   .4612353   .1461526     3.16   0.002     .1747814    .7476891
     partial |    .344851   .1465064     2.35   0.019     .0577037    .6319983
    continuo |   .5401067   .1549958     3.48   0.000     .2363205    .8438929
       speed |  -.0029923    .003079    -0.97   0.331     -.009027    .0030425
    lntotent |   .1780763   .0231643     7.69   0.000     .1326752    .2234774
       perhv |  -.0809848   .0089587    -9.04   0.000    -.0985435    -.063426
     fullacc |   .6214883   .0779469     7.97   0.000     .4687153    .7742614
      paracc |   .2124778   .1030702     2.06   0.039     .0104639    .4144918
     barrier |    .330481   .0527514     6.26   0.000     .2270902    .4338719
    surf_typ |  -.0592268   .0479074    -1.24   0.216    -.1531236      .03467
     lnwdt13 |  -.3697781   .0873532    -4.23   0.000    -.5409873   -.1985689
    nolanes5 |   .1315131   .0515782     2.55   0.011     .0304216    .2326046
       _cons |   .3292399   .3288924     1.00   0.317    -.3153772    .9738571
-------------+----------------------------------------------------------------
    /lnalpha |  -.6357816   .0444438                     -.7228899   -.5486733
-------------+----------------------------------------------------------------
       alpha |   .5295214    .023534                      .4853476    .5777157
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 8142.43 Prob>=chibar2 = 0.000
```

Table C.19 Nighttime Crash Frequency at Rural Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =        776
                                                  LR chi2(13)     =     173.47
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1511.4519                       Pseudo R2       =     0.0543
```

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| diamond | .0495629 | .1116904 | 0.44 | 0.657 | -.1693463 | .2684722 |
| full | .050679 | .1054561 | 0.48 | 0.631 | -.1560112 | .2573692 |
| partial | .1199328 | .0865097 | 1.39 | 0.166 | -.0496231 | .2894888 |
| continuo | .8774836 | .3702182 | 2.37 | 0.018 | .1518691 | 1.603098 |
| speed | -.0017407 | .0070229 | -0.25 | 0.804 | -.0155053 | .0120239 |
| lntotent | .142472 | .0333175 | 4.28 | 0.000 | .0771708 | .2077731 |
| perhv | -.0079899 | .0069776 | -1.15 | 0.252 | -.0216657 | .0056859 |
| fullacc | .5356503 | .1256403 | 4.26 | 0.000 | .2893997 | .7819008 |
| paracc | .0386781 | .1530931 | 0.25 | 0.801 | -.261379 | .3387351 |
| barrier | -.4162926 | .1046254 | -3.98 | 0.000 | -.6213545 | -.2112306 |
| surf_typ | .0946816 | .0742292 | 1.28 | 0.202 | -.050805 | .2401683 |
| lnwdt13 | -.0783337 | .0898913 | -0.87 | 0.384 | -.2545174 | .09785 |
| nolanes5 | .4583569 | .1339467 | 3.42 | 0.001 | .1958261 | .7208877 |
| _cons | -.6906927 | .5856986 | -1.18 | 0.238 | -1.838641 | .4572555 |
| /lnalpha | -.9649466 | .1207726 | | | -1.201657 | -.7282366 |
| alpha | .3810036 | .0460148 | | | .3006957 | .4827595 |

```
Likelihood-ratio test of alpha=0:  chibar2(01) =  186.65 Prob>=chibar2 = 0.000
```

Table C.20 Daytime Crash Frequency at Rural Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =        776
                                                  LR chi2(13)     =     357.00
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1815.4653                       Pseudo R2       =     0.0895
```

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| diamond | .251114 | .1079995 | 2.33 | 0.020 | .0394388 | .4627892 |
| full | -.0136433 | .1041885 | -0.13 | 0.896 | -.2178489 | .1905623 |
| partial | .1693693 | .0839384 | 2.02 | 0.044 | .004853 | .3338856 |
| continuo | 1.054558 | .3880196 | 2.72 | 0.007 | .2940538 | 1.815063 |
| speed | -.0171668 | .0065733 | -2.61 | 0.009 | -.0300503 | -.0042833 |
| lntotent | .2524002 | .032255 | 7.83 | 0.000 | .1891816 | .3156189 |
| perhv | -.0211035 | .0069488 | -3.04 | 0.002 | -.0347229 | -.0074841 |
| fullacc | .7322125 | .1211774 | 6.04 | 0.000 | .4947092 | .9697157 |
| paracc | .2587625 | .1446463 | 1.79 | 0.074 | -.0247391 | .5422641 |
| barrier | -.3906584 | .1007425 | -3.88 | 0.000 | -.5881101 | -.1932067 |
| surf_typ | .2379575 | .0724395 | 3.28 | 0.001 | .0959787 | .3799364 |
| lnwdt13 | -.2472917 | .0873613 | -2.83 | 0.005 | -.4185167 | -.0760667 |
| nolanes5 | .3772514 | .1336087 | 2.82 | 0.005 | .1153831 | .6391198 |
| _cons | -.351644 | .5578122 | -0.63 | 0.528 | -1.444936 | .7416479 |
| /lnalpha | -.7201592 | .0847137 | | | -.886195 | -.5541234 |
| alpha | .4866748 | .041228 | | | .4122213 | .5745757 |

```
Likelihood-ratio test of alpha=0:  chibar2(01) =  810.10 Prob>=chibar2 = 0.000
```

Table C.21 Nighttime Crash Frequency at Diamond Interchanges (Lighting Type)

Negative binomial regression — Number of obs = 1615; LR chi2(13) = 733.89

Dispersion = mean — Prob > chi2 = 0.0000

Log likelihood = -3968.4534 — Pseudo R2 = 0.0846

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | .2125802 | .0726168 | 2.93 | 0.003 | .070254 | .3549065 |
| full | .1559083 | .0855143 | 1.82 | 0.068 | -.0116967 | .3235133 |
| partial | .1455504 | .0810008 | 1.80 | 0.072 | -.0132082 | .3043091 |
| continuo | .4176826 | .1075653 | 3.88 | 0.000 | .2068584 | .6285068 |
| speed | -.0035751 | .0032585 | -1.10 | 0.273 | -.0099617 | .0028114 |
| lntotent | .1301624 | .0205571 | 6.33 | 0.000 | .0898712 | .1704536 |
| perhv | -.0341892 | .0060722 | -5.63 | 0.000 | -.0460904 | -.0222879 |
| fullacc | .6228469 | .0830713 | 7.50 | 0.000 | .4600303 | .7856636 |
| paracc | .2292486 | .1079074 | 2.12 | 0.034 | .017754 | .4407433 |
| barrier | .0047306 | .0546888 | 0.09 | 0.931 | -.1024575 | .1119186 |
| surf_typ | -.0763703 | .0474733 | -1.61 | 0.108 | -.1694163 | .0166757 |
| lnwdt13 | -.1481807 | .0737065 | -2.01 | 0.044 | -.2926428 | -.0037185 |
| nolanes5 | .423604 | .056806 | 7.46 | 0.000 | .3122663 | .5349417 |
| _cons | -.1061979 | .2768938 | -0.38 | 0.701 | -.6488997 | .4365039 |
| /lnalpha | -.7098989 | .0559341 | | | -.8195276 | -.6002701 |
| alpha | .4916939 | .0275024 | | | .4406397 | .5486634 |

Likelihood-ratio test of alpha=0: chibar2(01) = 1799.77 Prob>=chibar2 = 0.000

Table C.22 Daytime Crash Frequency at Diamond Interchanges (Lighting Type)

Negative binomial regression — Number of obs = 1615; LR chi2(13) = 1171.63

Dispersion = mean — Prob > chi2 = 0.0000

Log likelihood = -5019.5691 — Pseudo R2 = 0.1045

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | .3051294 | .0681999 | 4.47 | 0.000 | .1714601 | .4387987 |
| full | .3128049 | .0811578 | 3.85 | 0.000 | .1537386 | .4718712 |
| partial | .2676838 | .0765427 | 3.50 | 0.000 | .1176628 | .4177048 |
| continuo | .495613 | .1031926 | 4.80 | 0.000 | .2933593 | .6978667 |
| speed | -.0123486 | .0031986 | -3.86 | 0.000 | -.0186178 | -.0060794 |
| lntotent | .170865 | .0196581 | 8.69 | 0.000 | .1323358 | .2093942 |
| perhv | -.0507671 | .0059383 | -8.55 | 0.000 | -.0624059 | -.0391283 |
| fullacc | .7133024 | .0776562 | 9.19 | 0.000 | .5610989 | .8655058 |
| paracc | .3174688 | .0999074 | 3.18 | 0.001 | .1216539 | .5132837 |
| barrier | .068438 | .0523944 | 1.31 | 0.191 | -.0342532 | .1711292 |
| surf_typ | .028891 | .0463215 | 0.62 | 0.533 | -.0618974 | .1196794 |
| lnwdt13 | -.3398784 | .0704617 | -4.82 | 0.000 | -.4779807 | -.201776 |
| nolanes5 | .3717906 | .0546911 | 6.80 | 0.000 | .2645981 | .4789831 |
| _cons | .6581536 | .269108 | 2.45 | 0.014 | .1307116 | 1.185596 |
| /lnalpha | -.6019253 | .0442839 | | | -.6887201 | -.5151305 |
| alpha | .547756 | .0242568 | | | .5022185 | .5974226 |

Likelihood-ratio test of alpha=0: chibar2(01) = 6793.88 Prob>=chibar2 = 0.000

Table C.23 Nighttime Crash Frequency at Non-diamond Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =        406
                                                  LR chi2(13)     =     270.87
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1072.7903                       Pseudo R2       =     0.1121

------------------------------------------------------------------------------
    nighttim |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      urbsub |   .1248347   .1484617     0.84   0.400    -.1661449    .4158143
        full |   .2035552   .1841166     1.11   0.269    -.1573067    .5644172
     partial |   .1878414   .1765698     1.06   0.287     -.158229    .5339118
    continuo |   .1700752   .2191404     0.78   0.438    -.2594322    .5995825
       speed |  -.0086179    .005717    -1.51   0.132    -.0198231    .0025873
    lntotent |   .6849858   .0821675     8.34   0.000     .5239404    .8460312
       perhv |   .0204653   .0148336     1.38   0.168     -.008608    .0495387
     fullacc |   .3790001   .1295413     2.93   0.003     .1251039    .6328964
      paracc |   .1406452   .1700513     0.83   0.408    -.1926493    .4739397
     barrier |    .363226   .0928127     3.91   0.000     .1813165    .5451355
    surf_typ |  -.0117255   .0821484    -0.14   0.886    -.1727334    .1492824
     lnwdt13 |   .3016958   .1514532     1.99   0.046      .004853    .5985387
    nolanes5 |  -.1619467   .0961415    -1.68   0.092    -.3503805    .0264872
       _cons |   -6.26873   .9754592    -6.43   0.000    -8.180595   -4.356865
-------------+----------------------------------------------------------------
    /lnalpha |  -.9891551   .1080902                     -1.201008   -.7773021
-------------+----------------------------------------------------------------
       alpha |   .3718908   .0401978                      .3008908    .4596444
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  470.86 Prob>=chibar2 = 0.000
```

Table C.24 Daytime Crash Frequency at Non-diamond Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =        406
                                                  LR chi2(13)     =     348.08
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -1342.6007                       Pseudo R2       =     0.1148

------------------------------------------------------------------------------
     daytime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      urbsub |   .3271697   .1356175     2.41   0.016     .0613642    .5929752
        full |   .0906225    .165918     0.55   0.585    -.2345708    .4158157
     partial |  -.0255347   .1588141    -0.16   0.872    -.3368046    .2857352
    continuo |   .0864141   .2012844     0.43   0.668    -.3080961    .4809243
       speed |  -.0005987   .0055803    -0.11   0.915    -.0115359    .0103384
    lntotent |   .7283955   .0735428     9.90   0.000     .5842543    .8725368
       perhv |  -.0016569   .0134777    -0.12   0.902    -.0280727    .0247589
     fullacc |   .2757798   .1218686     2.26   0.024     .0369217    .5146378
      paracc |   .2158403   .1509708     1.43   0.153    -.0800571    .5117377
     barrier |    .363756   .0878199     4.14   0.000     .1916323    .5358798
    surf_typ |  -.0162186   .0763145    -0.21   0.832    -.1657923    .1333551
     lnwdt13 |   .2938381   .1374394     2.14   0.033     .0244618    .5632144
    nolanes5 |  -.2153681   .0908847    -2.37   0.018    -.3934988   -.0372373
       _cons |  -6.242172    .884343    -7.06   0.000    -7.975452   -4.508891
-------------+----------------------------------------------------------------
    /lnalpha |   -.920495    .087857                     -1.092691   -.7482985
-------------+----------------------------------------------------------------
       alpha |   .3983218   .0349953                      .3353128     .473171
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) = 1420.72 Prob>=chibar2 = 0.000
```

Table C.25 Nighttime Crash Frequency at Urban Diamond Interchanges (Lighting Type)

| | |
|---|---|
| Negative binomial regression | Number of obs = 466 |
| | LR chi2(12) = 292.56 |
| Dispersion = mean | Prob > chi2 = 0.0000 |
| Log likelihood = -1231.5924 | Pseudo R2 = 0.1062 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| full | .5600503 | .2180803 | 2.57 | 0.010 | .1326208 | .9874797 |
| partial | .7344886 | .2179416 | 3.37 | 0.001 | .3073309 | 1.161646 |
| continuo | .7270632 | .2419297 | 3.01 | 0.003 | .2528897 | 1.201237 |
| speed | .0035578 | .0051365 | 0.69 | 0.489 | -.0065097 | .0136252 |
| lntotent | .1772599 | .0388581 | 4.56 | 0.000 | .1010994 | .2534204 |
| perhv | -.0875188 | .0130346 | -6.71 | 0.000 | -.1130661 | -.0619714 |
| fullacc | .4184602 | .1564349 | 2.67 | 0.007 | .1118533 | .725067 |
| paracc | .1255205 | .194602 | 0.65 | 0.519 | -.2558925 | .5069334 |
| barrier | .1130591 | .0953088 | 1.19 | 0.236 | -.0737427 | .2998608 |
| surf_typ | -.1132147 | .088925 | -1.27 | 0.203 | -.2875046 | .0610752 |
| lnwdt13 | -.173215 | .1367571 | -1.27 | 0.205 | -.441254 | .094824 |
| nolanes5 | .598687 | .1071284 | 5.59 | 0.000 | .3887192 | .8086548 |
| _cons | -.7833711 | .4942474 | -1.58 | 0.113 | -1.752078 | .185336 |
| /lnalpha | -.6597377 | .0986081 | | | -.853006 | -.4664694 |
| alpha | .5169869 | .0509791 | | | .4261321 | .6272128 |

Likelihood-ratio test of alpha=0: chibar2(01) = 713.20 Prob>=chibar2 = 0.000

Table C.26 Daytime Crash Frequency at Urban Diamond Interchanges (Lighting Type)

| | |
|---|---|
| Negative binomial regression | Number of obs = 466 |
| | LR chi2(12) = 327.19 |
| Dispersion = mean | Prob > chi2 = 0.0000 |
| Log likelihood = -1589.2177 | Pseudo R2 = 0.0933 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| full | .7000366 | .1981071 | 3.53 | 0.000 | .3117538 | 1.088319 |
| partial | .782898 | .1997471 | 3.92 | 0.000 | .3914008 | 1.174395 |
| continuo | .775838 | .2248789 | 3.45 | 0.001 | .3350835 | 1.216592 |
| speed | -.0004519 | .0050899 | -0.09 | 0.929 | -.0104279 | .0095241 |
| lntotent | .1950326 | .0386205 | 5.05 | 0.000 | .1193377 | .2707274 |
| perhv | -.1025425 | .0123189 | -8.32 | 0.000 | -.126687 | -.078398 |
| fullacc | .3802499 | .1518463 | 2.50 | 0.012 | .0826366 | .6778633 |
| paracc | .1532543 | .1845147 | 0.83 | 0.406 | -.208388 | .5148965 |
| barrier | .2757623 | .0936338 | 2.95 | 0.003 | .0922435 | .4592811 |
| surf_typ | -.0066816 | .0886592 | -0.08 | 0.940 | -.1804504 | .1670871 |
| lnwdt13 | -.454892 | .1323436 | -3.44 | 0.001 | -.7142807 | -.1955033 |
| nolanes5 | .4382126 | .1087254 | 4.03 | 0.000 | .2251146 | .6513105 |
| _cons | .1419965 | .4866766 | 0.29 | 0.770 | -.811872 | 1.095865 |
| /lnalpha | -.4968215 | .0769223 | | | -.6475864 | -.3460566 |
| alpha | .6084616 | .0468042 | | | .5233073 | .7074724 |

Likelihood-ratio test of alpha=0: chibar2(01) = 2840.05 Prob>=chibar2 = 0.000

## Table C.27 Nighttime Crash Frequency at Urban Non-diamond Interchanges (Lighting Type)

| | |
|---|---|
| Negative binomial regression | Number of obs = 120 |
| | LR chi2(11) = 76.34 |
| Dispersion = mean | Prob > chi2 = 0.0000 |
| Log likelihood = -370.56565 | Pseudo R2 = 0.0934 |

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| full | .4545781 | .2465339 | 1.84 | 0.065 | -.0286195 | .9377757 |
| partial | .4337998 | .2754187 | 1.58 | 0.115 | -.1060109 | .9736105 |
| speed | -.0152856 | .0101833 | -1.50 | 0.133 | -.0352445 | .0046732 |
| lntotent | .5448123 | .2230273 | 2.44 | 0.015 | .1076868 | .9819378 |
| perhv | .078321 | .0563747 | 1.39 | 0.165 | -.0321715 | .1888134 |
| fullacc | 1.174483 | .371772 | 3.16 | 0.002 | .4458229 | 1.903142 |
| paracc | .6371858 | .4356302 | 1.46 | 0.144 | -.2166337 | 1.491005 |
| barrier | .6055226 | .2191533 | 2.76 | 0.006 | .1759901 | 1.035055 |
| surf_typ | -.2456323 | .1539256 | -1.60 | 0.111 | -.5473209 | .0560563 |
| lnwdt13 | .623976 | .303799 | 2.05 | 0.040 | .0285409 | 1.219411 |
| nolanes5 | -.010661 | .1624301 | -0.07 | 0.948 | -.3290182 | .3076962 |
| _cons | -5.337056 | 2.550683 | -2.09 | 0.036 | -10.3363 | -.33781 |
| /lnalpha | -.9372173 | .1724746 | | | -1.275261 | -.5991733 |
| alpha | .3917164 | .0675611 | | | .279358 | .5492655 |

Likelihood-ratio test of alpha=0: chibar2(01) = 222.16 Prob>=chibar2 = 0.000

## Table C.28 Daytime Crash Frequency at Urban Non-diamond Interchanges (Lighting Type)

| | |
|---|---|
| Negative binomial regression | Number of obs = 120 |
| | LR chi2(11) = 123.30 |
| Dispersion = mean | Prob > chi2 = 0.0000 |
| Log likelihood = -434.43032 | Pseudo R2 = 0.1243 |

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| full | .4734692 | .1953083 | 2.42 | 0.015 | .0906719 | .8562664 |
| partial | .3988096 | .2198603 | 1.81 | 0.070 | -.0321087 | .8297278 |
| speed | -.0022131 | .0083227 | -0.27 | 0.790 | -.0185252 | .0140991 |
| lntotent | .7188654 | .1718031 | 4.18 | 0.000 | .3821376 | 1.055593 |
| perhv | .0844686 | .0439908 | 1.92 | 0.055 | -.0017518 | .170689 |
| fullacc | .733237 | .2636334 | 2.78 | 0.005 | .216525 | 1.249949 |
| paracc | .6437047 | .327587 | 1.96 | 0.049 | .001646 | 1.285763 |
| barrier | .7450055 | .1742896 | 4.27 | 0.000 | .4034043 | 1.086607 |
| surf_typ | -.3780411 | .1211872 | -3.12 | 0.002 | -.6155635 | -.1405186 |
| lnwdt13 | .6597441 | .2419108 | 2.73 | 0.006 | .1856076 | 1.133881 |
| nolanes5 | -.1425303 | .1320049 | -1.08 | 0.280 | -.401255 | .1161945 |
| _cons | -6.942101 | 1.985387 | -3.50 | 0.000 | -10.83339 | -3.050814 |
| /lnalpha | -1.329501 | .1617878 | | | -1.6466 | -1.012403 |
| alpha | .2646092 | .0428106 | | | .1927041 | .3633449 |

Likelihood-ratio test of alpha=0: chibar2(01) = 357.46 Prob>=chibar2 = 0.000

Table C.29 Nighttime Crash Frequency at Rural Diamond Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =       1149
                                                  LR chi2(12)     =     443.61
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -2691.7711                       Pseudo R2       =     0.0761
```

| nighttim | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| full | .4022339 | .0907031 | 4.43 | 0.000 | .2244591 | .5800087 |
| partial | .1805795 | .0855958 | 2.11 | 0.035 | .0128148 | .3483442 |
| continuo | .6680329 | .1250235 | 5.34 | 0.000 | .4229912 | .9130745 |
| speed | -.0081448 | .0040414 | -2.02 | 0.044 | -.0160659 | -.0002238 |
| lntotent | .1389713 | .0230366 | 6.03 | 0.000 | .0938203 | .1841222 |
| perhv | -.025811 | .006278 | -4.11 | 0.000 | -.0381157 | -.0135063 |
| fullacc | .6692238 | .0970382 | 6.90 | 0.000 | .4790324 | .8594151 |
| paracc | .209954 | .1297849 | 1.62 | 0.106 | -.0444198 | .4643277 |
| barrier | -.1529727 | .0674982 | -2.27 | 0.023 | -.2852668 | -.0206786 |
| surf_typ | -.0468044 | .054372 | -0.86 | 0.389 | -.1533715 | .0597627 |
| lnwdt13 | -.1782746 | .0868645 | -2.05 | 0.040 | -.3485259 | -.0080234 |
| nolanes5 | .2481416 | .0659828 | 3.76 | 0.000 | .1188177 | .3774655 |
| _cons | .0604212 | .3409122 | 0.18 | 0.859 | -.6077544 | .7285969 |
| /lnalpha | -.879225 | .0726006 | | | -1.021519 | -.7369305 |
| alpha | .4151045 | .0301368 | | | .3600474 | .4785807 |

```
Likelihood-ratio test of alpha=0:  chibar2(01) =  823.12 Prob>=chibar2 = 0.000
```

Table C.30 Daytime Crash Frequency at Rural Diamond Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =       1149
                                                  LR chi2(12)     =     851.66
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -3396.894                        Pseudo R2       =     0.1114
```

| daytime | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| full | .5352535 | .0876326 | 6.11 | 0.000 | .3634967 | .7070103 |
| partial | .2806184 | .0815224 | 3.44 | 0.001 | .1208375 | .4403994 |
| continuo | .7688094 | .1213595 | 6.33 | 0.000 | .5309492 | 1.00667 |
| speed | -.0233217 | .0039565 | -5.89 | 0.000 | -.0310763 | -.0155672 |
| lntotent | .1940611 | .0221872 | 8.75 | 0.000 | .150575 | .2375472 |
| perhv | -.0434733 | .0062153 | -6.99 | 0.000 | -.0556551 | -.0312915 |
| fullacc | .8891747 | .0914814 | 9.72 | 0.000 | .7098744 | 1.068475 |
| paracc | .3817694 | .1217049 | 3.14 | 0.002 | .1432323 | .6203066 |
| barrier | -.1017126 | .0646759 | -1.57 | 0.116 | -.2284752 | .0250499 |
| surf_typ | .0055046 | .053035 | 0.10 | 0.917 | -.0984422 | .1094513 |
| lnwdt13 | -.3118469 | .0835229 | -3.73 | 0.000 | -.4755487 | -.1481451 |
| nolanes5 | .3275902 | .0632632 | 5.18 | 0.000 | .2035966 | .4515839 |
| _cons | 1.068946 | .3292504 | 3.25 | 0.001 | .4236272 | 1.714265 |
| /lnalpha | -.7281015 | .0554411 | | | -.8367641 | -.619439 |
| alpha | .4828247 | .0267683 | | | .4331098 | .5382463 |

```
Likelihood-ratio test of alpha=0:  chibar2(01) = 3569.16 Prob>=chibar2 = 0.000
```

.

## Table C.31 Nighttime Crash Frequency at Rural Non-diamond Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =        286
                                                  LR chi2(12)     =     184.69
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -680.98324                       Pseudo R2       =     0.1194

------------------------------------------------------------------------------
    nighttim |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        full |   .2586021   .1757134     1.47   0.141    -.0857899    .6029941
     partial |    .246244   .1715155     1.44   0.151    -.0899202    .5824082
    continuo |   .5259468   .2183847     2.41   0.016     .0979206    .9539731
       speed |  -.0003231    .006417    -0.05   0.960    -.0129001     .012254
    lntotent |   .7319519   .0858068     8.53   0.000     .5637738    .9001301
       perhv |   .0315855   .0137803     2.29   0.022     .0045766    .0585944
     fullacc |   .2104543   .1412358     1.49   0.136    -.0663628    .4872713
      paracc |   .1425024   .1819403     0.78   0.433    -.2140939    .4990988
     barrier |    .143729   .1116889     1.29   0.198    -.0751772    .3626353
    surf_typ |   .0408278   .0943689     0.43   0.665    -.1441318    .2257874
     lnwdt13 |   .1418625   .1764717     0.80   0.421    -.2040157    .4877407
    nolanes5 |   -.120154   .1156918    -1.04   0.299    -.3469058    .1065978
       _cons |  -7.330818   1.091274    -6.72   0.000    -9.469676   -5.191959
-------------+----------------------------------------------------------------
    /lnalpha |  -1.366836   .1677465                     -1.695613   -1.038059
-------------+----------------------------------------------------------------
       alpha |   .2549123   .0427606                      .1834867    .3541415
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  119.51 Prob>=chibar2 = 0.000
```

## Table C.32 Daytime Crash Frequency at Rural Non-diamond Interchanges (Lighting Type)

```
Negative binomial regression                      Number of obs   =        286
                                                  LR chi2(12)     =     215.39
Dispersion     = mean                             Prob > chi2     =     0.0000
Log likelihood = -891.51911                       Pseudo R2       =     0.1078

------------------------------------------------------------------------------
     daytime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        full |    .237724   .1767991     1.34   0.179    -.1087959    .5842439
     partial |   -.006474   .1725206    -0.04   0.970    -.3446083    .3316602
    continuo |   .4430714    .226901     1.95   0.051    -.0016464    .8877891
       speed |  -.0024781   .0070494    -0.35   0.725    -.0162947    .0113386
    lntotent |   .7055969   .0848468     8.32   0.000     .5393003    .8718934
       perhv |  -.0122576   .0141763    -0.86   0.387    -.0400426    .0155275
     fullacc |   .3287317   .1492835     2.20   0.028     .0361414    .6213221
      paracc |   .2392197   .1806743     1.32   0.185    -.1148955    .5933349
     barrier |   .0771245   .1186562     0.65   0.516    -.1554374    .3096864
    surf_typ |   .1227255   .0983114     1.25   0.212    -.0699613    .3154124
     lnwdt13 |   .1283808    .167984     0.76   0.445    -.2008618    .4576234
    nolanes5 |  -.1824885   .1205776    -1.51   0.130    -.4188163    .0538393
       _cons |  -5.766343    1.09359    -5.27   0.000    -7.909739   -3.622947
-------------+----------------------------------------------------------------
    /lnalpha |  -.8880867    .109885                     -1.103457   -.6727161
-------------+----------------------------------------------------------------
       alpha |   .4114422   .0452113                      .3317222    .5103206
------------------------------------------------------------------------------
Likelihood-ratio test of alpha=0:  chibar2(01) =  820.95 Prob>=chibar2 = 0.000
```

Table C.33 Log-linear Regression Model of Urban Interchanges

```
      Source |       SS       df       MS              Number of obs =    1139
-------------+------------------------------           F( 11,  1127) =    2.77
       Model |  12.4272795    11  1.12975268           Prob > F      =  0.0015
    Residual |  460.277195  1127  .408409224           R-squared     =  0.0263
-------------+------------------------------           Adj R-squared =  0.0168
       Total |  472.704474  1138  .415381788           Root MSE      =  .63907

------------------------------------------------------------------------------
    lnntoday |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     diamond |  -.1277896   .0585071    -2.18   0.029    -.2425847   -.0129945
       light |  -.2306861   .1328849    -1.74   0.083    -.4914156    .0300435
       speed |   .0018104   .0024822     0.73   0.466    -.0030599    .0066808
    lntotent |  -.0288369   .0206638    -1.40   0.163    -.0693807    .0117069
       perhv |   .0215339   .0071606     3.01   0.003     .0074842    .0355835
      paracc |  -.0275371   .0888615    -0.31   0.757    -.2018897    .1468155
     fullacc |  -.0385467   .0675241    -0.57   0.568    -.1710337    .0939404
     barrier |  -.0258315   .0444998    -0.58   0.562    -.1131432    .0614802
    surf_typ |  -.0484136   .0403932    -1.20   0.231     -.127668    .0308408
     lnwdt13 |   .0283369   .0752873     0.38   0.707    -.1193822    .1760561
    nolanes5 |   .0157572   .0445332     0.35   0.724    -.0716202    .1031346
       _cons |  -.4270475   .2867746    -1.49   0.137    -.9897196    .1356246
------------------------------------------------------------------------------
```

.

Table C.34 Log-linear Regression Model of Rural Interchanges

```
      Source |       SS       df       MS              Number of obs =     540
-------------+------------------------------           F( 11,   528) =    5.61
       Model |  37.1319621    11  3.37563292           Prob > F      =  0.0000
    Residual |  317.899786   528  .602082929           R-squared     =  0.1046
-------------+------------------------------           Adj R-squared =  0.0859
       Total |  355.031748   539   .65868599           Root MSE      =  .77594

------------------------------------------------------------------------------
    lnntoday |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     diamond |  -.2663474   .1136009    -2.34   0.019    -.4895127   -.0431821
       light |   .1221284   .0793937     1.54   0.125    -.0338378    .2780947
       speed |   .0094993    .007342     1.29   0.196    -.0049239    .0239224
    lntotent |  -.1425275   .0336019    -4.24   0.000    -.2085374   -.0765176
       perhv |   .0156582   .0067593     2.32   0.021     .0023798    .0289367
      paracc |  -.0878803   .1531726    -0.57   0.566    -.3887829    .2130222
     fullacc |  -.1639949    .125753    -1.30   0.193    -.4110324    .0830427
     barrier |   .0894413   .1097379     0.82   0.415    -.1261352    .3050178
    surf_typ |  -.1574963   .0749011    -2.10   0.036     -.304637   -.0103556
     lnwdt13 |   .2165555   .0906839     2.39   0.017     .0384099    .3947011
    nolanes5 |  -.0116052   .1330552    -0.09   0.931    -.2729878    .2497774
       _cons |   .3341513   .5993671     0.56   0.577    -.8432856    1.511588
------------------------------------------------------------------------------
```

.

.

## Table C.35 Log-linear Regression Model of Diamond Interchanges

| Source | SS | df | MS |
|---|---|---|---|
| Model | 125.303878 | 11 | 11.3912616 |
| Residual | 617.896043 | 1303 | .474210317 |
| Total | 743.199921 | 1314 | .565601157 |

| | |
|---|---|
| Number of obs = | 1315 |
| F( 11, 1303) = | 24.02 |
| Prob > F = | 0.0000 |
| R-squared = | 0.1686 |
| Adj R-squared = | 0.1616 |
| Root MSE = | .68863 |

| lnntoday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | -.213694 | .060704 | -3.52 | 0.000 | -.3327823 | -.0946057 |
| light | -.0324865 | .0659919 | -0.49 | 0.623 | -.1619485 | .0969755 |
| speed | .0044613 | .0027853 | 1.60 | 0.109 | -.0010029 | .0099256 |
| lntotent | -.0715767 | .0181825 | -3.94 | 0.000 | -.1072469 | -.0359065 |
| perhv | .0193533 | .0049325 | 3.92 | 0.000 | .0096767 | .0290299 |
| paracc | -.032899 | .0941285 | -0.35 | 0.727 | -.2175589 | .1517609 |
| fullacc | -.0819577 | .0718943 | -1.14 | 0.255 | -.222999 | .0590835 |
| barrier | .0159106 | .0481889 | 0.33 | 0.741 | -.0786258 | .110447 |
| surf_typ | -.1221316 | .041329 | -2.96 | 0.003 | -.2032102 | -.0410529 |
| lnwdt13 | .1826476 | .0611144 | 2.99 | 0.003 | .0627542 | .3025409 |
| nolanes5 | .0090661 | .0500098 | 0.18 | 0.856 | -.0890424 | .1071745 |
| _cons | -.2098914 | .238285 | -0.88 | 0.379 | -.6773556 | .2575728 |

.

## Table C.36 Log-linear Regression Model of Non-diamond Interchanges

| Source | SS | df | MS |
|---|---|---|---|
| Model | 19.6642047 | 11 | 1.78765497 |
| Residual | 162.843429 | 352 | .462623377 |
| Total | 182.507633 | 363 | .50277585 |

| | |
|---|---|
| Number of obs = | 364 |
| F( 11, 352) = | 3.86 |
| Prob > F = | 0.0000 |
| R-squared = | 0.1077 |
| Adj R-squared = | 0.0799 |
| Root MSE = | .68016 |

| lnntoday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| urbsub | -.2136579 | .1252144 | -1.71 | 0.089 | -.4599203 | .0326044 |
| light | .1086375 | .150848 | 0.72 | 0.472 | -.1880393 | .4053142 |
| speed | .0015166 | .0050659 | 0.30 | 0.765 | -.0084467 | .0114798 |
| lntotent | -.1633519 | .0758218 | -2.15 | 0.032 | -.3124726 | -.0142313 |
| perhv | .0127651 | .0126003 | 1.01 | 0.312 | -.0120163 | .0375464 |
| paracc | -.206686 | .1409019 | -1.47 | 0.143 | -.4838015 | .0704294 |
| fullacc | -.00316 | .1116985 | -0.03 | 0.977 | -.2228403 | .2165203 |
| barrier | -.0329334 | .0867688 | -0.38 | 0.705 | -.2035838 | .1377171 |
| surf_typ | .0579744 | .0752334 | 0.77 | 0.441 | -.0899891 | .2059378 |
| lnwdt13 | -.1866263 | .1410135 | -1.32 | 0.187 | -.4639613 | .0907086 |
| nolanes5 | .0132089 | .0929819 | 0.14 | 0.887 | -.169661 | .1960789 |
| _cons | 1.030769 | .9022968 | 1.14 | 0.254 | -.7438022 | 2.80534 |

.

Table C.37 Log-linear Regression Model of Urban Diamond Interchanges

| Source | SS | df | MS |
|---|---|---|---|
| Model | 13.3906757 | 10 | 1.33906757 |
| Residual | 350.041654 | 863 | .405610259 |
| Total | 363.432329 | 873 | .416302783 |

| | |
|---|---|
| Number of obs = | 874 |
| F( 10, 863) = | 3.30 |
| Prob > F = | 0.0003 |
| R-squared = | 0.0368 |
| Adj R-squared = | 0.0257 |
| Root MSE = | .63688 |

| lnntoday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | -.2250823 | .140891 | -1.60 | 0.111 | -.5016115 | .0514468 |
| speed | .0031459 | .0028252 | 1.11 | 0.266 | -.0023992 | .0086909 |
| lntotent | -.0287067 | .0214944 | -1.34 | 0.182 | -.0708942 | .0134807 |
| perhv | .0210535 | .007623 | 2.76 | 0.006 | .0060917 | .0360153 |
| paracc | -.0358858 | .1068343 | -0.34 | 0.737 | -.2455714 | .1737997 |
| fullacc | -.0618309 | .0822548 | -0.75 | 0.452 | -.2232737 | .099612 |
| barrier | -.0029985 | .0515564 | -0.06 | 0.954 | -.1041891 | .0981921 |
| surf_typ | -.1318887 | .0466347 | -2.83 | 0.005 | -.2234194 | -.040358 |
| lnwdt13 | .1286007 | .0831545 | 1.55 | 0.122 | -.0346081 | .2918095 |
| nolanes5 | .0343464 | .0508729 | 0.68 | 0.500 | -.0655028 | .1341956 |
| _cons | -.6019637 | .2789425 | -2.16 | 0.031 | -1.149449 | -.0544786 |

Table C.38 Log-linear Regression Model of Urban Non-diamond Interchanges

| Source | SS | df | MS |
|---|---|---|---|
| Model | 6.24433639 | 10 | .624433639 |
| Residual | 102.447777 | 254 | .403337703 |
| Total | 108.692113 | 264 | .411712549 |

| | |
|---|---|
| Number of obs = | 265 |
| F( 10, 254) = | 1.55 |
| Prob > F = | 0.1228 |
| R-squared = | 0.0574 |
| Adj R-squared = | 0.0203 |
| Root MSE = | .63509 |

| lnntoday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | -.3722796 | .4348493 | -0.86 | 0.393 | -1.228649 | .4840897 |
| speed | -.0042373 | .0053472 | -0.79 | 0.429 | -.0147678 | .0062932 |
| lntotent | -.0814159 | .0921319 | -0.88 | 0.378 | -.2628557 | .1000239 |
| perhv | .0214624 | .0244337 | 0.88 | 0.381 | -.026656 | .0695808 |
| paracc | -.154575 | .1752647 | -0.88 | 0.379 | -.4997322 | .1905821 |
| fullacc | .0513421 | .1280509 | 0.40 | 0.689 | -.2008347 | .3035188 |
| barrier | -.0606219 | .093055 | -0.65 | 0.515 | -.2438794 | .1226357 |
| surf_typ | .215198 | .0832542 | 2.58 | 0.010 | .0512415 | .3791546 |
| lnwdt13 | -.4020498 | .1821883 | -2.21 | 0.028 | -.7608419 | -.0432578 |
| nolanes5 | -.0210153 | .0975534 | -0.22 | 0.830 | -.2131318 | .1711013 |
| _cons | .5407038 | 1.142283 | 0.47 | 0.636 | -1.708849 | 2.790257 |

Table C.39  Log-linear Regression Model of Rural Diamond Interchanges

| Source | SS | df | MS |
|---|---|---|---|
| Model | 32.2806687 | 10 | 3.22806687 |
| Residual | 261.654111 | 430 | .608497933 |
| Total | 293.93478 | 440 | .668033591 |

| | |
|---|---|
| Number of obs = | 441 |
| F( 10, 430) = | 5.30 |
| Prob > F = | 0.0000 |
| R-squared = | 0.1098 |
| Adj R-squared = | 0.0891 |
| Root MSE = | .78006 |

| lnntoday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .0821958 | .0891911 | 0.92 | 0.357 | -.093109 | .2575005 |
| speed | .0064064 | .0092051 | 0.70 | 0.487 | -.0116861 | .024499 |
| lntotent | -.1348812 | .0355562 | -3.79 | 0.000 | -.2047669 | -.0649956 |
| perhv | .0169776 | .0074324 | 2.28 | 0.023 | .0023694 | .0315859 |
| paracc | .0213879 | .1923734 | 0.11 | 0.912 | -.3567213 | .3994971 |
| fullacc | -.1382005 | .1589182 | -0.87 | 0.385 | -.4505537 | .1741526 |
| barrier | .1102506 | .1248885 | 0.88 | 0.378 | -.1352173 | .3557186 |
| surf_typ | -.102286 | .0852856 | -1.20 | 0.231 | -.2699146 | .0653426 |
| lnwdt13 | .2211673 | .0998911 | 2.21 | 0.027 | .0248316 | .4175029 |
| nolanes5 | -.0854514 | .1685862 | -0.51 | 0.613 | -.4168069 | .2459041 |
| _cons | .1570541 | .6543593 | 0.24 | 0.810 | -1.129087 | 1.443195 |

Table C.40  Log-linear Regression Model of Rural Non-diamond Interchanges

| Source | SS | df | MS |
|---|---|---|---|
| Model | 7.82859818 | 10 | .782859818 |
| Residual | 52.9527489 | 88 | .601735783 |
| Total | 60.7813471 | 98 | .620217828 |

| | |
|---|---|
| Number of obs = | 99 |
| F( 10, 88) = | 1.30 |
| Prob > F = | 0.2425 |
| R-squared = | 0.1288 |
| Adj R-squared = | 0.0298 |
| Root MSE = | .77572 |

| lnntoday | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| light | .3112015 | .2053023 | 1.52 | 0.133 | -.0967938 | .7191968 |
| speed | .0136779 | .0141793 | 0.96 | 0.337 | -.0145004 | .0418562 |
| lntotent | -.2007786 | .1697885 | -1.18 | 0.240 | -.5381976 | .1366404 |
| perhv | .0108193 | .0184307 | 0.59 | 0.559 | -.0258079 | .0474465 |
| paracc | -.1763366 | .2780215 | -0.63 | 0.528 | -.7288459 | .3761728 |
| fullacc | -.110433 | .2778528 | -0.40 | 0.692 | -.6626072 | .4417411 |
| barrier | -.1033108 | .2579074 | -0.40 | 0.690 | -.6158476 | .4092261 |
| surf_typ | -.3166209 | .1683 | -1.88 | 0.063 | -.6510818 | .01784 |
| lnwdt13 | .1304911 | .24477 | 0.53 | 0.595 | -.3559378 | .61692 |
| nolanes5 | .1300752 | .2703075 | 0.48 | 0.632 | -.407104 | .6672545 |
| _cons | .6609799 | 2.189874 | 0.30 | 0.763 | -3.690935 | 5.012894 |