VDOT Crash Analysis Procedures for Roadway Safety Assessments

Crash analysis is a critical component of road safety analysis. The crash analysis procedures defined in this document will help:

- Identify where to target resources for detailed crash analysis
- Assess the safety issues of a roadway segment or spot location (e.g., intersection or curve)
- Perform Roadway Safety Assessments (RSA) and
- Develop safety countermeasures.

The focus of the procedures in this document will be for assessing roadway segments, although an example intersection studied in detail is presented as a component of a segment. Crash data from approximately 13 miles of US 250 in Henrico County were analyzed to prepare for an RSA of this suburban corridor. The topics covered by this procedure include:

- Overview of Analysis Approach
- Finding High Crash Locations (using comparison statistics)
- Detailed Crash Analysis of a corridor and/or spot

<u>Overview of Analysis Approach:</u>

The roadway safety assessment of a segment should consider the environment (roadway type and conditions, terrain/alignment, adjacent land-use, weather), the driver (condition) and the vehicle (types/mix, volumes, speeds). To review these safety characteristics, the crash data should be analyzed to determine the current crash trends and related traffic issues should be identified. Using the results of the crash analysis and traffic volume summaries, a field safety review should be conducted to determine the appropriate and feasible improvements that should be made to mitigate the identified hazard situation. This process is known as conducting and documenting a Roadway Safety Assessment (RSA).

The basic steps in conducting an RSA to support the design recommendations and deploying of safety countermeasures are:

1. Conduct detailed crash analysis of the subject highway segment or intersection
2. Develop detailed crash trends and diagrams at high severe crash location for investigation
3. Using crash analysis results, conduct RSA field review and prepare report. Ask for local enforcement and maintenance personnel input on identified trends and severe crash locations
4. Classify the RSA recommended countermeasures as maintenance, operations, safety, or construction improvements
5. Identify, rank by B/C ratios, and implement all critical improvements that can be done quickly without ROW and seek HSIP funding and program long term improvements.

Before conducting a detailed crash analysis, the study area must be defined. Identifying the critical locations within a corridor to focus the RSA is an iterative process. For crash analysis purposes, the study area will be called the roadway segment. A roadway segment may be divided into homogeneous sub-sections for aggregate comparisons.

Analysis Approach to Define RSA:

The crash data analysis supporting an RSA should follow a funnel approach. Figure 1 shows the six steps that should be considered for the crash data analysis of an identified corridor, as follows:

- STEP 1: First, the overall crash record of the roadway segment is compared to overall statewide, region or jurisdictional averages with particular attention to severe crash density and rates. Statewide crash statistics have been compiled for all Interstates and Primary system roads to provide aggregate comparisons based on the functional class and configuration (cross-section) of the roadway. Multiple years of data from the VDOT Annual Summary of Crash Data Reports have been entered into Excel sheets to use for the initial comparisons. There is an on-going effort to compile the same statistics over multiple years for each route number (and direction for interstates). Contact HSIP staff for more details on comparison statistics.
- STEP 2: For longer segments, the corridor should be divided into sections of similar configuration and environments (e.g., cross-section, terrain, adjacent land-use/driveway density) to determine if there are areas requiring further analysis assessment. Listings or maps of high crash intersections should also be reviewed to determine any locations to target detailed analysis.
- STEP 3: There should be an assessment of the overall trends and influence of the roadway, traffic, weather/pavement, lighting and driver behavior based on identified conditions of the segment. Step three may summarize the following causal factors of crashes for the entire segment or by section as determined to be pertinent based on knowledge of the area :
    - Collision Type
    - Driver Action
    - Driver Condition
    - Driver Drinking
    - Surface and Light Conditions
    - Time of Day

  This analysis will be a trial and error refinement of the most important causal factors.
- STEP 4: Based on the issues identified, a detailed assessment of crash types and severity should be developed for smaller slices along the corridor segment or sub-sections. In general 0.25 mile slices will be small enough to pinpoint safety issues in the corridor. Identified high severe crash intersections should also have detailed analysis.
- STEP 5: Identify trends and high severe crash locations (slices and/or intersections) for further RSA investigation.

Figure 1 Corridor Crash Data Analysis Steps to Support Targeting RSAs

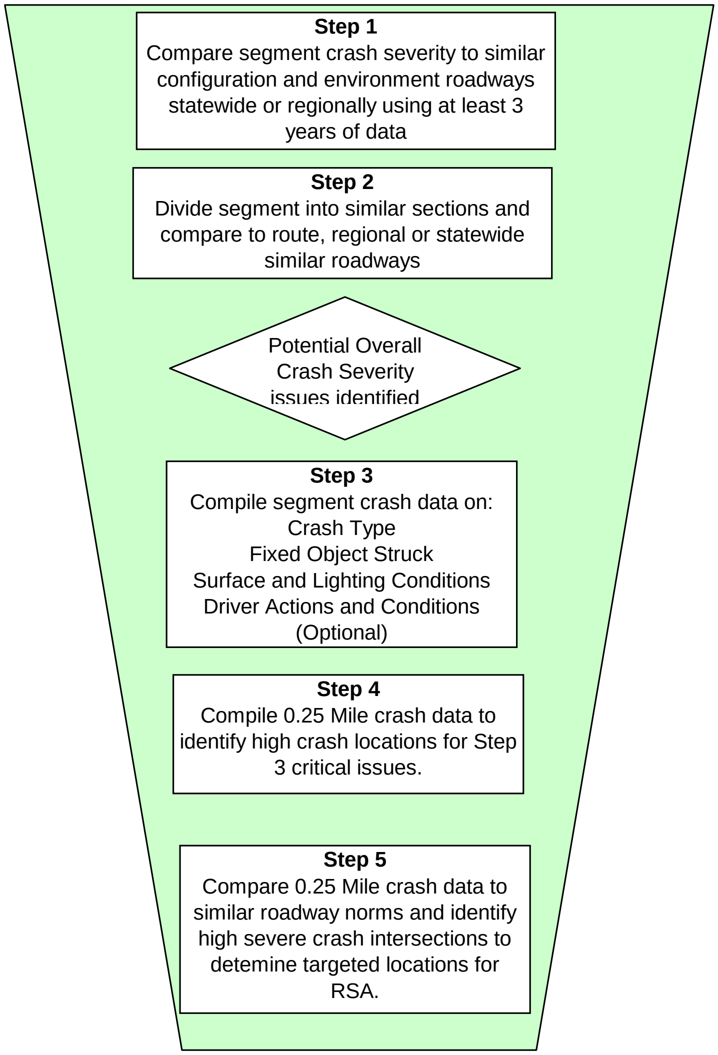
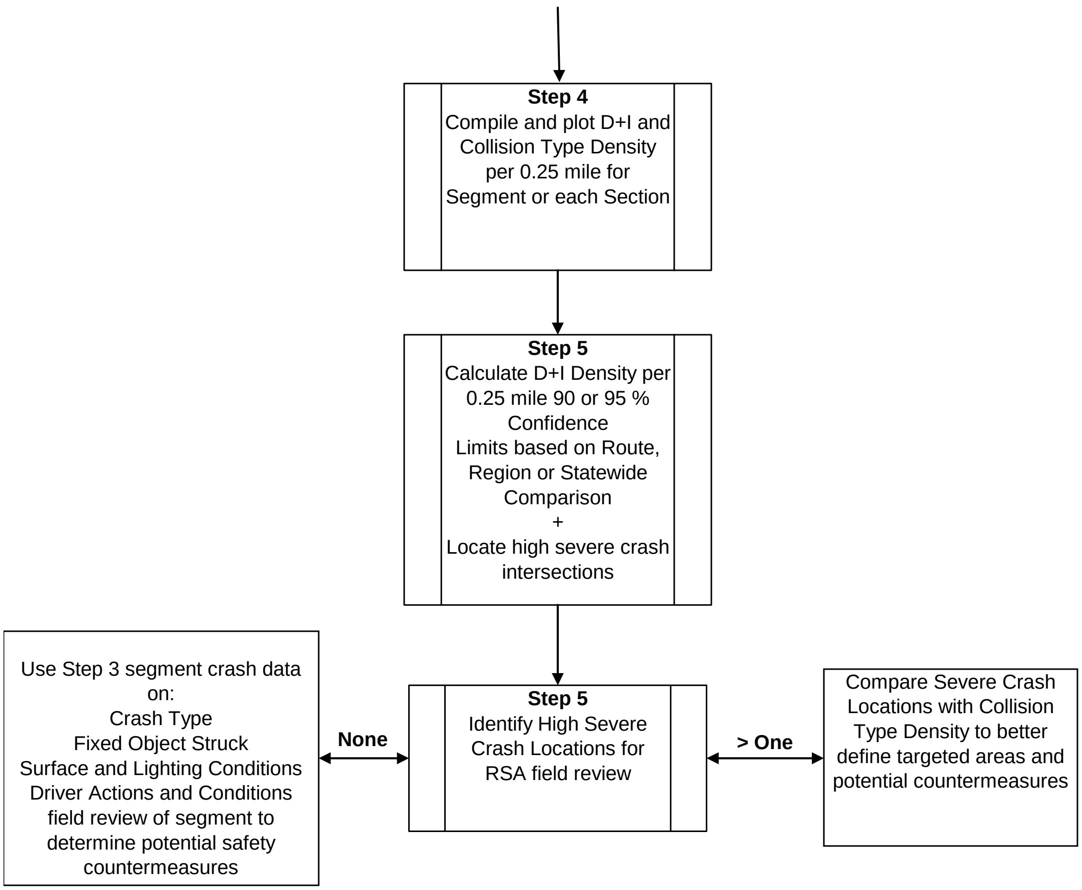


Figure 2 further defines the comparison process with each crash or injury density to similar roadways identified in STEP 4 and 5 for each 0.25 mile slice. STEP 4 involves creating histograms or counts of the total crashes, deaths plus injuries, and collision types (summing to total crashes) for each 0.25 mile slice of the study area.

Using the average crash or injury density of comparison routes (local, regional or statewide crash data), the 90 to 95 percent confidence limits (CL) can be determined using the Poisson distribution in STEP 5. Crash densities above the CL are considered to be statistically above average and are thus critical locations to investigate.

Review of the predominant collision types (STEP 3) plotted by 0.25 mile around the critical sections above the CL thresholds may reveal additional length and details to be considered with the RSA field review. The collision types (total crashes) by 0.25 mile should also be reviewed around the identified high injury locations to determine if the same issues may be present in adjoining slices that should be addressed. When no 0.25 mile severe crash density slices are identified for further review, then the collision type, driver and environment factors summarized in STEP 3 should be used to determine any systematic safety concerns and to identify potential countermeasures. For example, rural segments may have a prominence of run off the road or deer crashes that may deserve countermeasure development.

Figure 2 Detailed Crash Data Comparisons for RSA Development



<u>Detailed Crash Analysis for RSA Field Review:</u>

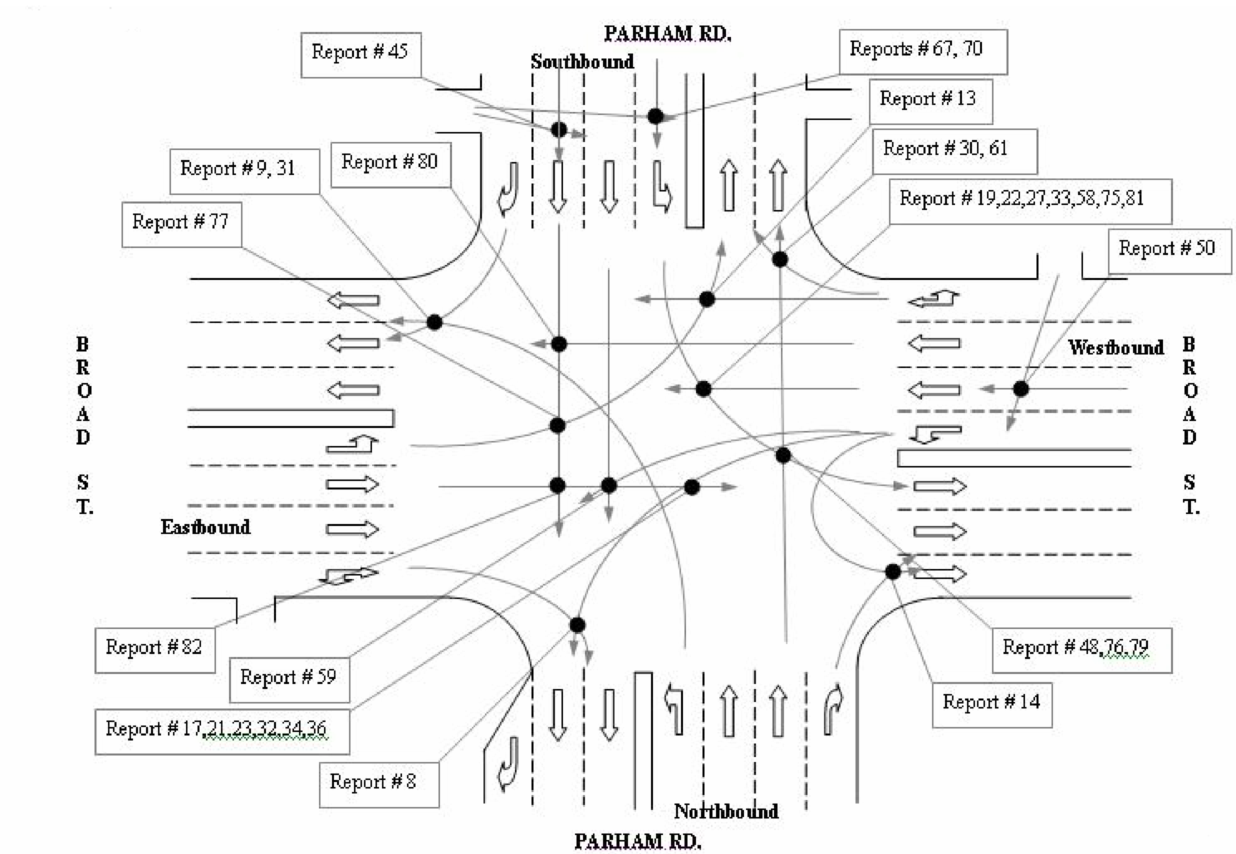
Crash density and collision type analysis can provide a starting point for safety analysis. With these preliminary results, RSA team can go out to field with questions and several emphasis areas. However, detailed analysis of the three to five years of crash trends and existing traffic conditions at the targeted locations should follow the above Step 3 assessment of the influence of the roadway, traffic, weather/pavement, lighting and driver behavior. Again, the following causal factors of crashes should be summarized from the database for the intersections and roadway segments to be field reviewed:

- Collision Type
- Time of Day
- Driver Action
- Driver Condition

- Driver Drinking
- Surface and Light Conditions

Review of the crash trends for these factors, combined with understanding of traffic volume movements and conditions, will begin to identify where and when to target the field review and what to observe. Comparisons to the overall corridor trends may be helpful. However, the actual police reports (FR300) should be reviewed and collision diagrams prepared for the intersections and segment slices of interest. A good diagramming approach is to number the crash reports for each identified intersection or segment location, then for each conflict point annotate the associated numbers crashes with a separate diagram by collision type. Figure 3 shows an intersection diagram annotated for the angle crashes. Crash severity of the numbers may be identified using colors or different fonts.

Figure 3 Example Intersection Collision Diagram for Angle Crashes



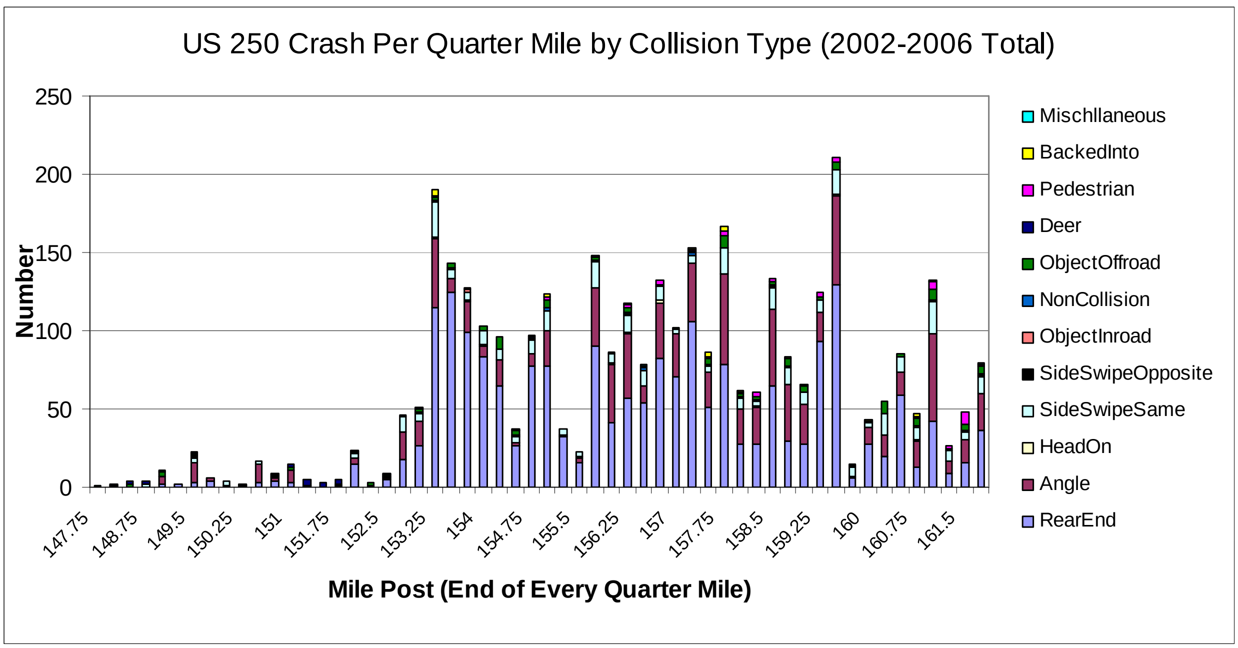
The analysis of the crash trends should lead to identifying the key issues relating to location, time and traffic maneuvers/movements to target during the field review. However, the RSA team should remain aware when scoping the field review, that highway, terrain and built environment upstream of the high crash locations may contribute to crashes where they are occurring. Crashes at an intersection, for example, may be influenced by conditions on the segment leading into the conflict point.

Example: US 250 Crash Data Analysis

US 250 (Broad Street) was determined to be the corridor which have the highest crash rates and frequencies in the VDOT Richmond District when assessed to define candidates for the Highway Safety Corridor program on primary roads. In particular, the west part of Broad Street (from Staples Mill Road to Pump Road) has extremely high crash density and number of injuries and deaths. This finding was primarily due to the much higher suburban area crash statistics in Richmond.

Crash summaries were compiled for US 250 for the five year period between 2002 and 2006. First, the crashes were summarized by collision type which revealed that 57.8 percent of the crashes are rear end crashes. 25.6 percent of crashes are angle crashes. 9.7 percent of crashes are sideswipe (same directional). A bar graph of 0.25 mile slice crash density by collision type is shown in Figure 4. Two slices experienced almost over 200 crashes, which are almost 40 per year. Several others experienced about 30 per year over the 5 year period.

Figure 4 US 250 Crashes per Quarter Mile by Collision Type (2002-2006 Total)



Identifying High Crash Locations

Number of crashes and number of injuries and deaths per quarter mile are compiled along the U.S. 250 as shown in Figure 5. The mile posts of major intersection are listed in Table 1. To better visualize the crash density along the Broad Street, the crash statistics are plotted in a GIS map (optional) as in Attachment 1. Although the mapping of the segment data is additional and optional effort, a map shows specific area of concern in relation to the road network, intersection and known land use. For example, the position of the 0.25 mile slice near intersections may suggest looking at adjacent slices or even using smaller slices. High severe crash intersection listing and maps may also be reviewed to find critical locations for review.

To determine the critical number of annual injuries and deaths, the statewide average crash statistics of six lanes divided roads with no access control is used as a bench mark. The average injuries and deaths per quarter mile in the past 6 years on this type of road are 3.16 per quarter mile per year. Assuming the number of injuries and deaths follow a Poisson distribution, a critical value of 6 is determined at around 95% confidence level. A Poisson distribution table should be referenced to obtain this number.

Figure 5 US 250 Crash Statistics per Quarter Mile (2002-2006 Average)

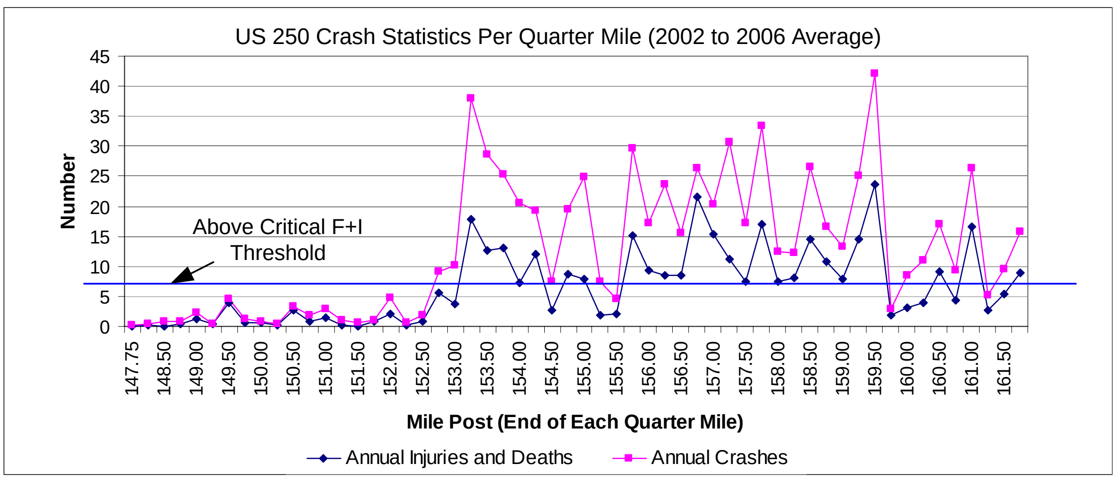


Table 1 US 250 Intersecting Side Street Mile Post

Mile Post	Intersecting Side Street
152.63	Entrance to Short Pump Mall
152.93	Spring Oak
153.17	Pump Road
153.5	Three Chop Road
154.39	I64 W Exit
154.76	Cox Road
155.57	Gaskin Road
157.64	Parham Road
159.43	Glenside Road

Figure 5 shows that most sections (slices) of the segment from Pump Road to Glenside has a number of injuries and deaths above the critical value of 6, indicating these sections have some characteristics different from an "average" six lanes divided roads. The higher than normal number of injuries and deaths may come from difference in ADT, roadway characteristics or driver behavior. This may be explained by that fact that this segment of Broad Street changes from an older high driveway density commercial corridor to a higher speed suburban corridor, which has a very high ADT and a lot of conflicting traffic movement activities. The high number of injuries and deaths warrants an engineering review of roadway features at intersections and segments to identify potential safety improvements.

Although the segments between Pump Road and Staples Mill Road all have high number of injuries and deaths, the peak locations in this segment (worst of the worst) should receive the most attention. As can be seen from the GIS map, it is as expected that several major intersections like Pump & Broad Street; Gaskin & Broad Street, Parham & Broad Street and Glenside& Broad Street have higher number of injuries. To better understand the types and location of these intersection crashes, collision diagrams were plotted using 3 years of crash data. Also, high number of I+D crashes occur near Tuckernuck Drive and West End drive, which are worth further investigation. Plotting the collision diagram on this segment is suggested as well.

For one high crash location, a sample database query summary of the crash trends at the intersection Broad Street and Parham Road (within 150 feet) is shown in Figure 6. An example intersection collision diagram was provided in Figure 3 for Broad Street at Parham Road.

Figure 6 Sample Broad Street at Parham Road Intersection Crash Casual Factors Analysis Summary

Crash Characteristics	Crash Frequency per Year						Total	
	2004		2005		2006			
	#	%	#	%	#	%	#	%
Total	29	100	32	100	28	100	89	100
DUI	2	6.90	3	9.38	3	10.71	8	8.99
Fatal	0	0.00	0	0.00	1	3.57	1	1.12
Injury								
overall	6	20.69	7	21.88	12	42.86	25	28.09
type 2	1	3.45	2	6.25	2	7.14	4	4.49
type 3	0	0.00	1	3.13	0	0.00	1	1.12
type 4	5	17.24	4	12.50	10	35.71	19	21.35
By Weather:								
clear (clear & cloudy)	21	72.41	25	78.13	25	89.29	71	79.78
adverse (all other)	8	27.59	7	21.88	3	10.71	18	20.22
By Roadway Surface Conditions:								
dry	20	68.97	25	78.13	23	82.14	68	76.40
slippery (all other)	9	31.03	7	21.88	5	17.86	21	23.60
By Light Conditions:								
day (dawn & daylight & dusk)	20	68.97	21	65.63	22	78.57	63	70.79
night (darkness-road lighted & not lighted)	9	31.03	11	34.38	6	21.43	26	29.21
By Type of Collision:								
rear-end	14	48.28	13	40.63	16	57.14	43	48.31
angle	11	37.93	12	37.50	10	35.71	33	37.08
sideswipe	2	6.90	4	12.50	1	3.57	7	7.87
ran-off-road	2	6.90	2	6.25	1	3.57	5	5.62
pedestrian	0	0.00	1	3.13	0	0.00	1	1.12

US 250 Safety Analysis Preliminary Findings and Recommendations

Assessment of the crashes occurring on US 250 in the study area reveals that 57.8 percent of the crashes are rear end crashes and 25.6 percent are angle crashes. In addition, 9.7 percent of the

crashes were side swipe crashes in the same direction. Besides the major intersections, the segment near Tuckernuck Drive and West End Drive also had high injury density.
The following recommendations for RSA team after a preliminary review of the crash data :

1. Plot collision diagrams for all of the major intersections as well as the identified segment near Tuckermuck Drive and West End drive.
2. Research where most of the rear end crashes happened, a density chart of rear end crashes at a smaller scale slices (0.1 mile) may help better identify these locations.
3. Research time of day for rear end and angle crashes

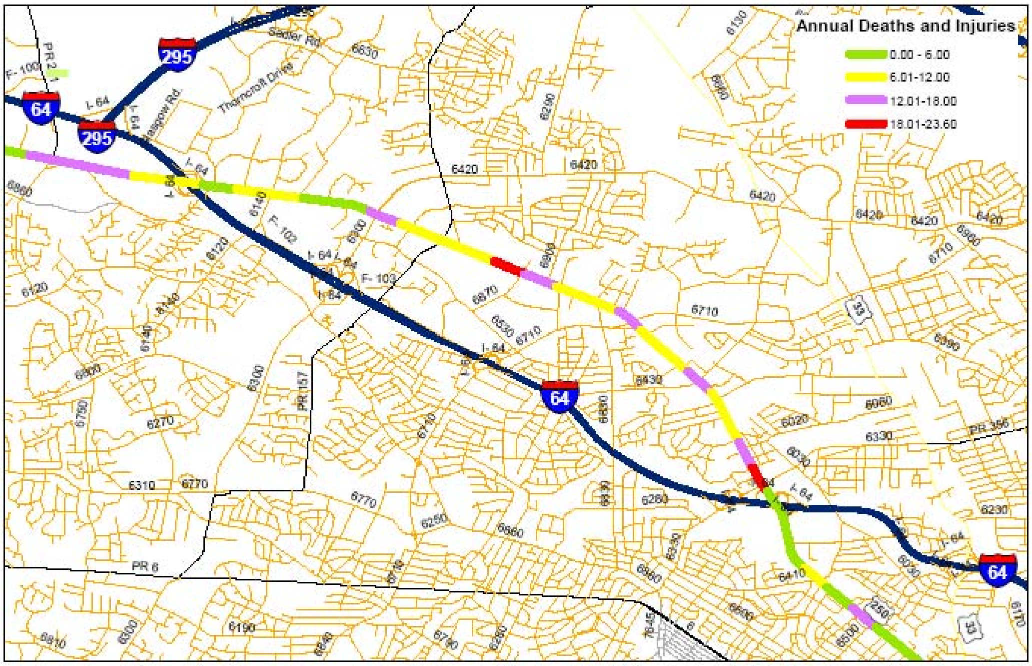
Data Source and Tools Needed to Conduct the Above Analysis on VDOT Roadways

The follow resources are available from VDOT HSIP staff:

1. A CD containing VDOT Crash Database which includes 2003-2007 crash information. The database is in MS Access format and comes with a data dictionary.
2. Structured Query Language (SQL) Programming is embedded in the above database to conduct the above analysis. With minimal training, staff should be able to conduct similar analysis for roadway segments and thus initiate RSAs.
3. Statewide Crash Summary Statistics to be referenced as a benchmark average for similar type of road crash. However, sound engineering judgment should be used to set an appropriate critical value to define high crash locations.
4. Collision diagram templates for intersections and segments.

Attachment 1: GIS Plot of 0.25 Mile Crash Density on US 250

US 250 Broad Street Annual Deaths and Injuries per Quarter Mile per Year (2002-06 Average)



Created by VDOT Traffic Engineering Division

Note: Crash density ranges (color coded) set based on comparison statewide roadway data.