# Crash Location Correction for Freeway Interchange Modeling

**Final Report**
**January 2017**

**Sponsored by**
Missouri Department of Transportation
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**16. Abstract**
The American Association of State Highway Transportation Officials (AASHTO) released a supplement to the *Highway Safety Manual* (HSM) in 2014 that included models for freeway interchanges composed of segments, speed-change lanes, and terminals. A necessary component when using the HSM is having the appropriate safety-related data. However, a high percentage, approximately 75 percent, of interchange crashes in the Missouri Department of Transportation (MoDOT) Transportation Management System (TMS) are landed on an incorrect location within an interchange. For example, crashes are frequently assigned to the midpoint of the ramp terminal instead of to one of the two ramp terminals. Another example includes crashes that are assigned to the freeway mainline when the crashes are related to the ramps. In order to properly calibrate and use HSM freeway interchange models, the location of crashes needs to be corrected. Crash landing correction involves the visual inspection of crash images compiled by the Missouri State Highway Patrol. A detailed procedure was established along with a reviewer test so that crash correction can be conducted uniformly among multiple reviewers. A total of 10,897 crashes were reviewed and 9,168 underwent detailed review and correction. Among the total crashes reviewed, 1,482 were partial cloverleaf crashes, 5,086 diamond interchange crashes, 780 ramp crashes, and 1,820 speed-change lane crashes. The crash location correction process helped to eliminate the error rate associated with interchange crash locations by 69 percent. Any analyst can correct crash locations by following the procedure detailed in this report.

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# CRASH LOCATION CORRECTION FOR FREEWAY INTERCHANGE MODELING

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**January 2017**


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# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

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## EXECUTIVE SUMMARY

The 2014 Supplement to the 2010 *Highway Safety Manual* (HSM) contains information on the modeling of freeway interchanges, which includes interchange facilities such as terminals, ramps, and speed-change lanes. In order to apply the HSM to a local jurisdiction, the HSM recommends calibration to local conditions.

Table ES1 and ES2 show the facilities involved in calibration for Missouri.

**Table ES1. Calibrated terminal interchange facility types**

| Acronym | Terminal Facility | Signalization | Crossroad Lanes | Urban/ Rural |
|---|---|---|---|---|
| D4SCR | Diamond (D4) | Stop-Controlled | All | Rural |
| D4SCU | Diamond (D4) | Stop-Controlled | All | Urban |
| D4SG2 | Diamond (D4) | Signalized | 2 | Both |
| D4SG4 | Diamond (D4) | Signalized | 4 | Both |
| D4SG6 | Diamond (D4) | Signalized | 6 | Both |
| A2SCR | Parclo (A2) | Stop-Controlled | All | Rural |
| A2SCU | Parclo (A2) | Stop-Controlled | All | Urban |
| A2SG4 | Parclo (A2) | Signalized | 4 | Both |
| Clover | Full Cloverleaf | N/A | N/A | N/A |

**Table ES2. Calibrated non-terminal interchange facility types**

| Acronym | Facility Type | Entrance/ Exit | Lanes | Urban/ Rural |
|---|---|---|---|---|
| SCLREN | Speed-Change Lane | Entrance | 4 | Rural |
| SCLU4EN | Speed-Change Lane | Entrance | 4 | Urban |
| SCLU6EN | Speed-Change Lane | Entrance | 6 | Urban |
| SCLREX | Speed-Change Lane | Exit | 4 | Rural |
| SCLUEX | Speed-Change Lane | Exit | 4, 6 | Urban |
| RPREN | Ramp | Entrance | 1 | Rural |
| RPREX | Ramp | Exit | 1 | Rural |
| RPUEN | Ramp | Entrance | 1 | Urban |
| RPUEX | Ramp | Exit | 1 | Urban |

These facility types cover most of the freeway interchange types in Missouri. The calibration process is data intensive and requires crashes to be located accurately at the appropriate interchange facility. This is important since safety treatments could differ for different interchange facilities. For example, crashes caused by queuing at ramp terminals are very different from ramp crashes caused by horizontal curvature. However, both crashes could have been physically located on a ramp because the first harmful event happened there. Missouri crash reports are completed by various police jurisdictions in Missouri and compiled and stored in a database supported by the Missouri State Highway Patrol and the Missouri Department of Transportation (MoDOT). A high percentage of interchange crash locations in this database are recorded incorrectly. For example, some crashes are arbitrarily placed in the middle of an interchange instead of at one of the ramp terminals, and some crashes are placed in the middle of the freeway segment instead of on one of the speed-change lanes. Therefore, in order to calibrate interchanges using the HSM for Missouri, interchange crash data needs to be correctly attributed to the proper facilities within interchanges.

Crash data correction is a labor intensive process that involves the manual review of the original crash reports along with additional information such as aerial photographs. Three particular sections from crash reports are crucial for crash location correction:

- Description of the crash location in terms of the road name, direction, intersection road, etc.
- Crash diagram that provides visual documentation of the vehicle(s) involved and the road
- Narrative section that includes the police narrative along with statements from witnesses and the parties involved

Sometimes, sections of the report might contain errors; thus, the sections could be inconsistent with each other. So, during the course of this project, a complete set of procedures or tutorials were developed for interchange crash correction, and detailed instructions were developed using the three aforementioned sections in a consistent manner. In addition, training tests were developed to ensure that reviewers interpreted and applied the procedures uniformly. Due to the enormous amount of labor required when reviewing crash reports, a large team of 25 research assistants and faculty was assembled. Every person involved in reviewing the crash reports was trained in the same procedures and completed and passed the tests.

Table ES3 summarizes the results of this project.

**Table ES3. Summary of crash review effort**

| Facility Type | Detailed Crash Review |
|---|---|
| Rural Stop-Controlled D4 Diamond Interchange Terminal | 412 |
| Urban Stop-Controlled D4 Diamond Interchange Terminal | 447 |
| Signalized D4 Diamond Interchange with Two Lane Crossroads Terminal | 864 |
| Signalized D4 Diamond Interchange with Four Lane Crossroads Terminal | 1,563 |
| Signalized D4 Diamond Interchange with Six Lane Crossroads Terminal | 1,800 |
| Rural Stop-Controlled A2 Partial Cloverleaf Interchange Terminal | 73 |
| Urban Stop-Controlled A2 Partial Cloverleaf Interchange Terminal | 441 |
| Signalized Partial A2 Cloverleaf Interchange Terminal | 968 |
| Rural Entrance/Exit Ramp | 214 |
| Urban Entrance/Exit Ramp | 566 |
| Rural Entrance/Exit Speed-Change Lane | 46 |
| Urban Four-Lane Entrance/Exit Speed-Change Lane | 189 |
| Urban Six-Lane Entrance/Exit Speed-Change Lane | 1,585 |
| Total | 9,168 |
| **Facility Type Totals** | |
| A2 Partial Cloverleaf Interchange Terminal Total | 1,482 |
| D4 Diamond Interchange Terminal Total | 5,086 |
| Entrance/Exit Ramp Total | 780 |
| Entrance/Exit Speed-Change Lane Total | 1,820 |
| **Total Crashes Reviewed for Project** | **12,409** |

A total of 12,409 crash reports were collected and reviewed. After an initial review to eliminate duplicate, extraneous, and deficient reports, 9,168 underwent the full set of procedures detailed in this report. The majority of the crashes were on interchange terminals, either at diamond (5,086 crashes) or parclos interchanges (1,482). The speed-change lanes had 1,820 crashes and ramps had 780. The project found that 69 percent of all reviewed crashes were landed incorrectly within the interchange. The error rates by facility type were 90 percent for ramps, 79 for terminals, and 53 for speed-change lanes. The police officers who complete crash reports are very important members in the collaborative highway safety effort, and any improvements made in the practice of recording crash landings on the front-end will help to facilitate safety analysis and countermeasure design on the back-end.

# CHAPTER 1. INTRODUCTION

The *Highway Safety Manual* (HSM) provides methods and tools to assist in the quantitative evaluation of safety. The HSM was recently updated to include the modeling of freeways including segments, speed-change lanes, and interchange terminals (AASHTO 2014). These new models need to be calibrated in order to reflect local driver populations, conditions, and environments. Some relevant local conditions include driver population, geometric design, signage, traffic control devices, signal timing practices, climate, and animal population.

In general, safety calibration involves the iterative process of aligning the expected average crash frequencies that have been estimated using HSM methodologies with the observed crash frequencies from selected field sites. The HSM recommends that calibration be performed every two to three years. Thus, the goal of this study was to develop a long-term process for calibration as opposed to producing a set of one-time calibration values.

The following five-step calibration process was followed: (1) identification of facility types, (2) selection of representative field sites, (3) collection of relevant site data, (4) prediction of HSM crash frequencies, and (5) fine-tuning calibration parameters by comparing predicted with actual crash frequencies. Step 1 consisted of identifying multiple facility types to be used in this project. Step 2 involved the selection of adequate field sites to a minimum of 30 to 50 sites and at least 100 crashes per year. The data for Step 3 were obtained from the Missouri Department of Transportation's (MoDOT's) Transportation Management System (TMS) and MoDOT district offices. Steps 4 and 5 involved the estimation of crash frequencies using HSM safety performance functions (SPFs) and then a comparison with actual observed crash frequencies.

As the research progressed through Steps 1 through 3, a major challenge was identified. As previously discussed, Step 3 involved the collection of site data, which included crash data. In Missouri, as in other states, crash reports are completed by police agencies such as a local law enforcement organization (LEO) or the state highway patrol. Despite the existence of a uniform reporting standard, the large number of police agencies involved in recording crashes result in a variance in reporting accuracy. Freeway interchange facilities are particularly challenging for crash reporting due to their complexity.

As will be discussed in detail in later sections of this report, freeway interchanges often involve multiple terminals (ramp intersections), on- and off-ramps, speed-change lanes, and freeway segments. Due to this complexity, the location data from crash reports were often recorded in error. For example, a crash that should be located on a ramp terminal was assigned instead to the crossroad between two ramp terminals. Figure 1.1 shows an example of a crash landing error where the yellow flag indicates the incorrect location and the red star shows the actual crash location.


**Figure 1.1. Sample crash landing error**

The prevalence of location errors, the so-called "crash-landing problem," meant that the existing crash data was not adequate for the calibration of freeway interchanges. After this problem was discovered, the researchers met with the project's technical advisory committee, which included members from MoDOT's Traffic Safety and Research Division. A joint decision was reached to expand the scope of research to include the correction of crash reports that were needed for the calibration of freeway facilities. Crash correction is a significant undertaking since crash reports need to be scanned manually and data fields, collision diagrams, and the narrative and statements need to be carefully reviewed. In addition, consistent methodology and training needs to be developed so that a large team can perform the crash review in a consistent manner. Subsequently, MoDOT funded an additional project that focused on crash landing correction for the data required to perform HSM freeway interchange calibration.

# CHAPTER 2. LITERATURE REVIEW

## 2.1 Literature on Crash Locating Methodology

Crash reporting is the process of compiling information regarding the circumstances of a roadway accident and its participants. A police officer is in charge of documenting all relevant information on a crash report form. This officer is typically from a local police jurisdiction such as a city or county but can also be from the state highway patrol. In Missouri, the *Missouri Uniform Accident Report Preparation Manual* (STARS 2002) and the *Missouri Uniform Crash Report Preparation Manual* (STARS 2012) include the most recent formats for crash reports. Both versions of the crash manual provide detailed instructions on how to complete crash forms. The Missouri State Highway Patrol (MSHP) is the state depository for traffic crash reports with the responsibility of training officers to complete the reports following the standards of the Missouri Statewide Traffic Accident Records System (STARS) Committee. The MSHP collaborates with MoDOT in managing Missouri's database of crash reports.

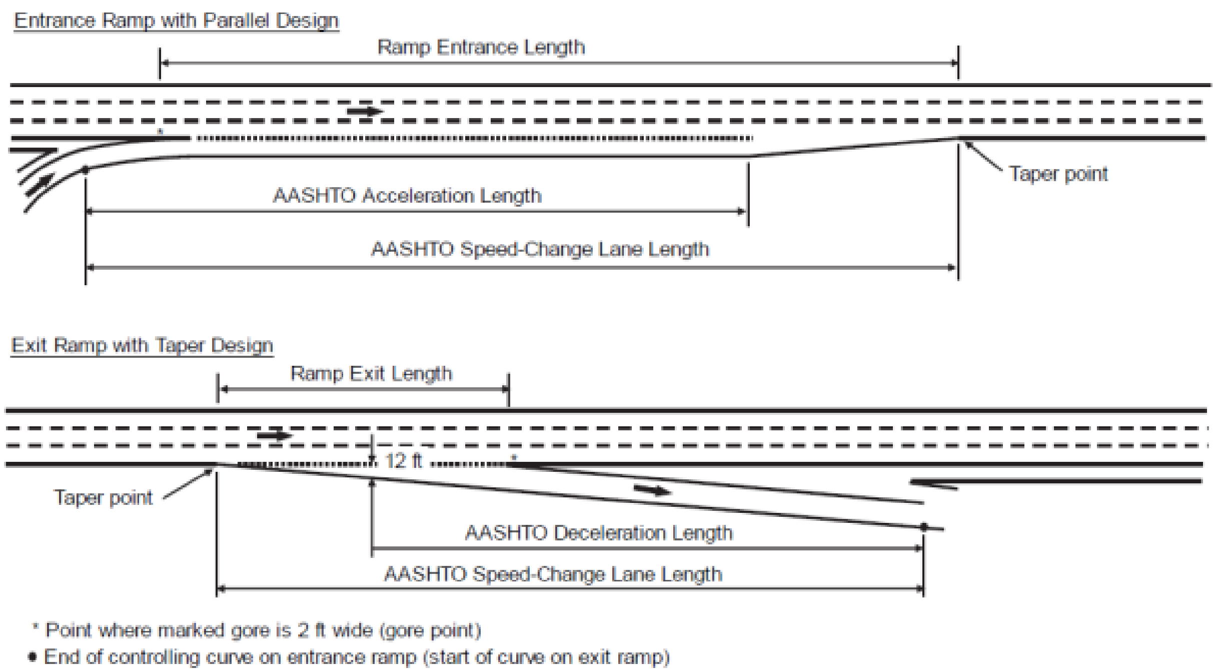
Unfortunately, it is difficult to obtain completely uniform crash reports due to different factors. These factors include the wide range of experience of police officers and supervisors and differences among jurisdictional resources, training, and crash report processing. The potential inconsistency in crash location information is well-known to those who use and analyze crash data. One type of inconsistency is the inaccurate reporting of crash locations on freeway interchanges, the so-called "crash-landing problem." This is a significant problem for the analysis of freeway interchange safety, because there is a need to locate crashes on the appropriate facility within the freeway interchange such as the mainline, ramps, speed-change lanes, or terminals, in order to use the HSM. An example that illustrates personnel and jurisdictional differences is the level of detail in the crash report's crash diagram. Some diagrams are drawn up with computer-aided design and drafting (CADD) software and labeled very clearly while others are sketched roughly by hand.

### *2.1.1 Freeway Interchange Terminals*

The National Highway Research Program (NCHRP) study (NCHRP 17-45) that produced the new HSM freeway interchange chapters discussed the criteria for identifying crossroad ramp terminal related crashes (Bonneson et al. 2012). Some states, such as Washington, DC, use an intersection-related variable in the Highway Safety Information System (HSIS) database, thus the variable identifies crossroad ramp terminal related crashes. Other states, such as California and Maine, do not have such a variable. For such states, the following criteria are used for classifying a crash as crossroad ramp terminal related: (1) a crash has to occur within 250 feet of a terminal intersection and (2) such a crash needs to be at an intersection; involve a pedestrian; involve a left, right, or U-turning vehicle or, if a multi-vehicle crash, the collision involves a sideswipe; rear-end; or angle impact. The 250-foot physical distance was based on previous research performed by Vogt (1999) and Bauer and Harwood (1998).

*2.1.2 Speed-Change Lanes and Freeway Crashes*

As discussed in NCHRP 17-45, none of the HSIS databases include a crash variable that identifies with certainty a speed change-related crash (Bonneson et al. 2012). Thus, existing crash location methodology for speed-change lanes and ramps currently use a crash's exact location as the sole criterion. The benefit of such a method is that it is straightforward and does not require transportation engineering knowledge, which is not part of typical police officer training. However, a drawback is that the actual cause of a crash might be from a different location, thus a crash could be located on the wrong facility for countermeasure design purposes. NCHRP 17-45 assumes that the crashes located at speed change-lane segments of freeways are speed change-related crashes (and are referenced by milepost). A speed-change lane was defined as a ramp entrance length or a ramp exit length segment as shown in Figure 2.1.

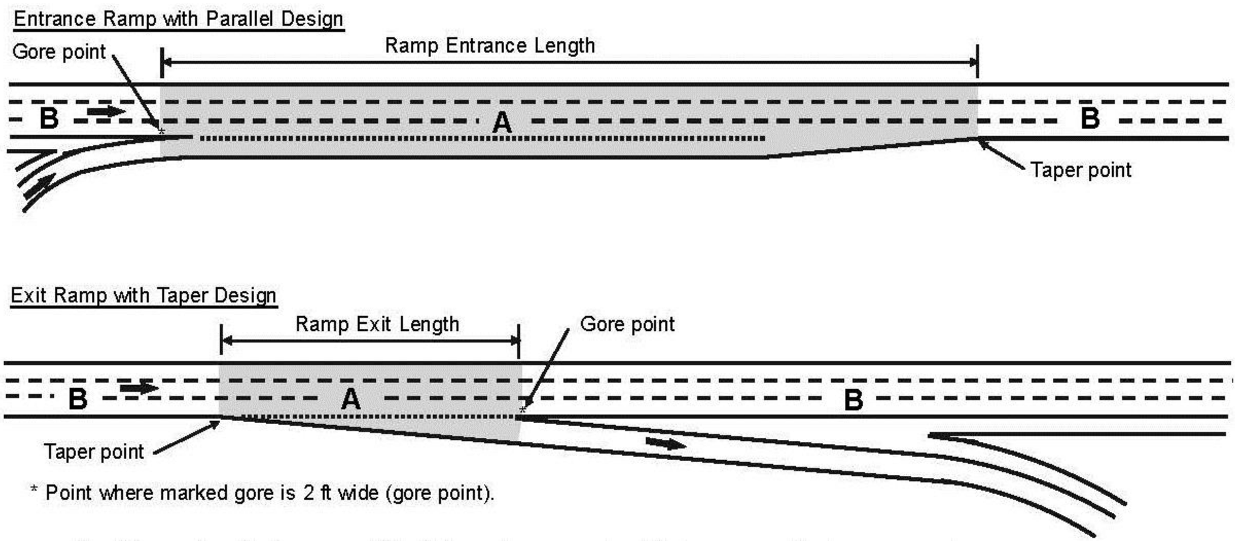



Bonneson et al. 2012, National Cooperative Highway Research Program

**Figure 2.1. Typical speed-change lanes**

Crashes located between the gore point and the taper point of an entrance ramp are assigned to the speed-change lane, regardless of whether they occur on the entrance ramp or the freeway lanes. Similarly, crashes located between the taper point and the gore point of an exit ramp are assigned to the speed-change lanes. The rest of mainline freeway crashes that are not assigned to speed-change lanes are assigned to the freeway mainline (Sarasua 2008).

Figure 2.2 illustrates this method of assigning freeway crashes to either speed-change lanes or freeway lanes. All crashes that happen in the shaded area A are classified as speed-change related crashes. Crashes that happen outside of area A (i.e., in area B) are classified as freeway segment crashes.



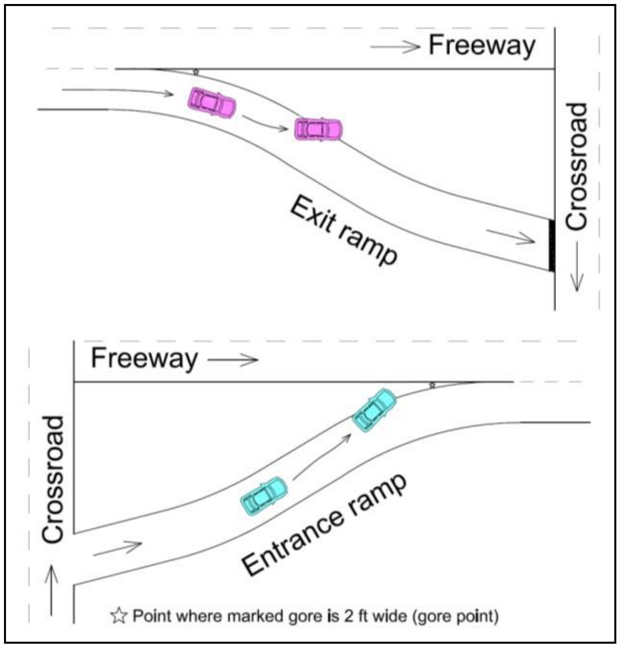

A=All crashes that occur within this region are classified as speed-change crashes
B=All crashes that occur within this region are classified as freeway segment crashes

Originally from Bonneson et al. 2012, National Cooperative Highway Research Program

**Figure 2.2. Method of assigning freeway crashes to either speed-change lanes or freeway segments**

*2.1.3 Ramp Segments*

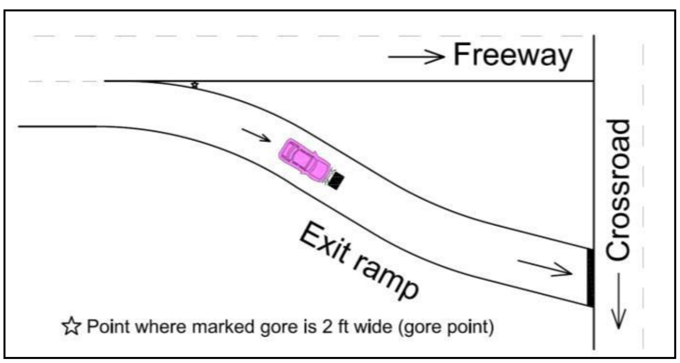
The most common crashes on ramp segments are vehicles running off the roadway or colliding with objects or animals (McCartt 2003). Other types of crashes also occur, such as rear-end crashes. At entrance ramps, drivers trying to find a gap on the freeway might collide before reaching the gore point. At ramps, curves are the design factor that cause the most crashes. Because of significant differences in design speeds between the ramp and the mainline, drivers might not be able to decelerate properly before reaching the curved ramp segment. Figure 2.3 illustrates cases where vehicles run off the exit and entrance ramps.




Claros and Khezerzadeh 2015

**Figure 2.3. Run-off-road crashes at exit/entrance ramp segments**

Another common crash type on ramps is a vehicle collision with objects or wild animals that have crossed onto the road. Figure 2.4 illustrates this crash type.




Claros and Khezerzadeh 2015

**Figure 2.4. Collisions involving object or wild animal on ramp segment**

## 2.2 Interchange Safety Influence Area

McCartt (2003) shows that a large proportion of fatal crashes on highways occur at interchanges (e.g., 11 percent in 2001). Figure 2.5 shows interchange-related crashes according to the American National Standards Institute (ANSI 2007). Crashes occurring 100 ft after the gore point of a speed-change lane of on-ramps and crashes occurring 100 ft after the taper point of the speed-change lane of off-ramps are both classified as interchange-related crashes. However, there is no exact definition for the interchange crash influence area.

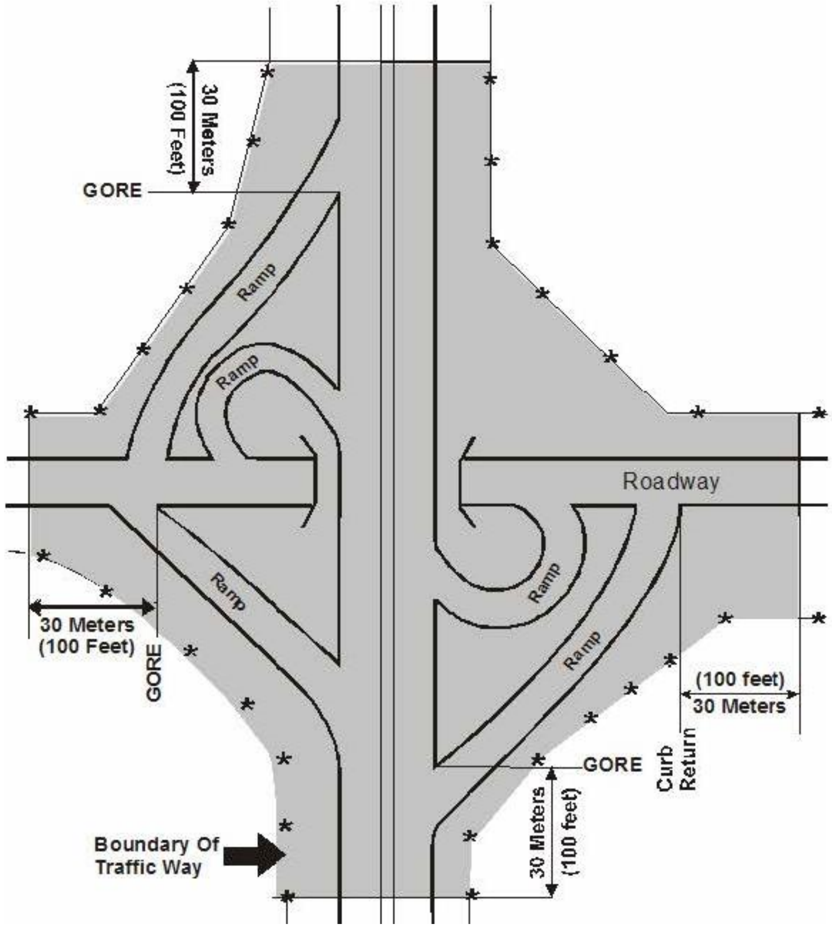
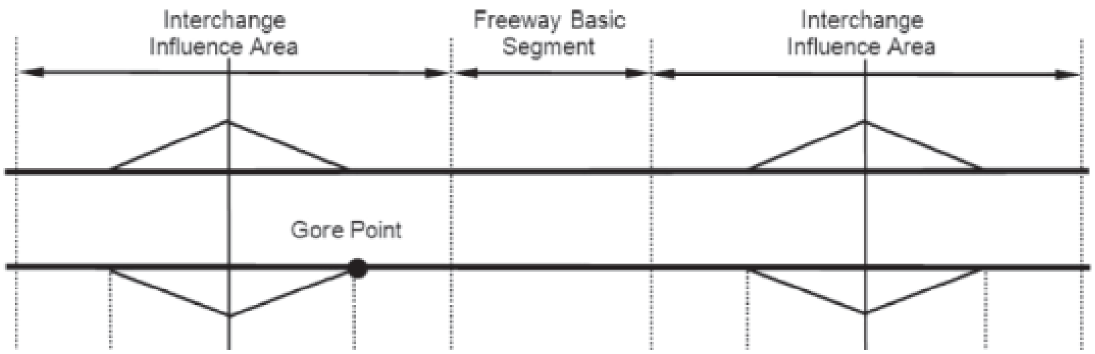


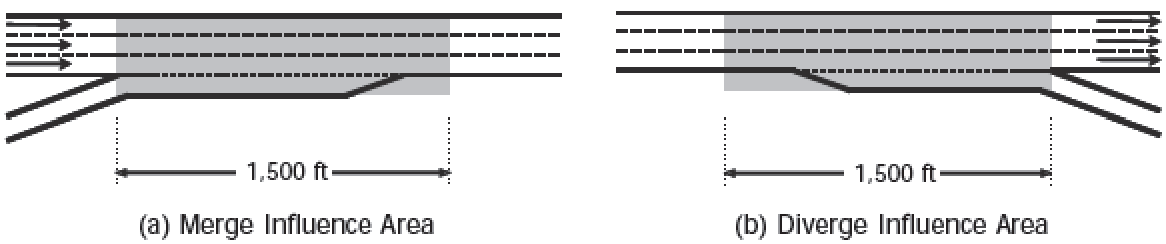



**Figure 2.5. Interchange-related crashes**

The most common application is to use 1,500 feet as an influence area (Lu et al. 2013, TRB 2010) as shown in Figure 2.6. Several factors affect the interchange influence area such as interchange type, merging and diverging area, speed-change lane length, and ramp safety. If the acceleration or deceleration lane is not an adequate length, drivers would find it difficult to operate a vehicle, thus leading to improper acceleration or deceleration and, in turn, an increase in crash rates.




Lu et al. 2013, Transportation Research Board of the National Academies




Originally from the *Highway Capacity Manual* 2000. © 2010 Transportation Research Board.

**Figure 2.6. Interchange influence area (top) and merge and diverge influence areas (bottom)**

There are four main factors that affect interchange safety, which are discussed in the following sections.

*2.2.1 Ramp-Related Factors*

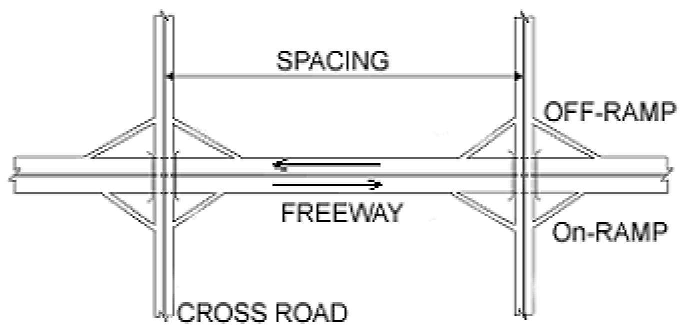
The presence of a ramp entrance or exit creates a large number of lane changes on the freeway and a notable variation in lane volumes (Kiattikomol et al. 2008). Kiattikomol et al. (2008) gathered three years of urban freeway segment crash data in North Carolina and Tennessee. Segments located more than 1,500 ft from the center of the interchange were considered "non-interchange" segments. The interchange segment crash rates were found to be about 200 percent higher than non-interchange segments. North Carolina and Tennessee data showed 42 and 82 crashes per 100 million vehicle-miles (mvm), respectively.

Segments located more than 0.3 mi (1,580 ft) from the nearest ramp gore were considered to be "outside" interchange segments by Torbic et al. (2007). The separate SPFs they developed for freeway segments also indicated that "within" interchange segments have more crashes than "outside" interchange segments. Torbic et al. (2007) explained that the higher within crashes were due to weaving and lane-changing associated with interchange ramps.

Moon and Hummer (2009) used 158 ramps (including 33 ramps with a left-side entrance or exit) for gathering crash data on freeways in North Carolina. Crashes that occurred in speed-change lanes and on the freeway segments up to 1,500 feet from the gore point were collected in the database. They concluded that entrances or exits located on the left side have about 70 to 150 percent more crashes than entrances or exits located on the right side. In addition, Zhao and Zhou (2009) collected crash data from 19 ramps (with four left-side exits) on Florida freeways. They also considered crashes in the speed-change lane, but their data differed from Moon and Hummer (2009) in that they gathered crashes on freeway mainlines up to 1,000 ft from the start of the deceleration length instead of 1,500 ft from the gore point. Their conclusion indicated that left-side exits have 180 percent more crashes than right-side crashes.

### *2.2.2 Interchange Spacing*

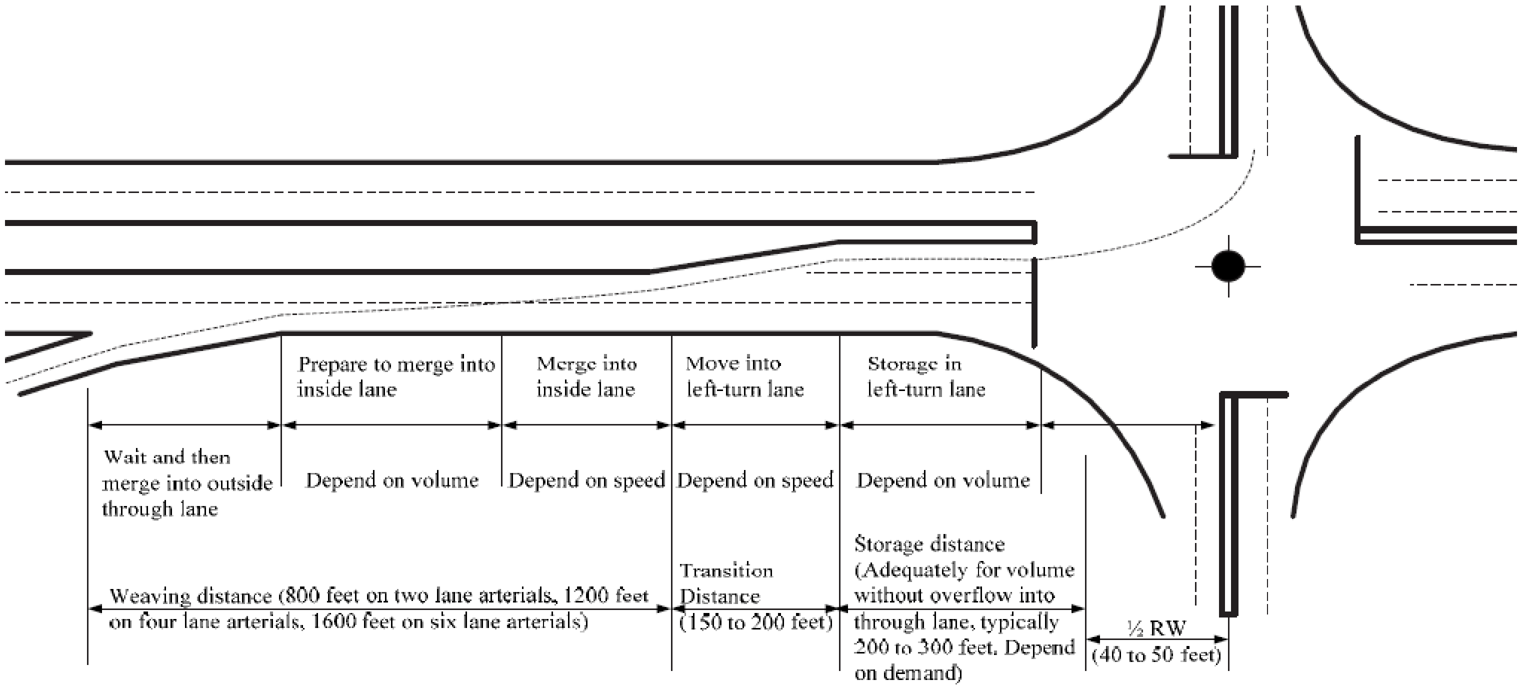
Interchange spacing is also an important factor that affects interchange safety. Interchange spacing is the distance between two interchange centers as shown in Figure 2.7.




Pilko et al. 2007, FHWA Turner-Fairbank Highway Research Center

**Figure 2.7. Interchange spacing**

The Transportation Research Board (TRB) *Access Management Manual* (Gluck et al. 1999) presented a minimum for interchange area access spacing that ranged from 230 to 805 m (750 to 2,640 ft). The minimum spacing recommendations depended upon the geometric characteristics of the interchange and crossroads and whether or not the access is signalized. As noted in Gluck et al. (1999), many states established stricter policies to reflect the significance of providing a sufficient length of access control and/or separation distance. Figure 2.8 breaks down the separation distance into different segments that undertake several functions when approaching an interchange. A benefit of acquiring additional limited access right-of-way around interchanges is the potential reduction of crashes that are due to traffic backups that cause lane blockages.



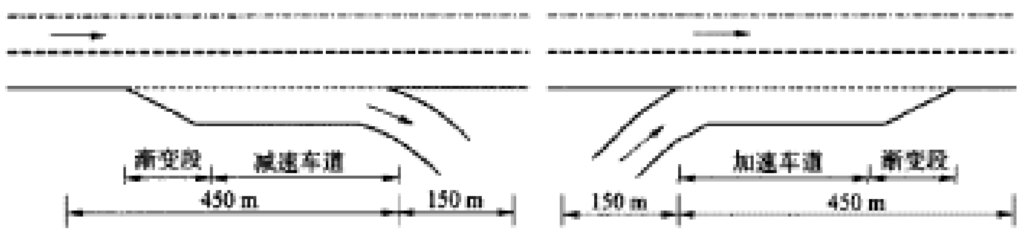

Gluck et al. 1999, National Cooperative Highway Research Program, © 1999 Transportation Research Board

**Figure 2.8. Recommended access separation distances**

### *2.2.3 Speed-Change Lane Length*

Kiattikomol et al. (2008) found that freeway segment crash rates near interchanges are considerably higher than those that are located away from interchanges. Interchanges caused more crashes despite less mileage occupancy, especially on ramps for entering or exiting freeways (McCartt et al. 2004). Several factors influence the impact of interchanges: interchange type, merging and diverging length, length of speed-change lane, whether a ramp is for entering or exiting, speed limit, and the number of lanes.

For stable traffic flow, the merging influence area begins 150 m (about 500 ft) upstream to 450 m (about 1,500 ft) from the gore point; the diverging influence area begins 450 m (about 1,500 ft) upstream to 150 m (about 500 ft) downstream. These measurements are shown in Figure 2.9 (Zhong et al. 2009).




Zhong et al. 2009, *Journal of Beijing University of Technology*

**Figure 2.9. Diverging and merging influence areas**

Table 2.1 shows accelerated and decelerated lane length in different countries. The United States has the longest distances of all the countries shown.

**Table 2.1. Acceleration/deceleration of lane lengths**

| | Deceleration Lane | | Acceleration Lane | | Gradation Zone | |
|---|---|---|---|---|---|---|
| **Country** | **One Lane** | **Two Lanes** | **One Lane** | **Two Lanes** | **Acceleration** | **Deceleration** |
| **America** | 164 m (538 ft) | 164 m (538 ft) | 430 m (1,410 ft) | 430 m (1,410 ft) | 91.5 m (300 ft) | 76.3 m (250 ft) |
| **Japan** | 100 m (328 ft) | 150 m (492 ft) | 200 m (656 ft) | 300 m (984 ft) | 70 m (230 ft) | 70 m (230 ft) |
| **Germany** | 120 m (393 ft) | 120 m (393 ft) | 120 m (393 ft) | 120 m (393 ft) | 80 m (262 ft) | 80 m (262 ft) |
| **China** | 100 m (328 ft) | 150 m (492 ft) | 200 m (656 ft) | 300 m (984 ft) | 70 m (230 ft) | 70 m (230 ft) |

Source: Zhong et al. 2009

### *2.2.4 Ramp Considerations*

Traveling on a ramp at interchanges can require a need for drivers to process additional information. The changes in speed and direction for these complex circumstances can increase the potential for crashes at interchanges. Previous studies indicate that urban areas are more likely to have crashes than rural areas, based on a regression model examined by Bauer and Harwood (1998); however, Torbic (2007) and other researchers found that the safety performance functions are not different for both areas.

Lundy (1965), Khorashadi (1998), and Bauer and Harwood (1998) analyzed data from different states and found that exit ramps have more crashes than entrance ramps, given the same traffic volume and configuration type. According to Garber and Fontaine (1999), off ramps have the highest accident rates due to high speed travel on horizontal curves and limited capacity at ramp terminals. Another factor that influences the crash rate is the number of lanes on the ramp. Bauer and Harwood (1998) indicated that more than two times the number of crashes happened on ramps with one lane when compared with ramps with two lanes. In addition, if the ramp length increased, the crash frequency rates increased as well.

# CHAPTER 3. CRASH REPORT LOCATION CORRECTION FOR TERMINALS

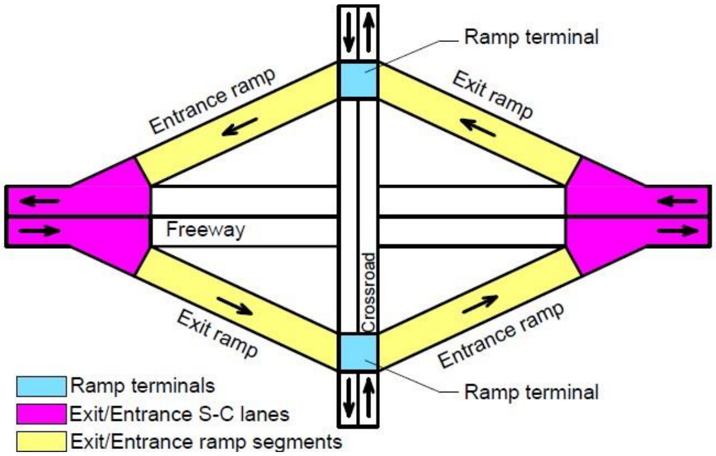
## 3.1 Introduction to Crash Location Correction for Terminals

This chapter discusses a methodology or tutorial for reviewing reports of crashes at interchanges and assigning those crashes to the correct facility within the interchange. This tutorial consists of two phases that are processed sequentially. The first phase determines if a crash is terminally related or not. The second phase further places the non-terminal related crash within the appropriate facilities of mainline, ramp, or speed-change lane.

The methodology presented in this tutorial uses the conventional diamond interchange as an example of a type of interchange facility. This section begins with a description of the conventional diamond interchange and its facility types. A description of the crash report formats is then presented along with the fields of a crash report that are used to facilitate the identification of the location and circumstances of crashes. The criteria for assigning crashes to the ramp terminals are described in detail. A consistent application of the crash correction procedure is important since a reviewer of a crash report has discretion over how to interpret it. For this reason, the most common scenarios in crash reports are described and explained to establish a uniform standard. Lastly, a test involving a small set of different crash reports is provided to evaluate a reviewers' familiarity with the established standards. This test provides valuable feedback to a reviewer in order to bring about greater consistency among separate reviewers of crash reports.

## 3.2 Description of Conventional Diamond Interchanges

A conventional diamond interchange is used to illustrate the crash correction methodology for interchange terminals. Other types of interchanges, such as the partial cloverleaf interchange, are similar. A conventional diamond interchange is a grade-separated intersection of a freeway and a crossroad. In order to connect the freeway and the crossroad, the design contains ramp terminals on each side of the freeway to distribute traffic with exit and entrance ramps to and from the freeway. Figure 3.1 shows in detail the components of the interchange and shows speed-change lanes in magenta, ramps in yellow, and terminals in blue. Speed-change lanes encompass the lane area between the ramp and the mainline from the gore point to the taper. Mainline freeway lanes adjacent to the speed-changes lanes are considered part of the interchange area and not as a generic freeway segment, since crashes could be caused by movements to or from the ramps to the mainline. Ramp terminals are intersections involving the crossroad and ramps and could be signalized, stop-controlled, or roundabout.




Claros and Khezerzadeh 2015

**Figure 3.1. Facilities at a conventional diamond interchange**

### 3.3 Description of Crash Reports

The crash report sections used most frequently for location correction are the image number, collision diagram, narrative, and statements of the crash. The image number is a unique number assigned by MoDOT to identify a crash report. The crash report has an identification number, but it is not used here because the electronic crash data available is not linked to that identification number. Figure 3.2 shows an example of a crash identification number, but the reviewer should not use this number. Instead, the reviewer should use the image number, which is compatible with the electronic crash report.

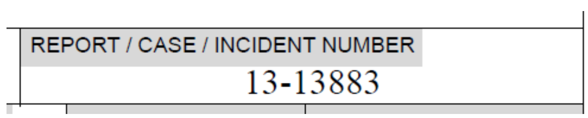

REPORT / CASE / INCIDENT NUMBER
13-13883

**Figure 3.2. Sample crash identification number**

The crash data format along with highlighted examples of image numbers are shown in Table 3.1. Crash report files are in either a portable document format (PDF) or a tagged image file format (TIFF). Each crash report has a filename containing the image number (e.g., 40073302.pdf).

**Table 3.1. Crash data format**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | US | 60 | W | 260.879 | REAR END | 8/23/2004 | PROPERTY DAMAGE ONLY | 1040034802 | 0 | 17.526 | | Y | | DAYLIGHT | DRY | CLEAR | 7783 | NONE | MON | 1630 |
| GREENE | US | 60 | W | 260.879 | REAR END | 8/24/2004 | PROPERTY DAMAGE ONLY | 1040034914 | 0 | 17.526 | | Y | | DAYLIGHT | DRY | CLEAR | 7783 | NONE | TUE | 1815 |
| GREENE | US | 60 | E | 79.732 | LEFT TURN | 8/27/2004 | PROPERTY DAMAGE ONLY | 1040035269 | 0 | 9.874 | | Y | | DARK | DRY | CLEAR | 7782 | NONE | FRI | 555 |
| GREENE | US | 60 | W | 260.879 | REAR END | 9/1/2004 | MINOR INJURY | 1040036166 | 0 | 17.526 | | Y | | DAYLIGHT | DRY | CLOUDY | 7783 | NONE | WED | 1655 |
| GREENE | US | 160 | E | 95.619 | PASSING | 9/3/2004 | PROPERTY DAMAGE ONLY | 1040036368 | 0 | 25.1 | | Y | | DAYLIGHT | DRY | CLEAR | 7806 | NONE | FRI | 1540 |

The second section of the crash report presents a description of the location of the crash. An example of this section is shown in Figure 3.3. In this section, important fields include the road in which the crash was assigned (ON), the roadway direction (RDWY. DIR.), the distance from (N/A, ft, Miles), the location (N/A, before, after, at), the intersecting road (INTERSECTING), and the intersecting road direction (INT. DIR.). These fields identify the road on which the crash occurred and the distance from the intersecting road. For example, Figure 3.3 shows a crash that occurred on eastbound Interstate 44 at the Kansas Expressway. Note that the accuracy of the distances and the reference point location could vary depending on the officer who completed the report. The provided location information should be used in conjunction with the collision diagram, narrative, and statements.

**2 - LOCATION**

| COUNTY | MUNICIPALITY | BEAT / ZONE | TRP/DIST/PCT | GPS COORDINATES (DD MM SS.S FORMAT) |
|---|---|---|---|---|
| 039-Greene | 2520-Springfield | 31/1 | D | LAT: N LONG: W |

| ON | RDWY. DIR. | DISTANCE FROM | LOCATION | INTERSECTING |
|---|---|---|---|---|
| IS 44 | East | 0 Feet; ___ . ___ Miles; [ ] NA | [ ] After [ ] Before [X] At [ ] NA | CST KANSAS EXPY |

| SPEED LIMIT | ROAD MAINTAINED BY | SPEED LIMIT | INT. DIR. | GEO - CODE |
|---|---|---|---|---|
| 60 | [X] State [ ] County [ ] Municipal [ ] Private Property [ ] Other [ ] Unknown | 40 | N | NA |

TRAFFICWAY
[ ] One-Way [ ] Two-Way; Not Divided [ ] Two-Way; Divided; Unprotected Median [ ] Other
[ ] Two-Way; Not Divided; Continuous Center Turn Lane [X] Two-Way; Divided; Positive Median Barrier [ ] Unknown

ROAD ALIGNMENT
[X] Straight [ ] Curve
[ ] Unknown (Explain)

ROAD PROFILE
[X] Level [ ] Downhill [ ] Dip
[ ] Uphill [ ] Hillcrest [ ] Unknown (Explain)

INTERSECTION TYPE [ ] NA
[ ] 4-way Intersection [ ] Y-Intersection [ ] 5-way / More [ ] Unknown (Explain)
[ ] T-Intersection [ ] Roundabout [X] Other (Explain)

ROAD CONDITION
[X] Dry [ ] Snow [ ] Slush [ ] Standing Water [ ] Sand / Gravel [ ] Unknown (Explain)
[ ] Wet [ ] Ice / Frost [ ] Mud / Dirt [ ] Moving Water [ ] Other (Explain)

ROAD SURFACE
[ ] Concrete [ ] Brick [ ] Dirt / Sand [ ] Cobblestone
[X] Asphalt [ ] Gravel [ ] Multi-Surface [ ] Unknown (Explain)

WEATHER CONDITION
[X] Clear [ ] Rain [ ] Sleet / Hail [ ] Fog / Mist [ ] Other (Explain)
[ ] Cloudy [ ] Snow [ ] Freezing (Temp) [ ] Severe Crosswind [ ] Unknown (Explain)

LIGHT CONDITION
[X] Daylight [ ] Dark-Lighted [ ] Dark-Unlighted [ ] Dark-Unknown Lighting [ ] Other (Explain) [ ] Unknown (Explain)

**Figure 3.3. Sample crash location description**

A collision diagram shows the circumstances and location of the crash. Figure 3.4 shows an example of a collision diagram involving a multi-vehicle collision. The north arrow of the collision diagram is typically located on the header of the page, although it is sometimes missing. The legend provides crucial information for interpreting the direction of travel of each vehicle involved in the crash. As seen in Figure 3.4, the north arrow is clearly marked for orientating the diagram.

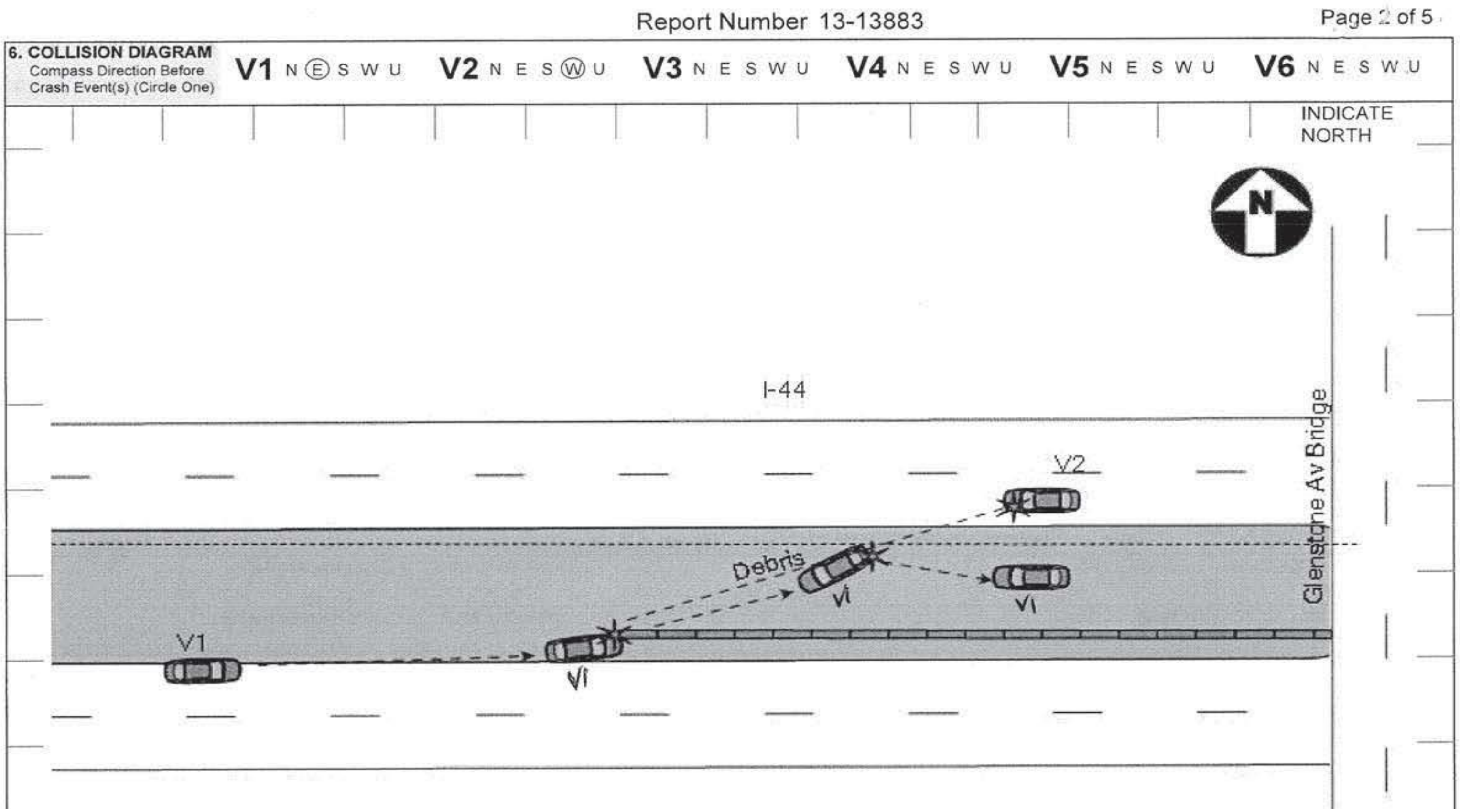



**Figure 3.4. Sample collision diagram**

The amount of detail contained in the collision diagram is dependent upon the reporting agency and personnel. If the crash was reported later at a police station, after the incident, then the crash report might not have a collision diagram. Therefore, the collision diagram might have limited or no information. If that is the case, then other resources, such as the narrative and statements of the crash, need to be used to pinpoint crash location.

The narrative contains a written description of the crash and statements collected from witnesses, people involved in the crash, and/or officer(s). The details in this section are also subject to the experience and expertise of the reporting personnel. Figure 3.5 shows an example of a narrative and statements for the same crash shown in Figure 3.4. This example contains a statement by the officer describing both vehicles (V1 and V2) and statements by both a driver (D1) and a witness (W1).

**9. NARRATIVE / STATEMENTS** (If additional room is necessary, use Section 11 - Narrative / Statements Continuation)

V1 WAS E/B ON I-44 IN THE #1 LANE IN THE AREA OF MO 13 (KANSAS EX.). V2 WAS W/B ON I-44 IN THE #1 LANE IN THE AREA OF MO 13. V1 SWERVED OFF THE ROADWAY LEFT COLLIDING WITH A METAL GUARDRAIL. V1 SPUN CLOCK-WISE AND WENT PARTIALLY AIRBORNE AS IT SPUN. IT CAME TO REST AND COLLIDED WITH THE MEDIAN CABLE BARRIER. DURING V1'S COLLISION WITH THE GUARDRAIL DEBRIS WAS THROWN AT THE WINDSHIELD OF V2 AS SHE WAS PASSING THE AREA OF IMPACT. THE DEBRIS CRACKED HER WINDSHIELD.

D1 SAID HE WAS E/ ON I-44 WHEN ANOTHER VEHICLE SWERVED TOWARDS HIS LANE. HE SAID HE SWERVED LEFT AND STRUCK THE GUARDRAIL. HE COULD NOT DESCRIBE ANYTHING ABOUT THE OTHER VEHICLE TO INCLUDE MAKE, MODEL OR COLOR. D1 SAID HE WAS NOT INJURED BUT DID APPEAR UNCOMFORTABLE AND LIMPED. HE DECLINED EMS.

W1 LEFT HIS INFORMATION WITH ANOTHER ON SCENE OFFICER THEN LEFT BEFORE I COULD INTERVIEW HIM. I WAS NOT ABLE TO CONTACT HIM LATER VIA THE PHONE NUMBER HE LEFT. HE DID TELL THE OTHER ON SCENE OFFICER THAT HE WAS BEHIND V1 AND SAW IT SWERVE LEFT FROM THE #1 LANE AND COLLIDE WITH THE GUARD RAIL.

**Figure 3.5. Sample narrative and statements**

### 3.4 Crash Review and Assignment Procedure

*Step 1: Crash Location Review*

The first step in reviewing a crash report is to determine the overall location of the crash. Initially, the travelway name, orientation, and direction of travel of the vehicle or vehicles involved needs to be found. The different fields in the crash report, as described in the previous section, should be used to find the specific location of the crash with respect to interchange orientation. Additionally, aerial photographs may be used to locate and visualize the facilities of an interchange. It is strongly recommended that the location be found on a map before making any decisions when assigning the crash. Otherwise, the information provided in the location, collision diagram, and narrative or statements sections could be inconsistent within the same report. One common reason for an inconsistent report is human error in data recording such as mistaking the direction of travel for the road name or on the diagram. Therefore, as a general rule, at least two of the three aforementioned sections should be in agreement.

*Step 2: Crash Circumstances Review*

The second step of the crash review consists of analyzing the scenario of crash events with respect to location. The statements provided by the witnesses and people involved in the crash should be carefully interpreted, because they are personal opinions, interpretations, and claims. Such statements might have been made to protect their own interests and to prevent negative consequences of their actions. A driver-made claim should be confirmed by the officer narrative. The narrative of the officer is not only intended to describe the crash events but to alos state the results of the investigation. Understanding the different factors involved in a crash will help the reviewer to correctly assign the crash to the appropriate facility (ramp terminal) or discard the crash if it is not ramp terminal related.

*Step 3: Assignment of Crashes to Ramp Terminals*

This is the most crucial step of the entire review process; the reviewer should be careful in understanding the concepts in this section to avoid misplacing or misclassifying crashes to the wrong ramp terminal facility. Crashes occurring on crossroad approaches and exit ramps may actually be ramp terminal related and could be assigned to one of the two ramp terminals of the interchange. Also, crashes that occur in the vicinity of a ramp terminal, such as on the entrance ramp that just exited the crossroad, could still be assigned to the ramp terminal that contributed to the crash.

The ramp terminal of the crash location should be designated based on the compass direction relative to the freeway direction: north (N), south (S), east (E), or west (W). If the freeway runs in the north to south direction, the crash location should be coded as E if the crash is being assigned to the ramp terminal located on the east side of the freeway and as W if the crash is being assigned to the ramp terminal located on the west side of the freeway. If the freeway runs in the east to west direction, the crash location should be coded as N if the crash is being assigned to the ramp terminal located on the north side of the freeway and as S if the crash is being assigned to the ramp terminal located on the south side of the freeway. If the freeway runs in a diagonal direction, the reviewer should estimate visually if the freeway runs closer to the north to south direction or east to west direction to make the crash location assignment. Note that this direction convention may be contrary to the one established in the crash report via the diagram and narratives. For example, a beltway type freeway could be named eastbound while actually traveling southbound. The use of an aerial photograph is recommended to determine the location and orientation of the ramp terminals. An accurate location is important because an incorrect assignment could alter the safety analysis of an interchange significantly. Figure 3.6 shows some examples of perfectly aligned and diagonal freeways in both the north to south and east to west directions.

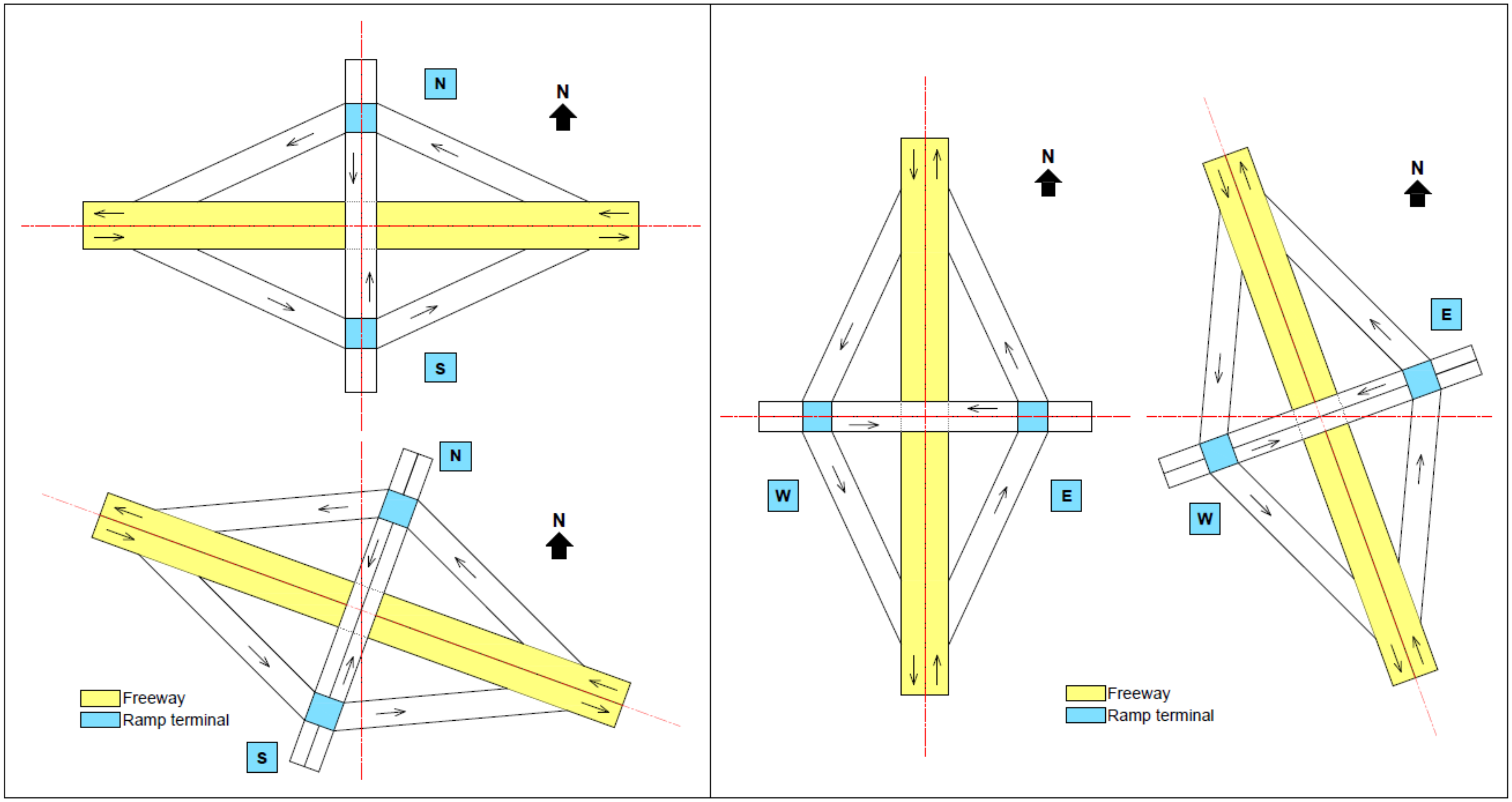



**Figure 3.6. Sample ramp terminal assignments**

### 3.5 Ramp Terminal Related Crashes

The objective in the first phase of crash review is to determine and/or verify if the crashes actually occurred at one of the ramp terminals of an interchange. Therefore, all crashes that are "ramp terminal related" are of interest. Ramp terminal related means that a crash occurred due to the ramp terminal geometric design, operations, or the influence of those factors on driver behavior. According to common crash reporting practices, crashes that are within 250 ft on the roadway away from the center of the intersection (i.e., in the approaching direction of the crossroad legs and exit ramp segment) are considered intersection-related crashes (Vogt 1999, Bonneson et al. 2012). However, there are some specific exceptions to this distance threshold. For instance, a crash that occurs beyond 250 ft in the exit ramp segment or crossroad legs that was caused by queuing at the ramp terminal is still ramp terminal related. Rear-end and sideswipe crashes due to the accumulation of traffic from the ramp terminal are considered ramp terminal related crashes because the crash circumstances were generated by ramp terminal congestion (Bauer and Harwood 1998). The crash assignment is conducted based on the location, circumstance of the crash, and ramp terminal related crash criteria.

Figure 3.7 illustrates in blue the possible locations of crashes that are of interest.

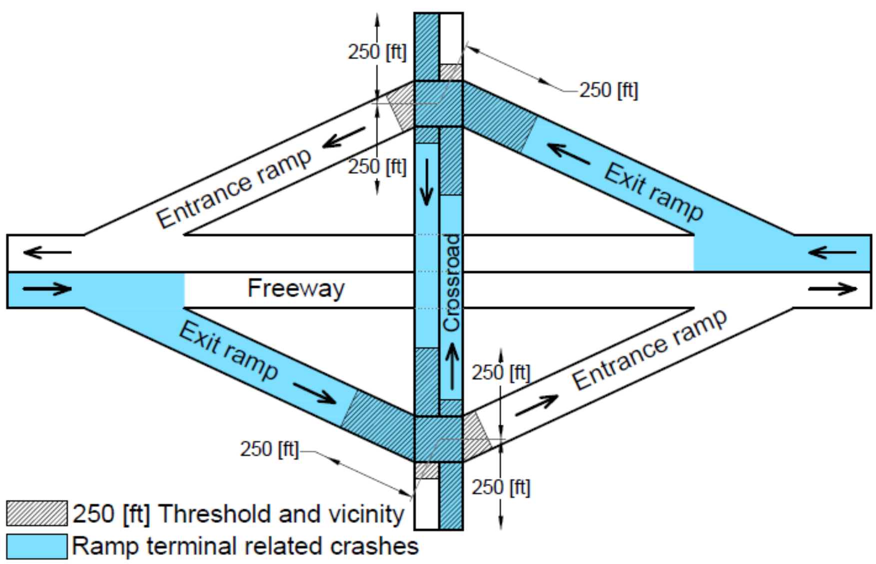



**Figure 3.7. Area of interest for ramp terminal related crashes**

The blue region in Figure 3.7 includes the ramp terminal itself, crossroad approach legs, exit ramps, an initial portion of entrance ramps, and a small section of the freeway adjacent to the exit ramps. Crashes that are located in the aforementioned areas and within 250 ft of the terminal center are considered ramp terminal related and should be assigned to one of the two ramp terminals. Also, crashes in the crossroad exiting direction and on the entrance ramp in the vicinity of a ramp terminal should be assigned to the ramp terminal that contributed to the crash. The assignment should be made according to the location of the ramp terminal with respect to the freeway (i.e., N, S, E, and W), as described in the previous section.

Figure 3.7 also highlights the exit ramp and some parts of the freeway. This is because of the ramp terminal related criterion that assigns some crashes that occur on the exit ramp or part of the freeway mainline due to queuing generated from the ramp terminal to the corresponding ramp terminal.

There are cases in which a crash occurred between two ramp terminals, and it might be difficult to determine the proper ramp terminal for the crash assignment. Figure 3.8 shows an example where one of the ramp terminals was so congested that a queue reached the other ramp terminal.

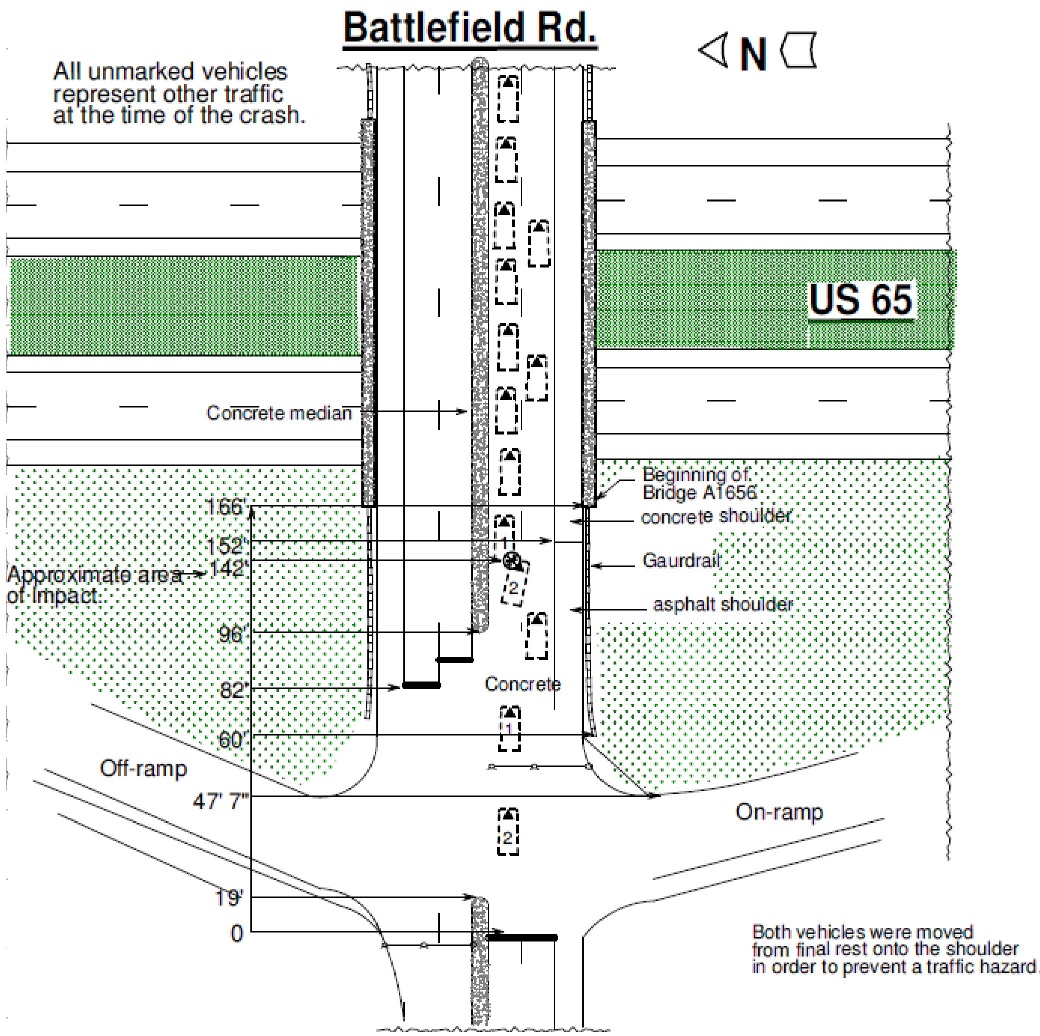
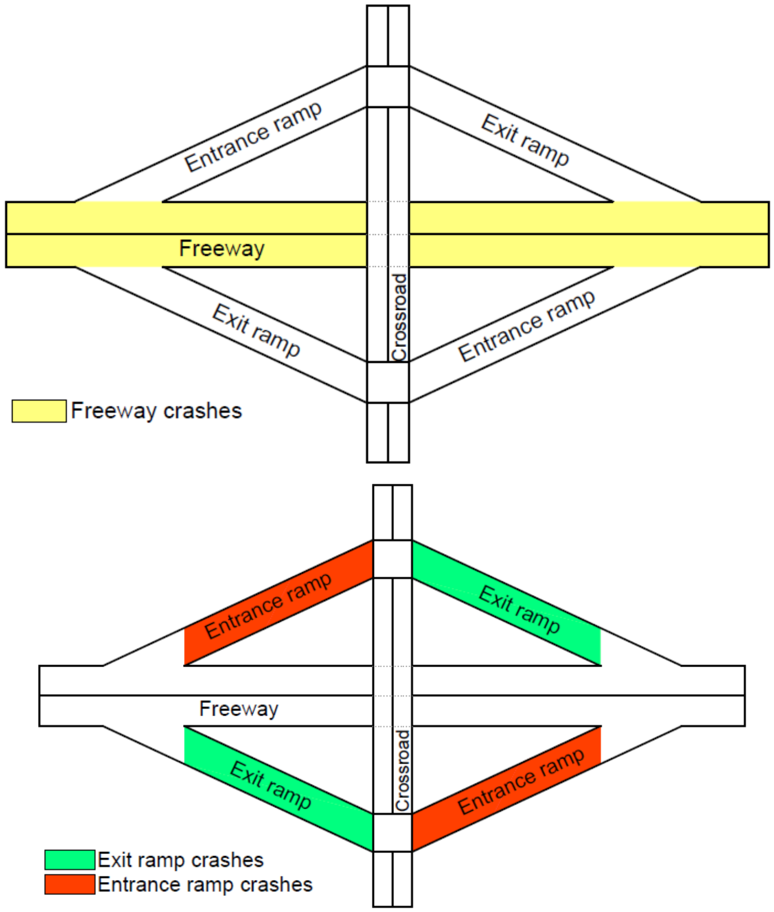



**Figure 3.8. Queue between ramp terminals**

This crash should be assigned to the ramp terminal that generated the queue instead of the upstream ramp terminal. In this example, even though the crash occurred closer to the west ramp terminal, it should be assigned to the east ramp terminal.

Figure 3.9 highlights the areas where non-terminal crashes can occur, which includes exit ramps, entrance ramps, and freeway segments. Crashes that occur on these facilities are not relevant at this stage of the review. These types of crashes should be coded with the letter X to be further processed in Chapter 4/Phase II.




Claros and Khezerzadeh 2015

**Figure 3.9. Areas not of interest for ramp terminal related crashes**

If a crash report describes an event that meets all the criteria previously mentioned, but the crash is due to a rare event in which the ramp terminal design was not a contributing factor, then it should also be assigned as none or X. An example of this is a crash due to crash-related congestion in which queuing vehicles were invading the opposing lane traffic. This situation occurs because drivers could decide to quit attempting to enter a ramp terminal because of congestion and decide to turn around and invade the median or the opposing lane traffic. This example is shown in Figure 3.10. Again, this crash should be assigned as X.

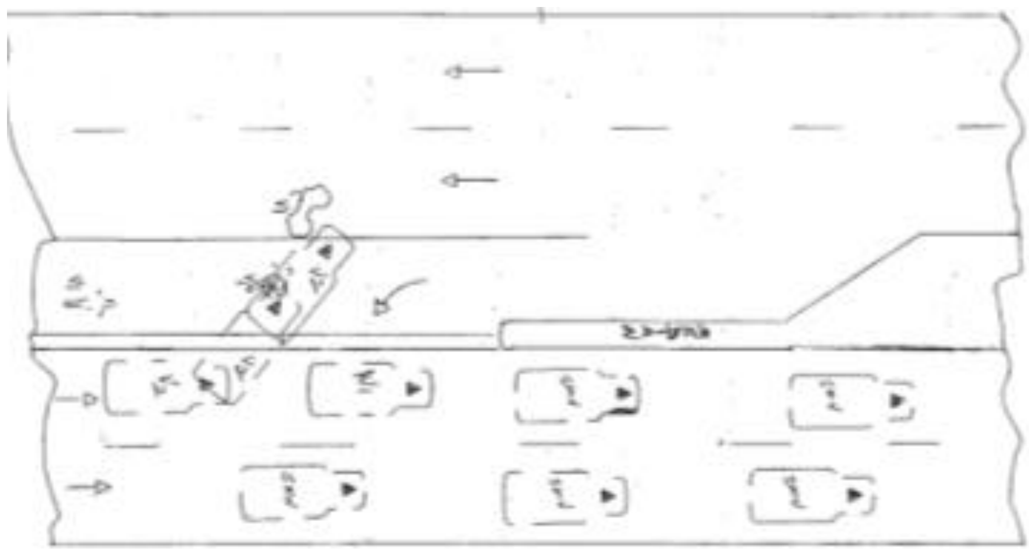


**Figure 3.10. Rare event crash**

There are several other cases involving unique circumstances or rare events that should be assigned X or non-terminal related. The following list provides some examples of rare events:

- A crash generated by a vehicle avoiding or hitting a movable object near the ramp terminal
- A crash generated by a vehicle avoiding or hitting a deer or other animal near the ramp terminal
- A crash generated by vehicles pulling over because of an emergency vehicle.
- A crash generated due to police pursuit
- A run-off-road crash due to a driver falling asleep
- A crash generated by a vehicle malfunctioning or a tire exploding
- Property damage by an object coming or blowing out from one vehicle damaging other vehicles on the road (e.g., windshield breakage)
- Injury or death due to a shooting
- Crashes due to a work zone and not the operation of the interchange
- A crash generated by congested traffic due to another crash (i.e., a secondary crash)

Cases in which a driver was distracted by a secondary task should not be considered a rare event. Some examples of a secondary task are drivers lighting up a cigarette, drinking water, putting on glasses, or picking up objects from the passenger seat. Any type of distraction while driving is considered part of driving behavior. Some drivers might attempt to cover up the fact that they were distracted, such as the reckless use of cellphones while driving.

Table 3.2 shows an example of the result of the crash review and assignment of five example crashes. In the crash data output, the last column was added to include the coding of the assignment according to the ramp terminal location or not ramp terminal related: N, S, E, W, or X. As shown in blue in Table 3.2, the four crashes were assigned to the north terminal and one to the south terminal.

**Table 3.2. Coding of reviewed crashes**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Interchange | Ramp terminal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | US | 60 | W | 260.879 | REAR END | 8/23/2004 | PROPERTY DAMAGE ONLY | 1040034802 | 0 | 17.526 | | Y | | DAYLIGHT | DRY | CLEAR | 7783 | NONE | MON | 1630 | 1 | N |
| GREENE | US | 60 | W | 260.879 | REAR END | 8/24/2004 | PROPERTY DAMAGE ONLY | 1040034914 | 0 | 17.526 | | Y | | DAYLIGHT | DRY | CLEAR | 7783 | NONE | TUE | 1815 | 1 | N |
| GREENE | US | 60 | E | 79.732 | LEFT TURN | 8/27/2004 | PROPERTY DAMAGE ONLY | 1040035269 | 0 | 9.874 | | Y | | DARK | DRY | CLEAR | 7782 | NONE | FRI | 555 | 1 | S |
| GREENE | US | 60 | W | 260.879 | REAR END | 9/1/2004 | MINOR INJURY | 1040036166 | 0 | 17.526 | | Y | | DAYLIGHT | DRY | CLOUDY | 7783 | NONE | WED | 1655 | 1 | N |
| GREENE | US | 160 | E | 95.619 | PASSING | 9/3/2004 | PROPERTY DAMAGE ONLY | 1040036368 | 0 | 25.1 | | Y | | DAYLIGHT | DRY | CLEAR | 7806 | NONE | FRI | 1540 | 1 | N |

### 3.6 Terminal Crash Examples

The following three crash examples illustrate the procedure and methodology of this tutorial. These examples illustrate in detail the most common terminal crash scenarios, interpretation of the crash reports, and use of different tools used in this tutorial.

*Example 1–US 160*

Step 1

Locate the interchange on an aerial photograph. Figure 3.11 shows an aerial photograph of the interchange on US 160.




**Figure 3.11. Interchange for Example 1 (US 160)**

Table 3.3 shows the electronic crash data of Example 1, which is located on US 160. To start the review using the image number (column: Image #), 3110016727, find and open the crash report from the crash reports folder.

**Table 3.3. Crash data for Example 1 (US 160)**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Interchange | Ramp terminal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | US | 160 | E | 95.675 | LEFT TURN RIGHT ANGLE COLLISION | 7/4/2011 | MINOR INJURY | 3110016727 | 652131 | 25.156 | Y | Y | | DAYLIGHT | DRY | CLEAR | 7806 | NONE | MON | 1605 | 1 | S |

Next, examine Section 2 of the crash report, where the location of the crash is described as previously discussed. Figure 3.12 shows the location section of the crash report for Example 1, which includes the intersection street.

| 2 - LOCATION | | | | | |
|---|---|---|---|---|---|
| COUNTY: Greene 039 | MUNICIPALITY: Non-City Or Unincorporated 9999 | | BEAT / ZONE: 01 | TRP / DIST / PCT: D | INVESTIGATED AT SCENE: [X] YES [ ] NO |
| ON: US 160 | DISTANCE FROM: ______ FEET ______ MILES | LOCATION: [ ] AFTER [ ] BEFORE [X] AT | INTERSECTING STREET OR ROADWAY: US 60 (E) | | |
| ROADWAY DIRECTION: E | SPEED LIMIT: 50 | | SPEED LIMIT: 55 | GEO - CODE: NA | GPS LONGITUDE W: 093 21 48.7 / LATITUDE N: 037 09 02.4 |
| ROAD MAINTAINED BY: [X] 1. STATE | [ ] 2. COUNTY | [ ] 3. MUNICIPAL | [ ] 4. PRIVATE PROPERTY | [ ] 5. OTHER | |

**Figure 3.12. Location of crash for Example 1 (US 160)**

Step 2

The rest of the crash report information should be reviewed to verify the location and circumstances of the crash. Section 7 of crash reports contain the collision diagram. Figure 3.13 shows a right angle collision that occurred in the ramp terminal with Vehicle 1 (V1) traveling southbound on US 160 in the through lane colliding at a right angle with Vehicle 2 (V2). V2 was traveling eastbound on the exit ramp from US 60 and made a left turn to proceed northbound on US 160. Also, a witness (W) was included in the diagram.

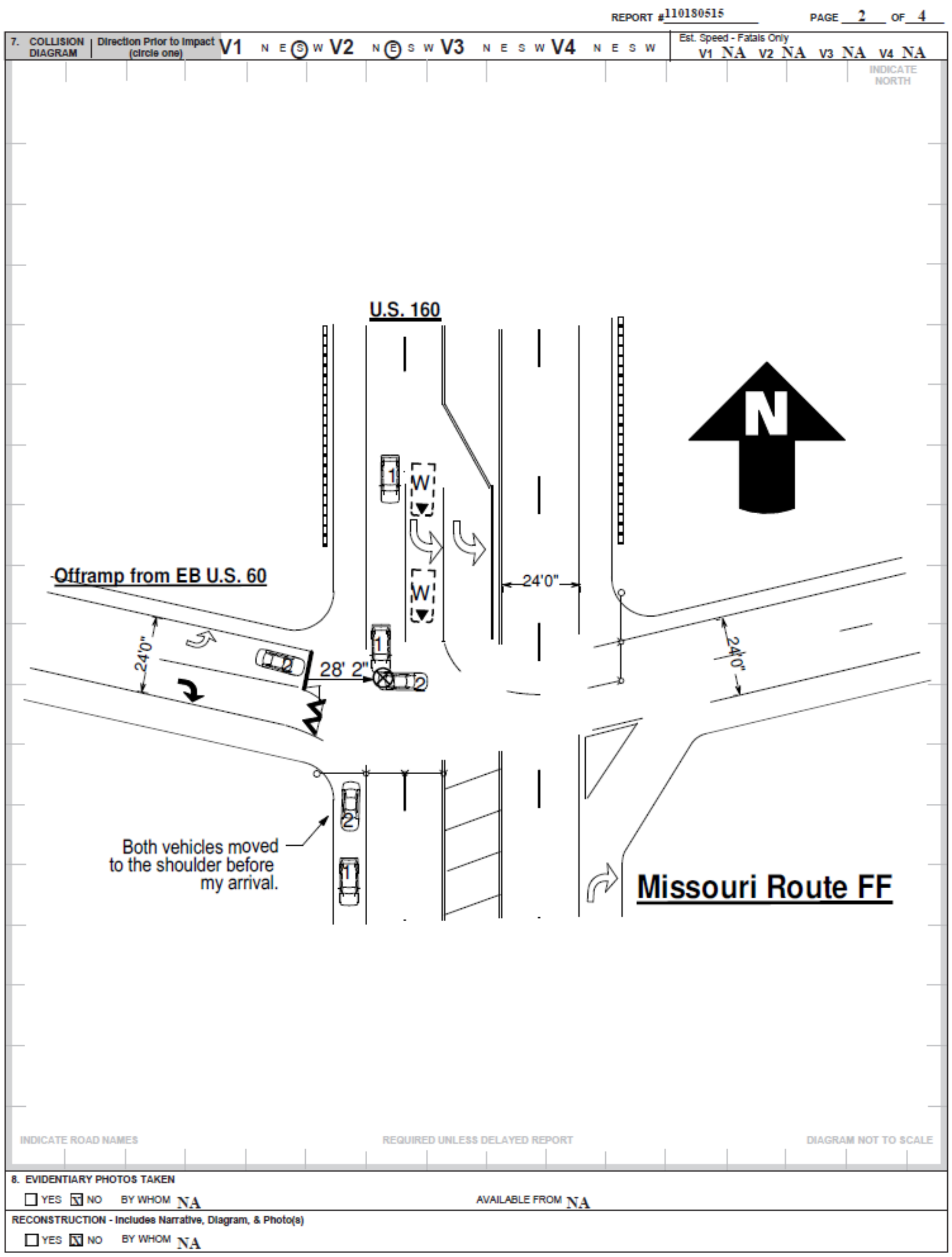



**Figure 3.13. Collision diagram for Example 1 (US 160)**

Step 3

Figure 3.14 shows Section 28 of the crash report, which presents the description and the narrative of the crash including the officer's investigation and the statements of the drivers and witnesses. Usually, this section alone could help determine the assignment of the crash. The narrative explains that the crash occurred in the southbound (S) ramp terminal of the interchange due to a driver running the red signal on the crossroad and hitting a vehicle coming from the exit ramp. Again, the final crash assignment of S can be seen in Table 3.3, in the column labeled ramp terminal.

28 - NARRATIVE / STATEMENTS (If additional room is necessary, attach a separate sheet.)

1. This accident apparently occurred as vehicle 1 was southbound on U.S. 160 at U.S. 60 and struck vehicle 2. Vehicle 2 was eastbound on U.S. 60, attempted a left turn to go north on U.S. 160 and was hit by vehicle 1 in the intersection.

2. Driver 1 said, "I ran the red light. I was in a hurry, late for an appointment. I saw her in the intersection. I looked up and my light was red. I slammed on my brakes." Driver 1 was inattentive by not seeing the red light until after he saw vehicle 2.

3. Driver 2 said, "I was stopped. My light turned green. I started through. I saw him coming and floored it to get out of his way. He hit me and spun me around. I got out and looked at the light over his lane. It was red."

4. Baker said, "I was stopped at a red light. The guy beside me went on through the red light and hit the car and spun it around." She clarified the light was red as they approached it. She stopped. He did not.

**Figure 3.14. Narrative and statements for Example 1 (US 160)**

*Example 2–US 60*

The procedure in Step 1 for Example 1 is the same for Examples 2 and 3. Table 3.4 contains the crash information for Example 2. Also, Figure 3.15 shows an aerial photograph of the interchange.

**Table 3.4. Crash data for Example 2 (US 60)**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Interchange | Ramp terminal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | CST | NATIONAL AVE | S | 2.268 | REAR END | 4/11/2008 | MINOR INJURY | 80044140 | 0 | 2.268 | | Y | | DAYLIGHT | DRY | CLEAR | 92536 | NONE | FRI | 1725 | 2 | N |



**Figure 3.15. Interchange for Example 2 (US 60)**

Step 2

The crash report information should be reviewed to determine the location and circumstance of the crash. The collision diagram for Example 2 (see Figure 3.16) shows that the crash occurred on the inside leg of the north ramp terminal of the interchange. The crash was a rear-end with a stopped vehicle. According to the narrative and statements, the cause of the crash was due to V1's inability to stop in time because the driver's foot slid off the brake pedal. The crash was not only within the 250 ft threshold but was also ramp terminal related. As an aside, Figure 3.16 also shows the on-ramp mislabeled as eastbound (EB) instead of westbound (WB).

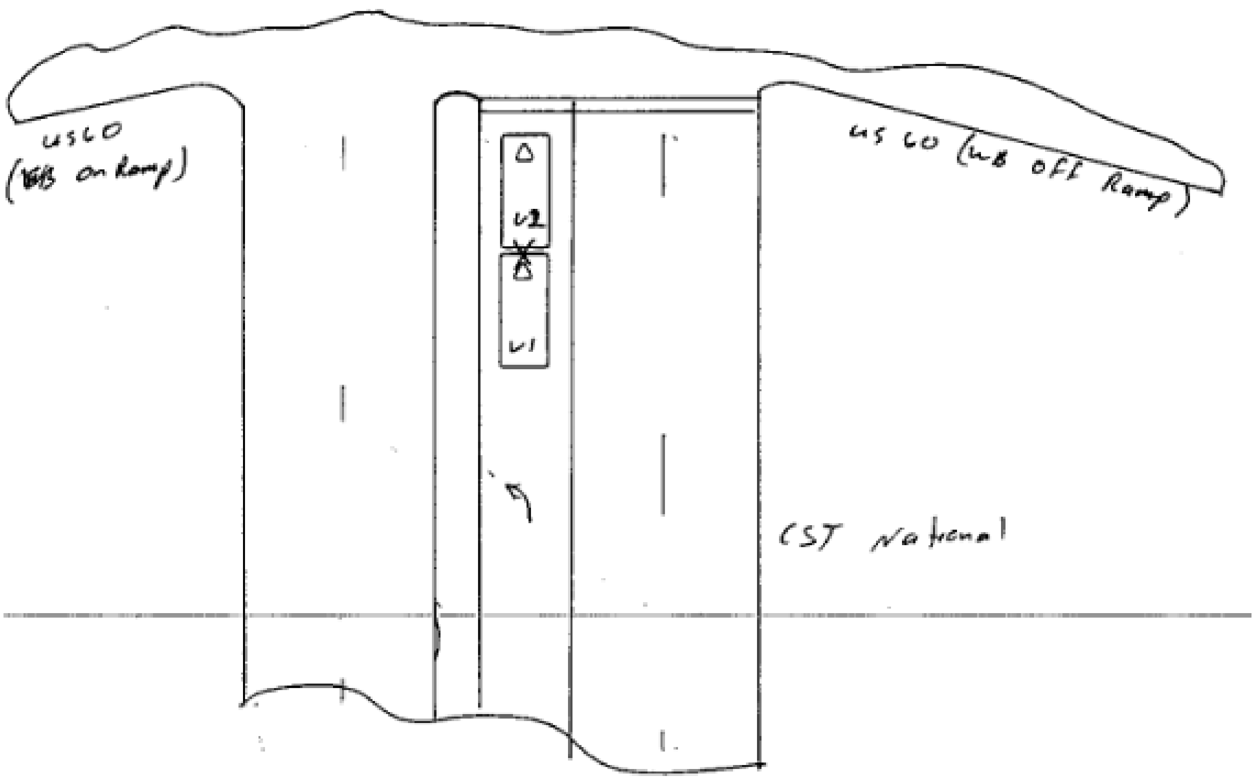



**Figure 3.16. Collision diagram for Example 2 (US 60)**

Step 3

Based on the previous two steps, the assignment of the crash is to the north ramp terminal.

*Example 3–US 60*

Again, the procedures in Step 1/Example 1 apply here. Table 3.5 contains the crash information for Example 3. Even though Example 3 is located at the same interchange as Example 2, Figure 3.17 shows the interchange in a different orientation than before.

**Table 3.5. Crash data for Example 3 (US 60)**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Interchange | Ramp terminal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | US | 60 | W | 255.625 | REAR END | 7/10/2007 | MINOR INJURY | 70079057 | 0 | 12.272 | | Y | | DAYLIGHT | DRY | CLOUDY | 7783 | NONE | TUE | 843 | 2 | N |


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**Figure 3.17. Interchange for Example 3 (US 60)**

Step 2

Figure 3.18 shows that the collision occurred on the exit lane of the freeway. There was queuing from the ramp terminal down through the ramp reaching the freeway. Three vehicles were involved in the crash. Vehicle A (VA) was able to avoid collision and went off the roadway towards the shoulder. The second vehicle or (V2) was unable to stop in time and hit the stopped vehicle (V1).

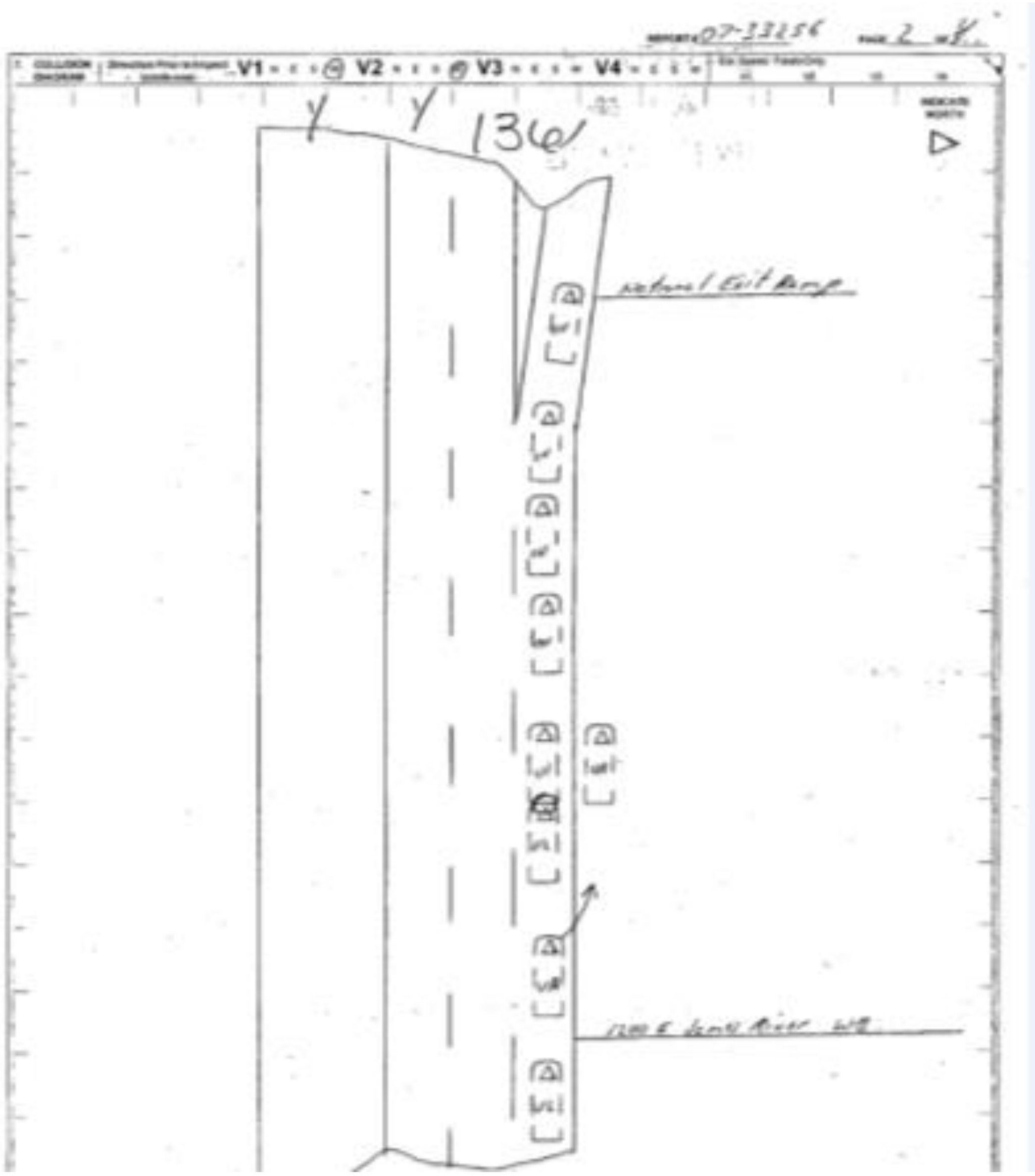


**Figure 3.18. Collision diagram for Example 3 (US 60)**

Step 3

Since the crash was caused by the queue that originated at the ramp terminal, it should be assigned to the north ramp terminal (N).

In addition to the three examples shown previously, a test dataset was created in order to verify a person's understanding of the tutorial. So, 75 crash reports were carefully selected to verify a reviewer's understanding of the tutorial steps. These crash reports included different scenarios related to crashes at interchanges. All the relevant information, such as the crash data, crash diagram, and narrative, were provided for each crash. The results of the test were evaluated by a designated specialist to provide feedback to the reviewer and to correct any inconsistences in the review of the crash reports. The test was administered before a reviewer started the actual data review. This test was another step taken to ensure that crashes were reviewed in the same way by different reviewers.

# CHAPTER 4. CRASH REPORT LOCATION CORRECTION FOR SPEED-CHANGE LANES AND FREEWAY RAMP SEGMENTS

## 4.1 Introduction to Crash Location Correction for Speed-Change Lanes and Ramps

The crash review tutorial in Chapter 3 focused on ramp terminal related crashes. Those crashes were assigned with the following notations: N, S, E, and W. Crashes that were not ramp terminal related were assigned the letter X. This chapter, the Phase 2 crash review, will focus on assigning the filtered (non-terminal related) crashes (i.e., those designated as X) to the corresponding facility of the interchange other than the ramp terminals. These facilities are the freeway segment, speed-change lanes, and ramp segments. Figure 4.1 illustrates graphically the different physical areas of an interchange for crash classification purposes: speed-change crash areas (in blue), ramps (in magenta), and mainline segments (in yellow). Each facility is described in detail in terms of operations, geometric design, influence over drivers, and type of crashes. Following the description of each facility, the Phase 2 tutorial contains the methodology to assign crashes for each facility and the criteria to determine the assignment. The criteria developed in this phase helps to maintain consistency among multiple reviewers of crash reports. This chapter establishes crash review standards and provides an illustrative example. A self-diagnostic test was developed so that a reviewer can test their understanding before actual crash review is performed.

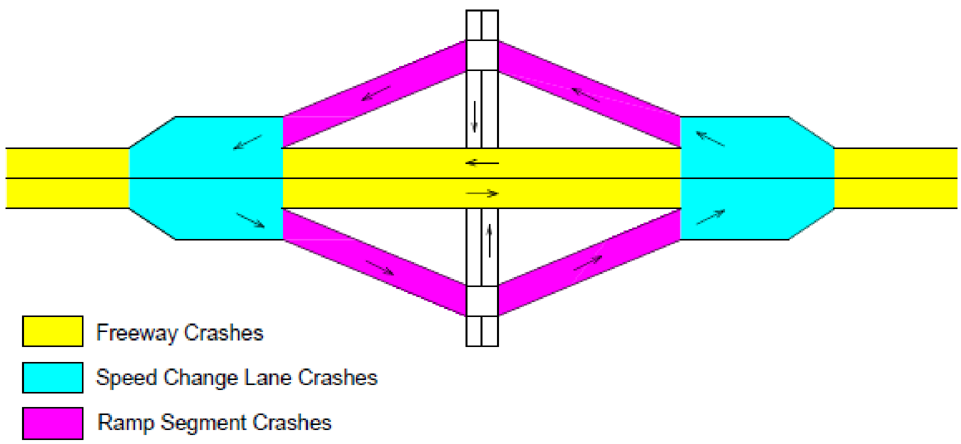


**Figure 4.1. Types of crashes on non-terminal facilities**

## 4.2 Description of Interchange Facilities

A conventional diamond interchange is used to illustrate the crash correction methodology for freeway segments, ramps, and speed-change lanes. The freeway segment of an interchange is the section of the freeway (in either direction) that is bracketed by the speed-change lanes (as previously shown in Figure 3.1). The gore point is the reference used when determining where the freeway segment begins and ends. The gore point is the location in which the ramp segment diverges or merges with the freeway. Within the interchange, there could be barriers associated with overpasses or underpasses, overpass bridge infrastructure, grade differentials, speed-change lane interactions, and other interchange-specific geometric designs (all of which could increase the risk of crashes). Therefore, the number of crashes occurring on the freeway segment within the interchange might be different than the number occurring outside the interchange.

Ramp segments are unidirectional auxiliary roadways located between speed-change lanes and ramp terminals. There are two types of ramp segments: exit and entrance ramp segments. An exit ramp segment allows through traffic to leave the freeway and connect with the crossroad using the ramp terminal. An entrance ramp provides crossroad traffic access to the freeway through the ramp terminal. For an exit ramp segment, the length is from the gore point to the stop line at the ramp terminal. For an entrance ramp segment, the length is from the edge of the crossroad to the gore point on the freeway. Figure 4.2 shows the locations and lengths of ramp segments at a diamond interchange.

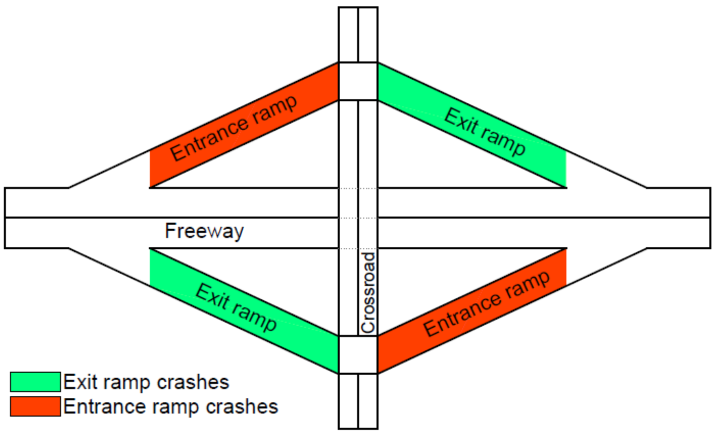


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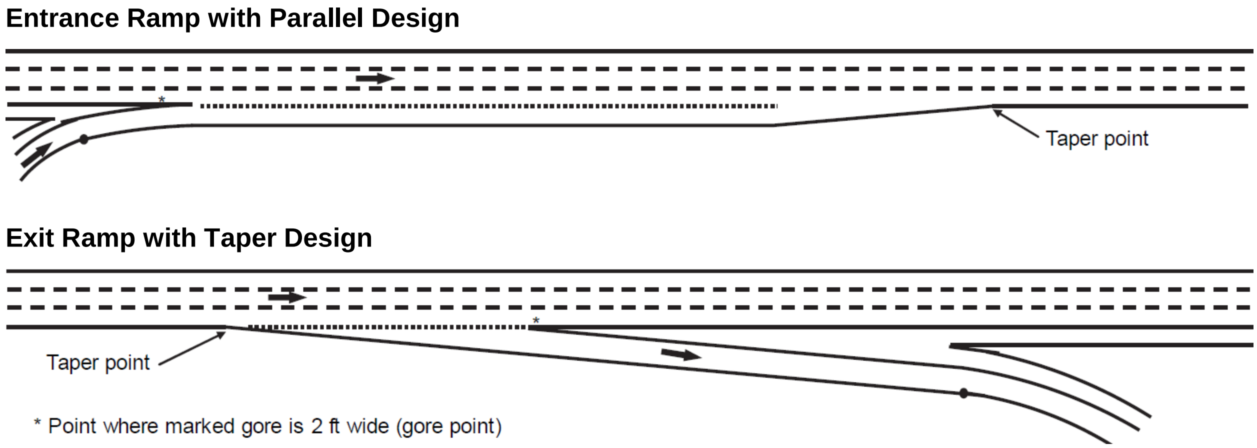
**Figure 4.2. Locations and length of ramp segments at a diamond interchange**

A speed-change lane is a unidirectional, uncontrolled terminal between a freeway and ramp segment (Bonneson et al. 2012). There are two types of speed-change lanes: exit and entrance. An exit speed-change lane gradually adds additional lane(s) to separate exiting traffic from through traffic and connects to the exit ramp segment. This gradual transition area in the speed-change lane is called the taper. An entrance speed-change lane gradually drops ramp lane(s), thus allowing vehicles to merge safely with the freeway through traffic. Typically, an interchange has four speed-change lanes. The length of speed-change lanes is measured from the gore point to the beginning or end of the taper. Figure 4.3 shows typical entrance and exit ramps with their associated speed-change lane, gore point, and taper. The bottom image in Figure 4.3 shows that the gore point is defined as the point where the mainline and the ramp is separated by 2 ft.




Bonneson et al. 2012, National Cooperative Highway Research Program

**Figure 4.3. Typical entrance and exit ramps with associated speed-change lanes**

It is important to note that speed-change lanes are different from add or drop lanes. An add lane is a lane that is added to the mainline and does not end with a taper. Figure 4.4 shows an example of a westbound add lane where the additional lane continues without terminating at a taper. A drop lane is a mainline lane that is terminated via an off ramp. Figure 4.4 also shows an example of an eastbound drop lane where the drop lane did not begin with a taper but ends at an off ramp.

**Figure 4.4. Example of add and drop lanes**

## 4.3 Description of Crash Reports

This section briefly describes the content of the crash reports that were used to perform the crash review and assignment. This material was previously covered in Chapter 3 for ramp terminals and is briefly repeated here so that the Chapter 4 tutorial can be self-contained. The crash report sections used for assignment consist of the image number, collision diagram, and narrative and statements of the crash.

The image number is a unique number assigned by MoDOT to identify a crash report, and it is compatible with the electronic crash report. Each crash report filename includes the image number identification (e.g., 40073302.pdf). The crash report presents a specific description of the location of the crash. The fields in these sections help identify the road on which the crash occurred and the distance from the intersecting road. Note that the accuracy of the distances and reference points vary according to the person who filled out the form. The location information should be used in conjunction with the collision diagram and narrative and statements. The collision diagram shows the circumstances and location of the crash. The legend of the collision diagram is located on the header of the page. The collision diagram might have limited or no information. If that is the case, then other resources, such as the narrative and statements of the crash, need to be used to locate the crash. The narrative contains a written description of the crash and the statements collected from witnesses and/or people involved in a crash. The details in this section are also subject to the experience and expertise of the reporting personnel.

### 4.4 Crash Review and Assignment Procedure: Physical Classification

Two different crash review methods—physical and the functional classification—are presented in this section. The physical classification method is the one used in the HSM. The functional classification method is a potentially more accurate method that is alluded to in the NCHRP studies that gave rise to the HSM. This method is included here to inform the reader of future advances in crash data analysis that could lead to improvements in data accuracy and countermeasure implementation.

The goal of this classification is to locate the crash on the appropriate non-terminal freeway interchange facility. Unlike Phase 1 (Chapter 3), there are two instead of three important steps. The **first step** in reviewing a crash report is to determine the specific location of the crash using the information provided in the location field, collision diagram, and narrative and statements. If the sections are inconsistent with each other, then, as a general rule, at least two of the three sections should be in agreement. The **second step** is to assign the filtered crashes from Phase 1 or those assigned with an X. Also, a different notation for assignment than Phase 1 will be used since there are multiple facilities. The following section describes in detail the new notation.

As compared with the terminal crash assignment, the assignment to speed-change lanes, ramps, and mainline segments is more complicated since there three different types of facilities to be considered. The objective of this section is to train the reviewer using a notation that will assist in the assignment of crashes. Characters are defined to specifically denote the type of facility (speed-change lanes, ramps, or freeway segments), entry or exit, and orientation (north, south, east, or west). Therefore, the notation of crash assignments has three components: 1) facility type, 2) exit or entry, and 3) direction with respect to the freeway centerline.

*Interchange Facility Designations*

There are three facilities that are considered for assignment in this phase of the tutorial: freeway segment (F), speed-change lanes (S), and ramp segments (R).

*Exit or Entry Designation Characters*

There are two designations: diverging or exiting from the freeway (D) and merging or entry into the freeway (M). These two designations only apply to speed-change lanes and ramps (not freeway segments). Thus crashes occurring on freeway segments are only designated with two characters.

*Direction with Respect to Freeway Centerline*

To be consistent with the conventions used in Phase 1, the crash direction is designated based on the compass direction relative to the freeway centerline. These characters include the following: N, S, E, and W. If a freeway runs in the north to south direction, the crash direction should be coded as E if the crash is being assigned to the facility located on the east side of the freeway and as W if the crash is being assigned to the facility located on the west side of the freeway. If a freeway runs in the east to west direction, the crash location should be coded as N if the crash is being assigned to the facility located on the north side of the freeway and as S if the crash is being assigned to the facility located on the south side of the freeway. If the freeway runs in a diagonal direction, the reviewer should decide via visual inspection if the freeway runs closer to the north to south or east to west direction. Note that the direction of the freeway centerline is determined by the compass direction and could be inconsistent with the actual name of the freeway. For example, a "northbound" freeway can travel in a westerly or an easterly direction for certain sections. The use of aerial photography is recommended for determining the direction of the speed-change lane or ramp with respect to the freeway centerline. This is a critical step for accurately performing the crash assignment to the correct facility.

*Crash Assignment Notation Example*

Assume a crash occurred on the exit speed-change lane on the east side of the freeway centerline. The notation for the assignment would be SDE (speed-change lane, diverging, and east). Now assume a crash occurred on the south side of an east to west freeway segment at an interchange; the assignment would be FS (freeway segment and south). Figure 4.5 graphically illustrates the crash assignment to all possible freeway facilities. The two or three character crash location assignment is labeled next to the corresponding facility.

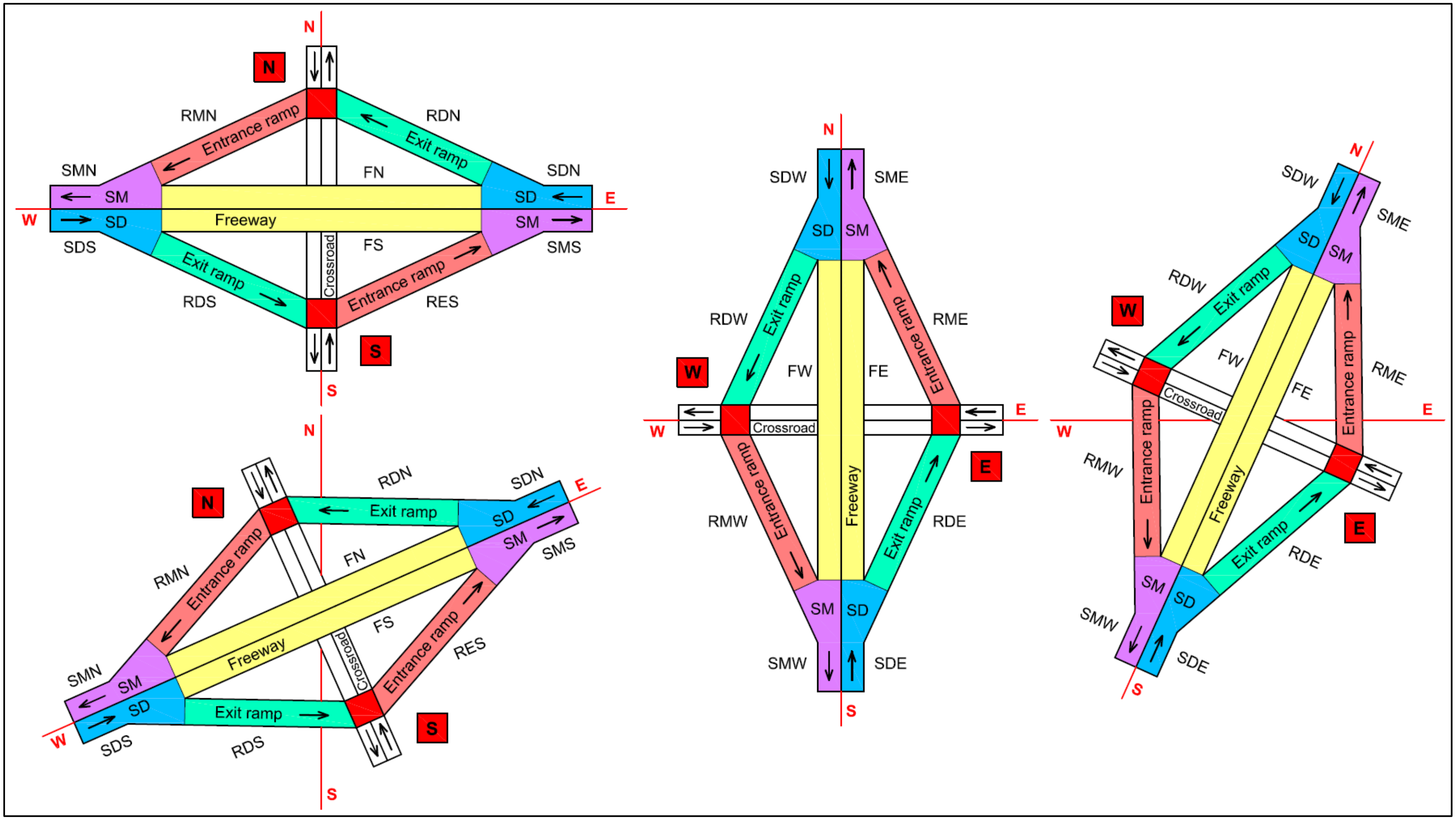



**Figure 4.5. Facility assignment notation examples**

Similarly to Phase 1, the previous assignments with notations should be recorded in the crash data spreadsheet in the Interchange Facility column. Table 4.1 shows the spreadsheet with the new column and corresponding assignment highlighted in green. Note that both of the crashes shown in Table 4.1 were already determined to be non-terminal crashes since they both have an X in the Ramp Terminal column.

**Table 4.1. Phase 2 interchange facilities assignment**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Log Unit | Intrchg | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Interchange | Period | Ramp terminal | Interchange Facility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | US | 160 | E | 95.436 | OUT OF CONTROL | 11/30/2004 | MINOR INJURY | 1040046510 | 24.917 | | DARK | ICE | CLEAR | 7806 | NONE | TUE | 2150 | 1 | B | X | SDE |
| GREENE | US | 160 | E | 95.619 | OUT OF CONTROL | 1/27/2005 | MINOR INJURY | 1050012588 | 25.1 | Y | DAYLIGHT | DRY | CLOUDY | 7806 | NONE | THU | 1110 | 1 | B | X | FS |

Note that in Phase 1, object- or animal-related crashes were considered rare events and were not assigned to the ramp terminal. This is because ramp terminals have different characteristics than mainline segments especially pertaining to the intersection operation such as signalization, intersection geometrics, conflict points, and interrupted traffic flow. However, for freeway and ramp segments, object or animal collisions are segment-related crashes, and they should be assigned to the physical facility in which the collision occurred.

*Physical Classification Example*

The following example is a step-by-step application of the criteria and methodology for crash report revision and assignment for this chapter. Table 4.2 contains the crash data necessary to start the review of the example crash.

**Table 4.2. Crash data for Phase 2 example crash**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Interchange | Period | Ramp terminal | Interchange Facility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JACKSON | IS | 435 | N | 14.486 | RIGHT TUR | 10/4/2009 | MINOR INJURY | 90101021 | 0 | 14.486 | | Y | | DAYLIGHT | DRY | CLEAR | 6039 | NONE | SUN | 1444 | 5 | B | X | SDE |

Step 1

Locate the interchange in an aerial photograph. Figure 4.6 shows the aerial image of the interchange.



**Figure 4.6. Interchangefor Phase 2 sample crash**

Use the image number (colored magenta in Table 4.2), 90101021, to find and open the crash report. Examine Section 2 of the report—where the location of the crash is described along with the different fields described previously. Figure 4.7 shows the corresponding location section of the crash report of the example.


2-LOCATION

| COUNTY | MUNICIPALITY | BEAT / ZONE | TRP / DIST / PCT | INVESTIGATED AT SCENE |
|---|---|---|---|---|
| JACKSON 048 | KANSAS CITY, MISSOURI 1280 | 342 | EPD | ☒ YES ☐ NO |

| ON | DISTANCE FROM | LOCATION | INTERSECTING STREET OR ROADWAY |
|---|---|---|---|
| (IS) I-435 | ____ FEET / 0.10 MILES | ☐ AFTER ☒ BEFORE ☐ AT | (CST) E 23 ST |

| ROADWAY DIRECTION | SPEED LIMIT | SPEED LIMIT | GEO-CODE | GPS |
|---|---|---|---|---|
| N | 65 | 35 | NA | LONGITUDE NA / LATITUDE NA |

ROAD MAINTAINED BY ☐ 1. STATE ☐ 2. COUNTY ☒ 3. MUNICIPAL ☐ 4. PRIVATE PROPERTY ☐ 5. OTHER

**Figure 4.7. Location of crash for Phase 2 crash example**

Step 2

Section 7 of the crash report contains the collision diagram. The diagram shows the collision and the direction of travel of vehicles. According to the diagram and the legend in Figure 4.8, there were two vehicles involved (V1 and V2). V1 was a small car and V2 was a motorcycle. The point of impact (POI), exit/entrance ramp segments, and crossroad orientations were labeled. The north arrow was also provided. The crash occurred just before the gore point. At this point in the crash report review, there is significant information to make the assignment to the exit speed-change lane in the east side of the interchange (assignment notation SDE). However, it is beneficial to also review the narrative to confirm that all the information from Sections 2 and 7 of the crash report were accurate. As a general rule, a minimum of two of the three sections should be consistent to finalize the crash assignment. Otherwise, the crash should not be assigned to any facility and should be labeled with the designation X, which means that a correct assignment was not feasible.

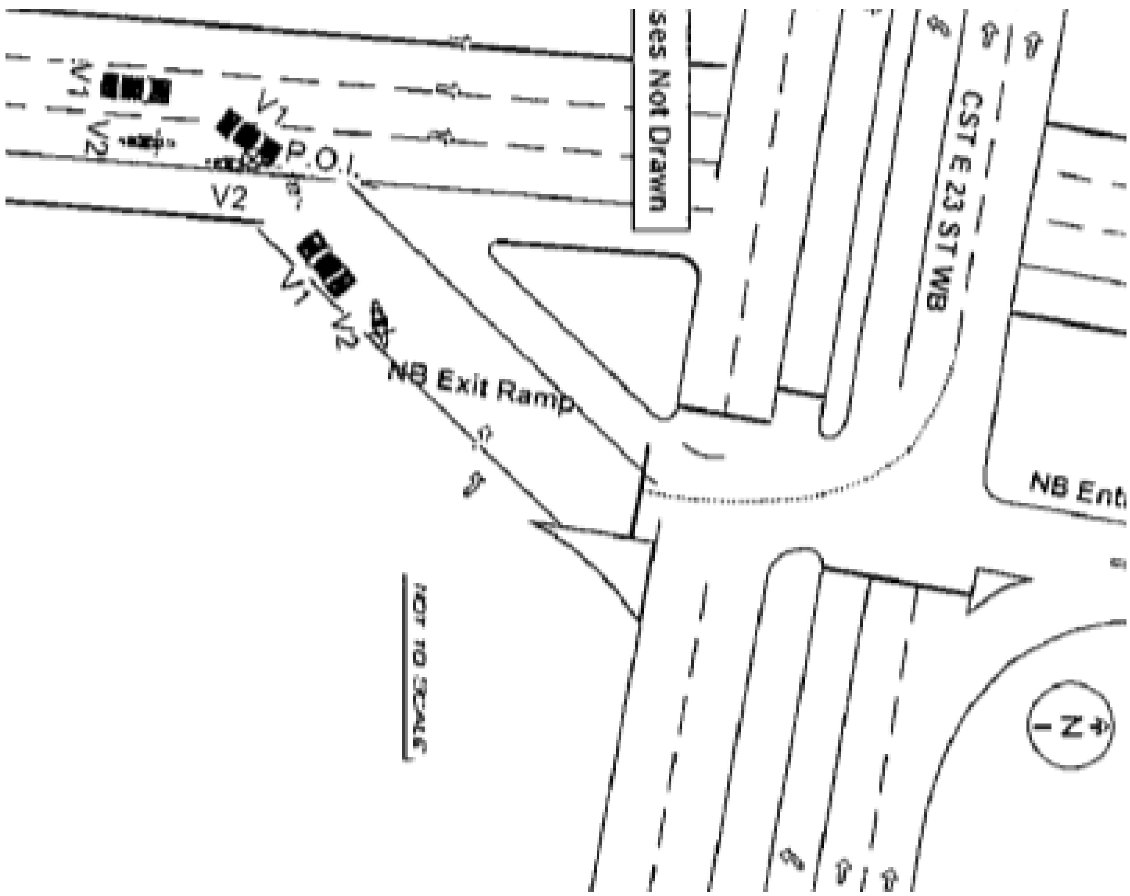



**Figure 4.8. Collision diagram for Phase 2 crash example**

The narrative section of the crash report is shown in Figure 4.9. The narrative supports the information from the location section and the collision diagram. In summary, the crash occurred when a vehicle tried to make the exit from the middle through lane (#2 lane) of the freeway. The driver claimed the she was not able to see the motorcycle coming on the rightmost lane. She cut off the path of the motorcycle causing the crash. The crash should be assigned to the exit speed-change lane on the east side of the interchange (assignment notation SDE). It should be recorded in the Interchange Facility column as shown in Table 4.2 (in green).

> Driver #1 reported she was travelling north on I-435 in the #2 lane of traffic when she realized she missed her exit (23rd St. Trafficway off ramp). Driver #1 reported she did not see anyone in the #3 lane of traffic and proceeded across the #3 lane of traffic onto the off-ramp to 23rd St. Trafficway. She stated she did not realize she struck Vehicle #2 until she saw Driver #2 airborne on the side of her vehicle. Driver #1 stated she then struck the guardrail face and her vehicle spun around coming to rest facing south on the north bound off-ramp. Driver #1 denied sustaining any injuries. She also denied any injuries to her passenger, her daughter.
>
> Driver #2 reported he was travelling north on I-435 near the 23rd St. Trafficway off-ramp. Driver #2 reported Vehicle #1 was travelling north on I-435 in the #2 lane of traffic. Driver #2 reported he saw Vehicle #1 begin to change lanes travelling toward the off-ramp. Driver #2 stated he attempted to exit with Vehicle #1 to avoid being struck. However, he reported Vehicle #1 struck his vehicle causing him to be ejected. He stated he then skidded across the pavement, as well as, his vehicle. He stated he came to rest at the guardrail. He stated his vehicle came to rest north of him also striking the guardrail. Driver #2 sustained multiple contusions, scratches and scrapes. He also sustained a large cut to his right lower leg. He was transported to Liberty Hospital via MAST #140. MAST employees advised Driver #2 had a possible broken leg, as well.
>
> Witness #1's statement is consistent with both Driver #1 and Driver #2. Witness #1 stated he saw the accident in his rear view mirror. He stated he observed Driver #1 exit from the #2 lane of I-435 onto the off-ramp. He stated Driver #2 was travelling north in the #3 lane of I-435 and was struck by Driver #1.
>
> My investigation revealed the statements of Driver #1, Driver #2, and Witness #1. I observed damage consistent with their statements. Vehicle #1 sustained heavy damage to the front bumper, front fenders, and hood. Vehicle #1 also sustained damage to the passenger side rear bumper and the driver's side where it struck the guardrail. Vehicle #2 sustained moderate damage to the left side of the fuel tank, handle bars, front headlamps, and front fender. Vehicle #2 had a sidecar attached and the frame and wheel appeared to be bent.
>
> Vehicle #1 was towed from the scene by private tow. Vehicle #2 was released at the scene to a family member to be towed at a later time by private means.

**Figure 4.9. Narrative and statements for Phase 2 crash example**

### 4.5 Crash Review and Assignment Procedure: Functional Classification

In the physical classification method, the only criterion for assigning crashes is their exact location. But in the functional method, in addition to the location of the crash, the circumstances of the crash events with respect to the location are considered. This method is potentially better for countermeasure analysis since a crash could be caused by an interchange facility that differs from the facility where the crash occurred. For example, a crash located on a ramp can be due to the loss of control that occurred due to the speed-change lane. There are three important steps for assigning crashes with the functional method:

- Step 1: Crash location review
- Step 2: Crash circumstances review
- Step 3: Assignment of crashes

The first and third steps are same as first and second steps in the physical method. Thus, the first and third steps are not repeated here. The **new second step** of the review consists of the analysis of the crash events with respect to the location. Understanding the different factors in the crash scenario helps the reviewer to assign the crash correctly.

As mentioned previously, there are two types of speed-change lanes: exit and entrance. Crashes at these facilities are usually caused by speed differential and distracted drivers. Vehicles exiting the freeway usually reduce speed considerably and change lanes to be able to exit the freeway and continue to the exit ramp segment. However, following vehicles might not be able to adjust in time to the movements of the exiting vehicle, which might lead to a crash. Cases 1, 2, and 4 of Figure 4.10 illustrate this type of crash.

For example, in Case 3, a distracted driver realizes that the exit will be missed and makes a sudden maneuver, which leads to a collision with the gore and a run-off-road crash. Also, as an example, in Case 5, a driver loses control just before the gore point. This type of crash is considered speed-change related if the information in the crash report suggests that the driver lost control of the vehicle due to the exit speed-change lane's geometric design or operation. Case 6 shows a particular crash type in which a driver aborts exiting the freeway and returns to the through lanes causing a collision with a vehicle on the freeway.

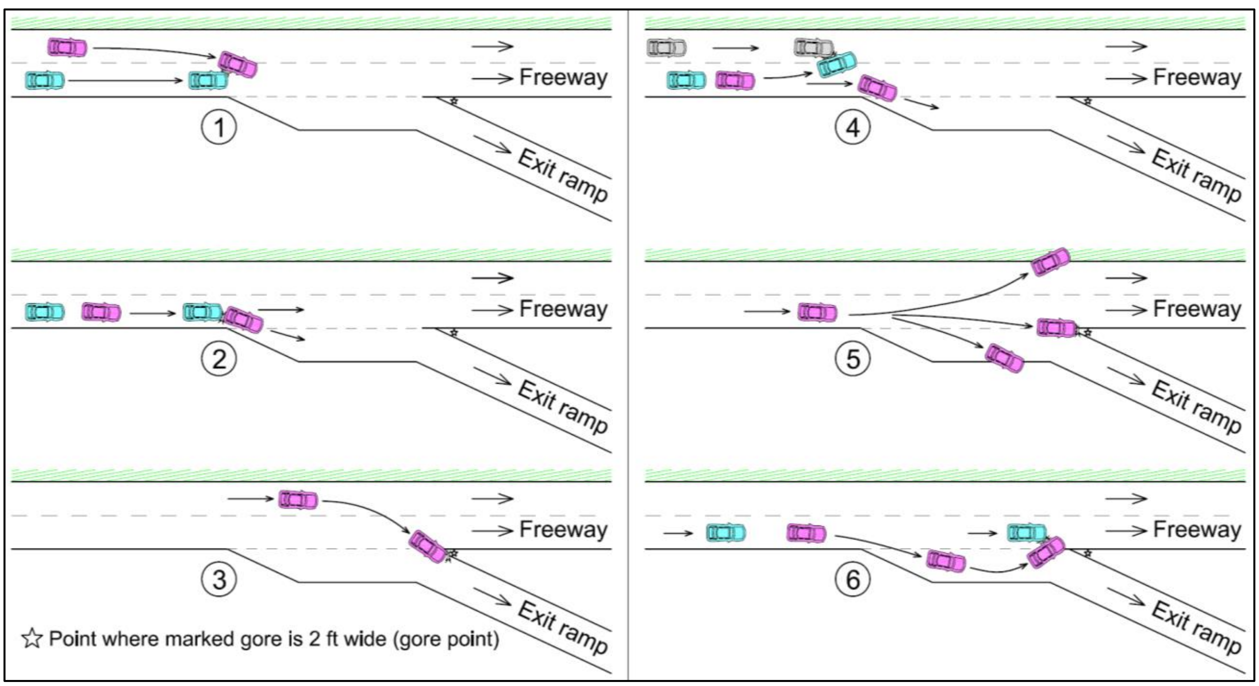



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**Figure 4.10. Common crash types at exit speed-change lanes**

Similar cases could occur at an entrance ramp where an entering vehicle might not be able to develop the necessary speed soon enough to keep up with mainline freeway traffic, which results in a collision with approaching vehicles. Cases 1 and 3 in Figure 4.11 both illustrate this type of crash. Figure 4.11 also illustrates other common crash type scenarios. Case 2 shows a crash due to a congested freeway where ramp vehicles have difficulty finding a gap to merge. After a queue is generated, a distracted driver then rear ends the end vehicle in the queue. Case 4 shows an example of a run-off-road or loss-of-control crash. Usually these crashes are generated because of distracted drivers who are unable to merge safely from the on-ramp to the mainline. This crash is considered speed-change related if the crash report information suggests that the loss of control occurred after the gore point.

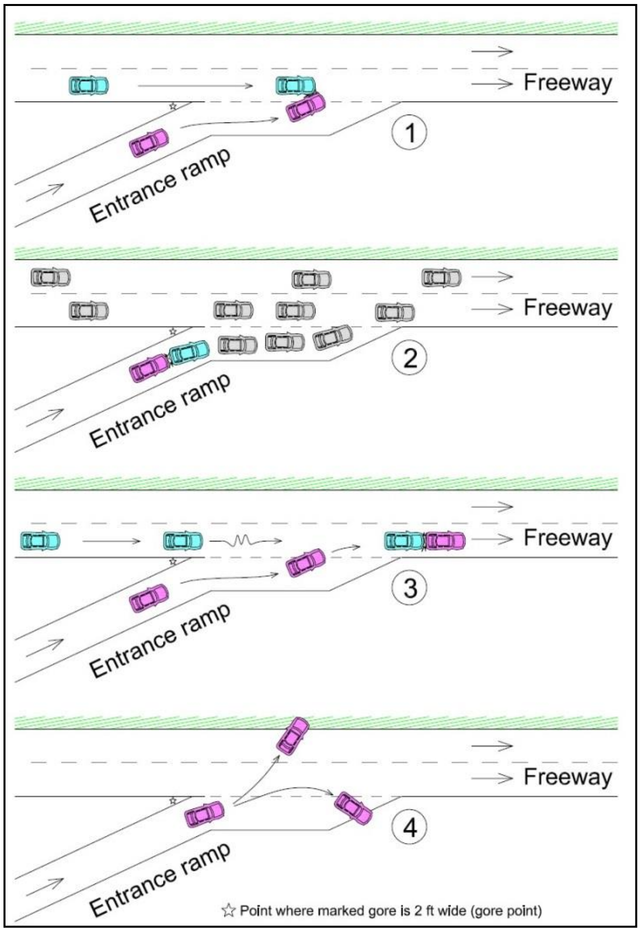


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**Figure 4.11. Common crash types at entrance speed-change lanes**

Geometric design characteristics of speed-change lanes can influence crashes as well. The taper configuration, number and width of lanes, and horizontal and vertical curves are factors that can significantly influence crashes. For instance, speed-change lanes with multiple lanes add risk because of the larger potential number of vehicle interactions. Short tapers might cause vehicles to perform late merging or quick diverging movements.

Crashes should be assigned to speed-change lanes if the geometric design and vehicle operations influenced the crash. As was extensively discussed in Phase 1 of this tutorial, the fact that a crash occurred within the boundaries of a facility does not mean that the main cause of the crash was located in that facility. When ramp terminals were reviewed in Phase 1, crashes that were caused by queuing from the ramp terminals were considered ramp terminal related. Those crashes occurred either on the boundaries of exit ramp segments or even on the freeway mainline, depending on the length of the queue.

*Functional Classification Example*

The following is a step-by-step example of the application of the criteria and methodology for crash report revision and assignment using functional classification. Table 4.3 contains the crash data necessary to start the crash review. Step 1 here is similar to the first step in the physical classification methodology and relates to locating the interchange on an aerial photograph. Figure 4.12 shows the aerial image of the interchange.

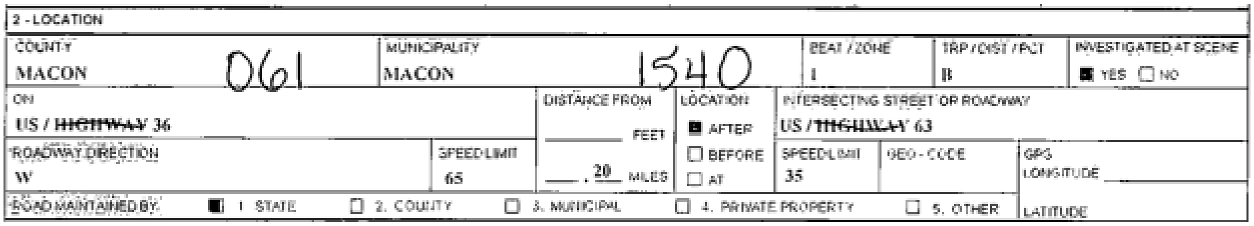
**Table 4.3. Crash data for functional classification example**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Category | Interchange | Ramp terminal | Interchange Facility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MACON | US | 36 | W | 62.632 | FIXED OBJECT | 5/17/2011 | MINOR INJURY | 110042759 | 0 | 9.462 | | | | DARK - NO ST | DRY | CLEAR | 3561 | MODOT | TUE | 2220 | SC_U | 12 | x | SMN |



**Figure 4.12. Interchange for functional classification example**

Examine Section 2 of the report involving the description of the crash location. Figure 4.13 shows Section 2 of the crash report for the example. Section 2 indicates that the crash occurred on US-36 after US-63.



2 - LOCATION

COUNTY: MACON 061
MUNICIPALITY: MACON 1540
BEAT / ZONE: 1
TRP / DIST / PCT: B
INVESTIGATED AT SCENE: ■ YES ☐ NO
ON: US / ~~HIGHWAY~~ 36
DISTANCE FROM: ____ FEET ____ . 20 MILES
LOCATION: ■ AFTER ☐ BEFORE ☐ AT
INTERSECTING STREET OR ROADWAY: US / ~~HIGHWAY~~ 63
ROADWAY DIRECTION: W
SPEED LIMIT: 65
SPEED LIMIT: 35
GEO - CODE
GPS LONGITUDE ____ LATITUDE
ROAD MAINTAINED BY: ■ 1. STATE ☐ 2. COUNTY ☐ 3. MUNICIPAL ☐ 4. PRIVATE PROPERTY ☐ 5. OTHER

**Figure 4.13. Location of crash for functional classification example**

The next step includes reviewing the collision diagram. According to Figure 4.14, there were two vehicles involved (V1 and V2). V1 was a tractor trailer and V2 was a small car. At first glance, the exact location of the crash appears to be on the westbound freeway lanes beside the median. However, it is difficult to accurately locate the crash to the mainline or the speed-change lane because there is no information about the exact location of the taper point (i.e., speed-change lane boundaries). The narrative will provide additional information.

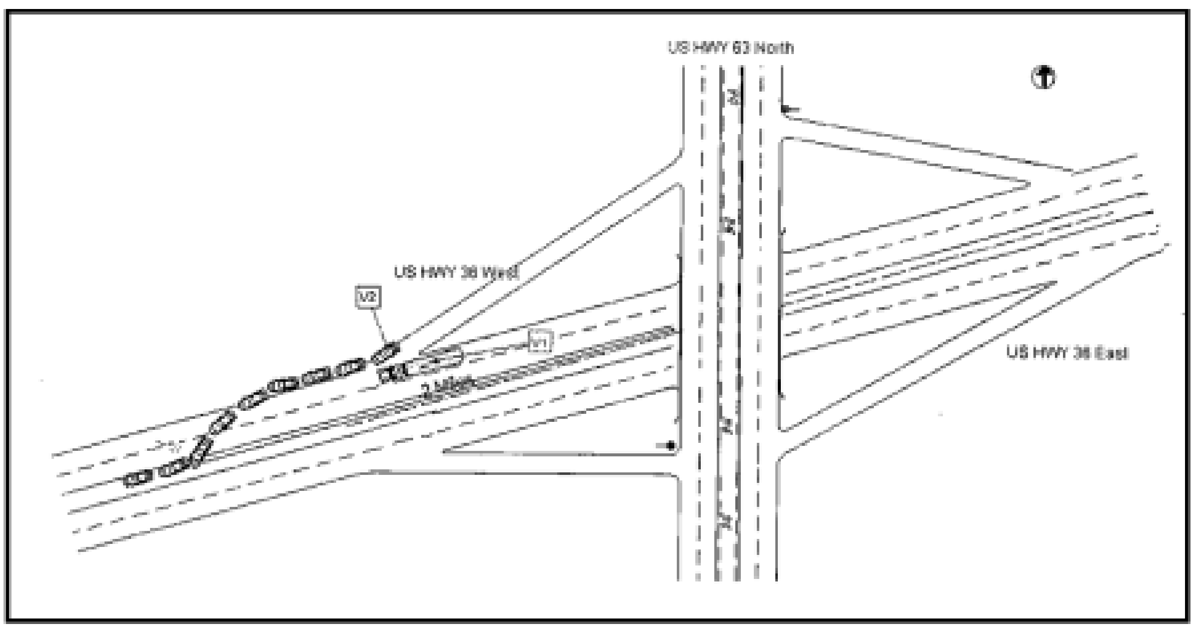
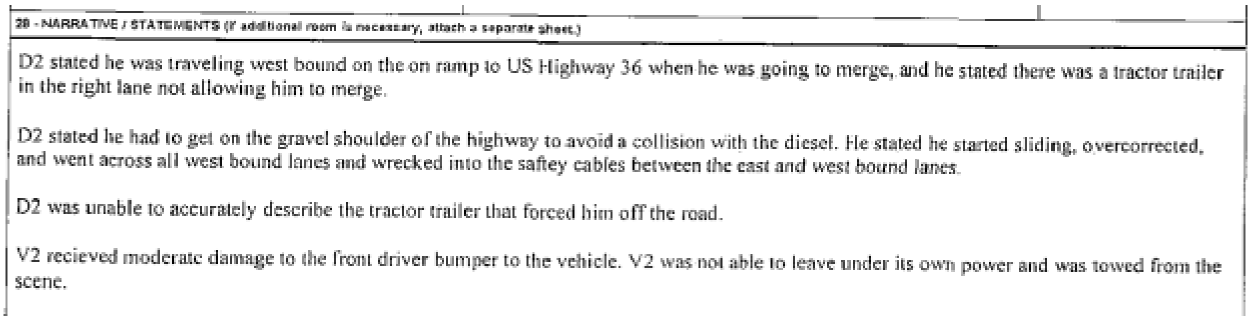



**Figure 4.14. Collision diagram for functional classification example**

The narrative section shown in Figure 4.15 includes the statements of Driver 2. In summary, V2 was trying to merge onto US-36 just after leaving the ramp entrance and the tractor trailer in the right lane did not allow the vehicle to merge. The driver attempted to avoid a collision with the tractor trailer, but started sliding, overcorrected, and then went across all west bound lanes until wrecking into the safety cables in the median. This scenario is similar to Case 4 in Figure 4.11, which shows common crash types at entrance speed-change lanes. The crash should be assigned to the entrance speed-change lane on the north side of the interchange (assignment notation

SMN). The classification is shown in Table 4.3 in the Interchange Facility column. This functional assignment differs from the physical assignment to the freeway mainline because the collision occurred at the median cable barrier.



28 - NARRATIVE / STATEMENTS (If additional room is necessary, attach a separate sheet.)

D2 stated he was traveling west bound on the on ramp to US Highway 36 when he was going to merge, and he stated there was a tractor trailer in the right lane not allowing him to merge.

D2 stated he had to get on the gravel shoulder of the highway to avoid a collision with the diesel. He stated he started sliding, overcorrected, and went across all west bound lanes and wrecked into the saftey cables between the east and west bound lanes.

D2 was unable to accurately describe the tractor trailer that forced him off the road.

V2 recieved moderate damage to the front driver bumper to the vehicle. V2 was not able to leave under its own power and was towed from the scene.

**Figure 4.15. Narrative and statements for functional classification example**

A test for non-terminal crash review was devised using 30 illustrative crash reports. The crash reports included different scenarios to observe the response and the comprehension of the materials explained in this tutorial. This test was administered to every reviewer trained for crash review. The results of the test were evaluated by a designated specialist to provide feedback to the reviewer and to correct any inconsistences in the review of the crash reports. The test, along with other standardized procedures, helped to ensure uniformity among crash reviewers.

### 4.6 Uncorrected Physical Classification

This section explains the consequences of using a physical crash classification approach that does not involve reviewing crash reports. This method involves identifying the location of crashes using a crash data table (e.g., Table 4.3) and then assigning the crash to one of the interchange facilities based on the facility boundaries. In this approach, the MoDOT linear reference system, or log miles, is used. The crash classification is based purely on the log mile location of the crash, the gore point, and the taper point. The following are the necessary steps for determining crash locations using an example.

First, locate the interchange using the Travelway ID as highlighted in the yellow Tway ID field in Table 4.4. Also, note the continuous log mile of the crash as shown in the orange Cont Log field in this table. In this example, the crash was located on Travelway 9 at log mile 88.817.

Next, use the TMS Map application from the TMS home page to locate the travelway. In TMS Map, choose the Search and Zoom icon and the Search and Zoom window appears. Select Search by Travelway in this window (see Figure 4.16). Enter the Travelway ID and Cont Log in Travelway ID box and Begin Log box respectively, and click on the Search button. The location of the crash will appear on the map as a yellow dot. In this way, the crash will be classified based on the location of the yellow dot with respect to the three types of facilities within an interchange.

**Table 4.4. Crash data for physical crash classification example**

| County | Desg | Travelway | Dir | Cont Log | Accident Class | Accident Date | Severity Rating | Image # | Intersection # | Log Unit | Intrsc | Intrchg | Grpd | Light Cond | Road Surf Cond | Weather Cond | Tway Id | Property Damage | Day of Week | Time | Category | Interchange | Ramp terminal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENE | IS | 44 | E | 88.817 | OTHER | 7/8/2010 | PROPERTY DAMAGE ONLY | 100065622 | 50679 | 28.84 | Y | Y | | DAYLIGHT | DRY | CLEAR | 9 | NONE | THE | 1210 | SC U | 1 | FS |


**Figure 4.16. Search and zoom window in TMS Map application**

As shown in Figure 4.17, the crash here occurred on the eastbound freeway after the gore point associated with the off ramp. Thus, the crash was assigned to a freeway segment in the southern part of the interchange (FS).


**Figure 4.17. Crash location window in TMS Map application**

Even though this method is very simple, it has the main drawback of being inaccurate due to the incorrect log mile in the crash database. Often the crash location is shown at the exact center of the interchange since the officer completing the report did not locate the crash within the confines of the interchange. Another challenge in using this method is that the resolution of map images makes the precise identification of location difficult. This is due to the limits of resolution in terms of the zoom levels. There are also ways of supplementing the TMS Map using a higher resolution image. For example, you can use the automated road analyzer (ARAN) viewer or a third-party aerial photograph viewer such as Google Earth or Google Maps.

ARAN is a road condition analyzer and data collector that collects videos of roadways referenced to log miles along with other road information. The ARAN videos are available via the TMS Map application. To use the ARAN viewer, enter the Travelway ID and the Cont Log in the Search and Zoom window and click on view ARAN instead of Search, as shown in Figure 4.18. Then a new window will open in the internet browser (see Figure 4.19). The first image might not show the exact location of the entered log mile (Cont Log). Two buttons, shown in the yellow circles shown in Figure 4.19, can be utilized for moving forwards and backwards to find the closest captured frame to the entered log mile. The orange box shows the location and log mile. For finding a new location, the New Location icon, shown in the red box in Figure 4.19, can be utilized. Since the distance between each two consecutive frames in the ARAN viewer is 0.02 mi, the precision of the location is limited to that resolution.

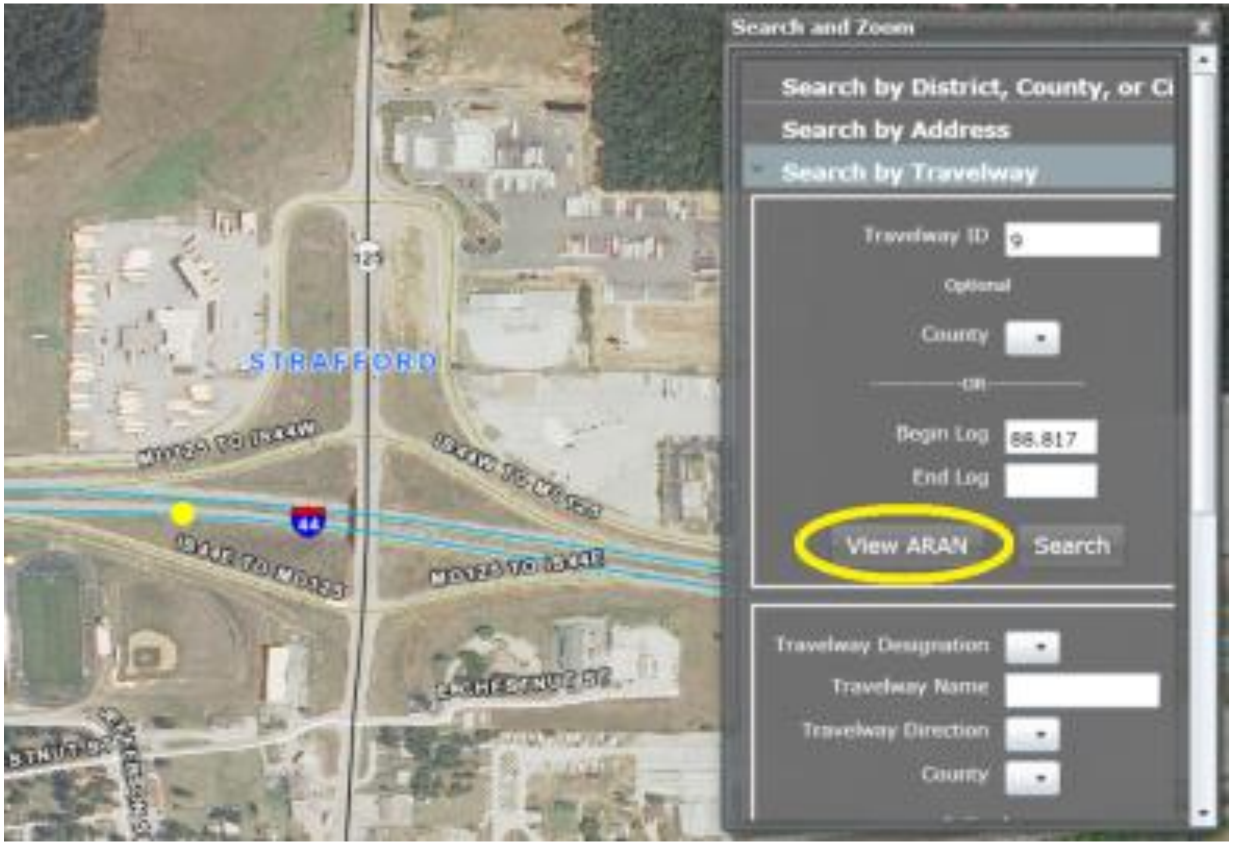



**Figure 4.18. Selecting ARAN viewer in TMS Map application**

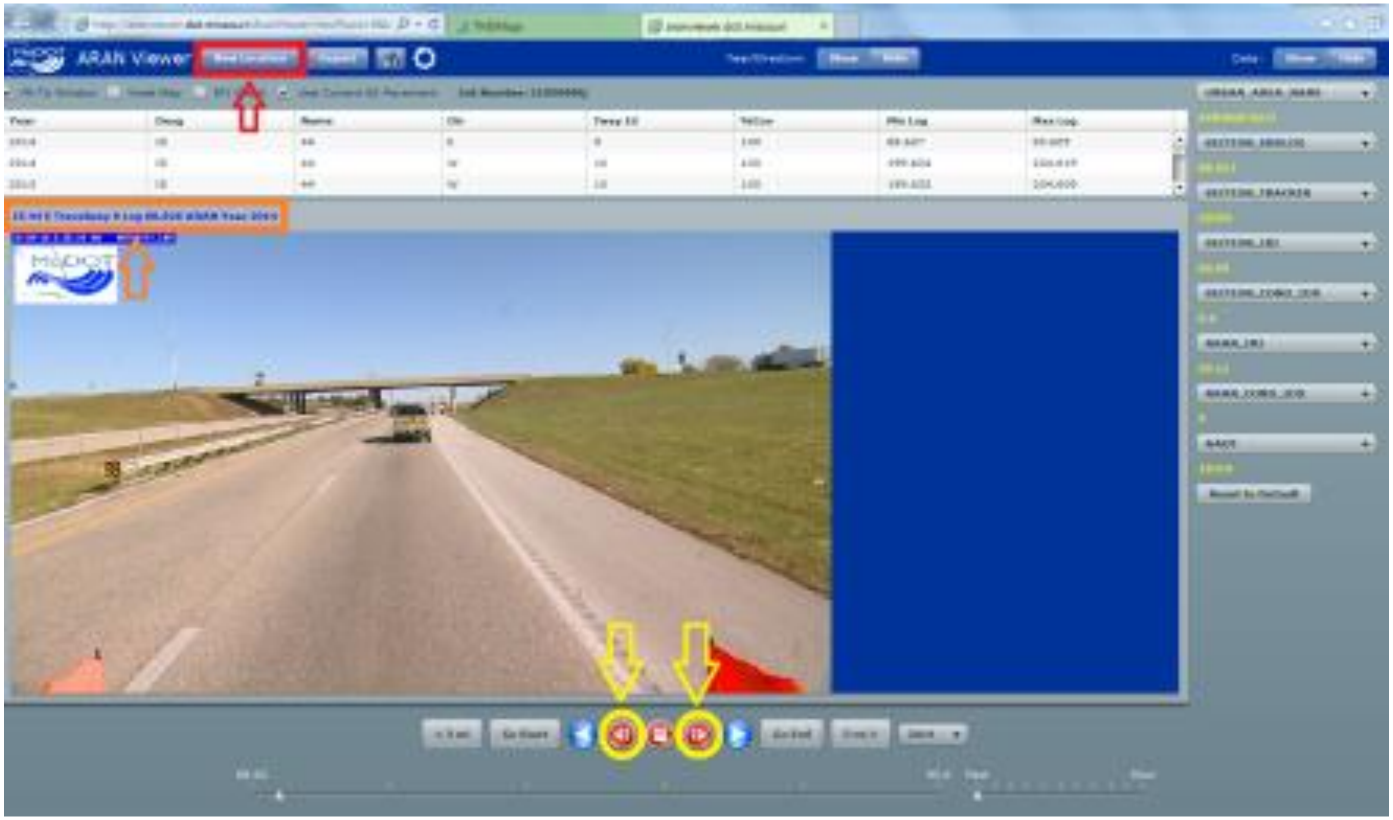



**Figure 4.19. ARAN viewer highlighting scrolling buttons (yellow arrows) and New Location icon (red arrow)**

To use a third-party aerial viewer, such as Google Maps, use the TMS map first to locate the coordinates of the crash location. Click on the TMS Location icon on the TMS map and select the crash location found previously; then a window containing location information will appear. Verify that the TRAVELWAY ID and LOG are identical to the Travelway ID and Cont Log recorded in the crash data table. Then, copy the coordinates shown in the yellow box shown in Figure 4.20. Open the third-party viewer and enter the coordinates with latitude first and then longitude (see Figure 4.21). Since the resolution of map images in a third-party viewer is possibly higher than in the TMS Map, the third-party image provides more details that could be helpful in locating crashes within the interchange geometry.


**Figure 4.20. Collecting coordinates from TMS Map application**

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**Figure 4.21. Imputing crash location in Google Maps**

## CHAPTER 5. RESULTS FROM CRASH CORRECTION

Recall that the main motivation for this crash location correction project was to provide the data necessary to perform HSM calibration for freeway interchange facilities. Thus, the crash data relates to specific freeway interchange facilities. Tables 5.1 and 5.2 list the facilities involved with HSM calibration in Missouri. Table 5.1 lists the terminal facilities while Table 5.2 lists the non-terminal facilities. Since full cloverleaf interchanges do not contain interchange intersections, their calibration only involves ramps and speed-change lanes. As shown in Table 5.1, Missouri freeways involve a wide range of diamond interchanges, which include both stop-controlled and signalized ramp terminals. Another popular type of interchange is the partial cloverleaf (parclo) (A2). The two main types of non-terminal interchange facilities are speed-change lanes and ramps. Speed-change lanes can be associated with either entrance ramps or exit ramps. Crash reports were collected and reviewed for all 19 interchange facility types listed in Table 5.1 and 5.2.

**Table 5.1. Calibrated terminal interchange facility types**

| Acronym | Terminal Facility | Signalization | Crossroad Lanes | Urban/ Rural |
|---|---|---|---|---|
| D4SCR | Diamond (D4) | Stop-Controlled | All | Rural |
| D4SCU | Diamond (D4) | Stop-Controlled | All | Urban |
| D4SG2 | Diamond (D4) | Signalized | 2 | Both |
| D4SG4F4* | Diamond (D4) | Signalized | 4 | Both |
| D4SG4F6* | Diamond (D4) | Signalized | 4 | Both |
| D4SG6 | Diamond (D4) | Signalized | 6 | Both |
| A2SCR | Parclo (A2) | Stop-Controlled | All | Rural |
| A2SCU | Parclo (A2) | Stop-Controlled | All | Urban |
| A2SG4 | Parclo (A2) | Signalized | 4 | Both |
| Clover | Full Cloverleaf | N/A | N/A | N/A |

* Since the number of freeway lanes does not affect interchange safety modeling, both of these facility types share the same calibration values.

**Table 5.2. Calibrated non-terminal interchange facility types**

| Acronym | Facility Type | Entrance/ Exit | Lanes | Urban/ Rural |
|---|---|---|---|---|
| SCLREN | Speed-Change Lane | Entrance | 4 | Rural |
| SCLU4EN | Speed-Change Lane | Entrance | 4 | Urban |
| SCLU6EN | Speed-Change Lane | Entrance | 6 | Urban |
| SCLREX | Speed-Change Lane | Exit | 4 | Rural |
| SCLUEX | Speed-Change Lane | Exit | 4, 6 | Urban |
| RPREN | Ramp | Entrance | 1 | Rural |
| RPREX | Ramp | Exit | 1 | Rural |
| RPUEN | Ramp | Entrance | 1 | Urban |
| RPUEX | Ramp | Exit | 1 | Urban |

Table 5.3 shows a summary of the crashes reviewed for this project. A total of 12,409 crash reports were reviewed. An initial review was performed to eliminate crash reports that were not needed for the companion HSM freeway interchange calibration effort.

**Table 5.3. Summary of crash review effort**

| **Facility Type** | **Detailed Crash Review** |
|---|---|
| Rural Stop-Controlled D4 Diamond Interchange Terminal | 412 |
| Urban Stop-Controlled D4 Diamond Interchange Terminal | 447 |
| Signalized D4 Diamond Interchange with Two Lane Crossroads Terminal | 864 |
| Signalized D4 Diamond Interchange with Four Lane Crossroads Terminal | 1,563 |
| Signalized D4 Diamond Interchange with Six Lane Crossroads Terminal | 1,800 |
| Rural Stop-Controlled A2 Partial Cloverleaf Interchange Terminal | 73 |
| Urban Stop-Controlled A2 Partial Cloverleaf Interchange Terminal | 441 |
| Signalized Partial A2 Cloverleaf Interchange Terminal | 968 |
| Rural Entrance/Exit Ramp | 214 |
| Urban Entrance/Exit Ramp | 566 |
| Rural Entrance/Exit Speed-Change Lane | 46 |
| Urban Four-Lane Entrance/Exit Speed-Change Lane | 189 |
| Urban Six-Lane Entrance/Exit Speed-Change Lane | 1,585 |
| Total | 9,168 |
| **Facility Type Totals** | |
| A2 Partial Cloverleaf Interchange Terminal Total | 1,482 |
| D4 Diamond Interchange Terminal Total | 5,086 |
| Entrance/Exit Ramp Total | 780 |
| Entrance/Exit Speed-Change Lane Total | 1,820 |
| **Total Crashes Reviewed for Project** | **12,409** |

There were several issues addressed by this initial review. One issue was that the same crash could appear on the query of different interchange facilities. Another issue was that some sites that were part of the initial random sample drawn for the HSM calibration were deficient, which was due to a variety of reasons (e.g., site geometrics or terminal configuration). Thus, the crashes from those sites were not further processed. Also, extra samples were initially selected in case of some of the original samples were faulty. Of those, 9,168 underwent detailed review. Detailed review refers to the procedures explained in the tutorials discussed in Chapters 3 and 4. This involved the manual review of crash images (i.e., Missouri uniform accident/crash reports). The focus was on sections involving location information, the crash diagram, and narratives and statements. Table 5.3 shows the number of crashes by interchange facility.

For the two ramp terminal facilities, diamonds included 77.4 percent of the terminal crashes reviewed and parclo included 22.6 percent. One reason for this disparity is that there were more diamond interchanges in Missouri and more used in the HSM calibration. For the non-terminal facilities, ramps included 30 percent of the non-terminal crashes reviewed and speed-change lanes included 70 percent. The percentage distribution of non-terminal facilities, on the other hand, actually reflects the frequency of crash occurrence since ramp and speed-change lane crashes were collected from the same number of interchanges. In other words, each ramp has an associated speed-change lane, so the crashes listed came from an equal number of facilities.

Of the total 9,168 crashes that were reviewed, 2,454 were assigned to one of the facilities of interest, either a terminal or a non-terminal facility. The severity distribution of the 2,454 crashes was examined for each facility type. The total distribution for fatal or injury (FI) crashes was 22.49 percent and 77.51 percent for property damage only (PDO) crashes. Table 5.4 shows the crash distribution by facility type.

**Table 5.4. Summary of crash severity distributions**

| | **Assigned Severity** | |
|---|---|---|
| **Facility** | **FI** | **PDO** |
| A2SCR | 16.67% | 83.33% |
| A2SCU | 27.14% | 72.86% |
| A2SG4 | 24.59% | 75.41% |
| D4SCR | 16.28% | 83.72% |
| D4SCU | 20.18% | 79.82% |
| D4SG2 | 21.27% | 78.73% |
| D4SG4 | 23.54% | 76.46% |
| D4SG6 | 19.78% | 80.22% |
| RPREN/EX | 10.00% | 90.00% |
| RPUEN/EX | 28.99% | 71.01% |
| SCLR4EN/EX | 20.59% | 79.41% |
| SCLU4 EN/EX | 19.23% | 80.77% |
| SCLU6 EN/EX | 25.97% | 74.03% |
| **Total** | 22.49% | 77.51% |

FI=fatal or injury, PDO=property damage only

Even though there is some variation in the severity distribution, the reader is reminded that some of the facilities contain a relatively low number of crashes. Thus Table 5.4 should be interpreted as a description of the crashes sampled for this project and not as a reflection of the overall severity distribution of crashes in Missouri interchange facilities.

In order to undertake the review of such a large number of crashes, a group of 25 reviewers was used. A team composed of three faculty members and four graduate students led the overall tutorial development and crash review process. This team developed the crash review tutorials, devised the tutorial tests, trained other reviewers, coordinated the review effort, and performed some of the review. An additional 18 undergraduate research assistants were trained and also reviewed crash reports. A large labor force was needed since crash review can only be performed in moderation; otherwise, errors can occur from the prolonged reviews.

Different crash location performance measures were generated in order to illustrate the importance of crash location correction. According to the STARS (2012) Committee, ramp crashes should be identified with a designation of RP. The ramp error rate then consists of the percentage of missed ramp crashes that were not identified as RP. If a crash occurred at an interchange ramp terminal, then it should be identified as an intersection crash. The terminal error rate consists of the percentage of missed terminal crashes that were not identified as being at an intersection. The performance measure for speed-change lanes is different from ramps and terminals, since there is no field in the crash report that indicates that a crash occurred at a speed-change lane. Instead, a speed-change lane location error refers to a log mile location that was assigned arbitrarily such as at the middle of an interchange. Thus, multiple crashes at the same interchange will show the same exact log mile even though the crash occurred at different locations within the interchange. This measure potentially undercounts the number of errors, since it does not catch instances when only a single crash was arbitrarily located or when a non-arbitrary location was incorrect. However, such a performance measure is still a fair estimate of the magnitude of the crash location problem.

Table 5.5 shows the crash landing error rates for freeway interchange facilities.

**Table 5.5. Crash landing error rates**

| Facility | Errors | Crashes | Error |
|---|---|---|---|
| RP | 52 | 58 | 89.7% |
| Terminals | 2,105 | 2,672 | 78.8% |
| SCL | 906 | 1,708 | 53.0% |
| Total | 3,063 | 4,438 | 69.0% |

The result from the crash review is considered the ground truth. Table 5.5 shows an overall error rate of 69 percent. In terms of specific interchange facilities, the error rate was 89.7 percent for ramps, 53.0 for speed-change lanes, and 78.8 for terminals. It is unclear why the error rate was so high for ramps while the error rate was around 50 percent for speed-change lanes. The error rate was also examined separately for rural and urban facilities for ramps and speed-change lanes. This analysis was not undertaken for terminals since some HSM terminal types apply to both urban and rural conditions. For ramps, the error rates for rural and urban ramps were almost identical being 89.5 and 89.7 percent, respectively. For speed-change lanes, the rural error rate was 56.0 percent, and the urban error rate was 52.4 percent. It does not appear that the error rates differed significantly between rural and urban facilities. Regardless of the exact reasons for crash landing errors, it is clear from the data that the error rate is high for all interchange facilities and that crash landing correction improves the safety analysis of interchange facilities.

# CHAPTER 6. CONCLUSION

The freeway interchange calibration effort in Missouri encountered significant problems related to crash landing errors. Consequently, this project was funded, and critical procedures necessary to correct the crash landing problem were developed. Without these valuable procedures, calibration would not be feasible since the exact locations of crashes within an interchange would be unknown.

This report documents in detail a set of procedures for clearly determining where a crash occurred within an interchange. Specifically, the procedures assign a crash to a specific terminal, ramp, speed-change lane, or mainline. The specific facility is referenced with respect to the freeway centerline using the compass direction. This procedure was tested and refined and contains both a detailed set of instructions as well as a robust test for reviewers. Twenty-five research assistants and faculty took the test and applied the procedure for analyzing crashes at different freeway interchange facilities, which included diamond interchanges, partial cloverleaf interchanges, entrance/exit ramps, and entrance/exit speed-change lanes. One long term value of this report is the establishment of a uniform procedure so that crash review for freeway interchanges can be performed consistently.

The process of manually reviewing crash images was an enormous undertaking. As previously mentioned, 25 trained undergraduate and graduate research assistants and faculty were involved in reviewing crashes. This large number of reviewers was necessitated not just by the large number of facility types and sites required but also by the dangers of crash review burnout and error. Although crash review can be very interesting, since every crash is unique and reflects a unique set of circumstances, it can also be somewhat repetitive. The system utilized was one in which multiple reviewers were employed using a uniform procedure, and the reviewers performed cross-checks in order to eliminate errors.

The use of a large number of research assistants resulted in some benefits beyond the project itself. This project necessitated the involvement of many students, some of whom were undergraduate honors scholars, undergraduate research assistants, or graduate assistants. Thus, many students were given the opportunity to experience safety research. This project, therefore, furthered MTC's educational objective of training the next generation of transportation engineers.

Finally, the review of 12,409 freeway interchange crash reports, and the detailed review of 9,168 of those crash reports, found that the crash landing problem is severe for Missouri interchange crashes. The overall error rate was 69 percent with an error rate of 89.66 percent for ramps, 53.04 for speed-change lanes, and 78.78 for terminals. Traffic safety involves a diverse collection of professionals. One important group of professionals is the police officers who investigate crashes and complete crash reports. They provide the necessary data so that safety analysis can be conducted and safety countermeasures can be implemented. If crashes can be landed more precisely, then it will improve the performance of the safety analysts who are involved in the collaborative highway safety effort.

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