Crash Location Correction for Freeway Interchange Modeling

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16. Abstract
AASHTO released a supplement to the Highway Safety Manual (HSM) in 2014 that includes models for freeway interchanges composed of segments, speed-change lanes and terminals. A necessary component to the use of HSM is having the appropriate safety-related data. However, a high percentage, approximately 75 percent, of interchange crashes on the MoDOT TMS systems are landed on an incorrect location within an interchange. For example, crashes are frequently placed in the midpoint of the ramp terminal instead of properly assigned to one of the two ramp terminals. Another example is crashes that are assigned to the freeway mainline when the crashes are related to ramps. In order to properly calibrate and use HSM freeway interchange models, the location of crashes needs to be corrected. The 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. Of the total, 1482 were partial cloverleaf crashes, 5086 were diamond interchange crashes, 780 were ramp crashes, and 1820 were speed-change lane crashes. The crash location correction process helped to eliminate the error rate of 69% associated with interchange crash locations. Any analyst can correct crash locations by following the procedure detailed in this report.

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EXECUTIVE SUMMARY

The Highway Safety Manual (2014) contains a supplement that allows the modeling of freeway interchanges, including interchange facilities such as terminals, ramps, and speed-change lanes. In order to apply HSM in a local jurisdiction, HSM recommends calibrating to local conditions. Table ES1 and ES2 show the facilities involved with Missouri calibration. 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 MoDOT. A high percentage of interchange crashes in this database are landed 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 HSM interchanges for Missouri, interchange crash data needs to be corrected by landing them on the proper facilities within interchanges.

TABLE ES1 Terminal Interchange Facility Types Calibrated

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 Non-Terminal Interchange Facility Types Calibrated

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

Crash data correction is a labor intensive process which involves the manual review of the original crash reports along with additional information such as aerial photographs. Three sections from crash reports are crucial for crash location correction. One section is the description of the crash location in terms of the travelway name, direction, intersection road, etc. Another section is the crash diagram which provides a visual documentation of the vehicle(s) involved and the road. The third section is the 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. A complete set of procedures or tutorials was developed for interchange crash correction, and detailed instructions were developed on using the three aforementioned sections in a consistent manner. In addition, training tests were developed to ensure that reviewers interpret and apply the procedures uniformly. Due to the enormous amount of labor that was required for reviewing all the crash reports, a large team of 25 research assistants and faculty was assembled. Every person involved in crash review was trained in the same procedures and completed and passed the tests.

Table ES3 summarizes the results of this project. There were 12,409 crash reports that 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 interchanges (5,086 crashes) or at Parclos (1,482). The speed-change lanes had 1,820 crashes and ramps had 780 crashes. The project found that 69% of all reviewed crashes were landed incorrectly within the interchange. The error rates by facility type were 90% 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 crash landing on the front end helps to facilitate safety analysis and countermeasure design in the back end.

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	1563
Signalized D4 Diamond Interchange with Six Lane Crossroads Terminal	1800
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	1585
Total	9168
Facility Type Totals	
A2 Partial Cloverleaf Interchange Terminal Total	1482
D4 Diamond Interchange Terminal Total	5086
Entrance/Exit Ramp Total	780
Entrance/Exit Speed-Change Lane Total	1820
Total Crashes Reviewed for Project	12409

CHAPTER 1 INTRODUCTION

The Highway Safety Manual (HSM) provides methods and tools to assist in the quantitative evaluation of safety. The HSM added the modeling of freeways including segments, speed-change lanes, and interchange terminals. 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. HSM recommends that calibration be performed every two to three years. Thus, the goal is to develop a long term process for calibration as opposed to producing a set of calibration values once. 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 (2) involved the identification 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 MoDOT's Transportation Management System (TMS) and MoDOT district offices. Steps (4) and (5) involve the estimation of crash frequencies using HSM Safety Performance Functions (SPFs) and the comparison with actual observed crash frequencies.

As the research was progressing through steps (1)-(3), a major challenge was identified. As previously discussed, step (3) involves the collection of site data, including crash data. In Missouri, as in other states, crash reports are completed by police agencies such as 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 crash reporting results 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 in error. For example, a crash that should be located on a ramp terminal was assigned instead to the crossroad in 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. 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, researchers met with the project technical advisory committee that 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 involves carefully reviewing data fields, collision diagrams, and narratives and statements. In addition, consistent methodology and training need 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.

FIGURE 1.1 Example of Crash Landing Error

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 the state of Missouri, the Missouri Uniform Accident Report MUAR (2002-2011) (STARS 2002) and the Missouri Uniform Crash Report MUCR (STARS 2012) are 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 Statewide Traffic Accident Records System (STARS). MSHP collaborates with MoDOT in managing Missouri's database of crash reports.

Unfortunately, it is difficult to obtain completely uniform crash reporting 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 which illustrates personnel and jurisdictional differences is the level of detail in the reporting in the crash diagram. Some diagrams are drawn up with CAD and labeled very clearly while others are sketched roughly by hand.

2.1.1 Freeway Interchange Terminals

NCHRP 17-45 (Bonneson et al, 2012), the NCHRP study that produced the new HSM freeway interchange chapters, discussed the criteria for identifying crossroad-ramp-terminal-related crashes. Some states, such as Washington, use an intersection-related variable in the 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. First, a crash has to occur within 250 feet of a terminal intersection. And second, 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 (Bonneson et al., 2012), none of the Highway Safety Information System (HSIS) databases include a crash variable that identifies a speed-change-related crash with certainty. Thus, existing crash locating methodology for speed-change lanes and ramps uses the sole criterion of the exact location of a crash. The benefit of such a method is that it is straightforward and does not require transportation engineering knowledge, which is not part of a typical police officer’s 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 the speed-change lane segment of freeway are speed-change lane related crashes (marked by milepost). A speed-change lane was defined as a “ramp entrance length” or a “ramp exit length” segment as shown in Figure 2.1.2.1 (Bonneson et al., 2012). 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).

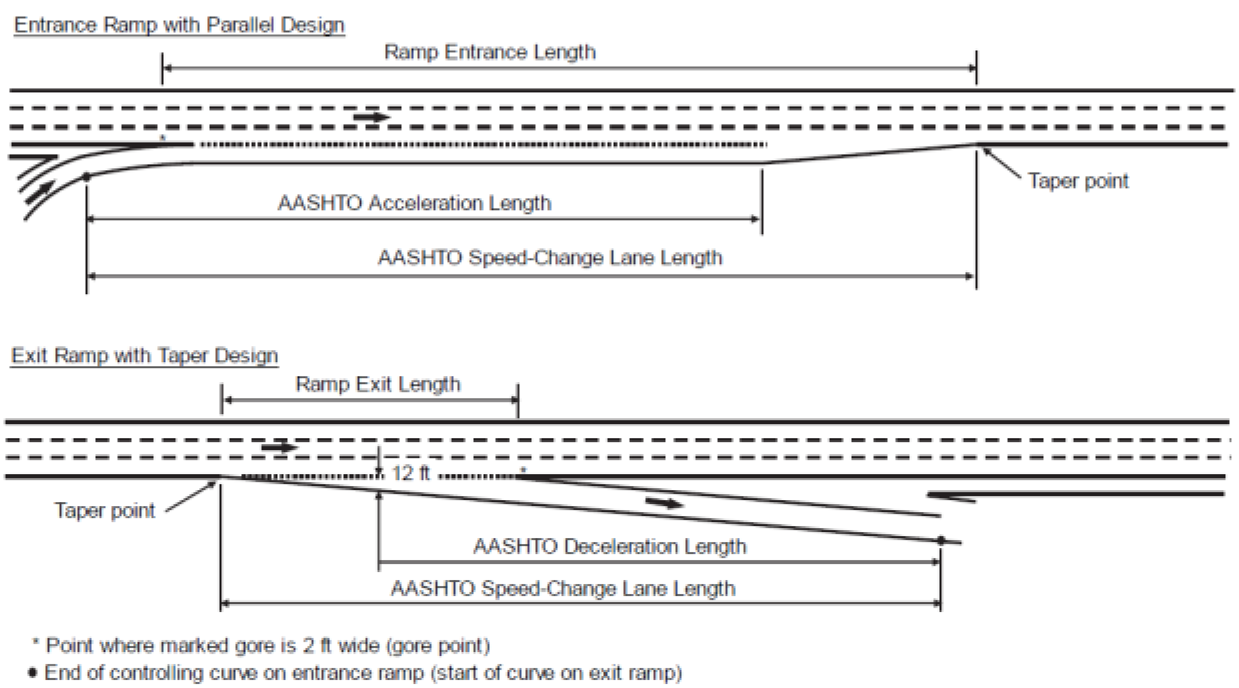


FIGURE 2.1.2.1 Typical Speed-change Lanes (NCHRP 17-45)

Figure 2.1.2.2 illustrates this method of assigning freeway crashes to either speed-change lanes or freeway lanes. All crashes that happen in Region A are classified as speed-change lane related crashes. Crashes that happen outside of Region A (i.e., in Region B) are classified as freeway segment crashes.

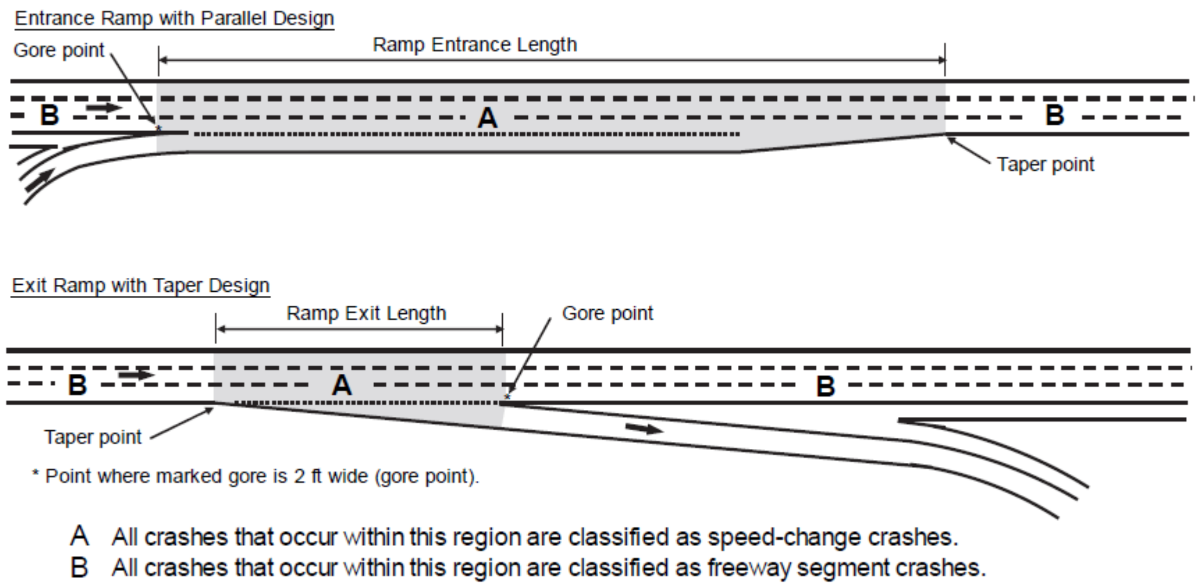


FIGURE 2.1.2.2 Definitions of Freeway Segments and Speed-Change Lanes (HSM, 2010)

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 causes 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 2.1.3.1 illustrates cases where vehicles run off the exit and entrance ramps.

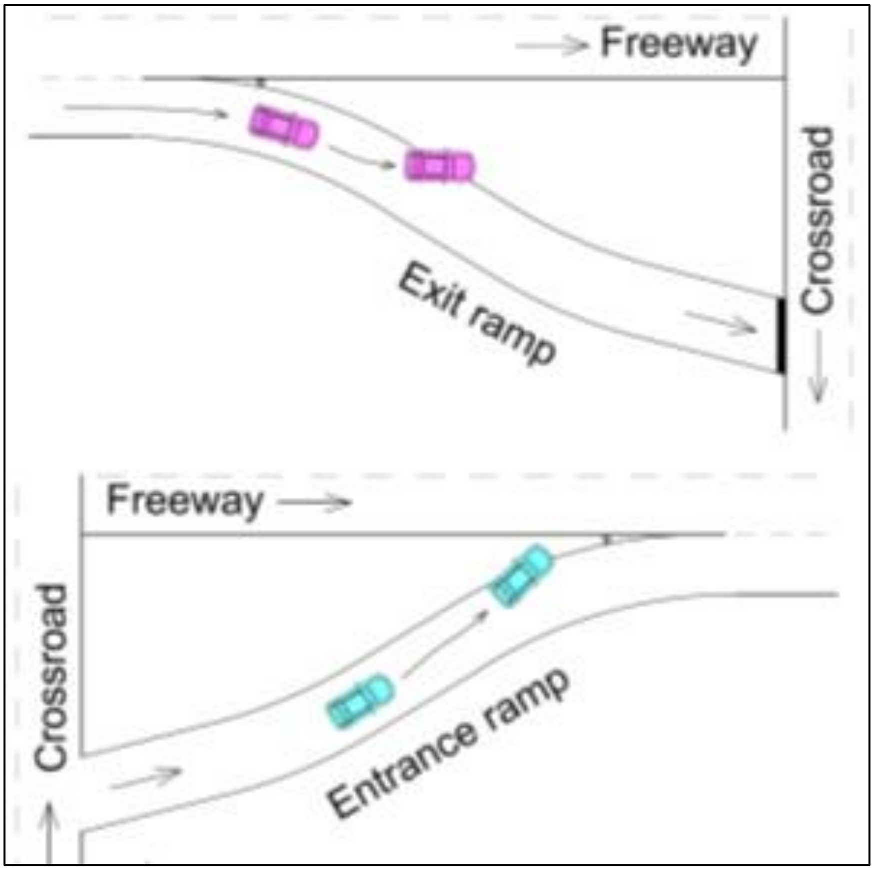


FIGURE 2.1.3.1 Run off the Road Crashes at Exit/Entrance Ramp Segments

Another common crash type on ramps is a vehicle collision with objects or wild animals that have crossed onto the road. Figure 2.1.3.2 illustrates this crash type.

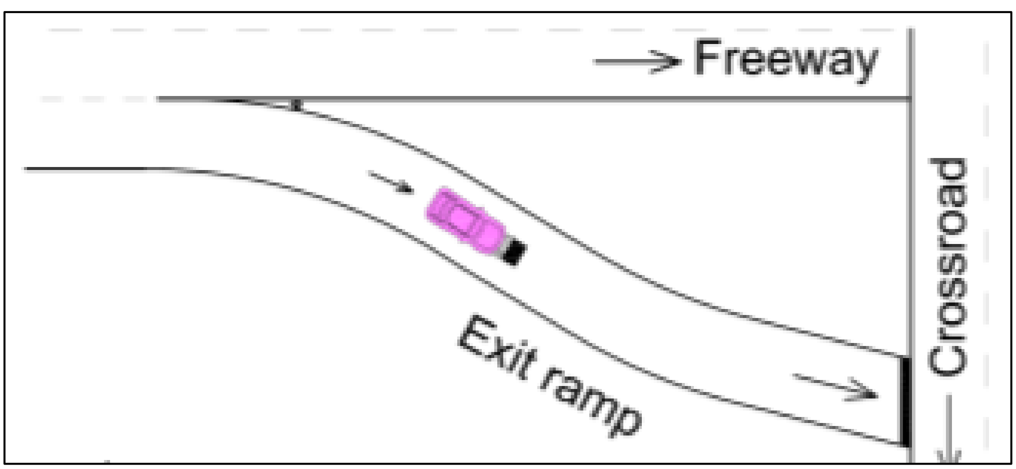


FIGURE 2.1.3.2 Collisions with Object or Wild Animal on Ramp Segment

2.2 Interchange Safety Influence Area

McCartt (2003) shows that a large proportion of fatal crashes on highways occur at interchanges, e.g., 11% in 2001. Figure 2.2.1 shows crashes that are interchange-related crashes according to ANSI (2007). Crashes occurring 100 feet after the gore point of a speed-change lane of on-ramps and crashes occurring 100 feet 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 interchange crash influence area.

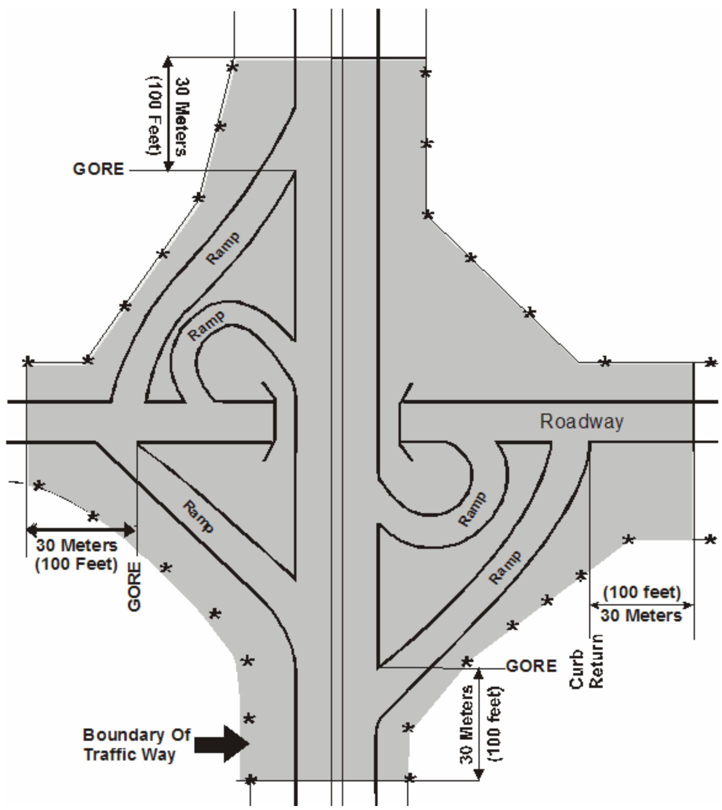


FIGURE 2.2.1 Interchange Accidents (ANSI-07D16)

The most common application is to use 1,500 feet as an influence area (Lu et al., 2013; HCM, 2010) as shown in Figure 2.2.2. 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.

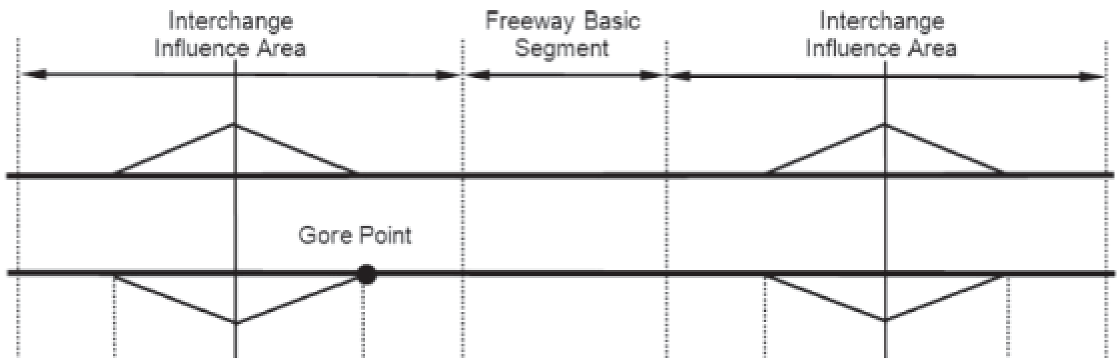


FIGURE 2.2.2 (a) Interchange Influence Area (Lu et al. 2013)

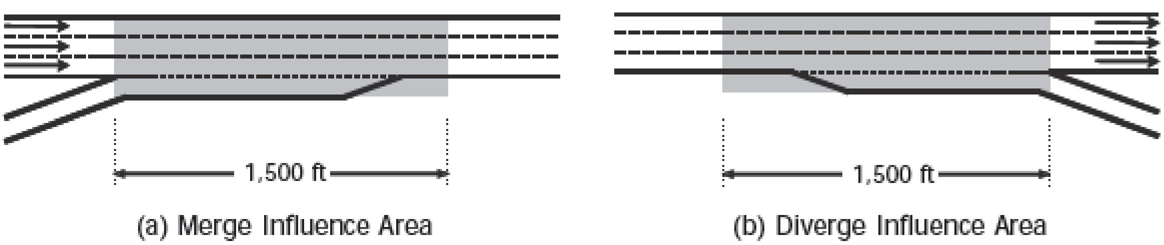


FIGURE 2.2.2 (b) Merge and Diverge Influence Area (HCM, 2010)

There are four main factors that affect interchange safety, and these 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 feet from the center of the interchange were considered “non-interchange” segments. The interchange segment crash rates were found to be about 200 % higher than non-interchange segments. North Carolina and Tennessee data showed 42 and 82 crashes per 100 million vehicle-miles (100 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 segment 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% 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 exit) of Florida freeways. They also considered crashes in the speed-change lane, but their data differed from Moon and Hummer in that they gathered crashes on freeway mainlines up to 1,000 feet from the start of the deceleration length instead of 1,500 feet from the gore point. Their conclusion indicated that left side exits have 180% 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 2.2.2.1.

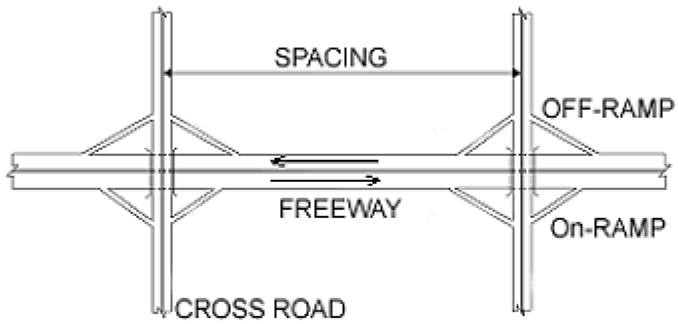


FIGURE 2.2.2.1 Interchange Spacing (Bared et al., 2007)

The TRB Access Management Manual (Gluck et al., 1999) presented minima for interchange area access spacing ranging from 230 m to 805 m (750 ft. 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 2.2.2.2 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 which cause lane blockage.

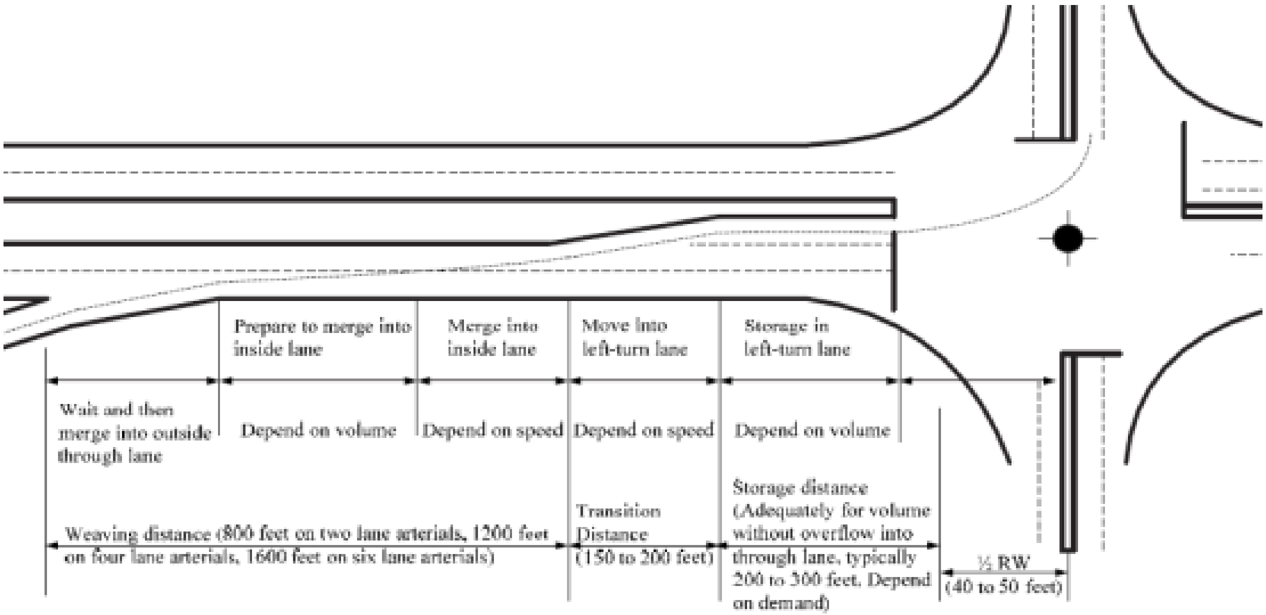


FIGURE 2.2.2.2 Recommended Access Separation Distances (Gluck et al., 1999)

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 meters (about 500 feet) upstream to 450 meters (about 1500 feet) from the gore point; the diverging influence area begins 450 meters (about 1500 feet) upstream to 150 meters (about 500 feet) downstream. These are shown in Figure 2.2.3.1 (Zhong et al., 2009). Table 2.2.3.1 shows accelerated and decelerated lane length in different countries. The United States has the longest distances of all the countries shown.

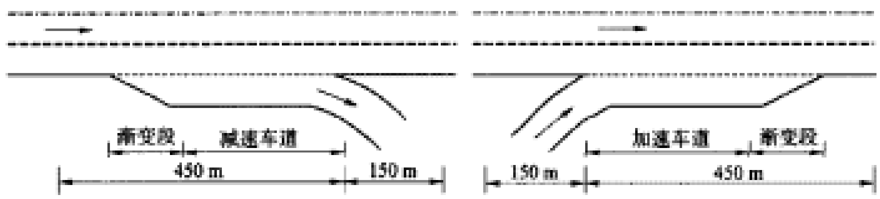


FIGURE 2.2.3.1 Diverging and Merging Influencing Areas (Zhong et al., 2009)

TABLE 2.2.3.1 Acceleration/Deceleration Lane Lengths (Zhong et al., 2009)

Country	**Deceleration lane (meter)**		**Acceleration lane (meter)**		**Gradation zone (meter)**	
	one lane	**two lanes**	**one lane**	**two lanes**	**Acceleration**	**Deceleration**
America	164 (538ft.)	164 (538ft.)	430 (1410ft.)	430 (1410ft.)	91.5 (300ft.)	76.3 (250ft.)
Japan	100 (328ft.)	150 (492ft.)	200 (656ft.)	300 (984ft.)	70 (230ft.)	70 (230ft.)
Germany	120 (393ft.)	120 (393ft.)	120 (393ft.)	120 (393ft.)	80 (262ft.)	80 (262ft.)
China	100 (328ft.)	150 (492ft.)	200 (656ft.)	300 (984ft.)	70 (230ft.)	70 (230ft.)

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) indicate 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 increases, the crash frequency rates increase 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 a 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 is processed sequentially. The first phase determines if a crash is terminal 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 the 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 a crash report. 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 reviewer's 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 3.2.1 shows in detail the components of the interchange and shows speed-change (S-C) lanes in magenta, ramps in yellow, and terminals in blue. S-C lanes encompass the lane area between the ramp and the mainline from the gore point to the taper. Mainline freeway lanes adjacent to the S-C 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 a roundabout.

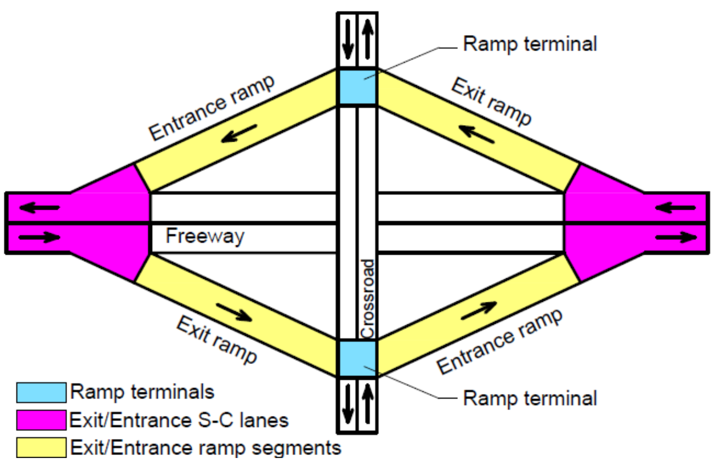


FIGURE 3.2.1 Facilities at a Conventional Diamond Interchange

3.3 Description of Crash Reports

The crash report sections used the most for location correction are the image number, collision diagram, and narrative/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 3.3.1 shows an example of an 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. The crash data format along with highlighted examples of image numbers are shown in Table 3.3.1. The file containing a crash report is in a pdf (Adobe portable data file) or a tif (tagged image file format) format. Each crash report has a filename containing the image number (e.g., 40073302.pdf).

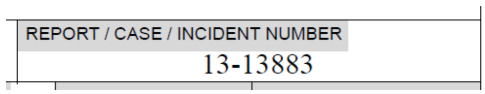
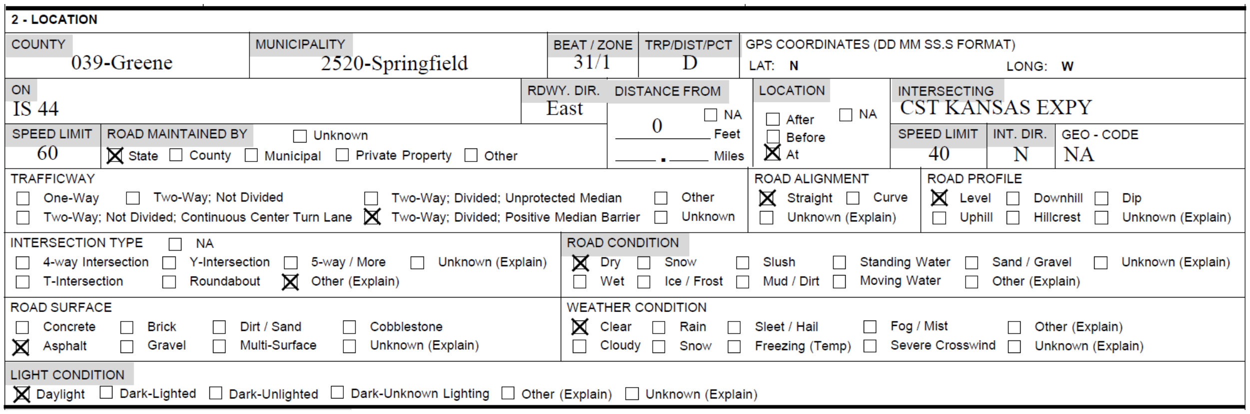


FIGURE 3.3.1 Crash Identification Number (Unused)

TABLE 3.3.1 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 3.3.2. 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 3.3.2 shows a crash 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 location information here should be used in conjunction with the collision diagram and statement/narrative.


2 - LOCATION

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

ON: IS 44 | RDWY. DIR.: East | DISTANCE FROM: 0 ☐ NA Feet ____ . ____ Miles | LOCATION: ☐ After ☐ Before ☒ At ☐ NA | INTERSECTING: CST KANSAS EXPY

SPEED LIMIT: 60 | ROAD MAINTAINED BY: ☐ Unknown ☒ State ☐ County ☐ Municipal ☐ Private Property ☐ Other | SPEED LIMIT: 40 | INT. DIR.: N | GEO - CODE: NA

TRAFFICWAY: ☐ One-Way ☐ Two-Way; Not Divided ☐ Two-Way; Divided; Unprotected Median ☐ Other ☐ Two-Way; Not Divided; Continuous Center Turn Lane ☒ Two-Way; Divided; Positive Median Barrier ☐ Unknown

ROAD ALIGNMENT: ☒ Straight ☐ Curve ☐ Unknown (Explain)

ROAD PROFILE: ☒ Level ☐ Downhill ☐ Dip ☐ Uphill ☐ Hillcrest ☐ Unknown (Explain)

INTERSECTION TYPE ☐ NA: ☐ 4-way Intersection ☐ Y-Intersection ☐ 5-way / More ☐ Unknown (Explain) ☐ T-Intersection ☐ Roundabout ☒ Other (Explain)

ROAD CONDITION: ☒ 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 ☒ Asphalt ☐ Gravel ☐ Multi-Surface ☐ Unknown (Explain)

WEATHER CONDITION: ☒ Clear ☐ Rain ☐ Sleet / Hail ☐ Fog / Mist ☐ Other (Explain) ☐ Cloudy ☐ Snow ☐ Freezing (Temp) ☐ Severe Crosswind ☐ Unknown (Explain)

LIGHT CONDITION: ☒ Daylight ☐ Dark-Lighted ☐ Dark-Unlighted ☐ Dark-Unknown Lighting ☐ Other (Explain) ☐ Unknown (Explain)

FIGURE 3.3.2 Location of the Crash

A collision diagram shows the circumstances and location of the crash. Figure 3.3.3 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 3.3.3, the north arrow is clearly marked for orientating the diagram.

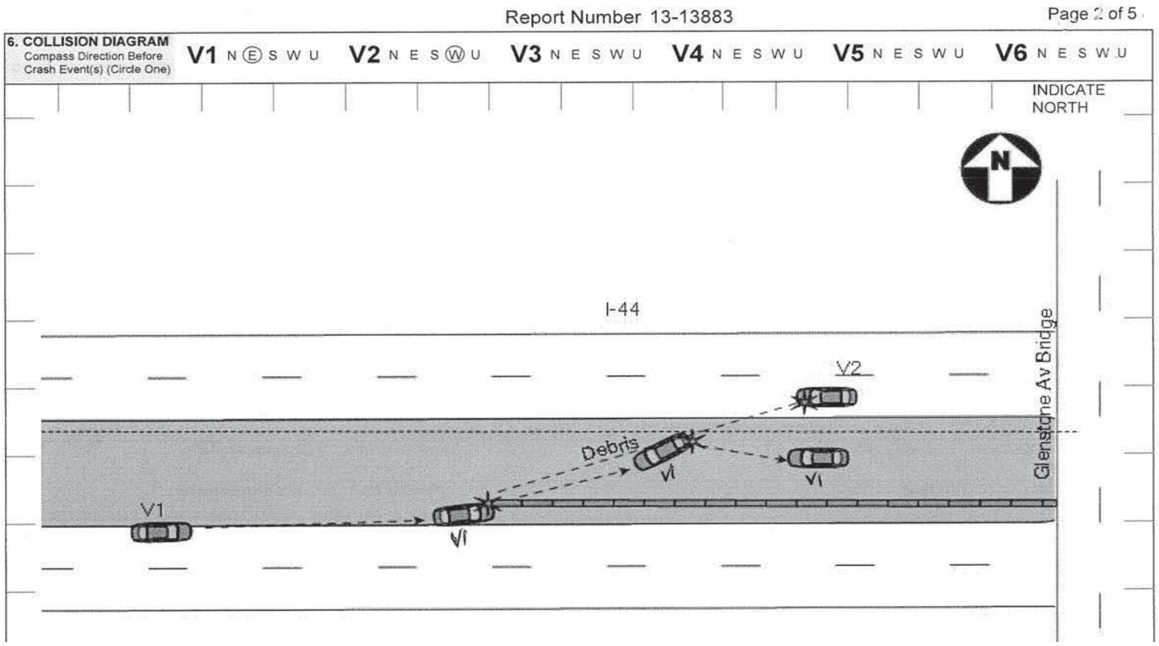


FIGURE 3.3.3 Collision Diagram

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 locate the crash.

The narrative contains a written description of the crash and statements collected from witnesses, people involved in a crash, and/or officer(s). The details in this section are also subject to the experience and expertise of the reporting personnel. Figure 3.3.4 shows an example of a narrative for the same crash shown in Figure 3.3.3. This example contains a statement by the officer describing both vehicles, V1 and V2, and statements by 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 3.3.4 Narrative and Statements Section

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 need to be found. The different fields of the crash report described in the previous section should be used to find the specific location of the crash with respect to the 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 to assign the crash. Otherwise, the information provided in the location, collision diagram, and statement/narrative 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 **2 out of the 3** aforementioned sections should be in agreement.

STEP 2: Crash Circumstances Review

The second step of the crash review consists of analyzing the scenario of the crash events with respect to the 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 state the results of the investigation. Understanding the different factors involved in a crash helps 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 that occurred on the 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 crashes 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-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-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-south direction or east-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 3.4.1 shows some examples of perfectly aligned and diagonal freeways in both the north-south and east-west directions.

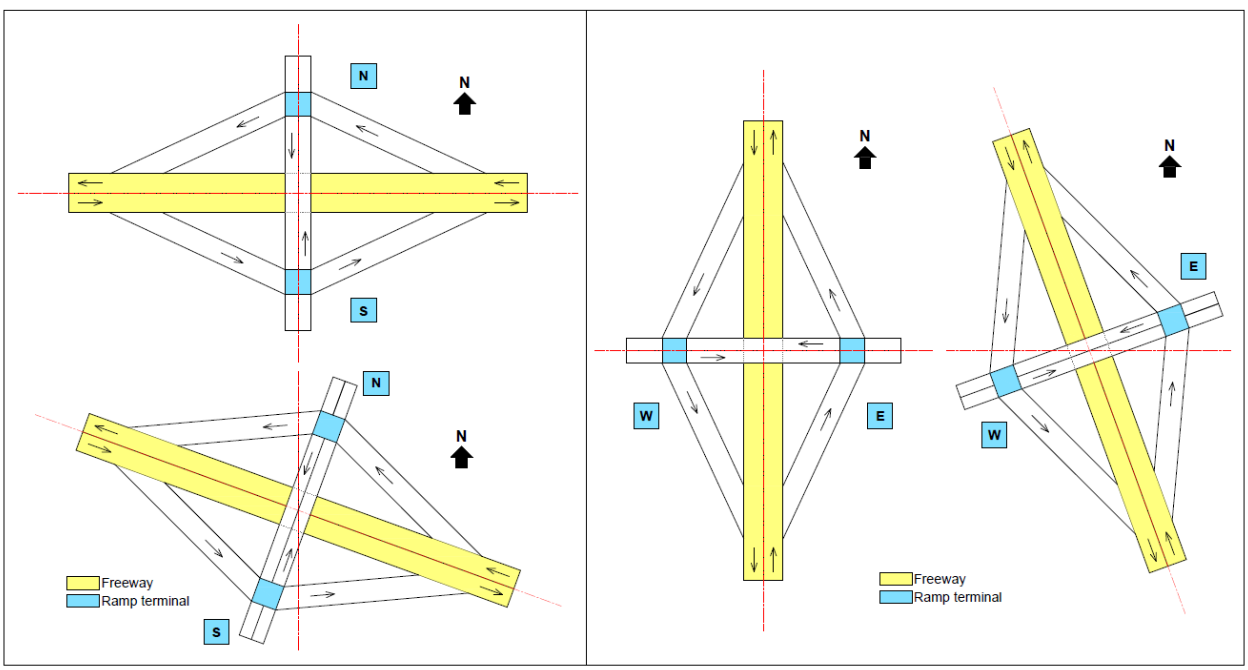


FIGURE 3.4.1 Ramp Terminal Assignment Examples

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 feet on the roadway away from the center of the intersection (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 1998). The crash assignment is conducted based on the location, circumstance of the crash, and ramp-terminal-related crash criteria.

Figure 3.5.1 illustrates the possible locations of crashes that are of interest in blue. The blue region in Figure 3.5.1 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 exit ramps. Crashes that are located in the aforementioned areas and are within 250 feet 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 that are 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., North (N), South (S), East (E), and West (W)), as described in the previous section.

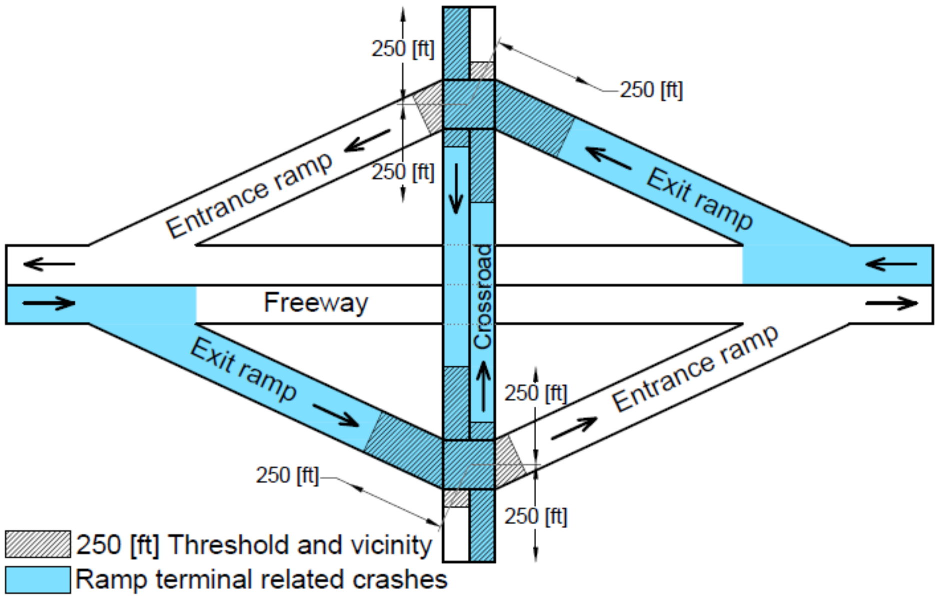


FIGURE 3.5.1 Area of Interest for Ramp Terminal Related Crashes

Figure 3.5.1 also highlights in blue 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 (N, S, E, or W).

There are cases in which a crash occurred between two ramp terminals, and it might be difficult to determine the proper ramp terminal for crash assignment. Figure 3.5.2 shows an example where one of the ramp terminals was so congested that a queue reached the other ramp terminal. This crash should be assigned to the ramp terminal which 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.

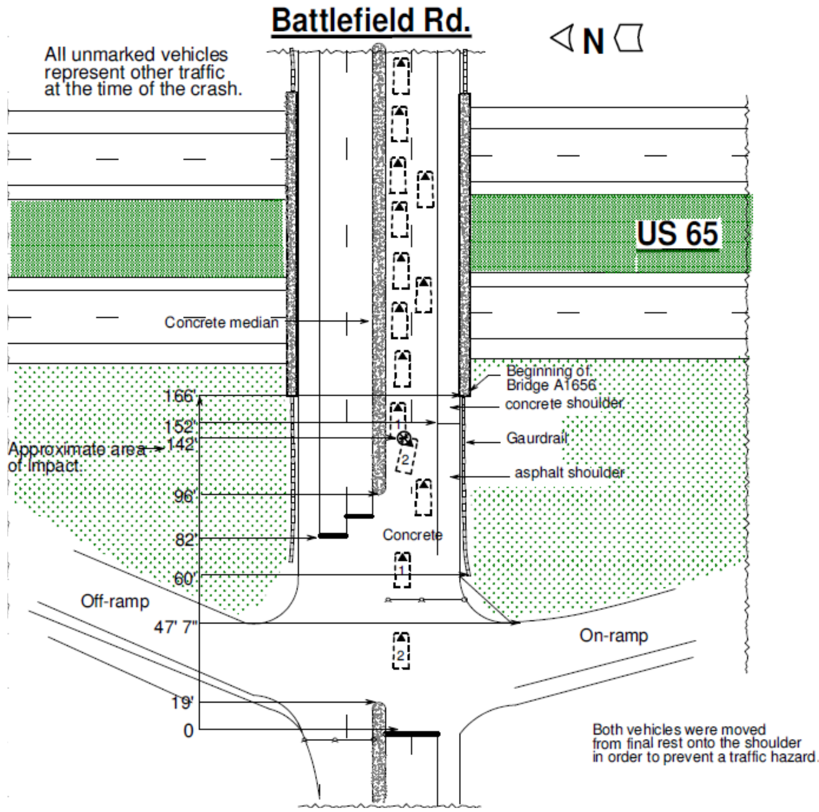


FIGURE 3.5.2 Illustration of Queue Between Ramp Terminals

Figure 3.5.3 highlights the areas where non-terminal crashes occur, including 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 and are further processed in Chapter 4/Phase II.

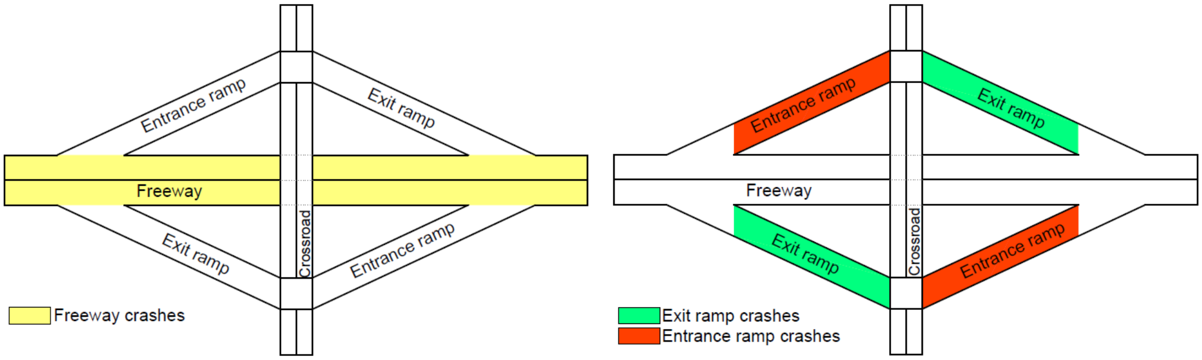


FIGURE 3.5.3 Areas Not of Interest for Ramp Terminal Crashes

If a crash report describes an event that meets all the criteria mentioned before, 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 (X). One example 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 3.5.4. This crash should be coded as X.

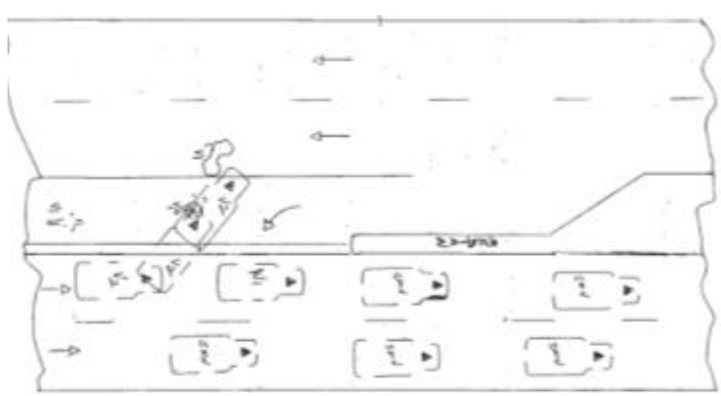


FIGURE 3.5.4 Rare Event Crash

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 animals 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 the 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 3.5.1 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 3.5.1, the four crashes were assigned to the north terminal and one to the south terminal.

TABLE 3.5.1 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, the interpretation of the crash reports, and the use of different tools used in this tutorial.

Example 1 – US 160

Step 1

Locate the interchange on an aerial photograph. Figure 3.6.1 shows an aerial photograph of the interchange on US 160.

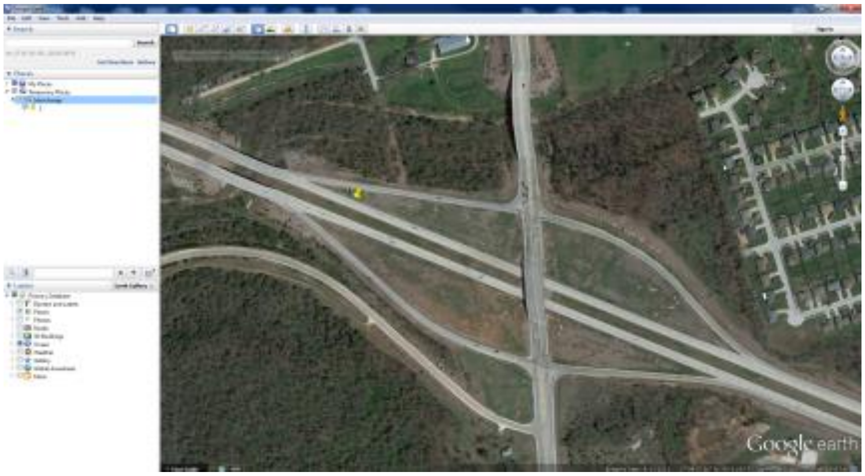


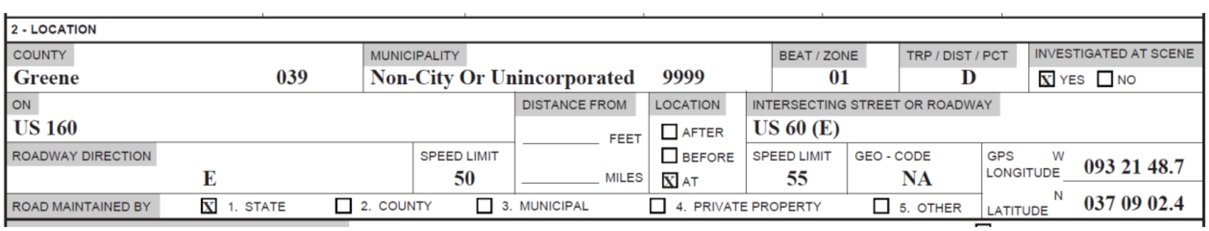
FIGURE 3.6.1 Location- Interchange 1 (Google 2014)

Table 3.6.1 shows the electronic crash data to start the review of Example 1 located on US 160.Using the image number (column: Image #), 3110016727, find and open the crash report from the crash reports folder.

TABLE 3.6.1 Crash Data-Example 1

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 3.6.2 shows the location section of the crash report for Example 1, including the intersection street, US 60.


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 3.6.2 Section 2 of Crash Report-Example 1

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 contains the collision diagram. Figure 3.6.3 shows a right angle collision that occurred in the ramp terminal with vehicle 1 (V1) traveling southbound on U.S. 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.

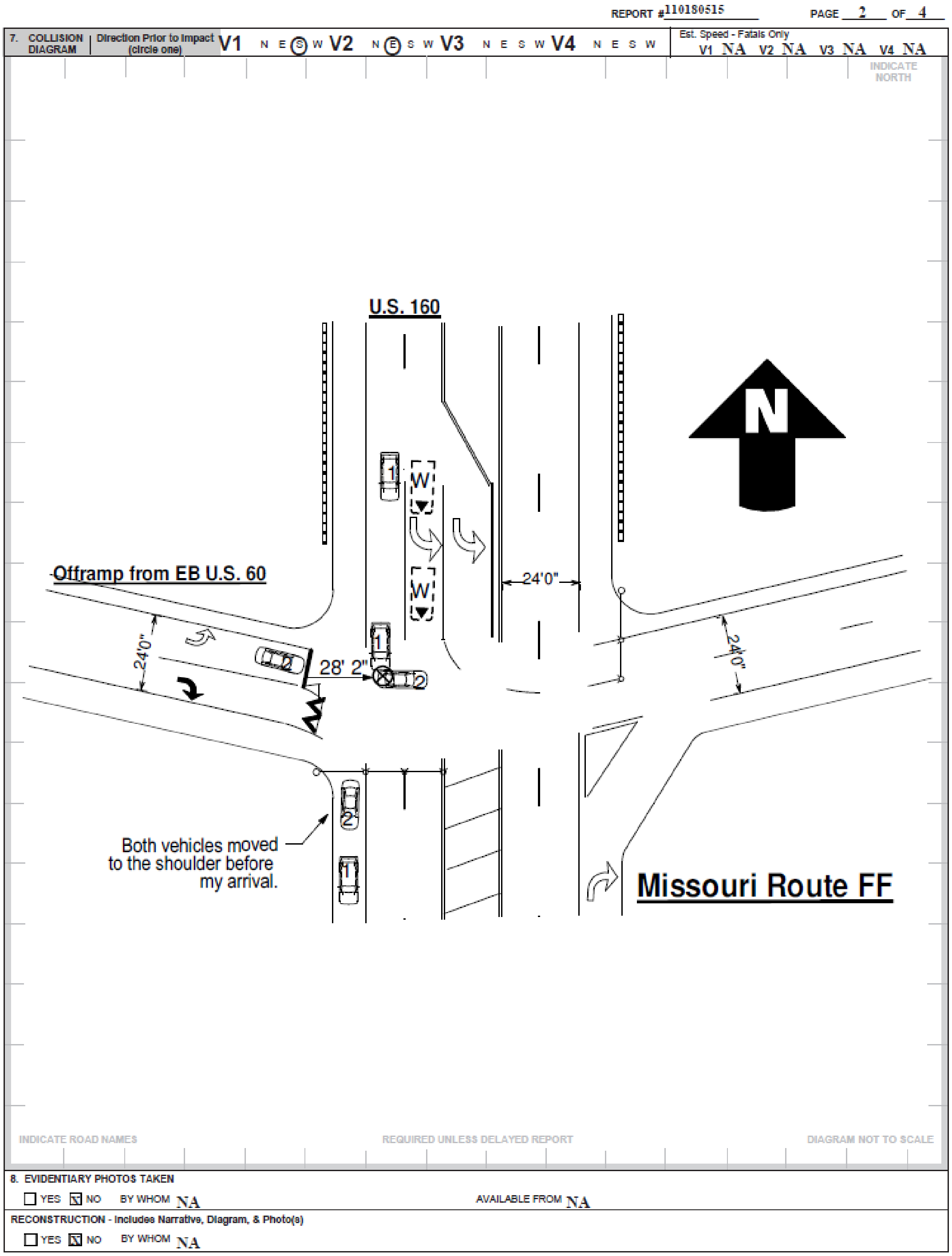


FIGURE 3.6.3 Collision Diagram-Example 1

Step 3

Figure 3.6.4 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 south (S) ramp terminal of the interchange due to a driver running the red signal on the crossroad, hitting a vehicle coming from the exit ramp. Again, the final crash assignment of S can be seen in Table 3.6.1, 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 3.6.4 Narrative/Statements for Example 1

Example 2 – US 60

The procedure in step 1 of example 1 is the same for examples 2 and 3. Table 3.6.2 contains the crash information for example 2. Also, Figure 3.6.5 shows an aerial photograph of the interchange.

TABLE 3.6.2 Crash Data-Example 2

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 3.6.5 Aerial Photograph of Interchange 2 (Google 2014)

Step 2

The crash report information should be reviewed to determine the location and circumstance of the crash. The collision diagram, Figure 3.6.6, shows 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/statements, the cause of the crash was vehicle 1 (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 a side note, Figure 3.6.6 shows the on-ramp mislabeled as EB instead of WB.

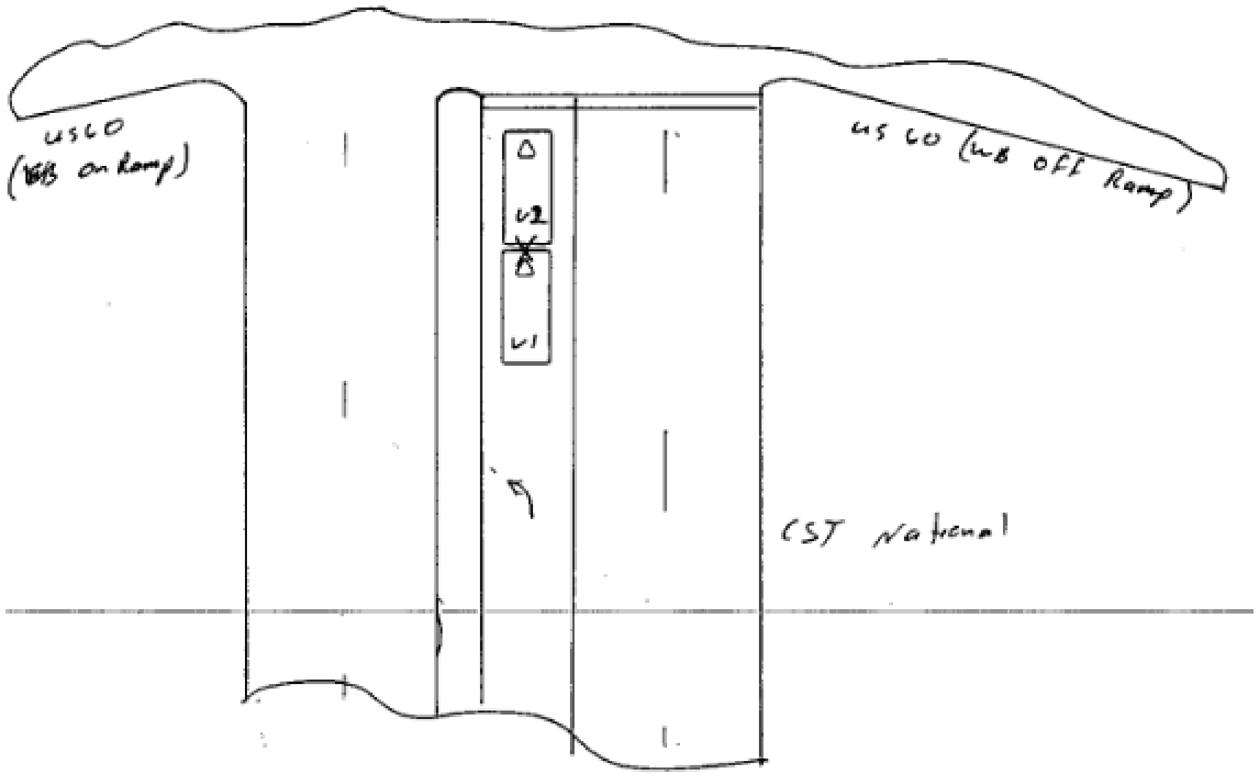


FIGURE 3.6.6 Collision Diagram-Example 2

Step 3

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

Example 3 – US 60

Again, the procedures in step 1 and outlined in example 1 apply here. Table 3.6.3 contains the crash information for example 3. Even though example 3 is located at the same interchange as example 2, Figure 3.6.7 shows interchange 2 in a different orientation than before.

TABLE 3.6.3 Crash Data-Example 3

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

FIGURE 3.6.7 Aerial Photograph of Example 3 (Google 2014)

Step 2

Figure 3.6.8 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 (V2) was unable to stop in time and hit the stopped vehicle (V1).

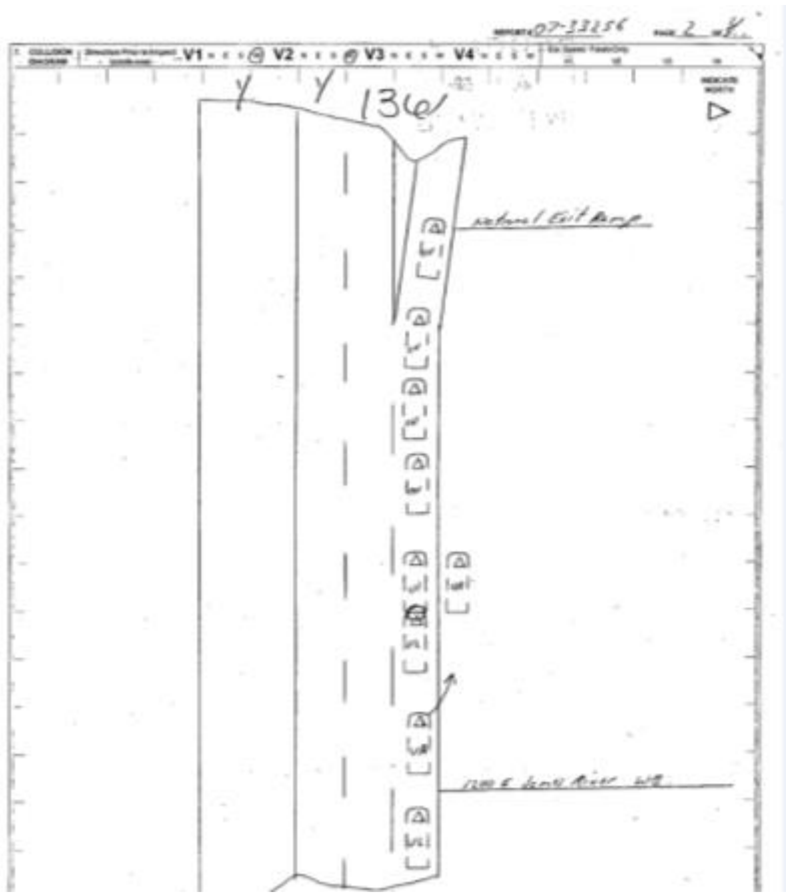


FIGURE 3.6.8 Collision Diagram-Example 3

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 that a person's understanding of the tutorial. Seventy-five crash reports were carefully selected to test and 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 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 a 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 notation: N, S, E, and W. Crashes that were not ramp-terminal-related were assigned the letter X. This chapter, or Phase 2 crash review, focuses on assigning the filtered (non-terminal related) crashes (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 4.1.1 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 his/her understanding before actual crash review is performed.

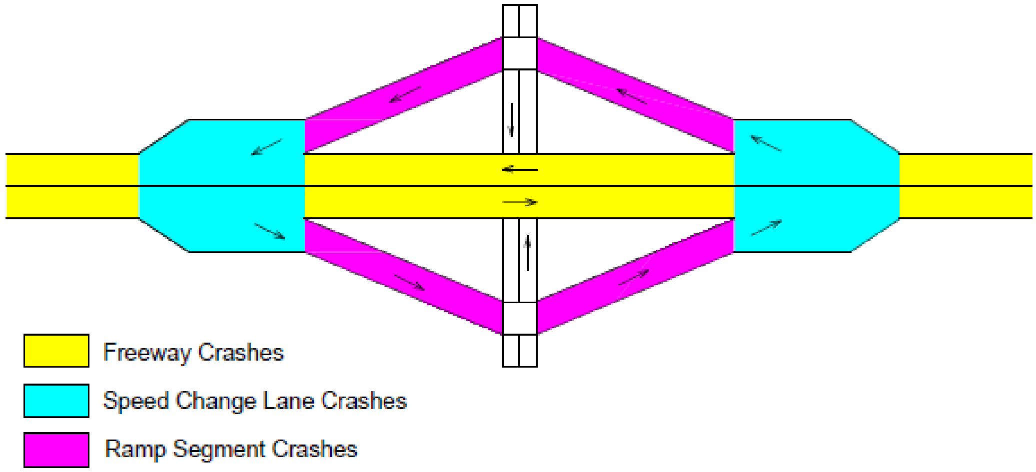


FIGURE 4.1.1 Crashes on Different Non-Terminal Facilities

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 was previously shown in Figure 3.2.1. The gore point is the reference to determine 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: 1) exit ramp segments and 2) 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 the 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 4.2.1 shows the locations and lengths of ramp segments at a diamond interchange.

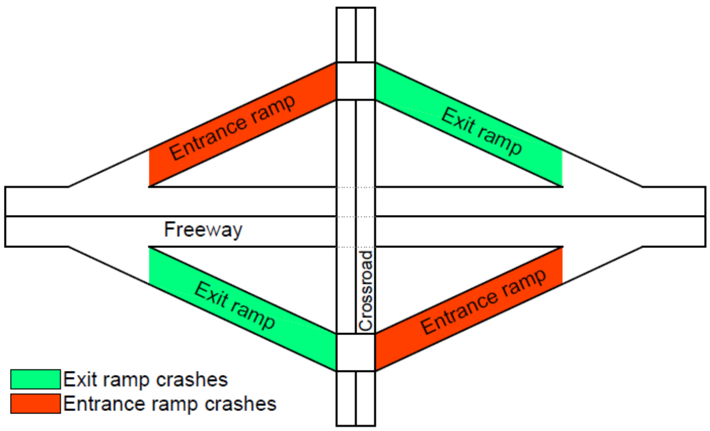


FIGURE 4.2.1 Ramp Segments Locations

A speed-change lane is a unidirectional, uncontrolled terminal between a freeway and ramp segments (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), 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 4.2.2 shows a typical entrance and exit ramp with the associated speed-change lane, gore point, and taper. As shown in Figure 4.2.3, the gore point is defined more specifically as the point where the mainline and the ramp is separated by 2 feet.

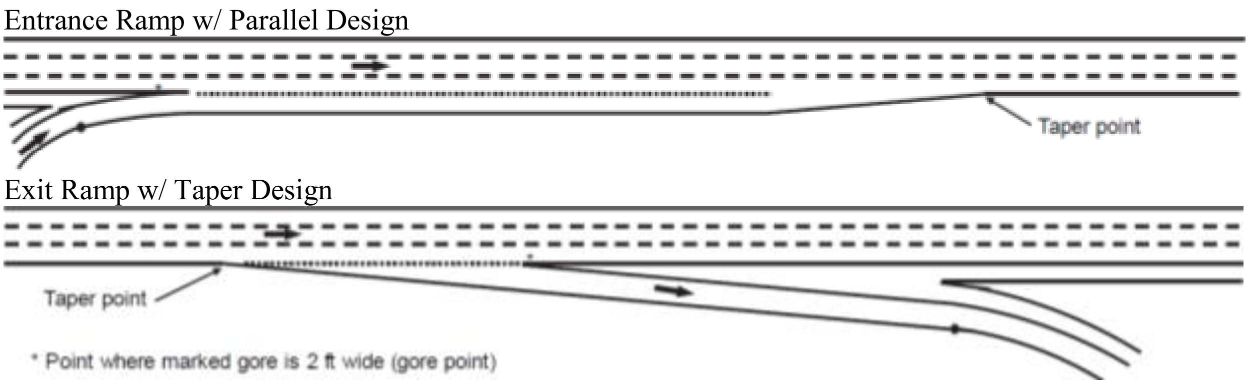


FIGURE 4.2.2 Speed-Change Lanes

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 4.2.3 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 4.2.3 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 4.2.3 Example of Add and Drop Lanes

4.3 Description of Crash Reports

This section briefly describes the content of the crash reports that are 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/statements of the crash.

The ***image number*** is a unique number assigned by the Missouri DOT 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 this 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 the reference point varies according to the person who filled out the form. The location information should be used in conjunction with the collision diagram and statement/narrative. 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 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, the 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 countermeasures 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 statement/narrative. If the sections are inconsistent with each other, then, as a general rule, at least ***2 out of the 3*** sections should be in agreement. The ***second step*** is to assign the filtered crashes from Phase 1 or those that were assigned with the letter 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 with 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 for crash assignment 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. They are: F = freeway segment, S = speed-change lanes, and R = ramp segments

Exit or Entry Designation Characters

There are two designations: D = diverging or exiting from the freeway and M = merging or entry into the freeway. 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 convention used in Phase 1, the crash direction is designated based on the compass direction relative to the freeway centerline. The characters are: N = north, S = south, E = east and W = west. If a freeway runs in the north-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-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-south direction or the east-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 photographs 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 is SDE (S = speed-change lane, D = diverging and E = east). Now assume a crash occurred on the south side of an east-west freeway segment at an interchange; the assignment is then FS (F = freeway and S = south). Figure 4.4.1 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.

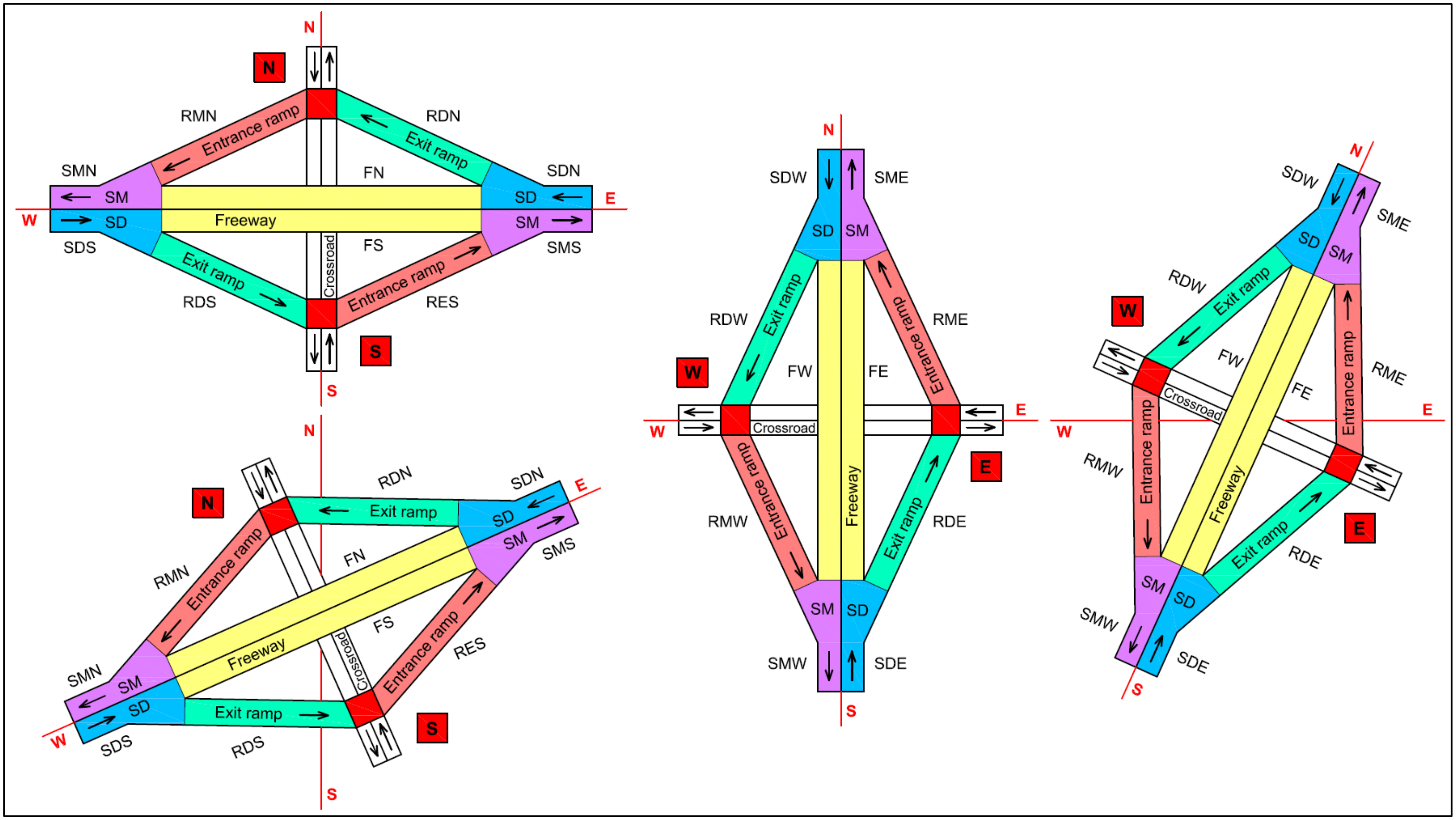


FIGURE 4.4.1 Examples of Facility Assignment Notation

Similarly to Phase 1, the assignments with the notations just described should be recorded in the crash data spreadsheet in the "Interchange Facility" column. Table 4.4.1 shows the spreadsheet with the new column and corresponding assignment highlighted in green. Note that both of the crashes shown in Table 4.4.1 were already determined to be non-terminal crashes since they both have an X in the "Ramp Terminal" column.

TABLE 4.4.1 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 of this Chapter. Table 4.4.2 contains the crash data necessary to start the review of the example crash.

TABLE 4.4.2 Crash Data Example 1

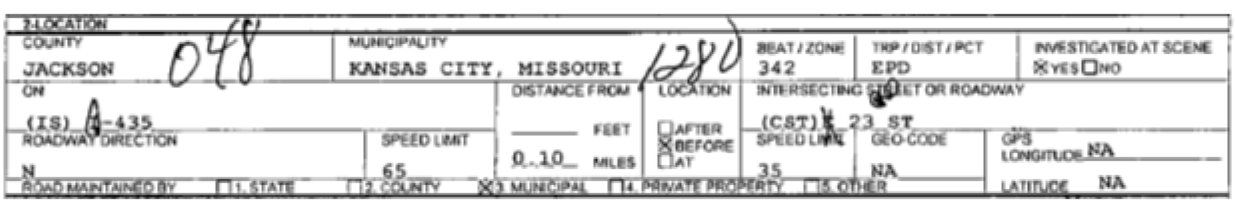
County	Desg	Travelway	Dir	Cont Log	Accident Class	Accident Date	Severity Rating	Image #	Intersection #	Log Unit	Intrsc	Intrchg	Grpd	Light Cond	Road Surf Cond	Weather Cond	Tway Id	Property Damage	Day of Week	Time	Interchange	Period	Ramp terminal	Interchange Facility
JACKSON	IS	435	N	14.486	RIGHT TUR	10/4/2009	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 4.4.2 shows the aerial image of the interchange.

FIGURE 4.4.2 Interchange 5 (Google Earth, 2015)

Use the image number (colored magenta in Table 4.4.2), 90101021, to find and open the crash report. Examine section 2 of the report where the location of the crash is described with the different fields described previously. Figure 4.4.3 shows the corresponding location section of the crash report of the example.



2-LOCATION
COUNTY: JACKSON 048
MUNICIPALITY: KANSAS CITY, MISSOURI 1280
BEAT / ZONE: 342
TRP / DIST / PCT: EPD
INVESTIGATED AT SCENE: ☒ YES ☐ NO
ON: (IS) I-435
DISTANCE FROM: ____ FEET 0.10 MILES
LOCATION: ☐ AFTER ☒ BEFORE ☐ AT
INTERSECTING STREET OR ROADWAY: (CST) E 23 ST
ROADWAY DIRECTION: N
SPEED LIMIT: 65
SPEED LIMIT: 35
GEO-CODE: NA
GPS LONGITUDE: NA
LATITUDE: NA
ROAD MAINTAINED BY: ☐ 1. STATE ☐ 2. COUNTY ☒ 3. MUNICIPAL ☐ 4. PRIVATE PROPERTY ☐ 5. OTHER

FIGURE 4.4.3 Section 2: Location Information of Crash Report

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 4.4.4, there were two vehicles involved, V1 and V2. V1 was a small car and V2 was a motorcycle. The point of impact (P.O.I), 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 2 out of the 3 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, meaning a correct assignment was not feasible.

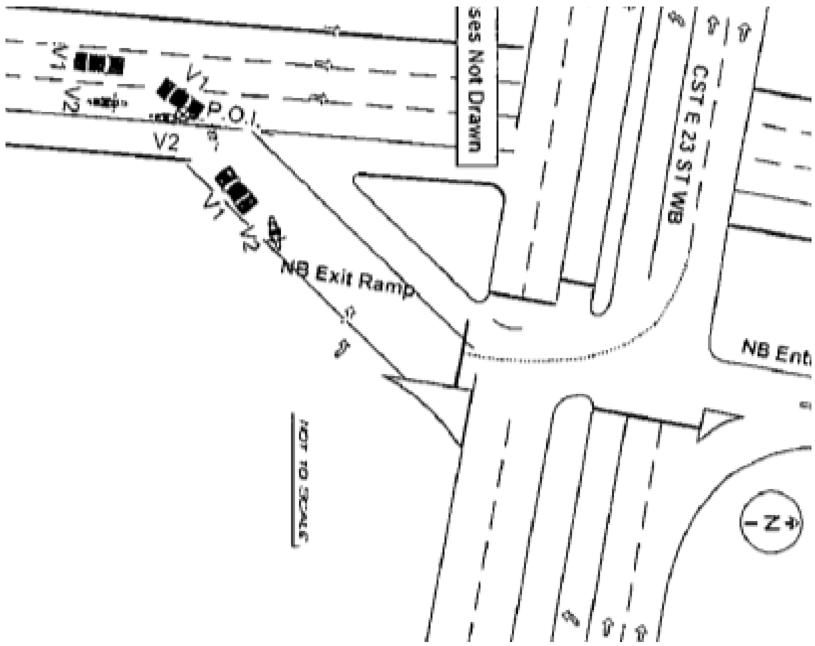


FIGURE 4.4.4 Section 7: Collision Diagram of Crash Report

The narrative section of the crash report is shown in Figure 4.4.5. 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 column “Interchange Facility” as shown in Table 4.4.2 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 4.4.5 Section 28: Narrative/Statements of Crash Report

4.5 Crash Review and Assignment Procedure: Functional Classification

In the physical classification method, the only criterion for assigning crashes is the exact location of crashes. 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, and 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: exits and entrances. 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 4.5.1 illustrate this type of crashes. For example in case 3, a distracted driver realizes that the exit will be missed and makes a sudden maneuver leading to a collision with the gore or running off the road. 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.

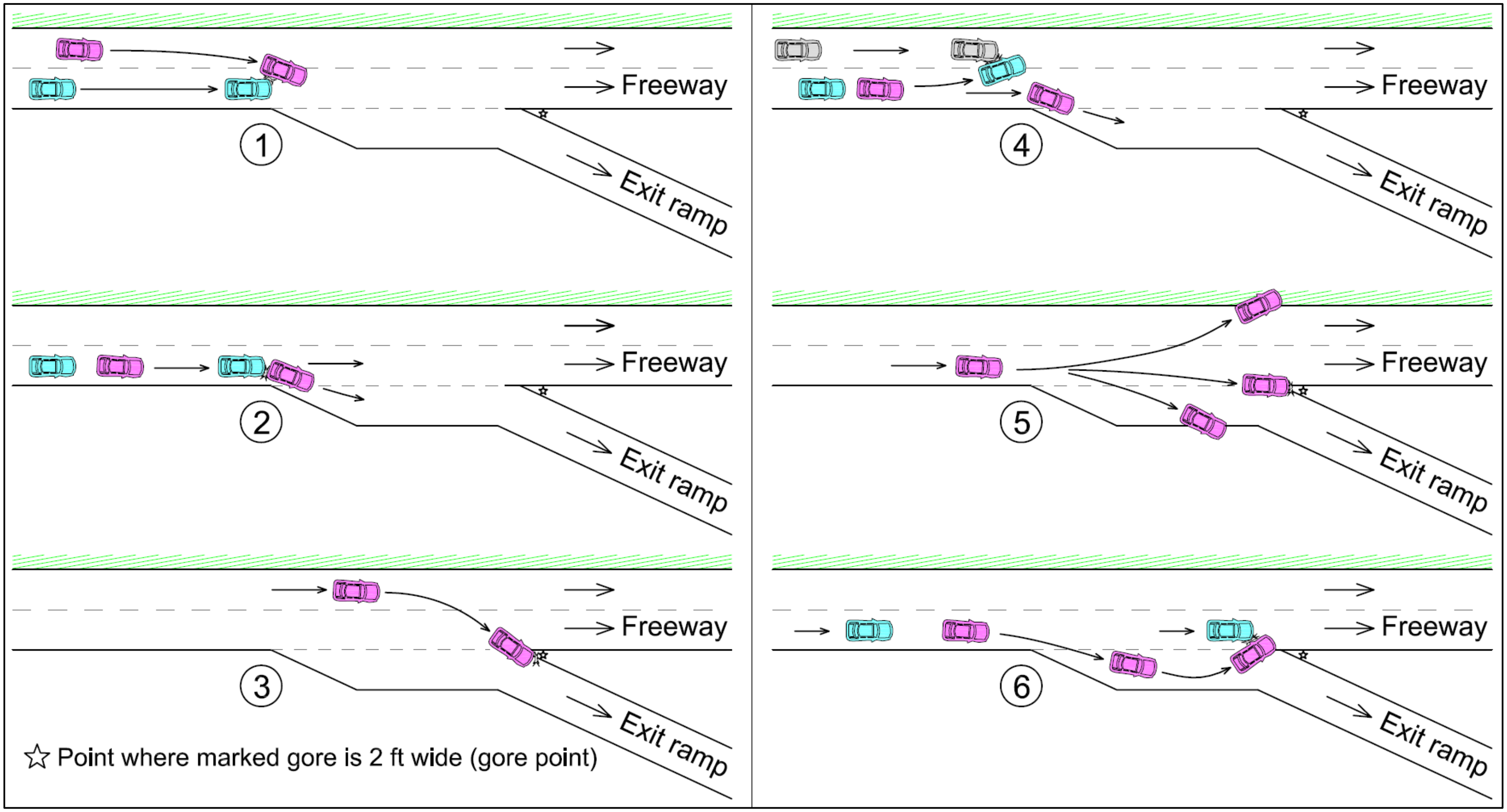


FIGURE 4.5.1 Common Crash Types at Exit Speed-Change Lanes

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, resulting in a collision with approaching vehicles. Cases 1 and 3 of Figure 4.5.2 illustrate these types of crashes. 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 of the queue. Case 4 shows an example of run off the 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.

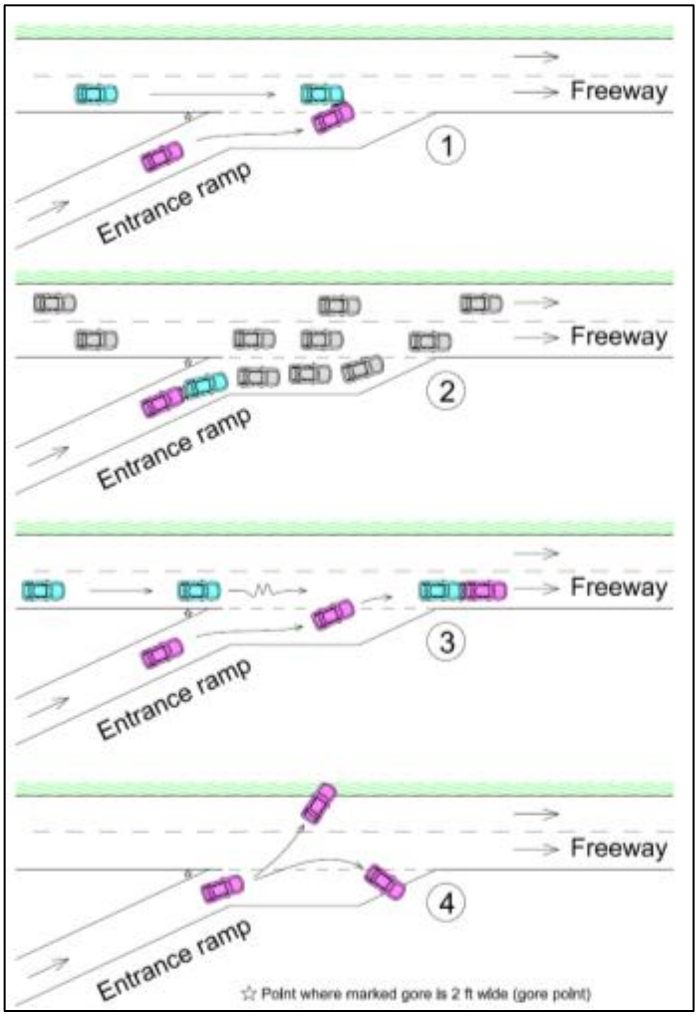


FIGURE 4.5.2 Common Crash Types at Entrance Speed-Change Lanes

Geometric design characteristics of speed-change lanes can influence crashes as well. The taper configuration, number of lanes, 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

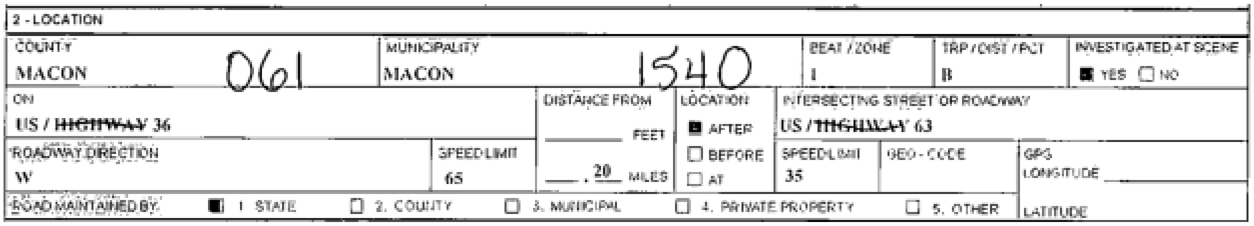
The following is a step by step example of the application of the criteria and methodology for crash report revision and assignment using functional classification. Table 4.5.1 contains the crash data necessary to start the crash review. Step 1 here is similar to the first step in the physical classification methodology and relates to locating the interchange on an aerial photograph. Figure 4.5.3 shows the aerial image of the interchange.

TABLE 4.5.1 Crash Data 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 4.5.3 Interchange 12 (Google Earth, 2015)

Examine section 2 of the report involving the description of the crash location. Figure 4.5.4 shows the 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: I | 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 4.5.4 Section 2: Location Information of Crash Report

The next step is reviewing the collision diagram. According to Figure 4.5.5, 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 review of the narratives provides additional information.

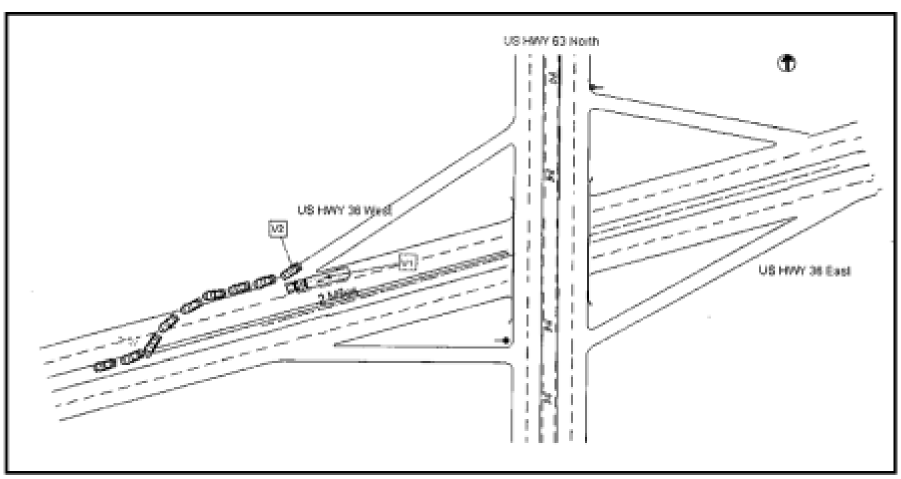


FIGURE 4.5.5 Section 7: Collision Diagram of Crash Report

The narrative section shown in Figure 4.5.6 includes the statements of driver 2. In summary, vehicle two was trying to merge onto US-36 just after leaving the ramp entrance, and a 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 went across all west bound lanes, wrecking into the safety cables in the median. This scenario is case 4 of the 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 4.5.1 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 4.5.6 Section 28: Narrative/Statements of Crash Report

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 4.4.4) 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 4.6.1 Also, note the continuous log mile of the crash as shown in the orange "Cont Log" field in Table 4.6.1. 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 will appear. Select "Search by Travelway" in this window (Figure 4.6.1). 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 in the map with 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. As shown in Figure 4.6.2, 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).

TABLE 4.6.1 Crash Data Table

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	PERTY DAMAGE ONLY	100065622	506759	28.84	Y	Y		DAYLIGHT	DRY	CLEAR	9	NONE	THU	1210	SC_U	1	FS

FIGURE 4.6.1 Search and Zoom Window in TMS Map

FIGURE 4.6.2 Crash Location in TMS Map

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 higher resolution image; two examples are the ARAN viewer and a third-party aerial photograph viewer, such as Google Earth/Maps. ARAN stands for automated road analyzer and 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 4.6.3. Then a new window will open in the internet browser (see Figure 4.6.4). The first image might not show the exact location of the entered log mile (Cont Log). Two buttons in yellow circles shown in Figure 4.6.4 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, can be utilized. Since the distance between each two consecutive frames in ARAN viewer is 0.02 mile, the precision of the location is limited to that resolution.

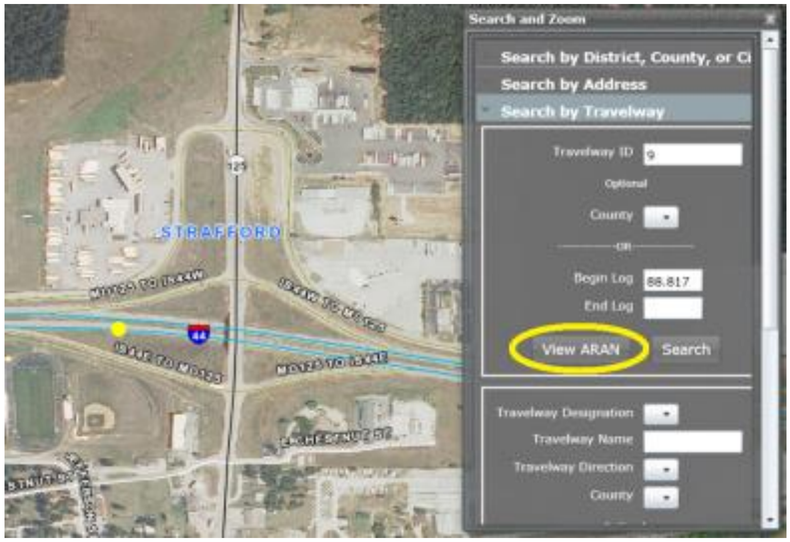


FIGURE 4.6.3 Selecting ARAN Viewer in TMS Map

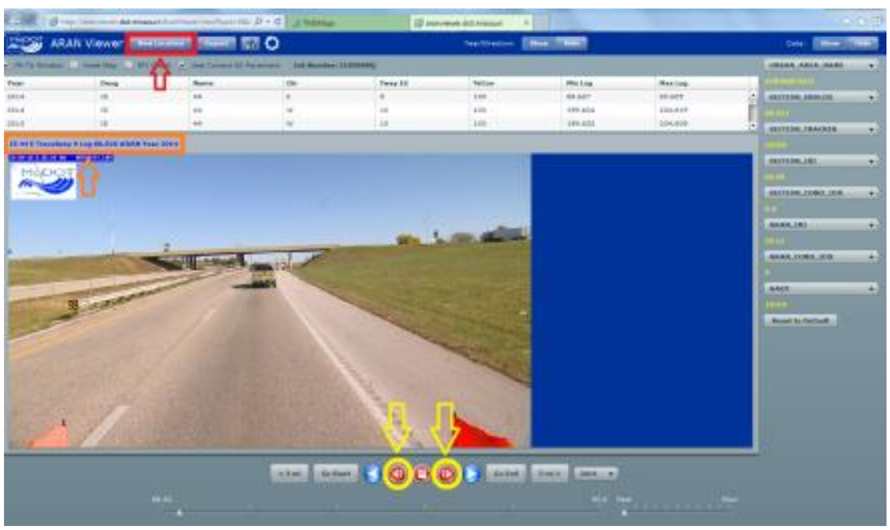


FIGURE 4.6.4 ARAN viewer

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 in 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 “Travelway ID” and “Cont Log” in crash data table. Then, copy the coordinates shown in the yellow box in Figure 4.6.5.

Open the third-party viewer and enter the coordinates with latitude first and then longitude (Figure 4.6.6). Since the resolution of map images in a third-party viewer is possibly higher than in TMS Map, the third-party image provides more details that could be helpful in locating crashes within the interchange geometry.

FIGURE 4.6.5 Collecting Coordinates from TMS Map


FIGURE 4.6.6 Crash location in Third-Party Viewer (Google, 2015)

CHAPTER 5 RESULTS FROM CRASH CORRECTION

Recall, that the main motivation for this crash location correction project is to provide the data necessary to perform HSM calibration for freeway interchange facilities. Thus, the crash data relate 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, including both stop-controlled and signalized ramp terminals. Another popular type of interchange is the A2 Parclo, or the three-leg partial cloverleaf ramp terminal at two-quadrant. 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 Terminal Interchange Facility Types Calibrated

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 Non-Terminal Interchange Facility Types Calibrated

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. 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, this was due to a variety of reasons, such as site geometrics or terminal configuration. Thus the crashes from those sites were not further processed. Also, there were some extra samples that were selected initially in case of faulty samples. 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 the MUAR/MUCR 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% of the terminal crashes reviewed and Parclo included 22.6%. One reason for this disparity is that there are more diamond interchanges in Missouri and more diamond interchanges were used in the HSM calibration. For the non-terminal facilities, ramps included 30% of the non-terminal crashes reviewed and speed-change lanes 70%. The percentage distribution of non-terminal facilities, on the other hand, actually reflect 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.

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	1563
Signalized D4 Diamond Interchange with Six Lane Crossroads Terminal	1800
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	1585
Total	9168
Facility Type Totals	
A2 Partial Cloverleaf Interchange Terminal Total	1482
D4 Diamond Interchange Terminal Total	5086
Entrance/Exit Ramp Total	780
Entrance/Exit Speed-Change Lane Total	1820
Total Crashes Reviewed for Project	12409

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 FI crashes was 22.49% and for PDO crashes was 77.51%. Table 5.4 shows the crash distribution by facility type. 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 does not reflect the overall severity distribution of crashes in Missouri interchange facilities.

TABLE 5.4 Summary of Crash Severity Distributions

Facility	Assigned Severity	
	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%

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 Manual (2012), 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. The result from the crash review is considered the ground truth. Table 5.5 shows an overall error rate of 69%. In terms of specific interchange facilities, the error rate was 89.7% 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% 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%, respectively. For speed-change lanes, the rural error rate was 56.0%, and the urban error rate was 52.4%. It does not appear that the error rates differ 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.

TABLE 5.5 Crash Landing Error Rates

Facility	Errors	Crashes	Percentage Error
RP	52	58	89.7
Terminals	2105	2672	78.8
SCL	906	1708	53.0
Total	3063	4438	69.0

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, including 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% with an error rate of 89.66% 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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