



Roadway Safety Technical Report

*For the C-470 Corridor
Revised Environmental Assessment*

November 2013

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1.0 INTRODUCTION

This Roadway Safety Technical Report for the C-470 Revised Environmental Assessment (EA) examines recent safety data for State Highway (SH) 470A, better known as C-470, from the Kipling Parkway interchange at approximately C-470 milepost 12.40 to the Interstate 25 (I-25) interchange at milepost 26.21. In 2013, the Colorado Department of Transportation (CDOT) and Federal Highway Administration (FHWA) are evaluating impacts of a Proposed Action that differs slightly from the preferred alternative in the C-470 EA that was approved by these same agencies in 2006.

C-470 is located about 13 miles south of downtown Denver. It passes through Arapahoe, Douglas, and Jefferson counties, as shown in Figure 1. CDOT and FHWA have initiated the Revised EA for the 13.75-mile portion of C-470 between Kipling Parkway and I-25 to address congestion and delay, and to improve travel time reliability for C-470 users.

Figure 1
C-470 Corridor and Surrounding Vicinity



The Proposed Action would add two managed tolled express lanes in each direction, expanding the four-lane freeway to an eight-lane freeway. To aid motorists in merging onto or off of the highway, auxiliary lanes would be provided between closely spaced interchanges (e.g., one mile apart). To aid motorists in entering the express lanes at the project's eastern end, new direct-connect ramps would be provided at I-25. Users of the new ramps would not have to weave across C-470 general purpose lanes to access the new express lanes. The Proposed Action does not include any new interchanges or any major interchange modifications. A minor modification at Santa Fe Drive would affect the westbound on-ramp to C-470.

2.0 SAFETY ANALYSIS FOR THE 2006 C-470 EA

CDOT's Safety and Traffic Engineering Branch analyzed three years of accident data (2000 to 2002) in support of the original C-470 EA. That analysis was documented in a February 2005 report entitled "Traffic Safety Chapter for the C-470 Corridor Environmental Assessment." The data examined in that report are now more than a decade old.

2.1 2005 CDOT Findings

The 2005 CDOT safety study examined a total of 1,565 crashes that occurred on the C-470 highway mainline, connecting ramps, and on crossing streets within interchanges. Of these, 850, or an average of 281 per year, occurred on the C-470 mainline. Those crashes occurred during the three-year period from January 1, 2000 to December 31, 2002. The study area extended westward to the Ken Caryl interchange, at C-470 milepost 10), and thus was 2.4 miles longer than the area considered in 2013.

The 2005 safety study identified the five highest accident frequency locations along the corridor and provided details about the types of accidents there. Key findings are noted in Table 1 below.

Table 1
Frequent-Accident Locations Identified from 2000 to 2002 Data

| Interchange | Mileposts | Length | Accidents | Most Common | Second Most |
|-------------|-------------|--------|-----------|------------------|------------------|
| Quebec | 22.63-24.88 | 1.49 | 158 | Rear end 43% | Fixed object 23% |
| Santa Fe | 16.13-17.69 | 1.56 | 139 | Rear end 66% | Fixed object 17% |
| Lucent | 17.70-19.09 | 1.39 | 109 | Rear end 57% | Fixed object 12% |
| I-25 | 24.89-26.21 | 1.32 | 81 | Fixed object 33% | Rear end 23% |
| Broadway | 19.10-20.30 | 1.20 | 74 | Rear end 64% | Sideswipe 11% |

The 2005 study noted that rear-end accidents were the most frequent type on mainline C-470, accounting for 48% of the total. It stated that, "most of these accidents are the direct result of one or more of the involved vehicles either unexpectedly slowing or actually stopping, due to congestion, on a high-speed roadway." Additional analysis showed that 75% of the rear end collisions occurred during the peak commute hours of 6 am to 9 am and 4 pm to 7 pm, with the number considerably higher in the afternoon peak, compared with the morning peak. Examination of 2008-2012 data in 2013 found that they were 72%. Rear-end accidents are largely associated with traffic congestion.

The 2005 safety report documented eight crashes that resulted in fatalities over the three year period of 2000 to 2002, an average of 2.33 fatal crashes per year. An unusual roadside sign along eastbound C-470 near the Chatfield Reservoir memorializes two Littleton teenagers who died in a single-vehicle rollover crash in

August 2006. That particular incident occurred prior to the years (2008 to 2012) that are included in this updated safety study. No similar signs are found along the corridor.

CDOT's overall assessment of safety conditions in 2005 was that the corridor generally had "better than expected safety performance" for a roadway of its type and intensity of use. This is called a Level of Service of Safety (LOSS) level two. The LOSS scale goes from one to four, where level one indicates low potential for accident reduction and level four indicates high potential for accident reduction.

Although the 2005 CDOT safety study gave the C-470 corridor a LOSS-II rating, it did point out an emerging safety issue that was expected to worsen in the future, as follows:

"Currently, highway users experience congested conditions, unnecessary delay and increased crash potential in several locations during peak morning and afternoon volume periods. Drivers at interchange merge-diverge zones contending with the increased vehicle density and reduced maneuvering room of peak hours initiate disruptions in the traffic stream that inevitably cause breakdown in the overall traffic flow and rapid backups. Without additional capacity, these conditions can only be expected to worsen with increased future freeway usage."

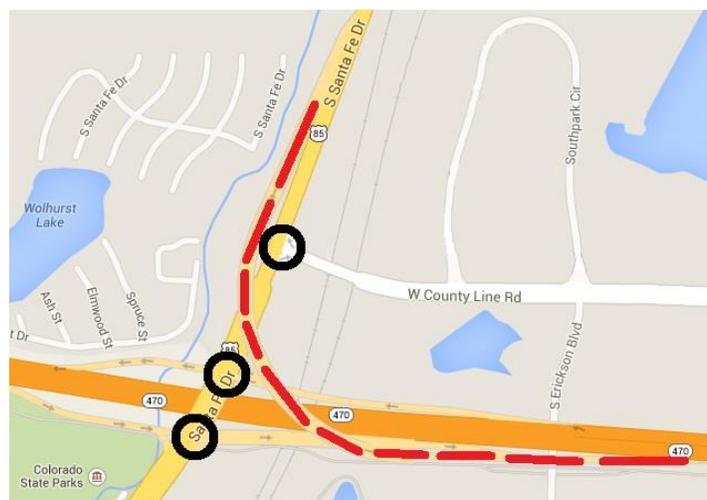
2.2 EA Project Purpose and Need

Due to the relatively safe conditions on C-470 at that time, the project purpose and need for highway improvements in the 2006 C-470 EA focused on reducing traffic congestion and improving travel time reliability, not safety improvements. However, capacity improvements could have safety benefits by reducing traffic density at freeway entrance ramps.

2.3 Santa Fe Interchange Safety Improvements

While giving the highway mainline an adequate safety rating of LOSS-II, the 2005 report did identify the C-470/Santa Fe Drive interchange as an area of safety concern, particularly due to rear-end crashes at traffic signals. That location underwent subsequent safety analysis and eventually a flyover ramp was built to carry southbound Santa Fe to eastbound C-470 traffic, thus removing a large volume of southbound traffic from three consecutive signalized intersections at the Santa Fe

Figure 2
C-470/Santa Fe Drive Interchange Flyover Ramp that Opened in December 2011



The dashed red line indicates path of new flyover ramp. Black circles indicate three signalized intersections receiving southbound traffic relief from the new ramp.

interchange. Figure 2 depicts the location and extent of the flyover ramp that opened to traffic in December 2011.

With only one full year (2012) of accident data that reflect the new interchange configuration, following two prior years of data affected by construction activity, it is premature to quantify safety benefits from the opening of the Santa Fe flyover ramp at this time.

Interchange reconstruction has also occurred recently at the C-470 ramp intersections at Quebec Street (2010) and Broadway (2013), but with no new ramps added.

3.0 DRCOG 2011 REPORT ON TRAFFIC SAFETY

In October 2011, the Denver Regional Council of Governments (DRCOG) published a study called *Report on Traffic Safety in the Denver Region*. While some of the regional statistics in this report were as new as 2010, detailed data regarding the C-470 corridor were not as new. The report's section on Freeway Crash Hot Spots is based on a 2007 DRCOG study which examined data from 2002 to 2004. These data are only slightly newer than the 2000 to 2002 data examined for the C-470 EA safety study in 2005, and similarly, they are now about a decade old.

In the DRCOG study of freeway crash hot spots, the regional freeway system was viewed as 156 freeway segments, of which five comprise the C-470 EA study area. Region-wide, 18% of the segments examined were rated at LOSS Level IV, having more crashes than expected and therefore a high potential for crash reduction. These 28 segments included one on C-470. LOSS III was the grade for 38% of the region's freeway segments, including two on C-470. The 2005 analysis rated the rest of C-470 (two segments) to be rated at LOSS level I or II, indicating fewer accidents than would be expected for a four-lane freeway in the Denver metro area. From west to east, the results for C-470 were as follows:

- Kipling to Platte Canyon Road (3 miles) – LOSS level I or II
- Platte Canyon Road to west of Lucent Boulevard (3 miles)– LOSS Level III
- West of Lucent Boulevard to University Boulevard (2.5 miles) – LOSS Level IV
- University Boulevard to milepost 23/Holly Street alignment (2 miles) – LOSS Level I or II
- Milepost 23 to I-25 (3 miles) – LOSS Level III

The DRCOG 2007 analysis and the CDOT 2005 analysis examined different years of data, with one year (2002) in common. The results therefore contrast the years 2000-1 with 2003-4. The highway did not change between these two data timeframes, and traffic volumes likely did not change dramatically during such a short period of time.

A prior DRCOG safety study, published in 2003, examined accidents in 1999 and classified freeway segments into three categories, based on number of crashes per mile. Every mile of C-470 was classified in the 0 to 39 crashes per year category, while

other freeway segments were found to have 40 to 99 (e.g., I-225, I-70), or 100 or more (I-25). The updated safety analysis, presented below, indicates that all miles of mainline C-470 in the study area today continue to experience 0 to 39 crashes per year.

4.0 UPDATED C-470 SAFETY ANALYSIS

For this updated safety analysis, a query of CDOT's database identified all reported accidents for the five years from 2008 to 2012, inclusive, on the C-470 mainline, its ramps, and selected cross-street intersections. The dataset examined for this safety study is summarized in Table 2. The dataset appears to be complete for the C-470 mainline, and possibly for ramps, but clearly excludes certain ramp intersections, including Wadsworth Boulevard, Santa Fe Drive, and University Boulevard. Nevertheless, there is sufficient data regarding ramp intersections to provide a reasonable picture of what occurs there.

Table 2
Summary of CDOT Five-Year Accident Dataset

| Starting Milepost | Cross-street or feature | Number of Accidents by Location Type | | | | Five-Year Total | Annual Avg. |
|-------------------|-------------------------|--------------------------------------|-------|----------------|----------------------|-----------------|-------------|
| | | Main-line | Ramps | Inter-sections | Intersection-Related | | |
| 12 (west)* | Kipling Parkway | 24 | 8 | 19 | 6 | 57 | 12 |
| 13 | Wadsworth Blvd. | 40 | 27 | 0 | 1 | 68 | 14 |
| 14 | Massey Draw | 69 | N/A | N/A | N/A | 69 | 14 |
| 15 | Platte Canyon Rd. | 73 | 4 | 0 | 0 | 77 | 15 |
| 16 | S. Platte River | 83 | N/A | N/A | N/A | 83 | 17 |
| 17 | Santa Fe Dr. | 140 | 32 | 0 | 0 | 172 | 34 |
| 18 | Lucent Blvd. | 119 | 18 | 43 | 9 | 189 | 38 |
| 19 | Broadway | 157 | 7 | 108 | 12 | 284 | 57 |
| 10 | None | 115 | N/A | N/A | N/A | 115 | 23 |
| 21 | University Blvd. | 137 | 54 | 2 | 1 | 194 | 39 |
| 22 | Colorado Blvd. | 82 | N/A | N/A | N/A | 82 | 16 |
| 23 | Holly St. | 92 | N/A | N/A | N/A | 116 | 23 |
| 24 | Quebec St. | 172 | 40 | 125 | 8 | 355 | 71 |
| 25 | Yosemite St. | 133 | 53 | 63 | 19 | 252 | 50 |
| 26 (east)* | Interstate 25 | 29 | 29 | 0 | 2 | 58 | 12 |
| Five-Year Total | | 1,465 | 425 | 363 | 58 | 2,311 | |
| Percent of Total | | 63.4% | 18.4% | 15.7% | 2.5% | 100.0% | |
| Annual Average | | 293 | 85 | 73 | 12 | | 463 |

*The starting and ending mileposts for the study are 12.45 and 26.2, so the segment 12 is only 0.55 mile long and segment 26 is only 0.2 mile long. All segments in-between (segments 13 to 25) are each one mile in length.

A primary focus of this analysis is C-470 mainline accidents, which accounted for 1,465 of the 2,311 total accidents. Following the extensive discussion of C-470 mainline accidents in the subsections which follow, accidents on ramps and at ramp intersections are examined separately, in shorter detail.

4.1 C-470 Mainline Accidents

Table 2 indicates that the average number of reported accidents on the C-470 mainline for the five-year period was 293 accidents per year. The type, location, and severity of mainline accidents, trends over time and contributing factors for these accidents are examined below.

4.1.1 Mainline Accidents by Type

Table 3 summarizes the five-year database for the C-470 mainline by accident type and location. It can be seen from Table 3 that the predominant category of C-470 mainline accidents was multi-vehicle collisions, which accounted for 62.2% of the total. This category is dominated by rear-end collisions, averaging 142 per year, which comprised nearly half (48%) of all accidents on mainline C-470.

The prevalence of rear-end collisions in 2008-2012 is the same percentage that was found in the 2005 C-470 safety study. The 2005 study stated that “most of these accidents are the direct result of one or more of the involved vehicles either unexpectedly slowing or actually stopping, due to congestion, on a high-speed roadway.” With continued growth and development in this portion of the metro area, C-470 traffic volumes and congestion have continued to increase since then.

The second type of accident included in the multi-vehicle collisions category is sideswipe collisions, averaging 40 per year on a corridor-wide basis. This is also the second most prevalent accident type overall on mainline C-470. Sideswipe accidents can occur when motorists attempt a lane change, inadvertently drift from their lane, or attempt to merge without adequate clearance.

Collisions with a fixed object were the second leading accident category, at 26.3%, which is less than half the multi-vehicle collision share. Collisions with cable rail (e.g., in the roadway median, dividing the two directions of traffic), guard rail (preventing drivers from entering areas with no opportunity to recover vehicle control), and other fixed objects all accounted for relatively similar shares of total accidents. CDOT minimizes the inclusion of fixed objects in the vicinity of the roadway in an attempt to avoid crashes of this nature. CDOT has strict criteria for installing cable rail, guard rail, and other structures to ensure that their benefits outweigh their risks. Much of the cable rail installation is fairly recent, preventing a vehicle from veering across the median to hit other vehicles in a more catastrophic head-on collision.

A motorist will hit a fixed object only if he or she has already failed to keep the vehicle on the road. Driving off the roadway may result from attempting to avoid a crash, from inattentive or impaired driving, or perhaps due to wet or icy roadway conditions. Those factors are discussed separately, later in this report.

Table 3
C-470 Mainline Accidents by Type and Location, 2008 to 2012

| Cross-street or other feature | Kipling | Wadsworth | Massey Draw | Platte Canyon | S. Platte River | Santa Fe | Lucent | Broadway | | University | Colorado | Holly alignment | Quebec | Yosemite | Interstate 25 | 5-Year Totals | Annual Average |
|--|---------|-----------|-------------|---------------|-----------------|----------|--------|----------|-----|------------|----------|-----------------|--------|----------|---------------|---------------|----------------|
| Starting Milepost | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | | |
| Collision with another moving vehicle (62.2%) | | | | | | | | | | | | | | | | | |
| Rear-end | 7 | 7 | 31 | 25 | 27 | 84 | 64 | 91 | 69 | 83 | 30 | 41 | 106 | 40 | 6 | 711 | 142 |
| Sideswipe | 4 | 11 | 8 | 10 | 16 | 15 | 10 | 16 | 16 | 9 | 12 | 17 | 16 | 31 | 9 | 200 | 40 |
| Collision with a fixed object (26.3%) | | | | | | | | | | | | | | | | | |
| Cable rail | 0 | 3 | 14 | 14 | 7 | 7 | 14 | 23 | 13 | 22 | 9 | 11 | 5 | 4 | 0 | 146 | 29 |
| Guard rail | 1 | 5 | 1 | 4 | 12 | 12 | 5 | 5 | 4 | 2 | 20 | 9 | 11 | 25 | 4 | 120 | 24 |
| Other fixed | 7 | 7 | 10 | 8 | 9 | 16 | 5 | 8 | 3 | 8 | 4 | 3 | 17 | 9 | 6 | 120 | 24 |
| Collision with a non-fixed object (6.1%) | | | | | | | | | | | | | | | | | |
| Debris | 0 | 1 | 1 | 3 | 0 | 2 | 4 | 6 | 3 | 6 | 2 | 2 | 6 | 6 | 1 | 43 | 8 |
| Wild animal | 1 | 1 | 3 | 2 | 6 | 0 | 4 | 3 | 1 | 2 | 0 | 2 | 2 | 1 | 0 | 28 | 6 |
| Other | 0 | 1 | 0 | 1 | 2 | 1 | 3 | 1 | 0 | 1 | 2 | 0 | 2 | 4 | 0 | 18 | 4 |
| Non-collision (5.4%) | | | | | | | | | | | | | | | | | |
| Overturning | 2 | 4 | 0 | 3 | 4 | 1 | 10 | 4 | 5 | 4 | 3 | 6 | 3 | 8 | 2 | 59 | 12 |
| Embankment | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 1 | 9 | 2 |
| Other | 1 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 11 | 2 |
| 5-Year Total | 24 | 40 | 69 | 73 | 83 | 140 | 119 | 157 | 115 | 137 | 82 | 92 | 172 | 133 | 29 | 1,465 | |
| Average/year | 5* | 8 | 14 | 15 | 17 | 28 | 24 | 31 | 23 | 27 | 16 | 18 | 34 | 27 | 6* | | 293 |

* Kipling and I-25 segments are less than one mile in length; all other segments are one mile.

Collisions with a non-fixed object (other than a moving vehicle) accounted for 6.1% of the five-year accident total on C-470. These include collisions with debris (8 accidents per year), wild animals (6 accidents per year) and other unspecified objects (4 accidents per year) which typically cannot be predicted or controlled. Several accidents listed in this category involved crashing with a motor vehicle that was parked along the roadway. Animal crossing warning signs exist in locations near the South Platte River and other areas where crashes with animals have been recorded.

The remainder (5.4%) of the five-year accident total consists of non-collision accidents, including an average of 12 rollover accidents per year, 2 cases of driving off of embankments (i.e., without hitting guardrail), and 2 other miscellaneous cases. Rollover accidents typically indicate traveling at high speed. C-470 has posted speed limits of 65

miles per hour, which obviously some motorists exceed, sometimes even under unfavorable driving conditions.

A different type of variable included within all accident types discussed above is involvement of big-rig heavy trucks. C-470 carries the lowest percentage of heavy trucks of any freeway in the Denver metro area, and the prevalence of truck involvement in C-470 accidents is proportional to those low volumes, at about 2.5% (57 accidents out of 2,311 total, including mainline, ramps, and intersections). If truck accidents were more prevalent, out of proportion with truck volumes, this could suggest the presence of roadway design deficiencies (e.g., tight curves), but they are not more prevalent and the accident data do not suggest any such deficiencies.

4.1.2 Mainline Accidents by Location

The bottom row of Table 3 on page 6 indicates the average number of accidents on mainline C-470 on a mile-by-mile basis, from Kipling Parkway (milepost 12.45) to I-25 (milepost 26.2). The segments at the respective project termini are less than one mile in length, and thus have substantially fewer accidents. All segments in-between are one mile long. Traffic volumes on C-470 are highest at the eastern (I-25) end, and gradually diminish for successive segments to the west. This explains why there appear to be fewer accidents per mile in the westernmost parts of the study area.

The average number of yearly accidents for the full-mile segments of the C-470 mainline was approximately 20 and ranged from a low of 8 in mile 13 (Wadsworth Boulevard) to a high of 34 in mile 24 (Quebec Street), as shown in Figure 3. The vicinity of Quebec Street also had the highest number of accidents reported in the 2005 CDOT safety study, based on the data available at that time. The 2008 to 2012 data for mile 24 includes 106 rear-end accidents out of a total of 172, accounting for approximately 62% of the total. This exceeds the 48% average for the corridor overall, and is likely due in large part to traffic congestion.

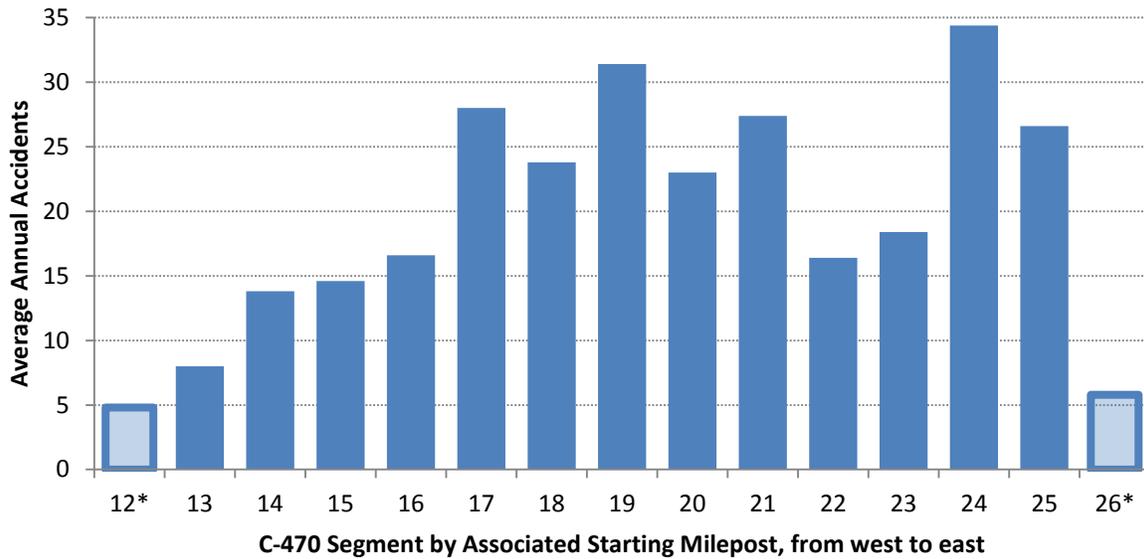
The locations with the highest average annual accidents during 2008 to 2012 were:

- mile 24 (includes the Quebec interchange) - 34 accidents per year
- mile 19 (includes the Broadway interchange) – 31 accidents per year
- mile 17 (includes the Santa Fe interchange) - 28 accidents per year
- mile 21 (includes the University interchange) - 27 accidents per year
- mile 25 (includes the Yosemite interchange) - 27 accidents per year

4.1.3 Accident Trend over Time

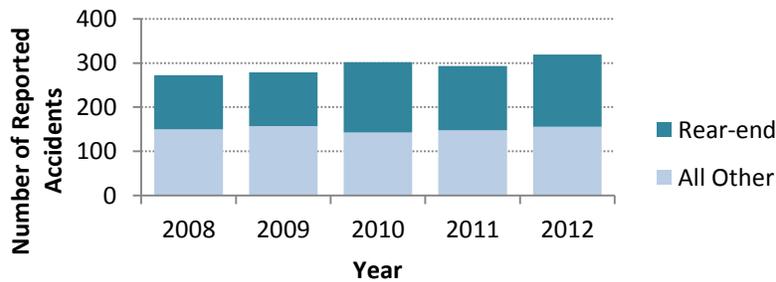
There has been a slight upward trend in the number of C-470 mainline accidents over the past five years, but only for rear-end accidents, as seen in Figure 4. The total number for all other accident types has been stable at about 150 per year, while rear-end accidents have increased and now account for just over half the mainline total.

Figure 3
Average Annual C-470 Mainline Accidents by Mile, 2008 to 2012



* Segment 12 (Milepost 12 to Kipling Parkway) is 0.55 mile long and segment 26 (Milepost 26 to I-25) is 0.2 mile long. All other segments are one mile long.

Figure 4
C-470 Mainline Rear-End and Total Accidents by Year, 2008 to 2012



4.1.4 Mainline Accidents by Severity

Of the 1,465 C-470 mainline accidents reported during 2008 through 2012, almost 92% resulted in property damage only, almost 8% resulted in one or more injuries, and one half of one percent (8 accidents) resulted in fatalities. The details are shown in Table 4.

Mile-by-mile comparison of injury accidents does not reveal any dense clusters of injury accident locations, and the same is true for the eight accidents that resulted in fatalities. The table reports the number of accidents, not the number of people who were injured or killed.

Table 4
C-470 Mainline Accidents by Mile by Severity, 2008 to 2012

| Mile | Vicinity/Landmark | Total Accidents | Property Damage Only | Accident Resulted in Injury | Accident Resulted in Fatality |
|-----------------|----------------------------|-----------------|----------------------|-----------------------------|-------------------------------|
| 12 ^a | Kipling (MP 12.45) | 24 | 21 | 2 | 1 |
| 13 | Wadsworth (MP 13.9) | 40 | 34 | 6 | 0 |
| 14 | Massey Draw (14.1) | 69 | 68 | 1 | 0 |
| 15 | Platte Canyon (15.44) | 73 | 67 | 6 | 0 |
| 16 | S. Platte River (16.56) | 83 | 73 | 9 | 0 |
| 17 | Santa Fe Drive (17.05) | 140 | 130 | 9 | 1 |
| 18 | Lucent Drive (MP 18.46) | 119 | 109 | 10 | 0 |
| 19 | Broadway (19.6) | 157 | 146 | 11 | 1 |
| 20 | Broadway to University | 115 | 103 | 10 | 2 |
| 21 | University Blvd (MP 21.05) | 137 | 128 | 9 | 0 |
| 22 | Colorado Boulevard | 82 | 69 | 11 | 2 |
| 23 | Holly Street alignment | 92 | 84 | 8 | 0 |
| 24 | Quebec Street (MP 24.15) | 172 | 159 | 13 | 0 |
| 25 | Yosemite Street (MP 25.57) | 133 | 124 | 8 | 1 |
| 26 ^b | Interstate 25 (MP 26.2) | 29 | 28 | 1 | 0 |
| | Corridor 5-Year Totals | 1,465 | 1,343 | 114 | 8 |
| | Average per Year | 293 | 268 | 23 | 2 |

^a Segment length is 0.55 mile, not one mile. ^b Segment length is 0.2 mile, not one mile.

4.1.5 Other Factors Contributing to Mainline Accidents

The issues of traffic congestion contributing to rear-end accidents and traffic density contributing to sideswipe (ramp merge or lane change) accidents have been noted above. Additionally, debris, wild animals, or other unexpected objects on the roadway have caused a small percentage of total accidents. Other factors contributing to accidents include driver behavior and weather conditions. These factors are examined below, but first they are examined with regard to the eight fatal accidents reported over the last five years. Table 5 indicates that of the eight accidents that resulted in fatalities, five involved drivers who were impaired (e.g., by alcohol) or had a medical condition that contributed to the crash.

One of the eight fatal accidents involved the very unusual condition of a pedestrian being hit on the highway at night. Three of the fatal accidents appear to have involved no unusual driver circumstances. None of the eight fatal accidents involved rain, snow or icy conditions. This small sample of less than one percent of the 1,465 total mainline accidents does not appear to indicate any particular highway design deficiency. The analysis of contributing factors continues below, examining instead the entire dataset, of which more than 99% did not result in fatalities.

Table 5
General Characteristics of C-470 Fatal Accidents, 2008 to 2012

| Mile | Year | Type | Weather and Lighting | Other Factors |
|------|------|--------------------|------------------------|--------------------------|
| 12 | 2008 | Other fixed object | None – dark, unlighted | Driver impaired |
| 16 | 2012 | Car hit pedestrian | None – dark, unlighted | None |
| 17 | 2008 | Sideswipe | None – daylight | Driver medical condition |
| 20 | 2009 | Rear end | None – dark, unlighted | Driver impaired |
| | 2012 | Rear end | None – daylight | None |
| 22 | 2009 | Cable rail | None – dawn or dusk | Driver medical condition |
| | 2012 | Guardrail | None – dawn or dusk | None |
| 25 | 2012 | Guardrail | None – dark, lighted | Driver impaired |

Table 6 indicates that a majority (53%) of the reported accidents on the C-470 mainline during 2008 to 2012 involved a driver behavior or condition that was considered to contribute to the crash. The most frequent identifiable factor related to driver behavior was distracted driving, at 23% of all accidents. Distracted driving may include cell phone calling or texting activity, adjusting a radio or other vehicle control, noise from other passengers, eating or drinking while driving, and a number of other possibilities. Cell phone use and texting have definitely increased in recent years. Transportation and law enforcement agencies have responded with public awareness campaigns to discourage distracted driving.

Table 6
Driver-Related Factors Contributing to C-470 Mainline Accidents, 2008 to 2012

| Driver Related Contributing Factor | Number of Accidents (Total is 1,465) | Percentage of Total Accidents |
|-------------------------------------|---|----------------------------------|
| No factor identified | 692 | 47% |
| Identifiable factor (details below) | 773 | 53% |
| Distracted driver | 338 | 23% |
| Driver inexperience | 139 | 9% |
| Driver impaired | 75 | 5% |
| Driver fatigue | 58 | 4% |
| Aggressive driving | 41 | 3% |
| Driver medical condition | 22 | 1% |
| Other identifiable factor | 100 | 8% |

The “driver inexperience” category includes new drivers, such as teenagers, but also includes the frequent response of “driver unfamiliar with the area”. For the entire 2,311 accident C-470 dataset (i.e., not just the mainline subset), 17.9% percent of the drivers involved were younger than age 21, and 4.5% of the 2,311 drivers had out-of-state driver’s licenses. At the other end of the age scale, 2.7% of the drivers were older than 70, and 0.5% (12 drivers) were more than 80 years old.

Three of the 41 “aggressive driving” cases in the table above were hit-and-run accidents, with the at-fault driver cited. An additional 26 hit-and-run accidents reported by victims or evidenced by resulting damage (e.g., guard rail, light poles) are included in the 692 “no factor identified” category, because the driver was not apprehended and could not be questioned. The total of 29 hit-and-run accidents over five years equate to an average of about 6 per year.

Weather and pavement conditions also can contribute to accidents on mainline C-470. Table 7 indicates that adverse weather was reported for 12% of C-470 accidents, and wet pavement conditions were reported for 15% of the accidents.

Table 7
Weather and Pavement Conditions for Reported C-470 Mainline Accidents, 2008 to 2012

| Conditions | | Number of accidents | Percentage of total accidents |
|---------------------------|---------------------------------|---------------------|-------------------------------|
| WEATHER | Dry, clear weather | 1,290 | 88% |
| | Adverse weather (details below) | 175 | 12% |
| | Rain | 109 | 7% |
| | Hail, sleet or snow | 54 | 4% |
| | Wind, fog or other | 12 | 1% |
| Weather condition totals | | 1,465 | 100% |
| PAVEMENT | Dry pavement | 1,244 | 85% |
| | Wet pavement | 221 | 15% |
| | Wet | 90 | 6% |
| | Snowy or slushy | 66 | 4.5% |
| | Icy | 65 | 4.5% |
| Pavement condition totals | | 1,465 | 100% |

The numbers for weather conditions and pavement conditions differ because slick pavement conditions can persist after snowfall or rainfall has stopped. Active precipitation reduces visibility while slick pavements reduce vehicle traction and maneuverability, often with splash-back from adjacent vehicles. Obviously, both conditions (active precipitation and wet pavement) occur simultaneously in most cases.

Another factor known to contribute to accidents on east-west portions of C-470 is sun glare. The CDOT accident database does not include statistics on this issue. Residents from along the C-470 corridor who commute eastbound in the morning toward I-25 and then reverse the trip in the late afternoon find themselves driving in the direction of the sun, due to the east-west orientation of the route. The low angle of the sun during peak commuting hours diminishes visibility and thus makes driving more hazardous than driving in the opposite direction. Clear, sunny conditions are far more prevalent in the area than adverse weather conditions, as is reflected by the data in Table 7.

4.2 Accidents on C-470 Ramps

While mainline accidents accounted for 63% of the CDOT accident dataset, accidents on freeway ramps accounted for 18%, the next largest grouping. Freeway ramps make the transition from arterial cross-streets to the high-speed freeway, and vice-versa. On-ramps differ significantly from off-ramps because motorists begin an on-ramp at low speed and accelerate to try to match freeway speeds, whereas off-ramps require deceleration from high speeds to make a stop or a slow turn at the intersection with the arterial. Speeds for traffic entering the highway are controlled by conditions on the highway, while speeds for traffic leaving the highway are controlled by the signalized intersection at the end of the ramp, as well as any traffic backup waiting at that intersection. These situations are highly influenced by the degree of traffic congestion at the particular location involved.

During peak hours, when C-470 traffic is congested, ramp meters at the freeway entrance require a full stop. These signals are intended to preserve traffic flow on the mainline, not to give priority to traffic entering the highway. Figure 5 is a photograph of one of these ramp meters along C-470.

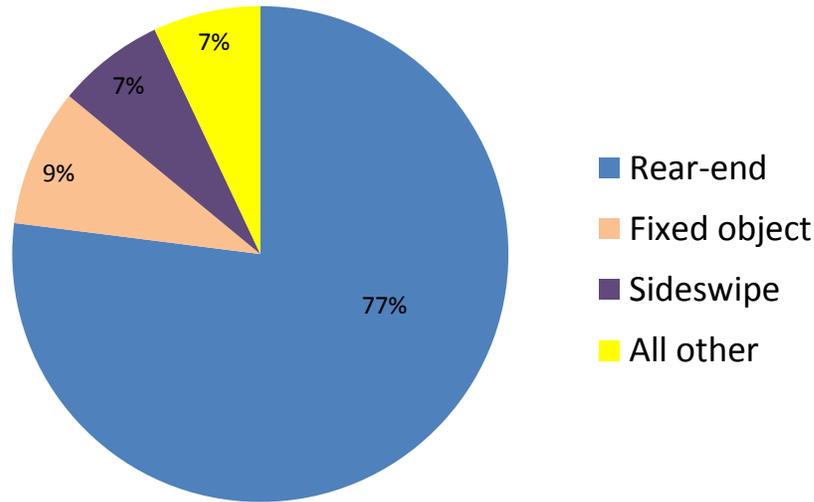
The number and location of accidents on C-470 freeway ramps was indicated earlier, in Table 2. The types of accidents reported on C-470 ramps are indicated in Figure 6.

While rear-end accidents account for half of mainline accidents, they amount to just over three quarters of the accidents on ramps, due to the operational characteristics discussed above. For ramp traffic exiting C-470, intersection improvements could help to address this issue. Note that as reported earlier, three C-470 interchanges have had major reconstruction in recent years, during a portion of the time covered by the 2008 to 2012 accident dataset. For ramp traffic entering the freeway, adding auxiliary lanes could ease some apparently inadequate merge sections, and adding roadway capacity (new through lanes) could reduce traffic density, thereby providing easier freeway entry.

Figure 5
Example of Ramp Meter for Traffic Entering C-470



Figure 6
Accidents on C-470 Ramps, by Type, 2008 to 2012



Note: For this pie chart, 100% = 425 accidents

4.3 Accidents at C-470 Interchange Intersections

The five-year CDOT dataset of C-470 corridor accident data provided for this study included accident data for five signalized intersections where CDOT on/off ramps meet perpendicular arterial cross streets. Records for 363 accidents, an average of 73 per year, included the following, which are ordered from highest number to lowest number of accidents: Broadway (27 per year), University (25 per year), Yosemite Street (13 per year), Lucent Boulevard (8 per year) and Kipling Boulevard (4 per year). Data were not included for (in west to east order): Wadsworth Boulevard, Platte Canyon Road, Santa Fe Drive and University Boulevard.

Multi-vehicle collisions in this sample accounted for 344 accidents, or approximately 95% of the 363 total accidents included in the intersection accident sample. Since the percentage of multi-vehicle collisions for the C-470 freeway mainline was 62.2%, a wider variety of accident types occurred on the C-470 mainline than at its ramp intersections.

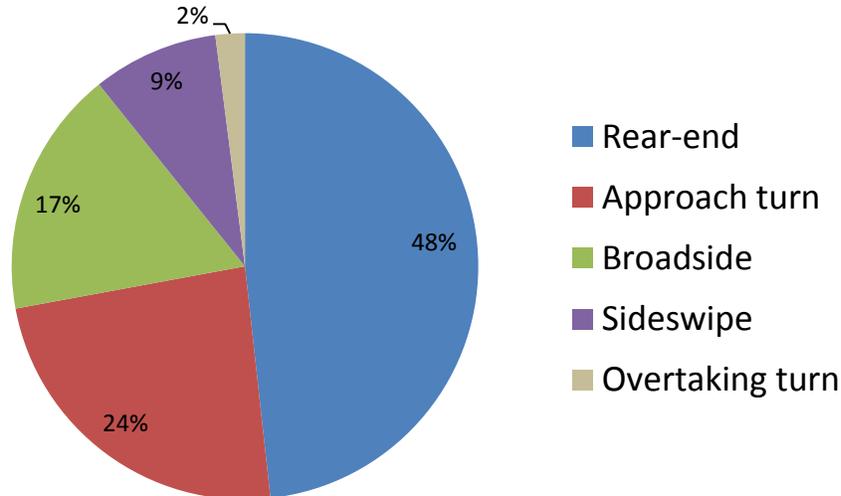
Multi-vehicle collisions accounted for 95% of the crashes reported at ramp intersections.

Figure 7 shows substantial percentages for multi-vehicle collision types that were not reported for the mainline: approach turn, broadside, and overtaking turn. Not included in the pie chart is a single head-on accident that occurred at a C-470 ramp intersection in 2011, involving an impaired driver going the wrong way at Quebec Street.

Weather and pavement conditions and prevalence of contributing driver behaviors were already explored for the much larger dataset of mainline accidents, and so are not repeated here. The key finding with respect to accidents at C-470 intersections is that motorists crashed into each other, not roadside objects or debris. Since traffic speeds at

intersections are much lower than the 65 mph mainline, motorists have more control of their vehicle and more reaction time.

Figure 7
Multi-Vehicle Collision Types at C-470 Ramp Intersections, 2008 to 2012



Note: For this pie chart, 100% = 343 accidents

Two of the 363 intersection accidents involved a collision between a motorist and a bicycle. These occurred at the Broadway and Quebec interchanges. Both of these occurred during daylight, with no adverse weather conditions or known contributing driver behaviors.

4.4 Other Intersection-Related Accidents

This reporting category of “intersection-related accidents” in the CDOT dataset is difficult to summarize because it includes accidents from all three categories previously discussed. Of 58 total accidents in this category, 28 apparently occurred on arterial cross-streets, 20 on C-470 ramps, and 8 on the CDOT mainline. The associated C-470 mile segments where these accidents occurred were reported in Table 2. The highest number, 19 accidents, was reported for mile 25, in the vicinity of Yosemite Street. At this location, there are various freeway to freeway ramps merging together, so there is some difficulty in identifying what to call a ramp, for reporting purposes. Nineteen accidents over the five-year data period average out to about four accidents per year, and in this segment (mile 25) C-470 has its highest corridor-wide traffic volume. The location with the second highest total, 12 accidents (2 per year) was Broadway. The remaining six “intersection-related” accidents per year were spread out four other full mile segments and both partial-mile segments of the C-470 study area.

Not surprisingly, given the mixed nature of these sites (mainline, ramp and cross-streets), the types of accidents recorded in this category reflects an averaging of the accident types reported earlier for those discrete location types. Rear-end accidents accounted for 58% of the total, sideswipes 14%, and three other multi-vehicle collision types at 9% (1 accident per year) or less. Three accidents involved hitting a fixed object

and one involved a vehicle hitting a pedestrian during daylight, in dry weather and pavement conditions, at the Yosemite Street intersection.

Additional analysis of this accident category is not deemed useful, due to the mixed nature of the sample locations and the difficulty in applying any findings to other locations. Additionally, because the number of accidents in this sample is so small, redistributing these 2.5% of all accidents to the other three categories (mainline, ramp and intersection) would not significantly alter any of the findings presented earlier above.

5.0 IMPACTS OF ALTERNATIVES

5.1 No-Action Alternative Safety Impacts

The 2005 CDOT safety analysis included the following findings:

“In general, the potential for exceptional accident reduction in the study area is only moderate. This is not a surprising result as this highway is of relatively recent construction and was designed to a high standard. This study, however, has revealed the strong association of elevated accident occurrence with periods of high traffic volume and congested conditions. The higher incidence of the characteristic, congestion-related rear end and same direction sideswipe collisions is noted on the mainline as well as throughout most of the included interchanges.

At the included interchanges, most of the safety problems can similarly be attributed to congestion and backups during periods of high traffic volume. Accident problems at interchange-related ramp intersections can be addressed by congestion mitigation such as adding travel and storage lanes, extending existing auxiliary lanes, using protected only left turn phases where approach turn problems exist and verifying adequate yellow and all-red times where broadside problems are present. In locations such as the Santa Fe and Broadway interchanges, more extensive modifications can provide commensurate operational and safety benefits.”

Since that time, interchange improvements have been made at the Quebec interchange (2010), Santa Fe Drive (2011) and Broadway (2013). These improvements are so recent that it is not feasible to quantify the safety improvements that have occurred at these locations with certainty. Meanwhile, it was seen in Figure 5 that rear-end accidents on mainline C-470 increased over the five-year period of 2008 to 2012.

Looking forward, increased traffic volumes are anticipated on C-470 with continued regional growth. Congestion on C-470 will continue to increase, potentially resulting in additional rear-end accidents.

5.2 Proposed Action Safety Impacts

The 2005 CDOT safety analysis included the following finding:

“From a safety improvement perspective, any steps taken to increase capacity and improve traffic operations will have an accident reduction benefit. An overall

reduction in accidents of 20% - 25% is expected to accompany capacity improvements such as adding an additional lane to the present freeway cross-section.”

The Revised EA’s Proposed Action would add one or two new lanes (varying by location and future year), potentially resulting in some of the accident reduction noted above.

A notable new feature of the current Proposed Action is that the managed toll express lanes would be separated from the general purpose lanes by a painted buffer width on the roadway surface, rather than by a concrete barrier. A concrete barrier, proposed in the 2006 EA, would have introduced a fixed object into the highway right-of-way, potentially increasing the number of fixed object collisions that currently account for about one quarter (26.3%) of reported C-470 accidents. The lack of a physical barrier between the new managed lanes and the adjacent general purpose lanes means that inevitably some motorists will change lanes across the buffer in locations where such a change is not permitted. This may pose a sideswipe hazard to motorists who expect to see ingress and egress movements occur only at the lawful locations.

Also, since the managed toll express lanes are expected to have higher operating speeds than the general purpose lanes, there would be a speed differential at ingress and egress locations. Speed differentials introduce accident potential at the designated merge locations.

Finally, increased accidents may occur at or near the locations of lawful ingress as motorists try to comprehend the toll information and make a last-second decision whether or not to enter the managed lanes. Advance signing would be installed, of course, to prepare motorists for this decision, but nevertheless some last-second changes of mind may occur. Clear, simple advanced signing is recommended to minimize this scenario. The addition of the needed new signage would introduce new fixed objects into the highway right-of-way, thereby increasing accident potential. However, as noted earlier, a motorist would have to already have lost control and veered off the roadway in order to hit a fixed object.

Recapping, the Proposed Action is expected to decrease rear-end accidents (by far the most prevalent C-470 accident type) by reducing congestion, but will introduce new merging locations, unlawful merges, speed differentials, and additional fixed objects. C-470 as a whole is not known to have high accident rates, and the purpose and need for C-470 improvements is based on traffic congestion and the need for improved travel time reliability, not safety problems. Nevertheless the Proposed Action will be designed in accordance with current, applicable safety standards, which will remedy some deficiencies of the existing freeway.