I-70 Mountain Corridor PEIS Safety Technical Report

August 2010

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Section 1. Introduction

1.1 What is in this report?

This *I-70 Mountain Corridor PEIS Safety Technical Report* (CDOT, August 2010) supports the information contained in **Chapters 1 and 2** of the *I-70 Mountain Corridor PEIS*. It identifies:

- **Section 2. Methodology** – Methods used to identify safety problems and determine potential impacts of alternatives
- **Section 3. Existing Conditions** – Description of the existing safety problems in the Corridor
- **Section 4. Future Conditions** – Consequences of the Alternatives evaluated in the I-70 Mountain Corridor PEIS\
- **Section 5. Findings and Considerations for the Tier 2 Process**

This Technical Report was completed through coordination with the Colorado Department of Transportation (CDOT).

Section 2. Methodology

2.1 How were safety problems identified?

Improving highway safety plays a strong role in the three interrelated needs of increasing capacity, improving mobility and accessibility, and decreasing congestion in the I-70 Mountain Corridor. Crashes are classified in three levels of severity:

- Fatalities
- Injuries to persons
- Other events, typically referred to as “property damage only”

Current highway crash rates (based on vehicle miles of travel [VMT] for the entire Corridor) were calculated from crash data from 2001 to 2005. Also, Weighted Hazard Index (WHI) – a measure of crash rates on a roadway segment compared to the statewide average for similar facilities – was used to identify specific locations where the crash rates indicate specific safety problems. WHI is calculated using detailed crash reports from police records for 2001 to 2005. Locations where the WHI is greater than zero were identified as high-crash locations. These locations were then analyzed further using a WHI criteria, which assigned priorities based on engineering judgment. These criteria provided a consistent basis for assigning priorities, which are described below:

- High Priority — WHI greater than 2.0
- Medium Priority — WHI between 1.0 and 2.0
- Low Priority — WHI between 0.0 and 1.0
- Normal — WHI less than 0.0

2.2 How were crash rates determined?

A comparison of the crash rates and weighted average crash rates for the I-70 Corridor as compared to the state wide average crash rates for rural highways are shown below:

$$\text{Average Crash Rate} = \frac{A}{(ADT * Length * D)/10^6}$$

$$\text{Weighted Average Crash Rate} = \frac{A_W}{(ADT * Length * D)/10^6}$$

Where, A = Number of crashes
ADT = Average Daily Traffic
$Length$ = Length of Section being investigated (miles)
D = Number of days in study period
A_W = Weighted number of crashes
$\{A_W = PDO + (5 * INJURY) + (12 * FATAL)\}$

- The Average Crash Rate for the corridor during this period was 1.37 (Crashes/million vehicle-miles).
- The Weighted Average Crash Rate for the corridor during this period was 3.06 (Crashes/million vehicle-miles).

2.3 How were alternatives compared?

For each alternative, the potential number of crashes was projected, based on the person miles of travel (PMT) in each of the following seven study sections:

- C-470 to Hyland Hills
- Hyland Hills to Empire Junction
- Empire Junction to Loveland Pass
- Loveland Pass to Silverthorne
- Silverthorne to Vail Pass
- Vail Pass to Edwards
- Edwards to Glenwood Springs

The number of crashes expected under any scenario is assumed to be a function of two factors: the 2035 PMT associated with the scenario and the highway improvements associated with the scenario. Hence, based on the PMTs calculated for each alternative, the number of crashes was estimated (before any reductions were made due to roadway improvements) for each of the seven sections mentioned previously. This was achieved by multiplying the crash rate (crashes per million vehicle miles) by PMT.

Roadway improvements, such as curve realignment, additional through lanes, and climbing lanes, were identified in each of the seven sections.

The Colorado Department of Transportation has developed Accident (crash) Reduction Factors (ARF) for each type of proposed improvement. These factors were applied to obtain a predicted number of crashes in improved sections. If there was more than one type of improvement, the highest ARF was used. If no major improvements were made to I-70, it was assumed that crash rates would remain the same in the future. The predicted total number of crashes by severity was divided by the forecasted PMT for comparison with the transit component of alternatives. ARFs were obtained from CDOT for each proposed improvement.

Reduction in crashes was calculated by applying the ARFs to the total number of related crashes. If an ARF was applicable only to a certain type of crash, then the reduction was assumed only in those crash types. If there were more than one improvement at a location, then the higher ARF was used.

For example, in the Minimal Action scenario for the segment "Highland Hills to Empire Junction," various improvements are proposed at different mileposts: curve realignment, interchange improvements, and auxiliary lanes. Each improvement is associated with an ARF, but in the case of curve realignment (at east of Twin Tunnels), the ARFs can be applied only to crashes related to curves. Thus, the ARFs were applied to all crashes in that segment of I-70 that were Fixed Object, Overturning, or Sideswipe.

2.3.1 Driver Expectancy

"Driver expectancy" is an important factor that influences highway safety rates. Elements of I-70 in the Corridor that may violate driver expectancy include:

- Unexpected and sharp curves, and steep grades associated with mountainous conditions
- Wide variation in the speeds of vehicles on the roadway
- Changes in posted speed limits (regulatory and advisory)
- Disabled vehicles, fallen rocks, animals, or other obstacles on the roadway
- Left-side on-and off-ramps, and other nonstandard geometric features
- Inclement weather conditions, including icy roads and bridges, and particularly, the ability of out-of-state residents who are not familiar with the I-70 mountain roadway to respond to these conditions
- The presence of large, fast-moving vehicles

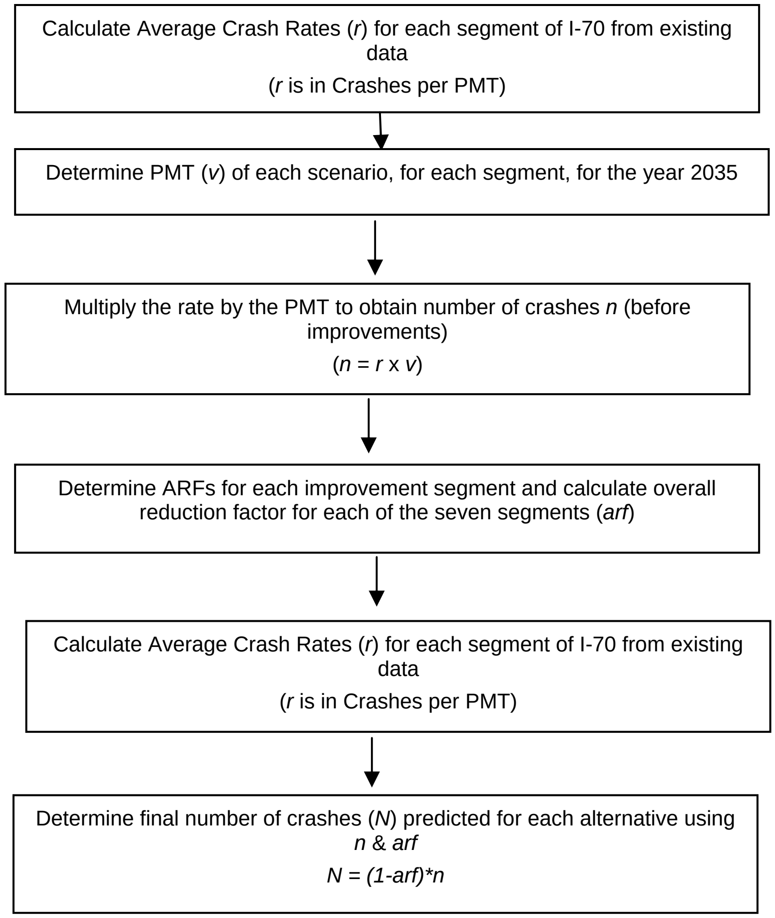
2.3.2 Calculation of Transit Crash Rates

Transit crash rates were calculated from the 2001 National Transit Database (NTD), from the average of systems with similar modes and fleet sizes. Because there is no Advanced Guideway System (AGS) currently in operation in the US, the safety goals in the Colorado Maglev Project "Task 3: Transit System Performance Requirements" were deemed reasonable estimates of AGS safety performance and were assumed as the crash rates for the AGS.

2.3.3 Safety Comparisons

To compare multimodal alternatives, fatality rates—the number of fatalities predicted per 100 million person miles (both Highway and Transit) —were evaluated for each alternative. **Figure 1** illustrates the process that was used to calculate the number of crashes for each alternative.

Figure 1. Flowchart for Calculating Number of Crashes for Each Alternative



Section 3. Existing Conditions

3.1 What safety problems currently exist in the Corridor?

For highway travel, high-crash locations are often associated with the geometric design of the roadway, physical constraints of the roadway, and inclement weather conditions. Existing safety problem areas are identified by a weighted hazard index (WHI) greater than zero, indicating an area with a higher weighted crash rate than the statewide average (measured by the number of observed crashes and their severity). WHI's were calculated for interchanges and mainline sections between interchanges.

A total of 32 locations were identified as having higher than average crash experience. These 32 locations were then analyzed further using a WHI criteria, which assigned priorities based on engineering judgment. These criteria provided a consistent basis for assigning priorities, which are described below:

- High Priority WHI greater than 2.0
- Medium Priority WHI between 1.0 and 2.0
- Low Priority WHI between 0.0 and 1.0
- Normal WHI less than 0.0

Six locations on I-70 were identified with WHI greater than 2.0, including:

1. West of Wolcott Curve
2. Westbound West side of Vail Pass
3. Eastbound EJMT to Herman Gulch
4. Westbound Morrison to Chief Hosa
5. Loveland Pass Interchange
6. Base of Floyd Hill

3.2 What are the crash rates in the corridor?

Crash rates were calculated using the crash rate formulas described in Section 2.2 for the seven sections of the Corridor, and are shown in **Table 1** below.

Table 1. Existing (2005) Crash Rates

Section	Property Damage	Injury	Fatality
C-470 to Hyland Hills	0.75	0.31	0.01
Hyland Hills to Empire Junction	0.90	0.47	0.02
Empire Junction to Loveland Pass	1.10	0.36	0.01
Loveland Pass to Silverthorne	0.81	0.37	0.01
Silverthorne to Vail Pass	0.51	0.19	0.02
Vail Pass to Edwards	1.09	0.41	0.00
Edwards to Glenwood Springs	0.57	0.21	0.00

Section 4. Future Conditions

4.1 What safety improvements were considered and included in the PEIS evaluation?

In addition to the existing safety problems identified in Section 3, future conditions were analyzed along the corridor to determine potential safety problems in the 2035 planning horizon. This analysis included the identification of potential safety issues at interchanges (including entry and exit ramps) and at sharp curves. An analysis of projected traffic was conducted at every interchange to determine if increased traffic would have an adverse impact on safety due to congestion.

A summary of the projected conditions is provided below.

4.2 Localized Highway Improvement Alternative Elements

4.2.1 Introduction

Localized Highway Improvements focus on reducing Corridor congestion and improving overall mobility and safety on the existing I-70 facility by making improvements to localized spots along the Corridor rather than adding capacity throughout the Corridor. This family includes an integrated package of localized highway improvement strategies that maximize the operational efficiency, safety, and person-moving capacity of the Corridor by correcting structural and functional deficiencies of interchanges, curves, and localized areas of congestion.

Localized Highway Improvement alternative elements can be implemented as stand-alone elements or integrated as a complement to other alternatives.

4.2.2 Alternative Elements Considered/Evaluated

The following three Localized Highway Improvement alternative elements are evaluated:

Interchange improvements**—**This alternative element consists of modifying structurally deficient and functionally obsolete interchanges to improve capacity in merging and weaving sections for more efficient entry onto or exit from I-70.

Many interchanges along the I-70 Mountain Corridor do not meet current standards. Some existing interchanges have substandard acceleration and deceleration lengths for entrance and exiting ramps. These types of roadway deficiencies are the cause of interchange capacity reduction and therefore result in safety problems, traffic delays and congestion on I-70 itself. The interchange improvements alternative element is to provide adequate roadway features that can approach or meet the current FHWA/CDOT design standards.

This alternative element includes extending the existing ramps to accommodate the increased traffic flow, adding acceleration and deceleration lanes to provide a smooth merge to I-70 mainline traffic, adding lanes to interchange on- and off-ramps to accommodate higher traffic demands, and considering interchange access consolidation. This alternative can also incorporate the usage of Travel Demand Management specific to interchanges, such as ramp metering.

Curve safety modifications**—**This alternative element is to replace sharp curves with smoother curves that better match the adjacent design speeds on I-70. This type of roadway geometric improvement can improve safety and increase the roadway capacity without adding additional lanes.

Auxiliary lanes—Provide additional lanes in key locations between interchanges to address localized congestion.

Interchange Improvements

Assessment of the need for improvement focused on mobility and capacity, as measured by the V/C ratio, and safety problems as measured by WHI and if ramp queues were backing up on to I-70, as well as local public support. See **Table 2** for details on the interchange improvements.

All interchanges are analyzed for improvements and given a priority rating of A, B, or C based on the criteria below.

- A priority rating of "A" is given if the interchange experiences severe congestion causing queues to back up onto mainline I-70 or if an interchange meets **both** of the following criteria:
  - V/C ratio greater than or equal to 1.00 and
  - WHI greater than or equal to 0.00.
- A priority rating of "B" is given if the interchange meets **either** of the following criteria:
  - V/C ratio greater than or equal to 1.00 or
  - WHI greater than or equal to 0.00 and public interest.
- A priority rating of "C" is given if the interchange meets **both** of the following criteria:
  - V/C ratio less than 1.00 and
  - WHI less than 0.00.

Table 2. Analysis of I-70 Interchanges

Name	WHI 2001 to 2005	2035 Critical V/C Ratio	Queues to Mainline in 2035	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
Glenwood Springs (milepost 116)	1.09	2.54	Yes	A	**Problem:** Inadequate westbound on-ramp and eastbound off-ramp geometry. Off-ramp traffic currently backs onto I-70. **Improvement:** Interchange improvements constitute the westernmost local safety and capacity improvement. Improvements include upgrades to all existing ramps, including widening and lengthening, and signalization of the interchanges on SH 82 at the bottom of the I-70 ramps.
Dotsero (milepost 133)	-1.73	0.31	No	C	Based on criteria, improvement not warranted.
Gypsum (milepost 140)	-0.62	2.23	Yes	A	**Problem:** Extensive development in western Eagle County is expected to result in excess travel demand at this unsignalized interchange. Future traffic is expected to backup onto I-70. **Improvement:** Upgrade stop signs to signals, which will improve capacity, mobility and safety.
Eagle & Spur Road (milepost 147)	-0.29	3.00	Yes	A	**Problem:** This interchange is expected to see traffic demand increasing with local development. There is inadequate ramp termini signal configuration. The spur road is currently overcapacity during peak hours. Future

Table 2. Analysis of I-70 Interchanges

Name	WHI 2001 to 2005	2035 Critical V/C Ratio	Queues to Mainline in 2035	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
					traffic is expected to back onto I-70. **Improvement:** Improvements reconstruct the interchange and increase the capacity of the spur road that connects I-70 and US 6.
Wolcott (milepost 157)	-0.80	1.35	No	B	**Problem:** The unsignalized intersections are inadequate for future demand. **Improvement:** This element adds traffic signals to improve capacity. Improvements will be examined in Tier 2.
Edwards & Spur Road (milepost 163)	0.62	1.94	Yes	A	**Problem:** Continued development in Edwards results in increased congestion at this interchange. There is inadequate ramp terminal signal configuration. The spur road is currently overcapacity during peak hours. Future traffic is expected to back onto I-70. **Improvement:** Improvements reconstruct the interchange and increase the capacity of the spur road that connects I-70 and US 6.
Avon (milepost 167)	1.53	1.40	Yes	A	**Problem:** The westbound off-ramp at Avon is anticipated to have traffic backing onto I-70 in the future. **Improvement:** The Avon interchange is modified with improved acceleration and deceleration lanes to create more capacity.
Minturn (milepost 171)	-0.09	2.51	No	B	**Problem:** The Minturn interchange is a partial-cloverleaf on a mainline curve. Tight ramp loops and the curves in the mainline contribute to a substantial crash rate. The eastbound off-ramp also has safety issues resulting from a single approach lane for both the through traffic to Minturn and the traffic turning right to go to Vail. **Improvement:** A separate right turn lane for the eastbound on-ramp traffic is provided, along with other minor reconstruction elements such as improving roadside lighting to improve safety and capacity. I-70 mainline curves are a separate issue that is addressed under curve safety.
Vail West/Simba Run (milepost 173)	1.63	1.40	Yes	A	**Problem:** The roundabouts at the Vail West Entrance carry heavy volumes of both local and regional traffic. The eastbound acceleration lane is too short and there is inadequate capacity to handle the high eastbound off-ramp volume. As a result, traffic currently backs onto eastbound I-70. **Improvement:** The improvement involves construction of the “Simba Run” underpass, which would connect the north and south frontage roads between the Vail West Entrance and Vail Main Entrance (milepost 176). This element relieves local traffic pressures on the interchange roundabouts and lengthens an inadequate eastbound on-

Table 2. Analysis of I-70 Interchanges

Name	WHI 2001 to 2005	2035 Critical V/C Ratio	Queues to Mainline in 2035	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
					ramp acceleration lane.
Vail (milepost 176)	0.59	0.87	No	C	Based on criteria, improvement not warranted.
Vail East (milepost 180)	0.79	0.92	No	C	Based on criteria, improvement not warranted.
Shrine Pass Rd. (milepost 190)	0.37	0.22	No	C	Based on criteria, improvement not warranted.
Copper Mountain (milepost 195)	1.89	0.66	No	B	**Problem:** Crashes primarily occur during adverse weather conditions, especially on eastbound on-ramp. Crashes also related to topography of roadway. **Improvement:** This local improvement modifies this interchange—also known as Wheeler Junction—to provide greater safety.
Officer's Gulch (milepost 198)	-0.25	0.04	No	C	Based on criteria, improvements not warranted.
Frisco/Main Street (milepost 201)	0.21	1.38	Yes	A	**Problem:** The unsignalized intersections are inadequate for future demand. Off-ramp traffic currently backs onto I-70. **Improvement:** This element replaces the current stop signs with traffic signals to improve capacity.
Frisco/SH 9 (milepost 203)	-0.23	1.63	No	B	**Problem:** The single-lane eastbound on-ramp has inadequate capacity. Ramp storage is inadequate for westbound off-ramp. The acceleration lane for the eastbound on-ramp is too short and is uphill. The primary issue is severe congestion on SH 9. **Improvement:** This improvement provides a two-lane eastbound on-ramp and acceleration lane approximately to the scenic overlook (milepost 202.5 to 203). The acceleration and deceleration lanes are lengthened. This allows southbound traffic on SH 9 to use both lanes throughout the town of Frisco, which helps to reduce or eliminate queuing at the multiple traffic signals. This increases the westbound off-ramp ramp storage.
Silverthorne (milepost 205)	1.93	2.39	Yes	A	**Problem:** High traffic volumes in the eastbound and westbound directions, along with several signalized intersections within a short distance, suggest need for redesign of interchange and adjoining intersections. Future off-ramp traffic is expected to back onto I-70 and significant congestion on US 6 and US 9 is also expected. **Improvement:** Rebuilding the interchange -likely as a single-point urban interchange (SPUI)—mitigates congestion and safety issues.
Loveland Pass (milepost 216)	4.53	0.66	No	B	**Problem:** Safety and capacity problems because of short merges in the eastbound and westbound directions.

Table 2. Analysis of I-70 Interchanges

Name	WHI 2001 to 2005	2035 Critical V/C Ratio	Queues to Mainline in 2035	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
					Improvement: This improvement provides longer acceleration and deceleration lanes at the Loveland Pass interchange. This results in greater capacity and safer merging.
Herman Gulch (milepost 218)	-0.87	0.03	No	C	Based on criteria, improvement not warranted.
Bakerville (milepost 221)	-0.93	0.16	No	C	Based on criteria, improvement not warranted.
Silver Plume (milepost 226)	0.91	0.21	No	B	**Problem:** There is public interest in moving the western ramps because the ramps are short (capacity problem) and very close to existing development. **Improvement:** The western ramps are moved to the location about 1 mile to the west where I-70 goes over the frontage road. At this new location, greater ramp capacity is provided.
Georgetown (milepost 228)	0.79	2.05	Yes	A	**Problem:** Unsignalized intersections are inadequate for future demand. Future traffic is expected to back onto I-70. **Improvement:** Proposed improvements are to signalize the ramps, provide turn bays, and build a roundabout at Argentine Street, which improve capacity.
Empire (milepost 232)	0.78	1.10	No	A	**Problem:** High eastbound traffic volumes, curve in road, and insufficient acceleration and deceleration lanes for the on- and off-ramps cause crashes in the ramp influence area; primarily a safety issue. **Improvement:** To improve safety, longer eastbound acceleration and deceleration lanes are provided.
Lawson (milepost 233)	-0.86	0.63	No	C	Based on criteria, improvement not warranted.
Downieville (milepost 234)	0.44	1.94	Yes	A	**Problem:** The north side of the Downieville interchange has two unsignalized intersections within about 50 feet of each other, where the crossroad meets up with the westbound ramps and then the frontage road. The intersections have limited capacity and often cause long queues on the frontage road today. Future traffic is expected to back onto the I-70 roadway. **Improvement:** Providing traffic signals at ramps and the four-way stop at the frontage road as well as providing turn bays improves capacity.
Dumont (milepost 235)	-0.13	0.50	No	C	Based on criteria, improvement not warranted.

Table 2. Analysis of I-70 Interchanges

Name	WHI 2001 to 2005	2035 Critical V/C Ratio	Queues to Mainline in 2035	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
Fall River Road (milepost 238)	-0.86	1.64	No	B	**Problem:** Eastbound off-ramp and westbound acceleration lane are inadequate. Fall River Road is not connected to the frontage road, which creates additional traffic. **Improvement:** Minor ramp modifications are made. Additionally, a spur road is constructed over Clear Creek to connect the interchange with the frontage road. The spur road, which provides a direct connection to the frontage road, removes local traffic from I-70 and improves local access. Improvements at the Fall River Road interchange address capacity issues.
Idaho Springs West (milepost 239)	-0.34	>2.00	No	B	**Problem:** At the intersection of the ramps and the frontage road, there are high levels of congestion, which affects I-70. **Improvement:** The intersection of the off-ramp and the frontage road and ramp geometry is modified, improving traffic flow.
Idaho Springs/SH 103 (milepost 240)	-0.67	1.58	No	B	**Problem:** There are no turn bays between ramp terminals and the ramps are narrow. There is also active pedestrian use. **Improvement:** Ramps are modified to improve pedestrian safety and left-turn bays are provided on the crossroad. Traffic flow is improved at ramp intersections.
Idaho Springs East (milepost 241)	-0.86	1.93	Yes	A	**Problem:** The eastbound off-ramp gets congested due to high through traffic on to the eastbound on-ramp. Acceleration and deceleration lanes are inadequate. There are very sharp curves for ramps with design speeds of 10 to 20 miles per hour. Currently, the heavy eastbound on-ramp volume blocks traffic using the eastbound off-ramp during peak hours. Future traffic is expected to back onto I-70. **Improvement:** This interchange is rebuilt with sufficiently long acceleration and deceleration lanes. The two loop off-ramps with 15 miles per hour advisory speeds are replaced, allowing safer and more efficient movement of local traffic.
Hidden Valley (milepost 243)	-1.56	0.56	No	C	Based on criteria, improvement not warranted.
Base of Floyd Hill/US 6 (milepost 244)	2.74	0.56	No	B	**Problem:** The westbound on-ramp is at the base of a steep hill, on a sharp curve, has a sight distance problem, and feeds a high traffic volume onto a highway that is often near capacity during peak hours before the merge. This is a critical safety issue in an area with very high demand.

Table 2. Analysis of I-70 Interchanges

Name	WHI 2001 to 2005	2035 Critical V/C Ratio	Queues to Mainline in 2035	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
					Improvement: This interchange is rebuilt with right-handed exit and entrance ramps to improve safety. Reconstruction of the interchange may result in a safer, higher design speed curve on the I-70 roadway. Capacity of the sub-standard westbound on-ramp is improved, lessening congested conditions that currently occur.
Hyland Hills (milepost 247)	-0.02	2.39	Yes	A	**Problem:** High volume traffic going from westbound off-ramp to frontage road can cause traffic to back onto I-70. Eastbound off-ramp has glare issues. Future traffic is also expected to back onto I-70. **Improvement:** The Hyland Hills interchange includes modified ramps to increase capacity and address glare issues.
Beaver Brook (milepost 248)	-0.02	2.39	Yes	A	**Problem:** High volume traffic going from westbound off-ramp to frontage road can cause traffic to back onto I-70. Eastbound off-ramp has glare issues. Future traffic expected to back onto I-70. **Improvement:** The Beaver Brook interchange includes modified ramps to increase capacity and address glare issues.
El Rancho (milepost 251)	-0.47	0.29	No	C	Based on criteria, improvement not warranted.
Evergreen/SH 74 (milepost 252)	-0.57	1.06	No	C	This interchange did not warrant an improvement during initial screening. More recent data shows a V/C ratio minimally over 1.00, therefore the C rating is retained. This interchange will be reexamined during Tier 2 with updated data.
Chief Hosa (milepost 253)	-0.83	0.77	No	C	Based on criteria, improvement not warranted.
Genesee (milepost 254)	-0.27	0.75	No	C	Based on criteria, improvement not warranted.
Lookout Mountain (milepost 256)	1.04	1.64	Yes	A	**Problem:** Unsignalized intersections are inadequate for future demand. There are no turn bays between the ramp terminals. Future traffic expected to back onto I-70. **Improvement:** The interchange is rebuilt to address future increases in demand.
Morrison (milepost 259)	-0.06	1.27	No	B	**Problem:** Future demand at this interchange with the Hogback park-and-ride would cause traffic to back onto I-70. **Improvement:** Improvements to help operations associated with the expanded Hogback park-and-ride facility at this interchange were recently completed. These improvements included an additional left turn lane for eastbound on-ramp traffic and a westbound acceleration lane with improvements at each on- and off-ramp as they intersect US 40.

Of the 40 interchanges evaluated for the Corridor, 15 were eliminated during the Level 3 screening. Assessment of the need for improvement focused on capacity, as measured by the V/C ratio, and safety problems as measured by WHI, and local public support. Based on a V/C ratio less than 1.00 and WHI less than 0.00, the following interchanges do not require any improvements and are eliminated from further consideration:

- Dotsero (milepost 133)
- Wolcott (milepost 156)
- Vail (milepost 176)
- Vail East Entrance (milepost 180)
- Vail Pass (Shrine Pass Road) (milepost 190)
- Officers Gulch (milepost 198)
- Herman Gulch (milepost 218)
- Bakerville (milepost 221)
- Lawson (milepost 233)
- Dumont (milepost 235)
- Hidden Valley (milepost 243)
- El Rancho (milepost 251)
- Evergreen Parkway/SH 74 (milepost 252)
- Chief Hosa (milepost 253)
- Genesee (milepost 254)
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Curve Safety Modifications

The need for the curve safety modifications in the Corridor is based on safety – as determined by WHI – and curve design – as determined by the design speed of the curve. A WHI threshold of 2.00 was selected because curves are generally more prone to crashes and high WHI values are not uncommon. Substandard design corresponds to locations where the highway design speed on the curves is less than the posted speed limit as well as adjacent portions of the highway. V/C ratio information is not applicable to the curve safety analysis.

Curves are given a priority rating of A, B, or C depending on the following critieria.

- An "A" rating is given if the curve meets **both** of the following criteria:
  - WHI greater than 2.00 <u>and</u>
  - Design speed less than 65 mph
- A "B" rating is given if the curve meets **either** of the following criteria
  - WHI greater than 2.00 or
  - Design speed less than 65mph
- A "C" rating is given if the curve meets **neither** of the following criteria:
  - WHI less than 2.00 <u>nor</u>
  - Design speed less than 65mph

Of the five curves identified for potential safety modifications, one was eliminated during Level 3 screening. Based on a WHI less than 2.00 and a 65 mph design speed, the "East of Wolcott Interchange" curve did not warrant any improvements and was eliminated from further consideration. See **Table 3** for details on each of the curve safety modifications.

Table 3. Curve Safety Analysis

Name	WHI 2001 to 2005	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
East of Wolcott Interchange (mileposts 158-159)	1.38	C	Based on criteria, improvement not warranted.
West of Wolcott Interchange (mileposts 155-156)	2.01	A	**Problem:** The design speed of the curve is less than that for surrounding portions of the highway. There is a critical safety issues in an area with relatively less demand. **Improvement:** Curve safety modifications improve safety.
Dowd Canyon (mileposts 170-173)	1.89	B	**Problem:** The design speed of the curve is less than that for surrounding portions of the highway. There is a critical safety issues in an area with very high demand. **Improvement:** Curve safety modifications improve safety.
Fall River Road (mileposts 237-238)	1.43	B	**Problem:** The design speed of the curve is less than that for surrounding portions of highway. There is a high amount of incident-related delay; not a major capacity issue. **Improvement:** Curve safety modifications improve safety.
East of Twin Tunnels to US 6 (mileposts 242-245)	1.16	B	**Problem:** The design speed of the curve is less than that for surrounding portions of the highway. There is a critical safety issues in an area with very high demand. **Improvement:** Curve safety modifications improve safety.

Auxiliary Lanes

The need for auxiliary lanes was assessed on the basis of capacity, mobility and safety. Capacity and mobility issues were determined based on substandard design. Substandard design issues include tight interchange spacing (less than 2 miles), steep grades, and inadequate acceleration or deceleration lanes. Safety issues were identified for locations with high WHI values. A threshold of 2.5 was selected because merge and diverge areas are generally more prone to crashes and high WHI values are not uncommon.

Auxiliary lanes were analyzed and given a priority rating of A, B, or C based on the criteria below:

- A priority rating of “A” is given if an auxiliary lane location meets **both** of the following criteria:
  - WHI greater than 2.50 and
  - substandard geometry
- A priority rating of “B” is given if an auxiliary lane location meets **either** of the following criteria:
  - WHI greater than 2.50 or
  - substandard geometry
- A priority rating of “C” is given if an auxiliary lane location meets **neither** of the following criteria:
  - WHI greater than 2.50 nor
  - substandard geometry

Volume-to-capacity ratios, WHI values, and design issues are presented with the assigned priority rating and potential improvements for auxiliary lanes in **Table 4**.

Of the 14 potential locations identified for auxiliary lanes, two were eliminated during Level 3 screening. Based on a WHI of greater than 2.5 and substandard design, the "Chief Hosa to Genessee, Flat" potential auxiliary lane location and the "US 6 to Hyland Hills" potential auxiliary lane location did not warrant any improvements and were eliminated from further consideration.

Table 4. Analysis of I-70 Auxiliary Lanes

Name	WHI 2001 to 2005	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
Avon to Post, Uphill (Eastbound) (mileposts 167-168)	-0.45	B	**Problem:** I-70 between Avon (milepost 167) and Post Boulevard (milepost 168) is uphill. Traffic merging from the Avon on-ramp has difficulty accelerating on the grade and finding sufficient gaps for merging. Traffic attempting to get from I-70 to the Post Boulevard off-ramp creates a problematic weaving issue. The interchanges are only 1 mile apart. **Improvement:** An auxiliary lane between these two interchanges increases safety and improves merge capacity. It also allows local traffic to stay in the auxiliary lane and not affect I-70 mainline.
West Side of Vail Pass, Uphill (Eastbound) (mileposts 180-190)	1.34	B	**Problem:** Steep 7 percent grades limit the highway capacity. Demand is expected to exceed capacity occasionally in the future. **Improvement:** A new eastbound auxiliary lane provides additional capacity by allowing more space for fast-moving vehicles to pass slow-moving vehicles struggling with the steep grades.
West Side of Vail Pass, Downhill (Westbound) (mileposts180-190)	4.78	A	**Problem:** There is a high amount of incident-related delay possible because of adverse weather conditions, steep grades and curves; not a major capacity issue. **Improvement:** Curve smoothing, more intensive winter maintenance practices with ice sensors and better signage helps to reduce the number of crashes. A westbound auxiliary lane is primarily a safety improvement, reducing the likelihood of rear-end collisions with slow-moving vehicles and also providing an increase in roadway capacity. Reducing the frequency of crashes also reduces the delay associated with clearing the disabled vehicles.
Frisco to Silverthorne (Eastbound) (mileposts 202.7-205.1)	0.23	B	**Problem:** Travel demand west of Silverthorne from local trips combined with through traffic results in Level of Service (LOS) F for eastbound travel between Frisco and Silverthorne. **Improvement:** An eastbound auxiliary lane is added between Frisco and Silverthorne starting east of the recent eastbound on-ramp extension at the Silverthorne SH 9 interchange. The addition of an eastbound auxiliary lane improves traffic operations and substantially reduces the number of hours of LOS F in the Frisco/Silverthorne area.- congestion
Eisenhower-Johnson Memorial Tunnels to Herman Gulch, Downhill (Eastbound) (mileposts 215-218)	2.56	A	**Problem:** The eastbound lanes from the Eisenhower-Johnson Memorial Tunnels' east portal to Herman Gulch currently experience an above-average crash rate related to narrow shoulders, steep grades, and an unexpected left-lane drop before the Loveland Pass on-ramp merge. There is an unusual existing lane configuration, with two lanes expanding to three at the Eisenhower-Johnson Memorial Tunnels and then merging back to two lanes shortly before eastbound on-ramp merge. There is a highly substandard 2-foot shoulder between the Loveland Pass off- and on-ramps. The lack of shoulders and an atypical left lane merge are not expected by drivers.

Table 4. Analysis of I-70 Auxiliary Lanes

Name	WHI 2001 to 2005	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
			Improvement: This improvement provides three standard, continuous eastbound lanes to address the safety and congestion issues in this portion of I-70. Shoulders are also improved to standard width throughout the section.
Bakerville to Eisenhower-Johnson Memorial Tunnels, Uphill (Westbound) (mileposts 215-221)	1.10	A	**Problem:** There is a high concentration of rear-end crashes around the Loveland Pass westbound on-ramp and around the Bakerville interchange. Steep grades westbound from the Bakerville interchange (milepost 221) to the east portal of the Eisenhower-Johnson Memorial Tunnels (milepost 215) cause large disparities in speed between vehicles in different weight classes. These differences in speed reduce capacity and make rear-end crashes more likely. **Improvement:** The addition of a climbing lane reduces the crashes, especially rear-end and sideswipe crashes. The additional lane also improves capacity in this area.
Georgetown to Silver Plume, Uphill (Westbound) (mileposts 226-228)	0.23	B	**Problem:** Steep 6 percent grades limit the highway capacity. Traffic demand is limited by two lanes east of Empire Junction. **Improvement:** A new westbound auxiliary lane provides additional capacity by allowing more space for fast-moving vehicles to pass slow-moving vehicles struggling with the steep grades.
Silver Plume to Georgetown, Downhill (Eastbound) (mileposts 226-228)	0.68	B	**Problem:** There is a high number of rear-end, sideswipe, and fixed-object crashes and a high amount of incident-related delay possible because of steep grades and curves; not a major capacity issue. **Improvement:** An eastbound auxiliary lane is a safety improvement, reducing the likelihood of rear-end, sideswipe, and fixed-object crashes and also providing an increase in roadway capacity. Reducing the frequency of crashes also reduces the delay associated with clearing the disabled vehicles.
Downieville to Empire, Uphill (Westbound) (mileposts 232-234)	-0.89	A	**Problem:** Westbound on-ramp traffic at Downieville, including vehicles stopping at the weight station, enters I-70 on a steep upgrade. There are also weaving concerns with traffic exiting at Empire Junction. **Improvement:** A westbound auxiliary lane mitigates safety and capacity issues caused by steep grades and minimizes the impact of the weigh station. The lane carries through to Empire Junction where I-70 mainline traffic demand decreases substantially.
Empire to Downieville, Downhill (Eastbound) (mileposts 232-234)	0.64	B	**Problem:** Rear-end crashes occur due to vehicles slowing, stopping in traffic, or changing lanes. There is a high amount of incident-related delay possible; not a major capacity issue. **Improvement:** An eastbound auxiliary lane is a safety improvement, reducing the likelihood of rear-end crashes and also providing an increase in roadway capacity. Reducing the frequency of crashes also reduces the delay associated with clearing the disabled vehicles.
US 6 Off-ramp to Hidden Valley Off-ramp, Uphill (Westbound) (mileposts 243-244)	0.03	A	**Problem:** If the Black Hawk Tunnel is not built, through traffic and traffic heading to the Central City Parkway combine to substantially exceed the capacity of this section. **Improvement:** An additional auxiliary lane is added to provide increased capacity for traffic.
US 6 to Hyland Hills, Uphill (Eastbound) (mileposts 244-247)	-0.81	C	**Problem:** There is an uphill capacity issue. **Improvement:** Based on criteria, improvement is not warranted..

Table 4. Analysis of I-70 Auxiliary Lanes

Name	WHI 2001 to 2005	Priority Rating	Descriptions of Problem Areas and Proposed Improvements
Chief Hosa to Genesee, Flat (Eastbound) (mileposts 252-253)	-0.89	B	While an auxiliary lane allows local traffic to stay in a separate lane from Evergreen to Genesee, there is insufficient demand to warrant improvement. Also, based on criteria, improvement is not warranted.
Morrison to Chief Hosa, Uphill (Westbound) (mileposts 253-259)	3.01	A	**Problem:** Steep 7 percent grades limit the highway capacity. Increased demand in the future will turn this section into a substantial bottleneck. **Improvement:** An additional westbound auxiliary lane provides additional capacity up this steep section with the highest traffic volumes in the Corridor.

4.2.3 Alternative Elements Advanced for Evaluation in the PEIS

Localized Highway Improvement alternative elements advanced for consideration in the PEIS include interchange improvements, curve safety modifications, and auxiliary lanes.

Interchange improvements—A majority of the interchanges in the I-70 Mountain Corridor are structurally deficient and/or functionally obsolete, or will be by 2035. Of the 40 interchanges evaluated for the Corridor, 25 were advanced for improvement. Assessment of the need for improvement focused on capacity (current or future traffic performance/congestion), safety problems, and local public support. The interchange improvement locations advanced include:

- Glenwood Springs (milepost 116)
- Gypsum (milepost 140)
- Eagle & Spur Road (milepost 147)
- Wolcott (milepost 157)
- Edwards & Spur Road (milepost 163)
- Avon (milepost 167)
- Minturn (milepost 171)
- Vail West/Simba Run (milepost 173)
- Copper Mountain (milepost 195)
- Frisco/Main Street (milepost 201)
- Frisco/SH 9 (milepost 203)
- Silverthorne (milepost 205)
- Loveland Pass (milepost 216)
- Silver Plume (milepost 226)
- Georgetown (milepost 228)
- Empire (milepost 232)
- Downieville (milepost 234)
- Fall River Road (milepost 238)
- Idaho Springs West (milepost 239)
- Idaho Springs/SH 103 (milepost 240)
- Idaho Springs East (milepost 241)
- Base of Floyd Hill/US 6 (milepost 244)
- Hyland Hills (milepost 247)
- Beaver Brook (milepost 248)
- Lookout Mountain (milepost 256)
- Morrison (milepost 259)

Curve safety modifications—Of the five locations of concern for curve safety, four were advanced for full analysis in the PEIS. The need was based on mobility where the speed on the curves was less than the surrounding portions of the highway, and safety issues where the WHI was greater than 0.00, ranging from 1.90 to 7.00. The four curve safety modification locations advanced include:

- West of Wolcott Interchange (mileposts 155-156)
- Dowd Canyon (mileposts 170-173)
- Fall River Road (mileposts 237-238)
- East of Twin Tunnels to US 6 (mileposts 242-245)

Auxiliary lanes—Of the 14 potential auxiliary lane locations, 12 were advanced for analysis in the PEIS. The need was assessed on the basis of mobility, and safety measured by a WHI greater than 2.5 and substandard design. Auxiliary lanes for slow-moving vehicles, primarily located in areas of steep grades, increase the capacity of a highway for relatively short lengths. The auxiliary lane locations advanced include:

Eastbound auxiliary lanes are located:

- Avon to Post Boulevard, Uphill (mileposts 167-168)
- West Side of Vail Pass, Uphill (mileposts 180–190)
- Frisco to Silverthorne (mileposts 202.7–205.1)
- Eisenhower-Johnson Memorial Tunnels to Herman Gulch, Downhill (mileposts 215–218)
- Silver Plume to Georgetown, Downhill (mileposts 226–228)
- Empire to Downieville, Downhill (mileposts 232–234)

Westbound auxiliary lanes are located:

- West Side of Vail Pass, Downhill (mileposts 180-–190)
- Bakerville to Eisenhower-Johnson Memorial Tunnels, Uphill (mileposts 215–221)
- Georgetown to Silver Plume, Uphill (mileposts 226–228)
- Downieville to Empire, Uphill (mileposts 232–234)
- US 6 Off-ramp to Hidden Valley Off-ramp, Uphill (mileposts 243–244)
- Morrison to Chief Hosa, Uphill (mileposts 253–259)

4.3 What is the forecasted safety performance of each alternative?

Every Build alternative was evaluated for how well it protects I-70 Mountain Corridor travelers. Alternatives that include a Fixed Guideway Transit component provide a safer means of transportation for travelers than highway vehicle travel. National crash rates for rail modes are markedly lower than the comparable rates for motor vehicles [crash rate statistics of fatalities and injuries per passenger mile indicate that Fixed Guideway Rail Transit is approximately 100 times safer than automobile travel (National Transportation Statistics 2010, Bureau of Transportation Statistics, USDOT, 2010)]. Buses operating in general purpose lanes are on average safer than automobile travel, but not as safe as rail technologies in fixed guideways. No separate statistics are available at a national level for buses operating in a separate guideway.

The Minimal Action highway components included in all of the Action Alternatives were developed to address high-priority safety problem areas as discussed in **Sections 3.2 and 4.2** of this technical report. For this reason the Action Alternatives are not substantially different in terms of highway safety. The safety problem areas in the Corridor addressed by all Action Alternatives include:

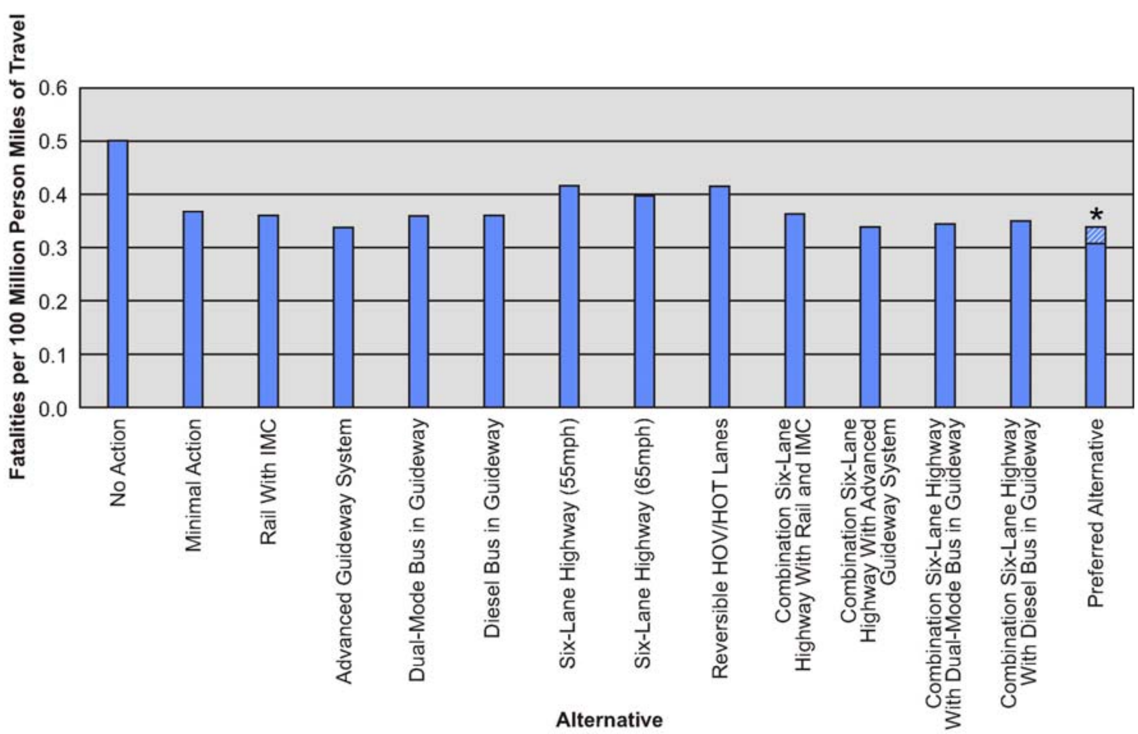
- Wolcott curve
- Dowd Canyon (not included with the Transit Alternatives)
- Silverthorne Interchange
- Eisenhower-Johnson Memorial Tunnels to Herman Gulch (eastbound)
- Base of Floyd Hill (Twin Tunnels to the US 6 interchange).

Figure 2 shows the overall multimodal fatality rate by alternative. Fatality rates were used for comparison as the best measure of safety collected consistently among the transportation modes. These blended rates reflect the relative amount of person trips using each mode and are based on projected fatalities per mode per 100 million person miles of travel. This calculation includes the application of the ARFs from CDOT for every improvement included in each alternative.

The No Action Alternative is projected to have a fatality rate of 0.50 per 100 million person miles. In comparison, the Minimal Action Alternative, with its components that address most highway safety problems, has a rate of 0.37. Highway Alternatives are higher, with fatality rates that range between 0.40 and 0.42, because traffic is increased in those alternatives and therefore more crashes are projected. Alternatives with transit, reflecting different transit technologies and usage, have rates ranging from 0.31 to 0.36. The Preferred Alternative has a fatality rate ranging from 0.31 to 0.34 per 100 million person miles.

Table 5 displays the fatality rates by mode in 2035 for each alternative and **Table 6** displays the annual crashes projected in 2035.

Figure 2. Fatality Rates by Alternative



* The Maximum Program Range presents the range of impacts that could occur with the Preferred Alternative. The solid bar represents the implementation of the Minimal Program only. The hatched bar area shows the range of the Maximum Program. It is presented as a range because the adaptive management component of the Preferred Alternative allows it to be implemented based on future needs and associated triggers for further action. The top end of the bar represents the full implementation of the Maximum Program. Section 2.7 of this document describes the triggers for implementing components of the Preferred Alternative.

Table 5. 2035 Crash Rates by Alternative and Mode

	Highway crash rates (per million person miles of travel)			Transit crash rates						Overall crash rates		
	Total	Injury	Fatality	Total (I-70 System)	Injury (I-70 System)	Fatality (I-70 System)	Total (Existing Systems)	Injury (Existing Systems)	Fatality (Existing Systems)	Total	Injury	Fatality
No Action Alternative	0.66	0.19	0.51	N/A	N/A	N/A	0.68	0.36	0.08	0.66	0.19	0.50
Minimal Action Alternative	0.53	0.15	0.38	0.88	0.57	0.07	0.68	0.36	0.08	0.54	0.16	0.37
Rail with IMC	0.59	0.15	0.40	0.50	0.27	0.11	0.68	0.36	0.08	0.58	0.17	0.36
Advanced Guideway System (AGS)	0.59	0.15	0.40	0.1	0.1	0.0	0.68	0.36	0.08	0.52	0.15	0.34
Dual-Mode Bus in Guideway	0.60	0.16	0.41	0.88	0.57	0.07	0.68	0.36	0.08	0.64	0.21	0.36
Diesel Bus in Guideway	0.60	0.16	0.41	0.88	0.57	0.07	0.68	0.36	0.08	0.63	0.21	0.36
6-Lane Highway 55 mph	0.56	0.15	0.42	N/A	N/A	N/A	0.68	0.36	0.08	0.56	0.15	0.42
6-Lane Highway 65 mph	0.55	0.14	0.40	N/A	N/A	N/A	0.68	0.36	0.08	0.55	0.14	0.40
Reversible/ HOV/HOT Lanes	0.56	0.15	0.42	N/A	N/A	N/A	0.68	0.36	0.08	0.57	0.15	0.42
6-Lane Highway with Rail and IMC	0.56	0.14	0.41	0.50	0.27	0.11	0.68	0.36	0.08	0.55	0.17	0.36
6-Lane Highway with AGS a/k/a Maximum Program 55 mph	0.55	0.14	0.41	0.10	0.10	0.00	0.68	0.36	0.08	0.49	0.14	0.34
6-Lane Highway with Dual-Mode Bus in Guideway	0.55	0.14	0.39	0.88	0.57	0.07	0.68	0.36	0.08	0.60	0.20	0.34
6-Lane Highway with Diesel Bus in Guideway	0.55	0.14	0.39	0.88	0.57	0.07	0.68	0.36	0.08	0.60	0.20	0.35
Minimum Program of Improvements (65 mph)	0.52	0.14	0.37	0.10	0.10	0.00	0.68	0.36	0.08	0.46	0.14	0.31
Maximum Program of Improvements (65 mph)	0.54	0.14	0.39	0.10	0.10	0.00	0.68	0.36	0.08	0.47	0.14	0.32

Table 6. 2035 Annual Crashes by Alternative and Mode

	Highway annual crashes			Transit annual crashes						Overall annual crashes		
	Annual Incidents - Total	Annual injuries	Annual fatalities	Annual Crashes (I-70 system)	Annual injuries (I-70 system)	Annual fatalities (I-70 system)	Annual Incidents: existing systems	Annual injuries: existing systems	Annual fatalities: existing systems	Annual Crashes	Annual injuries	Annual fatalities
No Action Alternative	3,228	906	25	N/A	N/A	N/A	36	19	0	3,264	925	25
Minimal Action Alternative	2,572	721	18	74	48	0	26	14	0	2,672	782	18
Rail with IMC	2,780	727	19	349	193	1	84	45	0	3,213	965	20
Advanced Guideway System (AGS)	2,770	724	19	86	86	-	54	29	0	2,910	839	19
Dual-Mode Bus in Guideway	2,802	733	19	674	436	1	18	10	0	3,494	1,178	20
Diesel Bus in Guideway	2,806	733	19	663	428	1	17	9	0	3,485	1,170	20
6-Lane Highway 55 mph	3,083	800	23	N/A	N/A	N/A	34	18	0	3,117	818	23
6-Lane Highway 65 mph	2,994	775	22	N/A	N/A	N/A	34	18	0	3,028	793	22
Reversible/ HOV/HOT Lanes	3,087	801	23	N/A	N/A	N/A	33	18	0	3,120	819	23
6-Lane Highway with Rail and IMC	2,808	730	21	368	203	1	87	47	0	3,263	980	22
6-Lane Highway with AGS a/k/a Maximum Program 55 mph	2,791	725	20	94	94	-	57	31	0	2,941	850	20
6-Lane Highway with Dual-Mode Bus in Guideway	2,773	724	20	733	474	1	21	11	0	3,527	1,209	20
6-Lane Highway with Diesel Bus in Guideway	2,788	728	20	686	444	1	18	10	0	3,492	1,181	20
Minimum Program of Improvements (65 mph)	2,575	721	18	89	89	-	55	29	0	2,718	839	18
Maximum Program of Improvements (65 mph)	2,710	703	20	94	94	-	57	31	0	2,861	827	20

Section 5. Findings and Considerations for the Tier 2 Process

The safety performances measures considered during the Tier 1 process were based on the performance of each alternative for the entire Corridor. The Preferred Alternative was determined to provide good overall safety performance for the Corridor.

During Tier 2 processes, individual improvements will be evaluated in greater detail and safety assessments will be performed to determine relative safety performance for each specific project.