Technical Support for Mobility IH-35 - Traffic Safety Evaluation

1. Task Description and Objectives

The purpose of this task is to perform an independent evaluation and review of the IH 35 Capital Expressway South Project relative to No Build Alternative, Alternative 1 with two proposed at-grade managed lanes in each direction and the Proposed Build Alternative with two proposed elevated managed lanes in each direction. As an essential component of the traffic engineering evaluation, the safety analysis intends to determine the predicted change in crash-related measures and operations. This study synthesizes and documents key findings from the safety analysis with respect to five major aspects as follows:

- Number of Conflict Points (locations where vehicle paths merge, diverge, or cross)
- Disproportionate crash history with regards to environmental justice (EJ)
- Total reduction in crashes (broken down by local ethnicity demographic for EJ consideration)
- Number of severe crashes expected to be prevented (broken down by local ethnicity demographic for EJ consideration)
- Anticipated reduction in crash rates

In this study, safety impacts, covering the project limits from STA 3480+00 to STA 3650+00, of the following three scenarios were thoroughly investigated and compared:

1) The No Build Alternative, where no modification is proposed to improve the existing structure;
2) Alternative 1 (A1): refers to the IH-35 improvement schematic introducing an additional two High-Occupancy Vehicle (HOV) managed lanes (each direction) at grade;
3) The Proposed Build Alternative, where two elevated High-Occupancy Vehicle (HOV) managed lanes (each direction) are proposed.

2. Data Collection and Integration

To perform the safety analysis, various data sources were identified. Then, relevant data was obtained either directly from TxDOT Austin District or from a publicly accessible open data portal, e.g., Google Earth and TxDOT Open Data Portal (https://gis-txdot.opendata.arcgis.com/). Specifically, these data sources include:

- Design schematics in .PDF, .DGN and .KMZ formats
- Google Earth Satellite Maps
- Texas Roadway Inventory Database (TRID)
- Texas Crash Records Information System (CRIS)
- Texas Highway Curvature GIS Layer

Since what is essential to this study is to predict the number of expected crashes for A1 and the Proposed Build Alternative, the study team employed the negative binomial regression technique to perform the prediction, considering that negative binomial regression can better characterize over-dispersed count data and yield more accurate prediction. In order to conduct the regression analysis, the process includes: 1) identify a series of potential significant factors that contribute to the crashes; 2) develop reference groups of highway segments that have similar characteristics to the No Build Alternative, A1, and the Proposed

Build Alternative; 3) obtain crash history information for each of the roadway segments in the reference group; and 4) conduct regression analysis.

The Texas Roadway Inventory Database (TRID) was used as the primary data source, from which the following parameters identified and retrieved:

- Indicators for Urban or Rural
- Functional Classification
- Number of Lanes
- Lane Width (ft)
- Median Type
- Shoulder Type
- Shoulder Width – Inside (ft)
- Shoulder Width – Outside (ft)
- Annual Average Daily Traffic (AADT)
- Truck AADT
- Speed Limit (mph)

Highway curvature information was obtained from Texas Highway Curvature GIS Map Layer. A comprehensive database that integrates TRID, CRIS, and Texas Highway Curvature information was created.

3. Safety Analysis

3.1. Number of Conflict Points

Design schematics were provided by TxDOT Austin District in PDF, .DGN, and .KMZ files. The length of the project is 17,000 feet (STA 3480+00 to STA 3650+00), or approximately 3.22 miles. For this analysis, the conflict points were identified by sketch drawing. The PDF schematics were used for A1 and the Proposed Build Alternative, and the Google Earth satellite imageries were used for the No Build Alternative. Two scenarios were considered in this study to address two different driver behaviors for vehicle maneuvers from the frontage road to the managed lanes specifically for A1. Scenario 1 assumes that drivers cut across the general-purpose lanes to merge onto the managed lanes immediately after merging to general purpose lanes from the frontage road. Scenario 2 assumes that drivers, once maneuvered to the general purpose lane from the frontage entrance ramp, merge one lane at a time across the general purpose lanes and then to the managed lanes. In both scenarios, there are merging and diverging conflict points. In addition, Scenario 1 has crossing conflict points. More specifically, merging conflict points occur at places where traffic merges into the traffic of direct flow from an adjacent lane; diverging conflict points occur at places where traffic diverges from the direct flow path; and crossing points occur at places where cut-through traffic path intersects with the direct flow path. Figure 1 illustrates an example of all three types of conflict points.

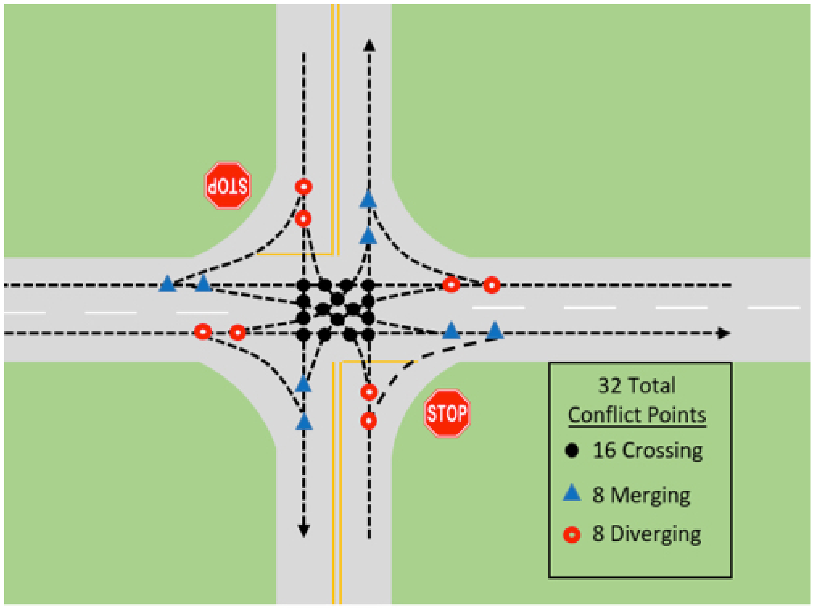

Figure 1. Illustration of Conflict Points

The total number of conflict points was determined for all three alternatives (the No Build Alternative, A1, and the Proposed Build Alternative) under two scenarios for both directions. The results are summarized and presented in Table 1.

Table 1. Summary and Comparison of Total Number of Conflict Points

Scenario	The No Build Alternative	A1 (vs. the No Build Alternative)	The Proposed Build Alternative (vs. the No Build Alternative)	The Proposed Build Alternative vs. A1 (%)
1	11	19 (+72%)	5 (-55%)	-14 (-74%)
2	11	26 (+136%)	5 (-55%)	-21 (-81%)

As can be seen from Table 1, due to the addition of two at-grade managed lanes, A1 has a 72% and 136% increase in number of conflict points compared with the No Build Alternative for Scenario 1 and Scenario 2, respectively. In the case of the Proposed Build Alternative with elevated managed lanes, there is a 55% reduction in conflict points compared with the No Build Alternative for both Scenario 1 and Scenario 2. In addition, when the Proposed Build Alternative is compared to A1, the reduction in conflict points is 74% and 81% for Scenario 1 and Scenario 2, respectively. Based on the schematic drawings, the travel distance in A1 that might pose maneuver safety risks is approximately 0.9 miles, which was determined using the length of the roadway from the point where the frontage road entrance ramp is located to the point where traffic is allowed to merge on to the managed lanes. This travel distance does not apply to the Proposed Build Alternative for the reason that elevated configurations are used for the managed lanes.

3.2. Disproportionate Crash History

The study team determined that Distance From Origin (DFOs) of 226.802 and 230.022 correspond to STA 3480+00 and STA 3650+00, respectively. Due to the potential impact of COVID-19 on traffic demands and patterns, crash data from 2017 to 2019 was used to describe and interpret crash history; and crash data for 2020 was excluded to eliminate the effects of the pandemic.

The study team extracted historical crash data of 2017 to 2019 from the TxDOT Crash Record Information System (CRIS) database for the segment of IH-35 from DFO 226.802 to DFO 230.022. Six levels of crash severity were investigated:

- Fatal (K)
- Incapacitating (Type A injury)
- Non-incapacitating (Type B Injury)
- Possible Injury
- Not Injured
- Unknown

Severe crashes include fatal crashes (K), incapacitating crashes (A), and non-incapacitating (B) crashes. In the literature, these crashes are sometimes referred to as KABs. Since the crash severity percentages are relatively stable over the three years, the study team used the same proportions to predict the number of crashes of each crash severity for A1 and the Proposed Build Alternative.

The detailed crash history with respect to crash severity is presented in Table 2 and Figure 2.

Table 2. 2017-2019 Historical Crashes by Year and Severity for the No Build Alternative (From STA 3480+00 to STA 3650+00)

Year	Fatal	Incapacitating	Non-incapacitating	Possible Injury	Not Injured	Unknown	Severe	Total
2017	0	5	67	60	195	6	72	333
Pct.	0.0%	1.5%	20.1%	18.0%	58.6%	1.8%	21.6%	
2018	0	10	75	72	179	10	85	346
Pct.	0.0%	2.9%	21.7%	20.8%	51.7%	2.9%	24.6%	
2019	1	8	72	60	151	4	81	296
Pct.	0.3%	2.7%	24.3%	20.3%	51.0%	1.4%	27.3%	
Total	1	23	214	192	525	20	238	975
Pct.	0.1%	2.4%	21.9%	19.7%	53.8%	2.1%	24.4%	

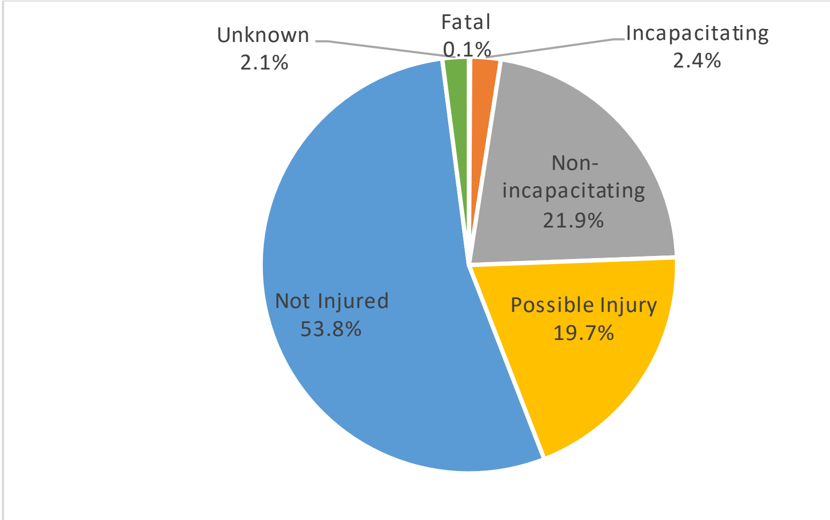

Figure 2. 2017-2019 Crash Statistics by Severity for the No Build Alternative (From STA 3480+00 to STA 3650+00)

As can be seen from Table 2 and Figure 2, from 2017 to 2019, of a total of 975 crashes that occurred on this specific IH-35 segment, most were non-injury (53.8%), followed by non-incapacitating crashes (21.9%), possible injury crashes (19.7%), incapacitating crashes (2.4%), unknown crashes (2.1%), and fatal crashes (0.1%). The percentage of severe crashes is 24.4%, which indicates that if a future crash occurs on this IH-35 segment, there is a chance of 24.4% that it will be a severe crash (either fatal, incapacitating, or non-incapacitating).

In terms of individuals involved in a crash, five race/ethnicity groups were considered:

- Hispanic
- White
- Black
- Asian
- Unknown

Assuming that the future traffic composition would remain consistent with the current traffic, the study team developed 2017 to 2019 historical crash statistics by person ethnicity groups. The results are presented in Table 3 and Figure 3.

Table 3. 2017-2019 Historical Crashes by Person Race/Ethnicity for the No Build Alternative (From STA 3480+00 to STA 3650+00)

Person Ethnicity	Number of Persons Involved in Crashes	Percentage
Hispanic	1,289	45.1%
White	1,094	38.3%
Black	253	8.9%
Asian	94	3.3%
Unknown	127	4.4%
Total	2,857	100%

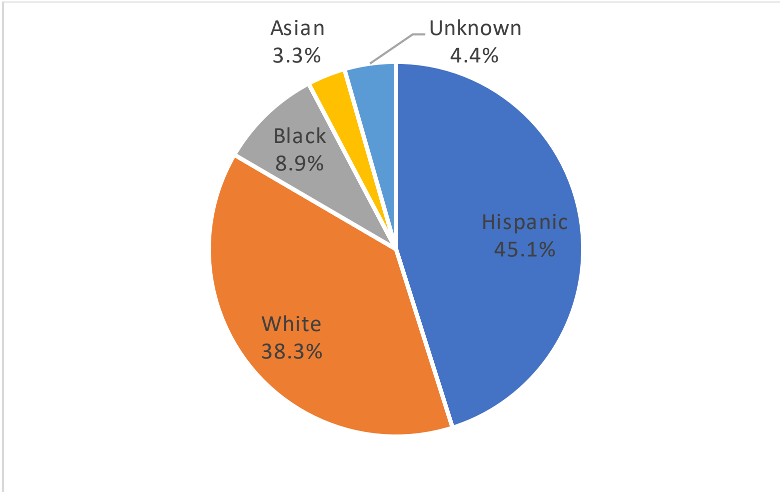

Figure 3. 2017-2019 Crash Statistics by Person Race/Ethnicity for the No Build Alternative (From STA 3480+00 to STA 3650+00)

As can be seen from Table 3 and Figure 3, from 2017 to 2019, a total of 2,857 individuals were involved in one or more crashes, with Hispanic being the highest (45.1%), followed by White (38.3%), Black (8.9%), Unknown (4.4%), and Asian (3.3%). Hispanic and White composed more than 80% (83.4%) of persons in a crash. Such historical results mean that if a person is involved in a crash on this IH-35 segment, there is a 45.1% chance that he/she will be a Hispanic (either as a driver or as a passenger).

A more comprehensive summary of the 2017-2019 crash history is presented in Table 4.

**Table 4. 2017-2019 Crash Statistics by Crash Severity and Person Race/Ethnicity for the No Build Alternative
(From STA 3480+00 to STA 3650+00)**

Crash Severity	Number of Crashes	Number of Persons					
		Hispanic	White	Black	Asian	Unknown	Total
Fatal	1	2	1	1	0	0	4
Incapacitating	23	21	27	12	0	1	61
Non-incapacitating	214	340	231	65	37	29	702
Possible Injury	192	310	218	38	23	21	610
Not injured	525	610	617	131	34	66	1,458
Unknown	20	6	0	6	0	10	22
Severe	238	363	259	78	37	30	767
Total	975	1,289	1,094	253	94	127	2,857

Based on Table 4, the information can be normalized into number of persons involved per 100 crashes, which is presented in Table 5. Note that the number of persons is rounded up when calculating, e.g., 9.4 persons is counted as 10 persons.

Table 5. Number of Persons by Person Race/Ethnicity per 100 Crashes for the No Build Alternative (From STA 3480+00 to STA 3650+00)

Crash Severity	Number of Crashes	Number of Persons					
		Hispanic	White	Black	Asian	Unknown	Total
Fatal	100	200	100	100	0	0	400
Incapacitating	100	92	118	53	0	5	268
Non-incapacitating	100	159	108	31	18	14	330
Possible Injury	100	162	114	20	12	11	319
Not injured	100	117	118	25	7	13	280
Unknown	100	30	0	30	0	50	110
Severe	100	153	109	33	16	13	324
Total Average	100	133	113	26	10	14	296

As can be observed from Table 5, on average, there are 296 persons involved per 100 crashes, including 133 Hispanic, 113 White, 26 Black, 10 Asian, and 14 unknown. In terms of severe crashes, there are 324 persons involved per 100 severe crashes, including 153 Hispanic, 109 White, 33 Black, 16 Asian, and 13 unknown.

3.3. Total Reduction in Crashes

In order to evaluate the number of crashes expected to be prevented, reference groups consisting of IH 35 roadway segments at other locations along the route with a similar number of lanes and other design factors were identified for comparison with each of the three Alternatives: the No Build Alternative, A1, and the Proposed Build Alternative. While most of the factors are readily available from existing databases, traffic volume information for A1 and the Proposed Build Alternative was obtained from the traffic operational analysis conducted in a separate task of this Study. The AM hourly peak traffic volumes from CORSIM, a traffic flow simulation model, based on 30 iterations was used as the input values to convert to Annual Average Daily Traffic (AADT). The reference group selection criteria are presented in Table 6.

Table 6. Reference Group Selection Criteria

Inputs	The No Build Alternative	Alternative 1	The Proposed Build Alternative
Indicators for urban or rural	Large Urbanized (Population 200,000+)	Large Urbanized (Population 200,000+)	Large Urbanized (Population 200,000+)
Highway functionality	Interstate	Interstate	Interstate
Indicator for horizontal curve	Non-curve	Non-curve	Non-curve
Highway Design	Two-way, divided	Two-way, divided	Two-way, divided
Number of lanes	3	5	3 + 2 elevated lanes
Lane width (feet)	12	11-12	12
Median type	Positive Barrier Rigid	Positive Barrier Rigid	Positive Barrier Rigid

Shoulder type	Bituminous Surface (paved)	Bituminous Surface (paved)	Bituminous Surface (paved)
Shoulder width - inside (feet)	10-12	4-10	10-12
Shoulder width - outside (feet)	10-12	8-10	10-12
AADT (Both directions)	154,231	175,373 (main lane) 31,963 (at-grade HOV) 207,336 (total)	181,294 (main lane) 33,059 (elevated HOV) 214,353 (total)
Truck percentage	8.3% of total AADT	8.3% of total AADT. All trucks in main lanes; no truck on managed lanes	8.3% of total AADT. All trucks in main lanes; no truck on elevated managed lanes
Truck AADT (Both directions)	12,811	17,209 (main lane) 0 (at-grade HOV) 17,209 (total)	17,791 (main lane) 0 (elevated HOV) 17,791 (total)
Non-truck AADT (Both directions)	141,420	158,164 (main lane) 31,963 (at-grade HOV) 190,127 (total)	163,503 (main lane) 33,059 (elevated HOV) 196,562 (total)
Speed limit (mile/h)	60-70	60-70	60-70

Note: the managed lanes are only for buses and vehicles with 2 or more people.

Based on the selection criteria from Table 6,

> A total of 197 roadway segments were identified as the reference group for the No Build Alternative existing IH 35 lane configuration.
>
> A total of 142 roadway segments were identified as the reference group for the A1 existing IH-35 lane configuration, and 98 roadway segments were identified as the reference group for A1 at-grade managed lanes configuration.
>
> A total of 123 roadway segments were identified as the reference group for the Proposed Build Alternative existing IH-35 lane configuration, and 90 roadway segments as the reference group for the Proposed Build Alternative elevated managed lanes.

The No Build Alternative, A1, and the Proposed Build Alternative have different numbers of reference group segments of the existing IH-35 lane configuration due to the differences in criteria such as AADT value, shoulder width, etc. These roadway segments in each reference group were further processed to obtain more reliable regression results, including such operations as merging segments with same ending DFO, starting DFO and eliminating outliers (extremely short reference segments).

After a close examination of the input variables, only non-truck AADT and truck AADT were used as predictors, as such operations simplify the model without sacrificing the accuracy. Non-truck AADT was used instead of AADT to avoid the correlation with truck AADT. The generalized expression of the negative binomial regression is:

$$P = \exp\left(\alpha + \beta_1 AADT_{ntru} + \beta_2 AADT_{tru}\right)$$

Where P = number of crashes per mile that occurred in a roadway segment per year

$AADT_{ntru}$ = non-truck AADT

$AADT_{tru}$ = truck AADT

α, β_1, β_2 are parameters to be estimated.

The SPSS Statistics software package developed by IBM was used to conduct the negative binomial regression analysis and the results are presented in Table 7.

Table 7. Negative Binomial Regression Results

Scenarios		α	β_1	β_2
The No Build Alternative		0.300	2.590E-5	5.206E-5
A1	Existing IH35 Part	0.313	1.881E-5	5.179E-5
	At-grade Managed Lanes	3.215	4.248E-6	N/A*
The Proposed Build Alternative	Existing IH35 Part	0.324	1.392E-5	7.253E-5
	Elevated Managed Lanes	3.182	5.412E-6	N/A*

*No truck allowed in managed lanes

According to the results in Table 7, the number of crashes per mile that occurred in this 3.22-mile roadway segment per year was calculated. Consequently, the predicted number of total crashes per year was obtained and presented in Table 8.

Table 8. Predicted Number of Total Crashes per Year without Lane Access Control Consideration (From STA 3480+00 to STA 3650+00)

Scenarios		**Number of Crashes per Year without Lane Access Control**
The No Build Alternative		330
A1	Existing IH-35 Part	211
	At-grade Managed Lanes	92
The Proposed Build Alternative	Existing IH-35 Part	202
	Elevated Managed Lanes	93

Based on the historical crash statistics presented in Section 3.2, for the No Build Alternative, there were 975 crashes that occurred during 2017 to 2019, an average of 325 crashes per year. The results from the negative binomial regression predicted that 330 crashes would occur during this same time period, which is highly consistent with the historical statistics.

Since most of the existing managed lanes are at-grade and there are no indicators in available databases to differentiate the elevation (if any), the number shown in Table 8 needs to be further processed to reflect the elevated configuration for the Proposed Build Alternative managed lanes. To solve this, the study team considered the concept of lane access control to further evaluate the safety impact of elevated configuration.

According to the Federal Highway Administration (FHWA), the benefits of access management include improved movement of traffic, reduced crashes, and fewer vehicle conflicts. Full control of access maximizes the capacity, safety, and vehicular speeds on the highway. The descriptions of full access control and partial access control are:

- Full Access Control: Connections to a facility provided only via ramps at interchanges. All cross-streets are grade-separated. No private driveway connections allowed.
- Partial Access Control: Connections to a facility provided via ramps at interchanges, at-grade intersections, and private driveways.

Based on discussions with Austin District engineers, the A1 at-grade managed lanes will be delineated with a double-white stripe with one-foot separation between the stripes to allow possible future installation of flexible posts. Thus, although the double white line indicates that it will be illegal for a vehicle to change lanes from the regular traffic lanes to the at-grade managed lanes, it is physically possible for a driver to make this maneuver. It is not possible for a vehicle to change lanes from the regular lanes to the elevated managed lanes in the Proposed Build Alternative.

Therefore, in this study, the at-grade managed lanes in A1 can be deemed as partial access control, and the elevated managed lanes in the Proposed Build Alternative is treated as full access control. Although the FHWA report on the impact of access control on crash rates was published in 1992 (FHWA, 1992), the relative impact of different levels of access control on crash rates is still valid today. According to the report, for urban area, the crash rate per million Vehicle Miles Travelled (VMT) of a full access control highway has a 62.5% reduction compared with that of a full access control highway.

Consequently, the final predicted number of total crashes for the Proposed Build Alternative elevated managed lanes (full access control) is 93*(1-62.5%) = 35. The predicted number of total crashes per year with lane access control consideration is presented in Table 9.

Table 9. Predicted Number of Total Crashes per Year with Lane Access Control Consideration (From STA 3480+00 to STA 3650+00)

Scenarios		Number of Crashes per Year with Lane Access Control
The No Build Alternative		330
A1	Existing IH-35 Part	211
	At-grade Managed Lanes	92
The Proposed Build Alternative	Existing IH-35 Part	202
	Elevated Managed Lanes	35

Table 9 indicates that the total number of predicted crashes for the No Build Alternative, A1, and the Proposed Build Alternative are 330, 303, and 237, respectively. Compared with the No Build Alternative, A1 results in a reduction of 27 total crashes (8.2%) per year, and the Proposed Build Alternative results in a reduction of 93 total crashes (28.2%) per year. According to Table 5, this indicates that about 80 persons will benefit from A1 compared with the No Build Alternative, including 36 Hispanic, 30 White, 7 Black, 3 Asian, and 4 unknown. When comparing the Proposed Build Alternative to the No Build Alternative, 275 individuals will be prevented from being involved in a crash, including 124 Hispanic, 105 White, 24 Black, 9 Asian, and 13 unknown. In addition, comparing with the Proposed Build Alternative to A1, there is a reduction of 66 total crashes (21.8% of the A1 total number of crashes).

3.4. Number of Severe Crashes Expected to be Prevented

Based on the historical statistics from Section 3.2, the proportion of severe crash is 24.4% or approximately 80 crashes per year. Comparing A1 and the No Build Alternative, a reduction of 27 total crashes leads to a reduction of 7 severe crashes. Comparing the Proposed Build Alternative and the No Build Alternative, a reduction of 93 total crashes is equivalent to a reduction of 23 severe crashes. According to Table 5, this indicates that about 23 persons will be prevented from being involved in a severe crash (A1 compared with the No Build Alternative), including 11 Hispanic, 8 White, 2 Black, 1 Asian, and 1 unknown. When comparing the Proposed Build Alternative to the No Build Alternative, 75 individuals will be prevented from being involved in a severe crash, including 35 Hispanic, 25 White, 8 Black, 4 Asian, and 3 unknown. In addition, comparing the Proposed Build Alternative with A1, there is a reduction of 16 severe crashes (228.6%) for the Proposed Build Alternative.

3.5. Anticipated Reduction in Crash Rates

The crash rate is calculated using the following formula:

$$CR = \frac{C \times 100,000,000}{V \times 365 \times N \times L}$$

Where CR = Roadway Departure crash rate for the road segment expressed as crashes per 100 million vehicle-miles of travel (VMT)

C = Total number of roadway departure crashes in the study period: (according to FHWA, a Roadway Departure (RwD) Crash is defined as a non-intersection crash in which a vehicle crosses an edge line or a centerline, or otherwise leaves the traveled way. Thus, departure crashes would include merging and diverging maneuver crashes)

V = Traffic volumes using Average Annual Daily Traffic (AADT) volumes

N = Number of years of data

L = Length of the roadway segment in miles

Based on the crash prediction and converted AADT volume, the annual crash rate of the No Build Alternative, A1, and the Proposed Build Alternative is calculated as 182.1, 124.3, and 94.1 crashes per 100 million VMT, respectively. Comparing A1, the Proposed Build Alternative and the No Build Alternative, an estimated reduction of 31.7% and 48.3% in crash rate, is anticipated respectively. It can be observed that, in terms of percentages, the reduction in crash rate is higher than reduction in crashes. This is because that in addition to a reduction in number of crashes, there is also an increase in AADT, which makes the crash rate of the Proposed Build Alternative much smaller than the No Build Alternative. Particularly, if the crash rates are focused only on the HOV managed lanes, the Proposed Build Alternative has a 63.2 % reduction in crash rate compared with A1 in anticipated crash rate per 100 million VMT per year.

3.6. Safety Analysis Summary

Based on the information presented in Section 3.1 to Section 3.5, the safety analysis results are compared and summarized in Table 10.

Table 10. Safety Analysis Comparison Summary

Task Objectives	The No Build Alternative	A1 (vs. the No Build Alternative)	The Proposed Build Alternative (vs. the No Build Alternative)	The Proposed Build Alternative vs. A1
# Conflict Points, assume cutting multiple lanes once	11	19 (+72%)	5 (-55%)	-14 (-74%)
# Conflict Points, assume changing lanes one at a time	11	26 (+136%)	5 (-55%)	-21 (-81%)
Number of Fatal and Severe Crashes Prevented per Year	--	7	23	16 (+228.6%)
Total Crashes per Year	330	303 (-8.2%)	237 (-28.2%)	-66 (-21.8%)
Anticipated Crash Rate per Year (per 100 million VMT)	182.1	124.3 (-31.7%)	94.1 (-48.3%)	-30.2 (-24.3%)
Anticipated Crash Rate per Year for HOV Managed Lanes Only (per 100 million VMT)	--	224.9	90.1	134.8 (-63.2%)

4. Economic Benefits

According to Section 3.2 and Section 3.4, comparing the No Build Alternative and A1, a reduction of 27 total crashes leads to a reduction of 7 severe crashes, 5 possible injury crashes, and 14 not injured crashes (unknown crashes are not considered). Comparing the Proposed Build Alternative and the No Build Alternative, a reduction of 93 total crashes is equivalent to a reduction of 23 severe crashes, 18 possible injury crashes, and 50 not injured crashes (unknown crashes are not considered). Currently TxDOT uses $3.6 million for either a fatal or an incapacitating crash and $0.5 million ($500,000) for a non-incapacitating crash to determine crash costs. Based on Table 2, using the total statistics of 2017 to 2019 (1 fatal crash, 23 incapacitating crashes, and 214 non-incapacitating crashes), the average cost of a severe crash is determined as:

$$\frac{\$3,600,000\times 1+\$3,600,000\times 23+\$500,000\times 214}{238}=\$812,605$$

Therefore, comparing with the No Build Alternative, A1 could help save about $5.7 million ($812,605 x 7) per year, and the Proposed Build Alternative could lead to a savings of approximately $18.7 million ($812,605 x 23) in crash costs per year. Comparing with A1, the Proposed Build Alternative saves 228.1% more in severe crash costs per year.

In terms of the additional economic benefits of possible injury crashes and property damage only crashes, the 2010 Highway Safety Manual uses $82,600 for a possible injury crash and $7,400 for a not injured (property damage only) crash to determine crash costs. Therefore, compared with the No Build Alternative, A1 could help save about $0.5 million ($82,600 x 5 + $7,400 x 14 = $516,600) per year, and the Proposed Build Alternative could lead to a savings of about $1.9 million ($82,600 x 18 +$7,400 x 50 = $1,856,800) in crash costs per year.

Overall, comparing with the No Build Alternative, A1 saves about $6.2 million ($5.7 million + $0.5 million) per year, and the Proposed Build Alternative helps save about $20.6 million ($18.7 million + $1.9 million) per year. Compared with A1, the Proposed Build Alternative saves 232.3% more in all types of crash costs per year (unknown injury crashes are not considered).

Based on Table 2, using the total statistics of 2017 to 2019, the average cost of a crash (unknown injury crashes are not considered) is determined as:

$$\frac{\$3,600,000\times 1+\$3,600,000\times 23+\$500,000\times 214+\$82,600\times 192+\$7,400\times 525}{955}=\$223,188$$

Considering the fact that the crash prediction was conducted only for one year ($N=1$), using the crash rates calculated in Section 3.5, the annual crash value per 100 million VMT for the No Build Alternative, A1, and the Proposed Build Alternative is estimated to be $40.6 million, $27.7 million, and $21.0 million, respectively. Therefore, compared with the No Build Alternative, A1 could help save $12.9 million (31.8%) in crash costs per 100 million VMT per year, and the Proposed Build Alternative could lead to a savings of $19.6 million (48.3%) in crash costs per 100 million VMT per year. Comparing with A1, the Proposed Build Alternative saves 24.2% more in crash costs per 100 million VMT per year.

5. Safety Impacts on Other Network Facilities

The increased traffic volumes on IH-35 for A1 and the Proposed Build Alternative indicate that traffic using other facilities has chosen new routes that include IH-35. That is, parallel arterial routes, including South Congress Avenue, South First Street, and South Lamar, would likely benefit from reduced traffic volumes due to travelers choosing the improved IH-35. The reduction in traffic volume in other routes will improve the safety as less crashes will occur. The study team foresees such additional safety benefits but the timeframe for this analysis did not allow quantitative analysis of parallel facilities.