5 Safety (Crash) Analysis

The proposed improvements are likely to have a positive impact on crash occurrence. As part of this study a safety analysis was conducted based on the required procedures and methodology for a SIMR per the FDOT SIO Interchange Access Request Users Guide (IARUG) dated January 2018 that follows the criteria contained in the Highway Safety Manual (HSM). The safety analysis was based on the following methodology:

- Identifying the Crash Type & Crash Severity
- Calculation of Crash Rates
- Description of Existing Crash Trends
- Development of Safety Performance Functions (SPF's)
- Development of Empirical Bayes Method
- Application of Crash Reduction Estimations (CRF's)
- Crash Reduction Benefit

5.1 Existing Crash Data Information

Crash statistics along I-4 and CR 532 were obtained from the Signal Four Analytics and FDOT Crash Analysis Reporting System (CARS) database based on the latest available five years of crash data (from January 1, 2012 to December 31, 2016). **Table 16** summarizes the crashes (by severity and conditions) for the freeway mainline, ramp merge/diverge areas, and ramp terminal intersections based on the segmentation process utilized for this SIMR. The specific segmentation process used for this study is shown below:

- I-4 Freeway Segment between US 27 & CR 532
- Eastbound I-4 Diverge to CR 532
- Eastbound I-4 and CR 532 Ramp Terminal
- Eastbound I-4 Merge from CR 532
- Eastbound I-4 Freeway Segment (between CR 532 & SR 429)
- Eastbound I-4 Diverge to SR 429
- Eastbound I-4 Merge from SR 429
- I-4 Freeway Segment (between SR 429 and World Drive/SR 417)
- Westbound I-4 Diverge to SR 429
- Westbound I-4 Merge from SR 429
- Westbound I-4 Diverge to CR 532
- Westbound I-4 and CR 532 Ramp Terminal
- Westbound I-4 Merge from CR 532
- SR 429 between I-4 and Sinclair Road

Table 16: Crash Summary by Severity & Conditions (Jan 2012-Dec 2016)

Crash Segment	Crash Severity & Conditions									
	Total	**Fatal**	**Injury**	**Property Damage Only**	**Daylight**	**Dark without Light**	**Dusk**	**Dawn**	**Dry**	**Wet**
I-4 between US 27 & CR 532	242	2	77	163	145	79	10	7	155	87
I-4 between CR 532 & SR 429	121	0	39	82	75	32	8	6	93	28
I-4 between SR 429 & World Dr	88	0	25	63	59	22	5	2	66	22
SR 429 between Sinclair Rd & I-4	2	0	0	2	1	1	0	0	2	0
EB I-4 Diverge to CR 532	33	2	3	28	23	10	0	0	26	7
EB I-4 Merge from CR 532	17	0	3	14	15	0	1	1	17	0
WB I-4 Diverge to CR 532	19	0	2	17	12	6	1	0	12	7
WB I-4 Merge from CR 532	11	1	1	9	5	6	0	0	5	6
EB I-4 Diverge to SR 429	14	0	7	7	7	5	1	1	8	6
EB I-4 Merge from SR 429	12	0	5	7	7	5	0	0	9	3
WB I-4 Diverge to SR 429	32	0	11	21	25	5	2	0	25	7
WB I-4 Merge from SR 429	23	0	7	16	15	4	3	1	15	8
I-4 at CR 532 EB Ramp Terminal	74	0	36	38	56	15	1	2	60	13
I-4 at CR 532 WB Ramp Terminal	149	0	53	96	105	40	4	0	134	15
Total	**837**	**5**	**269**	**563**	**550**	**230**	**36**	**20**	**627**	**209**
Percent of Total		**0.6%**	**32.1%**	**67.3%**	**65.7%**	**27.5%**	**4.3%**	**2.4%**	**74.9%**	**25.0%**

As shown in **Table 16**, a total of 837 crashes occurred during the five (5) year analysis period from January 2012 to December 2016. Out of the 837 total crashes there were 5 fatal crashes, 269 injury crashes and 563 property damage only crashes. A total of 550 crashes occurred during the daylight hours and 230 crashes were reported to have occurred during dark conditions (at night, dawn and dusk). In addition, a total of 627 crashes occurred during dry roadway conditions with the remaining 209 occurring during wet conditions.

Over this five-year time period, a total of 74 crashes occurred at the eastbound ramp terminal intersection and 149 crashes occurred at the westbound ramp terminal intersection. No fatalities were reported at these ramp terminal intersections between the year 2012 and year 2016.

5.2 Crash Summary by Crash Type

Table 17 shows the summary of the crashes by crash types. Per the summary, Rear End crashes accounted for the predominant crash type (about 46.7%) within the study area, followed by Sideswipe (14.5%), Left Turn (about 12.2%), Other (12.1%), and Off Road (about 8.7%) crashes.

Table 17: 5 Year Crash Summary by Type

Crash Segment	Crash Type											Total
	Rear End	Head On	Sideswipe	Roll Over	Angle	Left Turn	Right Turn	Off Road	Pedestrian & Bicycle	Animal	Other	
I-4 between US 27 & CR 532	99	0	47	20	0	1	0	32	1	1	41	242
I-4 between CR 532 & SR 429	67	0	30	4	0	1	0	5	0	1	13	121
I-4 between SR 429 & World Dr	58	0	9	1	0	1	0	11	0	0	8	88
SR 429 between I-4 & Sinclair Rd	0	0	1	0	0	0	0	0	0	1	0	2
EB I-4 Diverge to CR 532	16	1	8	0	0	1	0	7	0	0	0	33
EB I-4 Merge from CR 532	8	0	4	0	1	1	0	0	0	0	3	17
WB I-4 Diverge to CR 532	11	0	3	0	1	1	0	1	0	0	2	19
WB I-4 Merge from CR 532	4	0	1	1	0	1	0	2	0	0	2	11
EB I-4 Diverge to SR 429	6	0	1	0	0	1	0	1	0	0	5	14
EB I-4 Merge from SR 429	5	0	1	0	0	0	0	3	0	0	3	12
WB I-4 Diverge to SR 429	20	0	1	0	0	1	0	5	0	0	5	32
WB I-4 Merge from SR 429	15	0	5	1	0	1	0	1	0	0	0	23
I-4 at CR 532 EB Ramp Terminal	47	0	2	0	0	18	0	0	0	0	7	74
I-4 at CR 532 WB Ramp Terminal	35	0	8	0	15	74	0	5	0	0	12	149
Total	**391**	**1**	**121**	**27**	**17**	**102**	**0**	**73**	**1**	**3**	**101**	**837**
Percentage of Total	**46.7%**	**0.1%**	**14.5%**	**3.2%**	**2.0%**	**12.2%**	**0.0%**	**8.7%**	**0.1%**	**0.4%**	**12.1%**	**100%**

5.3 Crash Frequency & Crash Rate Development

Based on the required procedures and methodology for a SIMR per the FDOT SIO, crash rates and frequencies along the area of influence were developed based on the five (5) year crash information. **Table 18** summarizes the crash frequency and rates for each safety analysis segmentation for the study area.

The crash rates for the mainline segments are expressed as the number of crashes per million vehicle-miles traveled, the crash rates for the intersections are expressed as number of crashes per million entering vehicles. The following equations were utilized to develop the crash frequency and crash rates for this study:

$$Crash\ Rate\ of\ Segment = \frac{Total\ Number\ of\ Crashes\ x\ 1{,}000{,}000}{AADT\ x\ 365\ x\ Number\ of\ Years\ x\ Length\ of\ Roadway\ Segment}$$

$$Crash\ Rate\ of\ Intersections = \frac{Total\ Number\ of\ Crashes\ x\ 1{,}000{,}000}{AADT\ x\ 365\ x\ Number\ of\ Years}$$

5.3.1 Crash Rate Comparison

In addition to developing the five-year existing crash rates, a comparison of these actual crash rates with the FDOT statewide crash rates was conducted based on the most current FDOT CAR reporting database. For I-4, all the freeway segments have lower crash rates compared to the FDOT statewide crash rate of 0.924.

The eastbound ramp terminal, with an existing crash rate of 1.042, has a lower crash rate than the FDOT statewide crash rate at 1.51. The westbound ramp terminal, with an existing crash rate of 1.775, has a higher crash rate than the FDOT statewide crash rate at 1.51. Note that for the merge and diverge segments, based on discussions with FDOT Central Office (Crash Records and Research Department), FDOT does not provide crash rate statistics for merging and diverging segments.

Table 18: 5 Year Crash Frequency & Rate Summary

Crash Segment	Crash Frequency & Rate					
	Severity	No. of Crashes	Daily Volume	Segment Length (miles)	Total Crash Frequency	Total Crash Rate
I-4 between US 27 & CR 532	Total	242	137,000	2.00	48.40	0.48
	FI	79				
	PDO	163				
I-4 between CR 532 & SR 429	Total	121	153,700	0.81	24.20	0.53
	FI	39				
	PDO	82				
I-4 between SR 429 & World Dr	Total	88	139,500	0.83	17.60	0.41
	FI	25				
	PDO	63				
SR 429 between I-4 and Sinclair Rd	Total	2	25,800	0.34	0.40	0.12
	FI	0				
	PDO	2				
EB I-4 Diverge to CR 532	Total	33	68,500	0.09	6.60	2.79
	FI	5				
	PDO	28				
EB I-4 Merge from CR 532	Total	17	76,900	0.11	3.40	1.14
	FI	3				
	PDO	14				
WB I-4 Diverge to CR 532	Total	19	76,900	0.09	3.80	1.43
	FI	2				
	PDO	17				
WB I-4 Merge from CR 532	Total	11	68,500	0.13	2.20	0.66
	FI	2				
	PDO	9				
EB I-4 Diverge to SR 429	Total	14	76,900	0.12	2.80	0.81
	FI	7				
	PDO	7				
EB I-4 Merge from SR 429	Total	12	69,800	0.14	2.40	0.69
	FI	5				
	PDO	7				
WB I-4 Diverge to SR 429	Total	32	69,800	0.19	6.40	1.30
	FI	11				
	PDO	21				
WB I-4 Merge from SR 429	Total	23	76,900	0.11	4.60	1.52
	FI	7				
	PDO	16				
I-4 at CR 532 EB Ramp Terminal	Total	74	38,900	-NA-	14.80	1.04
	FI	36				
	PDO	38				
I-4 at CR 532 WB Ramp Terminal	Total	149	46,000	-NA-	29.80	1.77
	FI	53				
	PDO	96				

5.5 Safety Performance Functions

SPFs are crash equations used to predict or calculate the expected number of crashes per year at a specific study roadway segment, ramp terminals and merge and diverge areas. These SPF factors are only required for specific roadway improvement alternatives being considered and have an available CMF to show the effectiveness of the subject improvement. For this study, the Build alternative includes converting the existing diamond interchange to a DDI, adding auxiliary lanes along I-4 between CR 532 and SR 429, and adding auxiliary lane along northbound SR 429 between I-4 and Sinclair Road. Therefore, SPFs were developed for the I-4 and CR 532 interchange ramp terminals, I-4 freeway segment between CR 532 and SR 429, and the SR 429 segment between I-4 and Sinclair Road.

Calculating the SPF factors for each facility crash type has four primary steps. These four steps utilized for this SIMR study are summarized below:

1. Developing the Base Equation
2. Developing the SPF factors to be used in the Base Equation
3. Balancing the Fatal-Injury Crashes and Property Damage Only Crashes
4. Distribution of the appropriate Crash Severity or Crash Type

Table 19 summarizes the SPF's expected crashes for the No Build Condition. **Appendix K** contains the safety performance analysis worksheets and crash data utilized for this study.

Table 19: Safety Performance Function Expected Crash Summary

Study Segmentation	SPF No Build Summary		
	Fatal-Injury Crashes	Property Damage Only Crashes	Total Expected Crashes
I-4 between CR 532 and SR 429	7.62	18.67	26.29
SR 429 between I-4 and Sinclair Road	0.42	0.59	1.01
I-4 at CR 532 EB Ramp Terminal	5.51	10.08	15.59
I-4 at CR 532 WB Ramp Terminal	6.54	13.97	20.51

5.6 Empirical Bayes Method

Another step in the safety analysis is developing the expected crash frequency by the Empirical Bayes Method. This analysis method combines the Predicted Crash Frequency with the Observed Crash Frequency to obtain the Expected Crash Frequency. This method of analysis is implemented to improve the statistical reliability of developing the future expected crash frequency.

Table 20 summarizes the Empirical Bayes analysis summary utilized for this study for the appropriate segments. **Appendix K** contains the Empirical Bayes Method analysis worksheets and crash data utilized for this study.

Table 20: Empirical Bayes Method Analysis Summary

Crash Segmentation	Predicted Crash Totals		Observed Frequency		Expected Crash Frequency	
	FI	PDO	FI	PDO	FI	PDO
I-4 between CR 532 and SR 429	7.62	18.67	7.80	16.40	8.01	17.54
SR 429 between I-4 and Sinclair Road	0.42	0.59	0.00	0.40	0.36	0.55
I-4 at CR 532 EB Ramp Terminal	5.51	10.08	7.20	7.60	6.70	7.91
I-4 at CR 532 WB Ramp Terminal	6.54	13.97	10.60	19.20	9.54	18.71
Total	**20.09**	**43.31**	**25.60**	**43.60**	**24.61**	**44.71**

5.7 Crash Reduction Estimation

One of the last steps in evaluating whether the improvements provide a safety benefit is developing the crash reduction estimates based on the proposed study area improvements. For this study, the Build alternative includes converting the existing diamond interchange to a DDI, adding auxiliary lanes along I-4 between CR 532 and SR 429, and adding an auxiliary lane along northbound SR 429 between I-4 and Sinclair Road.

The first step in developing the crash reduction estimates is to determine the CMFs for the proposed alternative. Appropriate CMFs from the Crash Modification Factors Clearinghouse (CMF Clearinghouse) database are available for 1) converting a diamond interchange to a DDI and 2) adding auxiliary lanes between ramps. CMFs are currently not available for other improvements considered in the Build alternative.

Based on the CMF Clearinghouse database, the CMF to convert a diamond interchange to DDI is 0.592, and the CMF to add auxiliary lanes between ramps is 0.800. **Table 21** summarizes the crash reduction estimations in comparison to the No Build alternative for this study. **Appendix K** contains the crash data and crash reduction analysis worksheets utilized for this study.

Table 21: Crash Reduction Estimation for Build Alternative in Comparison to the No Build Alternative

Parameter	Crash Severity	Crash Segment				Total
		I-4 from CR 532 to SR 429	SR 429 from I-4 to Sinclair Rd	I-4 at CR 532 EB Ramp Terminal	I-4 at CR 532 WB Ramp Terminal	
Expected Crash Frequency (No Build)	Fatal Injury	8.01	0.36	6.70	9.54	**24.61**
	PDO	17.54	0.55	7.91	18.71	**44.71**
	Total	**25.55**	**0.91**	**14.61**	**28.25**	**69.32**
CMF	Fatal Injury	0.80	0.80	0.60*	0.60*	**-**
	PDO	0.80	0.80	0.60*	0.60*	**-**
Proposed Condition Expected Crash Frequency (Build)	Fatal Injury	6.41	0.29	3.97	5.65	**16.32**
	PDO	14.03	0.44	4.68	11.08	**30.23**
	Total	**20.44**	**0.73**	**8.65**	**16.73**	**46.55**

Note: The actual CMF (0.592) was used in the crash reduction calculation, but is rounded to 0.60 in this Table

5.8 Crash Reduction Benefit

The final step in the safety analysis is to estimate a crash reduction benefit in dollars. This process utilizes Empirical Bayes Method crash predictions and an assigned dollar amount to prevented crashes. The crash costs are developed using the procedure suggested in the latest Interchange Access Request Safety Procedure Webinar presented by SIO. The analysis follows this procedure, but using the latest costs found in the latest [2019 Edition] Florida Design Manual (FDM) Table 122.6.2, and fatal (K), severe injury (A), moderate injury (B), minor injury (C) and property damage only (O) [KABCO] distribution based on FDM and HSM crash costs.

For this study the following dollar amounts are used to develop the crash reduction benefit.

- Assigned Dollar Amount to Crash
    - 450,000 for Fatal/Injury Crash
    - 30,000 for Property Damage Only Crash

Table 22 summarizes the crash reduction benefit for the Build alternative in comparison to the No Build alternative.

Table 22: Crash Reduction Benefit

Build Alternative	Fatal-Injury Crashes	Property Damage Only Crashes	Total
Total Crash Reduction	8.29	14.48	**22.77 (~23)**
Total Crash Cost	$450,000	$30,000	**$480,000**
Total Crash Reduction Cost	**$3,730,500**	**$434,400**	**$4,164,900**

In summary, based on the safety analysis, the proposed Build alternative is anticipated to have a reduction in crash cost per year by $4,164,900 with an overall total reduction of approximately 23 crashes. **Appendix K** contains the crash data utilized for this study.