4.2. Safety Analysis for Future Conditions

Two Alternatives for future have been considered for the analysis (2045-No-Build & 2045 Build-Alternative 1-Tight Urban Diamond Interchange (modified TUDI) that was developed during the Project Development and Environment Study (PD&E) which retains the existing diamond interchange but with improvements. Alternative 2- Diverging Diamond Interchange (DDI). Alternative #2 is a better option because it reduces vehicle-to-vehicle conflict points, eliminates many of the most severe crash types and it has better overall performance, reducing delay. The DDI can accommodate twice the left turn traffic as the conventional design. The Alternative #2 – DDI helps travelers to save time and provides safer vehicular movements, safer movements for pedestrians and bikes. Alternative #2 provides additional safety benefits compared to Alternative#1- TUDI as follows:

- DDI reduces conflict points compared to TUDI. A reduction from 10 to 2 crossing conflicts compared to TUDI. A total of 14 conflict points which includes merging diverging and crossing movements.
- Reduces conflicts between vehicles and pedestrians for most crossing movements.
- Creates shorter pedestrian crossing distance for some movements.
- DDI safely accommodate pedestrians and bicyclists through interchange.
- DDI provides less delay and travel time when compared with TUDI.
- Reduced queue spillback potential, especially between ramp terminals as such reduces rear end collisions mostly caused by vehicular queues

4.2.1. Future 2045-No-Build Scenario

The study corridor for the analysis was the same used for the existing corridor which was divided into three segments and five signalized intersections. Forecasted Future 2045 AADT volumes were applied to this safety analysis obtained from I-95 at 10th Avenue North Interchange Traffic Data Collection and Traffic Projections Report dated December 21, 2017

Using the methodology in Part C, Chapter 12 of the HSM and as outlined above, the number of crashes for the No Build alternative is 49, see **Table 13.**

HSM Crashes - 2045 Future-No Build				
Name	**Limits**	**Predicted Crashes**	**Observed Crashes**	**Expected Crashes**
Intersection 1	MP 2.472 to MP 2.572	7.367	0	2.689
Segment 1A	MP 2.572 to MP 2.592	1.508	1	1.474
Intersection 2	MP 2.592 to MP 2.692	6.580	23	19.051
Segment 1B	MP 2.692 to MP 2.752	0.861	2	1.463
Intersection 3	MP 0.000 to MP 0.089	11.439	2	4.167
Intersection 4	MP 0.089 to MP 0.182	6.580	0	2.923
Segment 2	MP 0.182 to MP 0.195	0.294	1	0.379
Intersection 5	MP 0.195 to MP 0.295	6.071	20	16.394
	Totals	40.700	49	**48.539**

Table 13: HSM Crashes – Future -No-Build (2045)

The full details of the individual segment and intersection calculations are provided in **Appendix 3.**

A HSM crash distribution for urban 4-Divided-lane roads, obtained from FDOT's latest HSM Crash Distribution for Florida 2011-2015 (**Appendix 6**), and current crash costs from Chapter 122 of the FDOT Design Manual were used to develop the following cost of expected crashes under existing conditions- See **Table 14** below for Fatal (K), Severe Injury (A), Moderate Injury (B), Minor Injury (C) and Property Damage Only (O) costs for future No-Build.

Crashes	Distribution		Costs	Total
48.539	K	0.008	10,670,000	4,143,289.04
	A	0.050	872,612	2,117,785.69
	B	0.150	174,018	1,266,998.96
	C	0.235	106,215	1,211,558.92
	O	0.557	7,700	208,178.92
			Grand Total:	**$8,947,811.53**

Table 14: HSM Crash Cost Analysis- No-Build (2045)

4.2.2. Future 2045 - Build - Alternative # 1 (TUDI) and Alternative # 2 (DDI)

Two 2045 Build Alternatives for future have been considered for the analysis. Alternative 1-Tight Urban Diamond Interchange (TUDI) that was developed during the Project Development and Environment Study (PD&E) which retains the existing diamond interchange but with improvements. Alternative 2- Diverging Diamond Interchange (DDI). In order to facilitate analyses using HSM procedures, the corridor used for the analysis is the existing corridor divided into three segments and five signalized intersections, but with certain modifications due to the

proposed improvements, which retain the existing tight urban diamond interchange but with improvements including operational change, adding through and turning lanes and extending lanes to reconfigure the existing system to a Diverging Diamond Interchange (DDI). The DDI will improve traffic operations and safety providing less delay, reduction in congestion and improved geometric design to prevent crashes. Safety benefits of the DDI are better sight distance at turns, wrong way entry to ramps extremely difficult, pedestrian crossings are shorter, etc.

Using the methodology in Part C, Chapter 12 of the HSM and as outlined above, the number of crashes predicted, observed, and expected for the existing segments and intersections are listed in **Tables 15 and 16.**

HSM Crashes - 2045 Future Build-Alternative # 1 (TUDI)				
Name	**Limits**	**Predicted Crashes**	**Observed Crashes**	**Expected Crashes**
Intersection 1	MP 2.472 to MP 2.572	8.674	0	2.832
Segment 1A	MP 2.572 to MP 2.592	1.508	1	1.474
Intersection 2	MP 2.592 to MP 2.692	7.588	23	19.762
Segment 1B	MP 2.692 to MP 2.752	0.861	2	1.463
Intersection 3	MP 0.000 to MP 0.089	10.918	2	4.152
Intersection 4	MP 0.089 to MP 0.182	7.588	0	2.851
Segment 2	MP 0.182 to MP 0.195	0.297	1	0.382
Intersection 5	MP 0.195 to MP 0.295	5.770	20	16.075
	Total	43.204	49	**48.991**

Table 15: HSM Crashes -2045 Build- Alternative #1

HSM Crashes - 2045 Future Build-Alternative # 2 (DDI)				
Name	**Limits**	**Predicted Crashes**	**Observed Crashes**	**Expected Crashes**
Intersection 1	MP 2.472 to MP 2.572	7.367	0	2.689
Segment 1A	MP 2.572 to MP 2.592	1.508	1	1.474
Intersection 2	MP 2.592 to MP 2.692	6.580	23	18.975
Segment 1B	MP 2.692 to MP 2.752	0.861	2	1.463
Intersection 3	MP 0.000 to MP 0.089	10.875	2	4.117
Intersection 4	MP 0.089 to MP 0.182	6.580	0	2.759
Segment 2	MP 0.182 to MP 0.195	0.297	1	0.382
Intersection 5	MP 0.195 to MP 0.295	5.473	20	15.796
	Total	39.542	49	**47.656**

Table 16: HSM Crashes -2045 Build- Alternative #2

The details of the individual segment and intersection calculations are provided in **Appendix 4.**

FDOT's Crash Distribution & Costs for future conditions is also considered for distribution for 4-lane Divided Urban and Suburban Arterials (**Appendix 6**), and current crash costs from Chapter 122 of the FDOT Design Manual were used to develop the following cost of expected crashes under future conditions, note that differences from rounding may occur- See **Tables 17 and 18**

below for Fatal (K), Severe Injury (A), Moderate Injury (B), Minor Injury (C) and Property Damage Only (O) costs for Alternative # 1 (TUDI) and Alternative # 2 (DDI)

Crashes	Distribution		Costs	Total
48.991	K	0.008	10,670,000	4,181,871.76
	A	0.050	872,612	2,137,506.72
	B	0.150	174,018	1,278,797.38
	C	0.235	106,215	1,222,841.08
	O	0.557	7,700	210,117.50
			Grand Total:	**$9,031,134.44**

Table 17: HSM Crash Cost Analysis- Build (2045)- Alternative#1

Crashes	Distribution		Costs	Total
47.696	K	0.008	10,670,000	4,071,330.56
	A	0.050	872,612	2,081,005.10
	B	0.150	174,018	1,244,994.38
	C	0.235	106,215	1,190,517.20
	O	0.557	7,700	204,563.37
			Grand Total:	**$8,792,410.61**

Table 18: HSM Crash Cost Analysis- Build (2045) - Alternative#2

The details of the individual segment and intersection calculations are provided in **Appendix 5.**

Appendix 7 shows the analysis performed for modified TUDI

The 5-year historic crash data on a roadway segment is shown below. The average number of crashes on this segment from 2014-2018 is 198. Crash modification Factors for Alternative 1 and 2 are shown below in the table. Crashes per year are computed with the adjusted CMFs

Crash Type	Year					Total	Average
	2014	2015	2016	2017	2018		
Total # of Crashes	28	43	48	30	49	198	39.6

CMF for Alternative # 1 is 0.85 = 0.85 *39.6 = 33.6; 39.6-33.6 = **6 crashes/year (reduction)**
CMF for Alternative # 2 is 0.592 = 0.592 * 39.6 = 23.44; 39.6-23.44 = **16.16 crashes/year (reduction)**
Further for additional lanes 0.85*23.44 = 19.92; 39.6-19.92 = **19.68 crashes/year (reduction)**
With Alternative #2 we can expect 50% is crash reduction per year

Crash Type	Year					Total	Average
	2014	2015	2016	2017	2018		
Total # of Crashes	28	43	48	30	49	198	39.6
CMF for Alternative # 1 is 0.85 = 0.85 *39.6 = 33.6; 39.6-33.6 = **6 crashes/year (reduction)**							
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Further for additional lanes 0.85*23.44 = 19.92; 39.6-19.92 = **19.68 crashes/year (reduction)**							
With Alternative #2 we can expect 50% is crash reduction per year							

Table 19: Estimated Crash Frequency for Observed Crashes with adjusted CMFs

4.3. Crash Rate Calculation

Crash rates are calculated for segments and intersection in the project area and compared with average crash rates for similar facilities. The comparison can either be with FDOT district or with statewide averages. Roadway segment crashes are calculated per Million Vehicles Miles Travel (MVMT). Intersection crash rates are calculated per Million Entering Vehicles (MEV). See **Table 20** for crash rate calculation**.** Statewide averages were procured from FDOT Crash Analysis Reporting (CARS) system.

Crash Rate for Segment (MVMT):

$$\frac{\text{Total Number of Crashes X 1000000}}{\text{Segment Length X AADT X No. of years X 365}}$$

Crash Rate for Intersection (MEV):

$$\frac{\text{Total Number of Crashes X 1000000}}{\text{Total Intersection Volume Entering Per Day X No. of Years X 365}}$$

Crash Rate Calculation

Name	Location	Limit	Year	No. of Crashes	Fatality	Injury	PDO	AADT	Crash Rate	Statewide Avg. Crash	Seg Length
Intersection 1	10th Ave N @ Detroit St	MP 2.472 to MP 2.572	2014	6	0	8	0	43500			
Intersection 1			2015	7	0	7	5				
Intersection 1			2016	8	0	2	6				
Intersection 1			2017	0	0	0	0				
Intersection 1			2018	0	0	0	0				
Intersection 1	**10th Ave N @ Detroit St**	**MP 2.472 to MP 2.572**		**21**	**0**	**17**	**11**		**0.264525**	**0.8092**	N/A
Segment 1A	Between Intersection 1 and 2	MP 2.572 to MP 2.592	2014	1	0	0	1	43500			
Segment 1A			2015	0	0	0	0				
Segment 1A			2016	2	0	3	1				
Segment 1A			2017	1	0	0	1				
Segment 1A			2018	1	0	0	1				
Segment 1A	**Between Intersection 1 and 2**	**MP 2.572 to MP 2.592**		**5**	**0**	**3**	**4**		**3.14911**	**6.1094**	0.02
Intersection 2	10th Ave N @ Barnett Dr	MP 2.592 to MP 2.692	2014	3	0	0	4	43500			
Intersection 2			2015	10	0	9	3				
Intersection 2			2016	17	0	11	7				
Intersection 2			2017	12	0	6	8				
Intersection 2			2018	23	0	3	20				
Intersection 2	**10th Ave N @ Barnett Dr**	**MP 2.592 to MP 2.692**		**65**	**0**	**29**	**42**		**0.818769**	**0.6835**	**N/A**
Segment 1B	Between Barnett Dr and I95 SB ON/OFF Ramps	MP 2.692 to MP 2.752	2014	1	0	0	1	43500			
Segment 1B			2015	1	0	1	0				
Segment 1B			2016	0	0	0	0				
Segment 1B			2017	0	0	0	0				
Segment 1B			2018	2	0	0	2				
Segment 1B	**Between Barnett Dr and I95 SB ON/OFF Ramps**	**MP 2.692 to MP 2.752**		**4**	**0**	**1**	**3**		**0.839763**	**3.7859**	0.06
Intersection 3	10th Ave N @ I95 SB ON/OFF Ramp	MP 0.000 to MP 0.089	2014	5	0	4	1	12500			
Intersection 3			2015	4	0	8	0				
Intersection 3			2016	10	0	4	6				
Intersection 3			2017	4	0	0	4				
Intersection 3			2018	**2**	**0**	**0**	**2**				
Intersection 3	**10th Ave N @ I95 SB ON/OFF Ramp**	**MP 0.000 to MP 0.089**		**25**	**0**	**16**	**13**		**1.09589**	**1.5341**	N/A
Intersection 4	10th Ave N @ I95 NB ON/OFF Ramp	MP 0.089 to MP 0.182	2014	2	0	1	1	15000			
Intersection 4			2015	7	0	2	5				
Intersection 4			2016	3	0	0	3				
Intersection 4			2017	0	0	0	0				
Intersection 4			2018	1	0	0	1				
Intersection 4	**10th Ave N @ I95 NB ON/OFF Ramp**	**MP 0.089 to MP 0.182**		**13**	**0**	**3**	**10**		**0.474886**	**1.5341**	N/A
Segment 2	Between Intersection 4 and Inersection 5	MP 0.182 to MP 0.195	2014	0	0	0	0	**32500**			
Segment 2			2015	0	0	0	0				
Segment 2			2016	0	0	0	0				
Segment 2			2017	1	0	0	1				
Segment 2			2018	0	0	0	0				
Segment 2	**Between Intersection 4 and Inersection 5**	**MP 0.182 to MP 0.195**		**1**	**0**	**0**	**1**		**1.296912**	**3.7895**	0.013
Intersection 5	10th Ave N @ A St	MP 0.195 to MP 0.295	2014	10	0	9	2	32500			
Intersection 5			2015	14	0	7	7				
Intersection 5			2016	8	0	1	7				
Intersection 5			2017	12	0	3	10				
Intersection 5			2018	20	0	6	16				
Intersection 5	**10th Ave N @ A St**	**MP 0.195 to MP 0.295**		**64**	**0**	**26**	**42**		**1.079031**	**0.6835**	N/A

Table 20: Crash Rate Calculation

4.4. Quantitative Safety Analysis

Crash prediction was analyzed for SR 9/I 95 ramps and ramp terminals at 10th Avenue N. The analysis was conducted by using HSM Enhanced Interchange Safety Analysis Tool ISATe provides information about the relationship between various design features and safety. The crash prediction analysis follows the methodology outlined in the Highway Safety Manual (HSM). Expected crashes were predicted for the No-Build during the 10-year crash analysis period from the 2025 opening year to 2034 mid-year using the ISATe, See **Appendix 9.** The expected crashes along the arterials for 2025 opening year and 2045 design year were also estimated for the Build Alternatives using **APPENDIX 4** to obtain average crash per year from2025 to 2034 for each alternative. To find the expected crashes for the two Build Alternatives, Crash Modification Factors (CMF) obtained from the Federal Highway Administration (FHWA) CMF Clearinghouse was applied to the expected crashes for the No-Action Alternative. For Build Alternative #1 (TUDI), there is roadway capacity improvements from 4 lanes to 6 lanes. The CMF for Alternative #1 is 0.85 with crash reduction of 15% (CMF ID: 7924) was utilized. For Build Alternative #2 (DDI), a CMF of 0.592 with 40.8% crash reduction (CMF ID: 9104) was utilized for converting TUDI to DDI. In addition, a CMF of 0.85 (15% crash reduction) for roadway capacity improvements from 4 lanes to 6 lanes (CMF ID: 7924) was utilized for 10th Ave N widening, see **APPENDIX -10.** Comparison of Benefit Cost Ratio for the two alternatives is shown below:

	Alternative # 1 (TUDI)	Alternative # 2 (DDI)
Benefit Cost Ratio	**1.72**	**5.80**

Table 21: Comparison of Benefit Cost Ratio

5. CONCLUSIONS

Although this project is justified from a benefit cost ratio based on safety alone, safety and societal costs will be greatly upgraded through the improvements of the 10th Avenue North corridor recommended in the Alternative #2- Diverging Diamond Interchange (DDI).

The recommended Alternative would:

- Improve Traffic Operations
- Enhance Safety
- Reduce congestion
- Reduce crashes due to proposed reduction in the number of conflict points (**Appendix 8**)

Existing Crash data for the 10th Avenue N segment showed a total of 198 crashes and for I-95 segment showed a total of 435 crashes. Rear end collisions are leading the crash type with 51.01 % for 10th Avenue North and 62.5 % for I-95, followed by Angle collision as second predominant type of crash with 14.14 % and 9.7% respectively.

Nighttime crashes exceed the statewide average and it is recommended to provide street lighting at the proposed intersection including crosswalk for pedestrian safety. Continuous corridor lighting within the limits of the project, along 10 Avenue N and ramps are recommended.

The three major crash clusters along the 10th Avenue North corridor occurred at the following locations:

- Barnett Drive: Total of 65 Crashes
- ON/Off SB I-95 Ramps: Total of 25 crashes
- N "A" Street: Total of 64 crashes.

The number of crashes expected for the segments and intersections under existing conditions was 46.170 and the number of crashes expected for the segments and intersections under proposed future -No build condition for 2045 was 48.539.

Considering the 2045 future Build (Alternative #2), the expected number of crashes under proposed future conditions dropped from 48.539 to 47.696, a further decrease of 1.75%. While the expected crashes for TUDI (Alternative #1) model would be 48.991.

Societal costs of crashes were calculated from tables above and resulted in a decrease from $8,947,811.53 (2045 No-Build) to $8,792,410.61 (2045 Build-Alternative#2) for a net benefit of $ 155,400.92.

Benefit Cost (B/C) Analyses were conducted for both alternatives (TUDI and DDI) by using FDOT benefit cost analysis tool. B/C analysis provides the ratio of benefits to the cost spent for the proposed improvements. Benefit cost were analyzed for Arterial and Ramp Terminal for both alternatives. The benefit cost ratio for Alternative #1 is 1.72 and for Alternative # 2 is 5.80. The Crash Reduction factors (CRF) for calculating the B/C were obtaining from FHWA CMF Clearing House. Alternative # 2, has large Benefit Cost when compared with Alternative # 1

Societal benefits will also include reduction in fuel consumption and delay.

Alternative #2 (DDI) will eliminate left turn movement with opposing through traffic crashes and reduce rear end crashes. Channelization of all turns onto the ramp and off the ramps is required to prevent wrong-way maneuvers. Minimizing the radius and speed of channelized turns with crosswalks will improve pedestrian safety. Minimized crossing distance for pedestrian is an advantage.

Bicycle lanes wider than five feet are recommended for Alternative #2 (DDI) to provide bicyclists with safe and convenient facilities to travel across the interchange. The bicycle lanes should be located to the right of the travel lanes for motorized traffic, which is generally where bicyclists expect to travel.