TECHNICAL MEMORANDUM

Date:	April 6, 2023
To:	Joanna Liu, City of Livermore
From:	Ruta Jariwala, Himangi Mutha, TJKM
Subject:	Systemic Safety and Trend Analysis, and Identification of High Injury Network for the City of Livermore Local Roadway Safety Plan (LRSP)

This technical memorandum summarizes the results of the collision analysis of collisions that have occurred in the City of Livermore between January 1, 2015 and December 31, 2019, as part of the Local Roadway Safety Plan (LRSP). This memorandum includes the following sections:

1. Data Collection
2. Collision Data Analysis
3. Fatal and Severe Injury Collision Analysis
4. Geographic Collision Analysis
5. High Injury Network

The LRSP focuses on systemically identifying and analyzing traffic safety issues and recommends appropriate safety improvements. The memorandum starts with a comprehensive analysis of collisions of all severity types in the City of Livermore and compares this with the fatal and severe injury (F+SI) collisions. Factors such as collision severity, type of collision, primary collision factor, lighting, weather, and time were analyzed. Following this, a more detailed analysis was conducted for fatal and severe injury (F+SI) collisions that have occurred on the city's roadways, including analyzing intersection and roadway segment collisions separately. **Figure 1** illustrates all the injury collisions that have occurred in the City of Livermore from 1/1/2015 to 12/31/2019.

Figure 1. Injury Collisions in the City of Livermore (2015-2019)

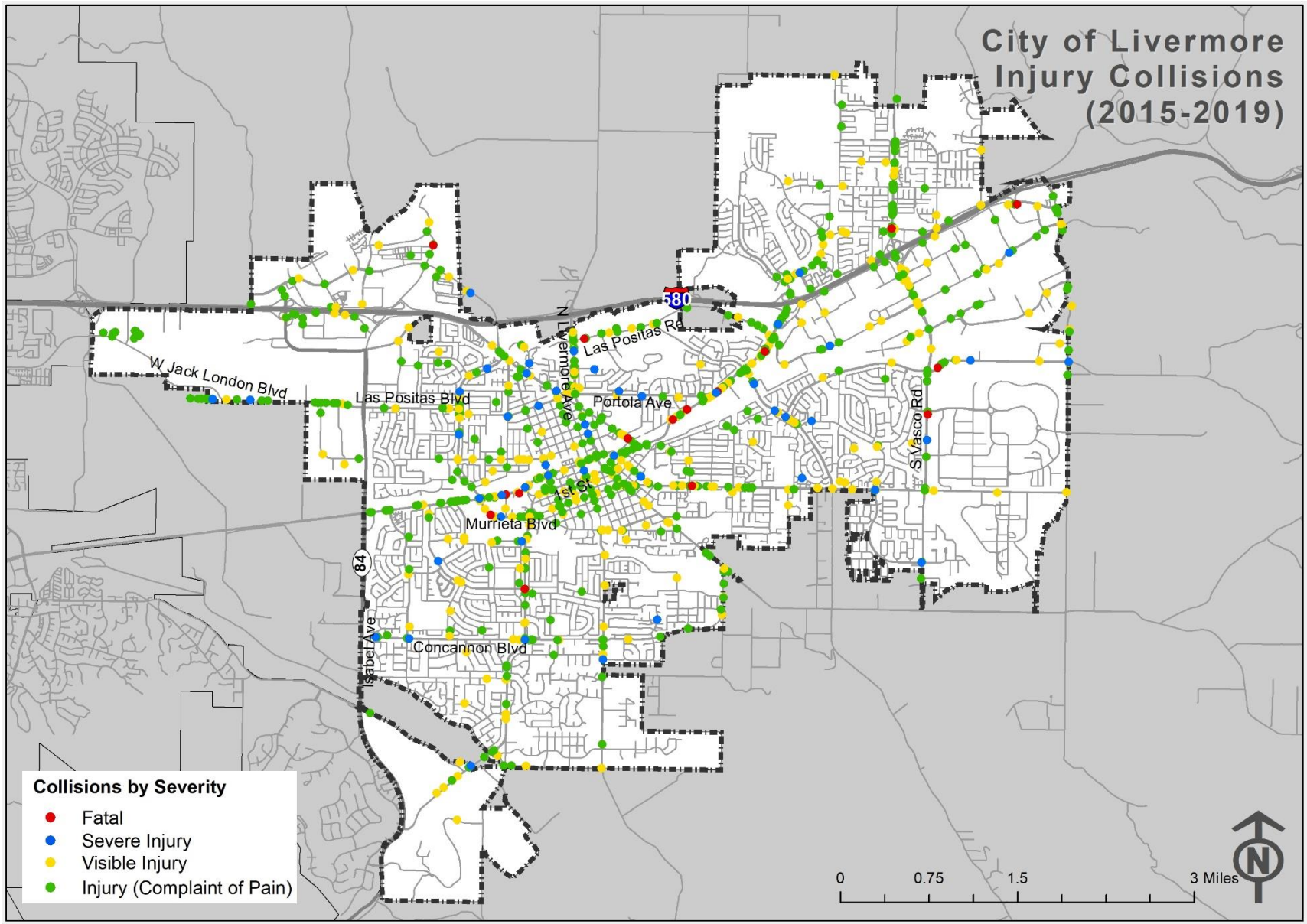
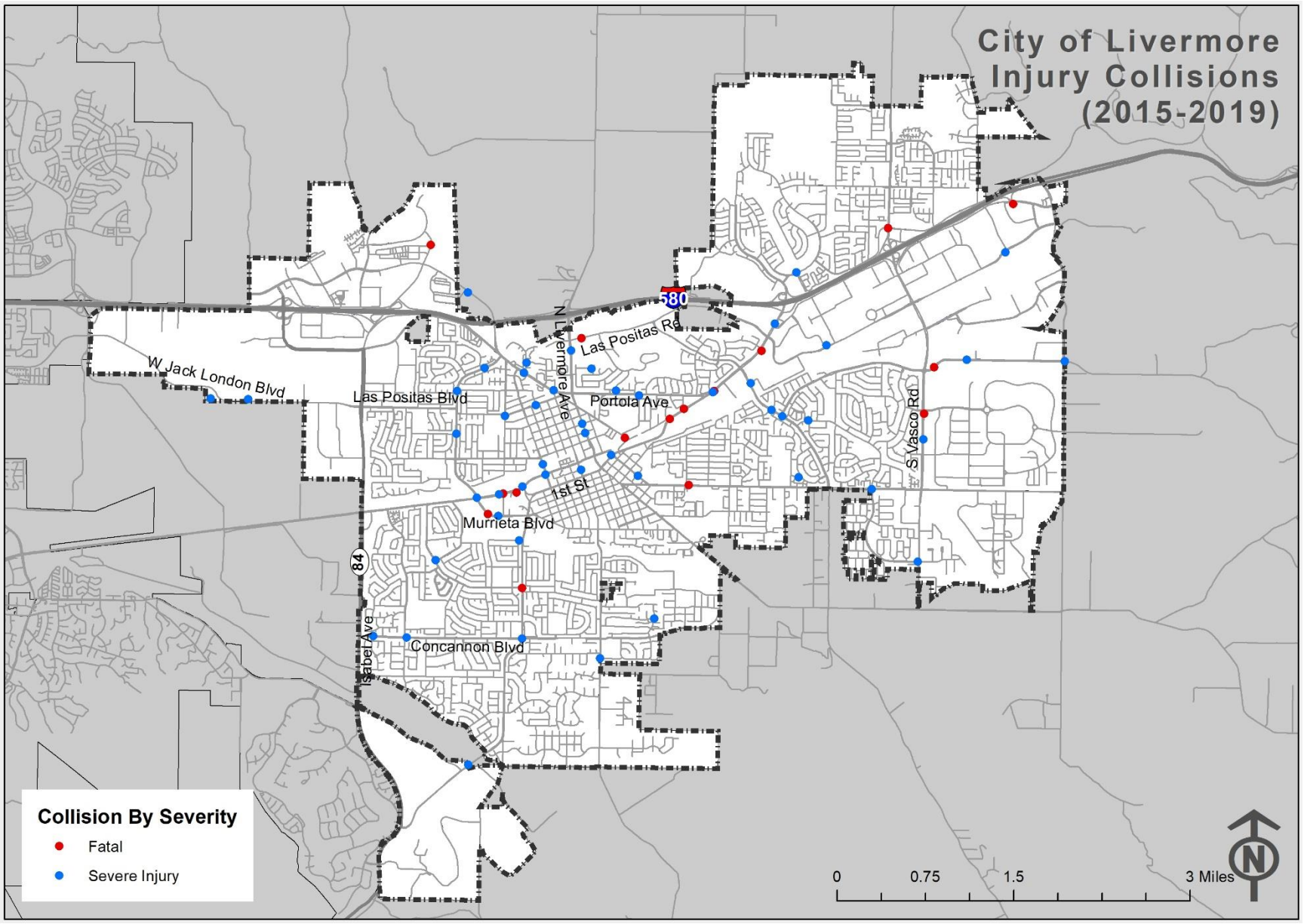


Figure 2. Fatal and Severe Injury Collisions in the City of Livermore (2015-2019)



DATA COLLECTION

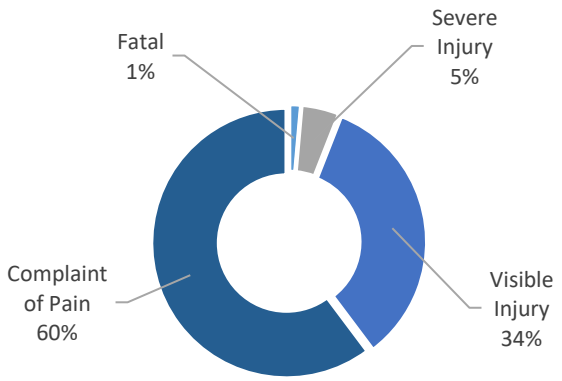
Collision data helps to understand different factors that might be leading to collisions and influencing collision patterns in a given area. For the purpose of this analysis, five-years of jurisdiction-wide collision data (2015 to 2019) was retrieved from CROSSROADS. Collisions that occurred on the SR 84 are not part of this analysis since SR 84 is relinquished by the City. The collision data was analyzed and plotted in ArcMap to identify high-risk intersections and roadways segments.

COLLISION DATA ANALYSIS RESULTS

Collision Analysis by Severity

A total number of collisions reported in five years (2015-2019) were 4,520. Amongst all collisions, 1,363 injury collisions were reported on the City of Livermore roads and 3,157 collisions were PDO's (Property Damaged Only). Amongst 1,363 collisions 221 were found to be on Isabel Ave (SR84).

Figure 3. Collisions by Severity (2015 -2019)



There were a total of 1,142 collisions reported on the City of Livermore roads from 2015 to 2019. Out of these, 688 collisions (60%) led to complaint of pain injury and 386 collisions (34%) led to a visible injury. There were 68 F+SI (fatal and severe injury) collisions, of which 52 collisions (5%) led to a severe injury and 16 collisions (1%) led to a fatality. **Figure 3** illustrates the classification of all collisions based on severity.

The analysis first includes a comparative evaluation between all collisions and F+SI collisions, based on various factors including (but not limited to): collision trend, primary collision factor, collision type, facility type, motor vehicle involved with, weather, lighting, and time of the day. Following this, a comprehensive analysis is conducted for only F+SI collisions. F+SI collisions cause the most damage to those affected and to infrastructure. The aftermath of these collisions can lead to great expenses for jurisdiction administration. The LRSP process thus focuses on these collision locations to proactively identify and counter safety issues leading to these F+SI collisions.

The collision data was separated by facility type, i.e. based on collisions occurring on intersections and roadway segments. For the purposes of the analysis and in accordance with HSIP (Highway Safety Improvement Program) guidelines, a collision was designated to have occurred at an intersection if it occurred within 250 feet of it. The reported collisions categorized by facility type and collision severity are presented in **Table 1**.

Table 1. Collision by Severity and Facility Type:

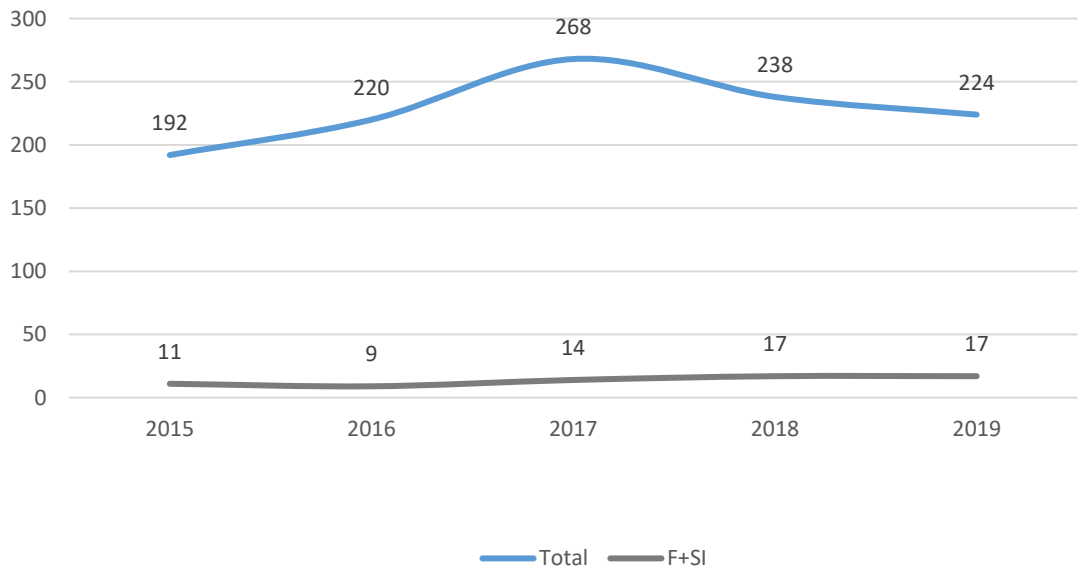
Collision Severity	Roadway Segment	Intersection	Total
Fatal	5	11	16
Severe Injury	8	44	52
Visible Injury	74	312	386
Complaint of Pain	115	573	688
Total	**202**	**940**	**1,142**

COLLISION ANALYSIS

Yearly Trend

The number of reported collisions of all severity overall increased between 2015 and 2017, whereas the collisions decreased from 2017 to 2019. The year with the highest number of collisions was 2017 (268 collisions), while the year with the lowest number of collisions was 2015 (192 collisions). The yearly total of 68 F+SI collisions occurred in the City of Livermore during the study period, is overall consistent from 2015 to 2019. The least number of F+SI collisions occurred in 2016 (9 collisions), while the most occurred in 2018 (17 collisions) and 2019 (17 collisions). **Figure 4** illustrates the five-year collision trend for all collisions, and F+SI collisions.

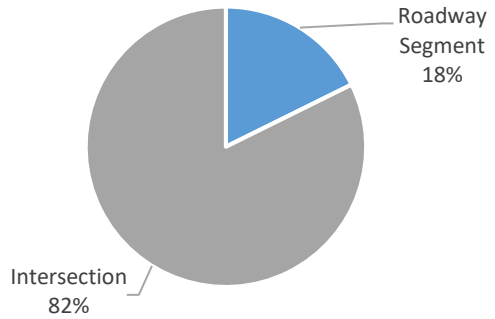
Figure 4. Five Year Collision Trend:



Roadway Segment vs. Intersection

When evaluating the locations of injury collisions, most collisions occurred at intersections and not along roadway segments. In the City of Livermore, 82% of all collisions (940 collisions) occurred at intersections whereas 17% (202 collisions) occurred on roadway segments. This classification by facility type can be observed in **Figure 5**.

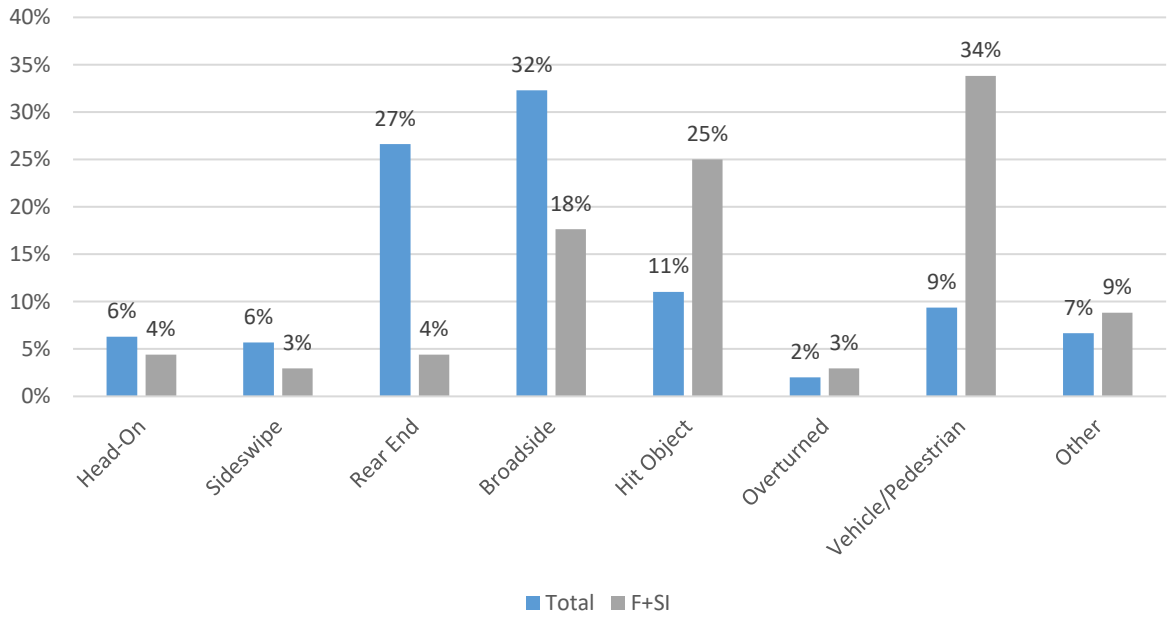
Figure 5. Intersection vs Roadway Collisions - All Collisions and F+SI



Collision Type

For collisions of all severity, the most commonly occurring collision type was broadside type collisions (32%) and rear-end type collisions (27%). The collision types for F+SI collisions follow a different pattern, where the most commonly occurring collision type was vehicle/pedestrian collisions (34%), hit object collisions (25%) and broadside (18%). **Figure 6** illustrates the collision type for all collisions as well as F+SI collisions.

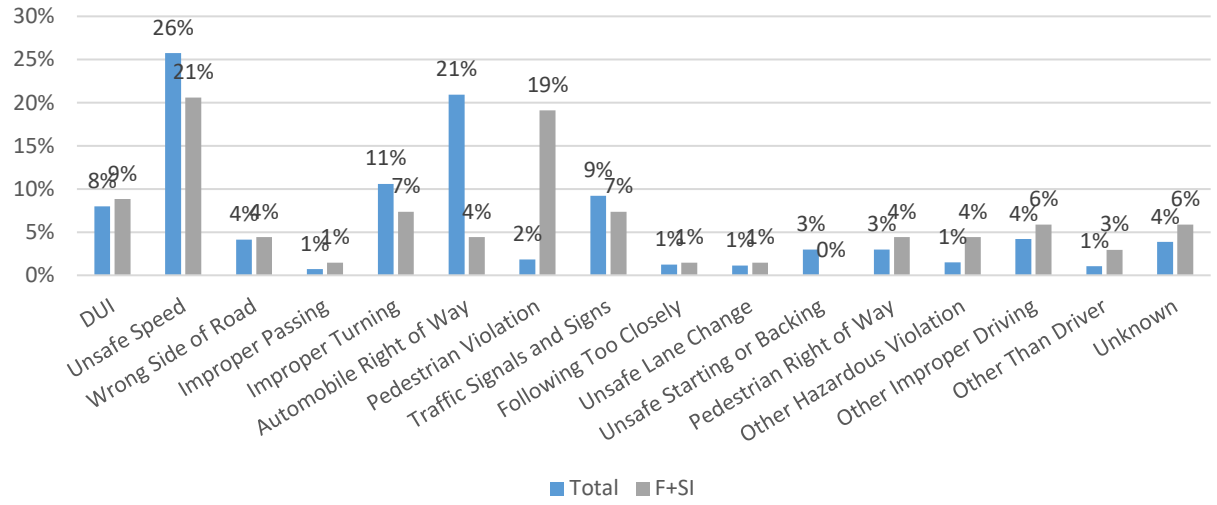
Figure 6. Collision Type - All Collisions vs F+SI Collisions:



Primary Collision Factor

For collisions of all severity, the most common violation category was observed to be unsafe speed (26%) and automobile right of way (21%). The most common primary violation categories for F+SI collisions were unsafe speed (21%), pedestrian violation (19%), driving under influence (9%), and improper turning and traffic signals and signs (7%). **Figure 7** illustrates the violation category for collisions of all severity and F+SI collisions.

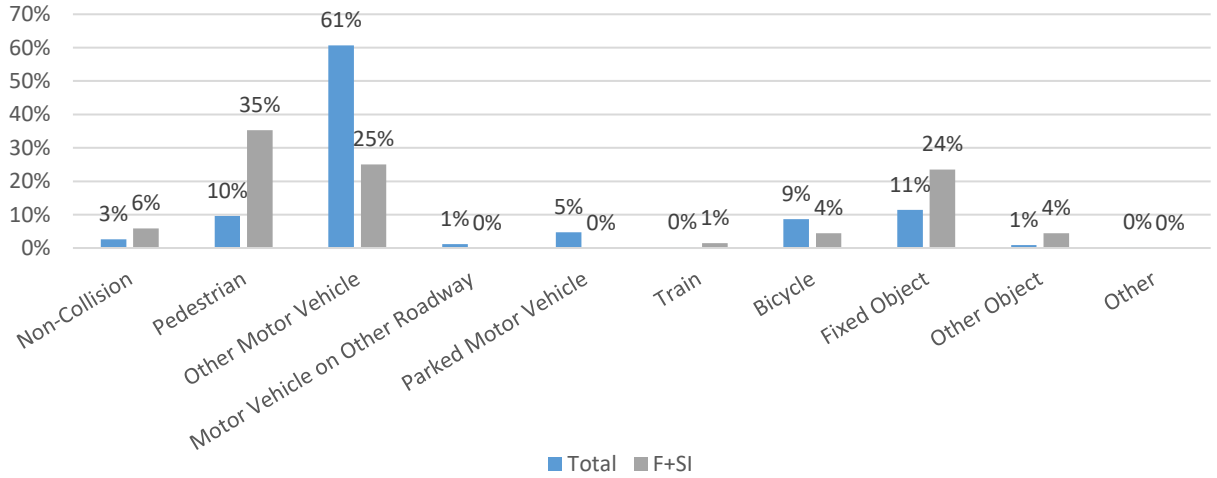
Figure 7. Violation Categories: All Collisions vs F+SI:



Motor Vehicle Involved With

For collisions of all severity, 61% of the collisions occurred due to motor vehicle colliding with other vehicles. This was followed by fixed object collisions (11%), and pedestrian collisions (10%). For F+SI collisions, 35% involved pedestrians, 25% of the collisions involved motor vehicles, and 24% involved fixed object. **Figure 8** illustrates the motor vehicle involved with category for all collisions as well as F+SI collisions.

Figure 8. Motor Vehicle Involved With: All Collisions vs F+SI Collisions:

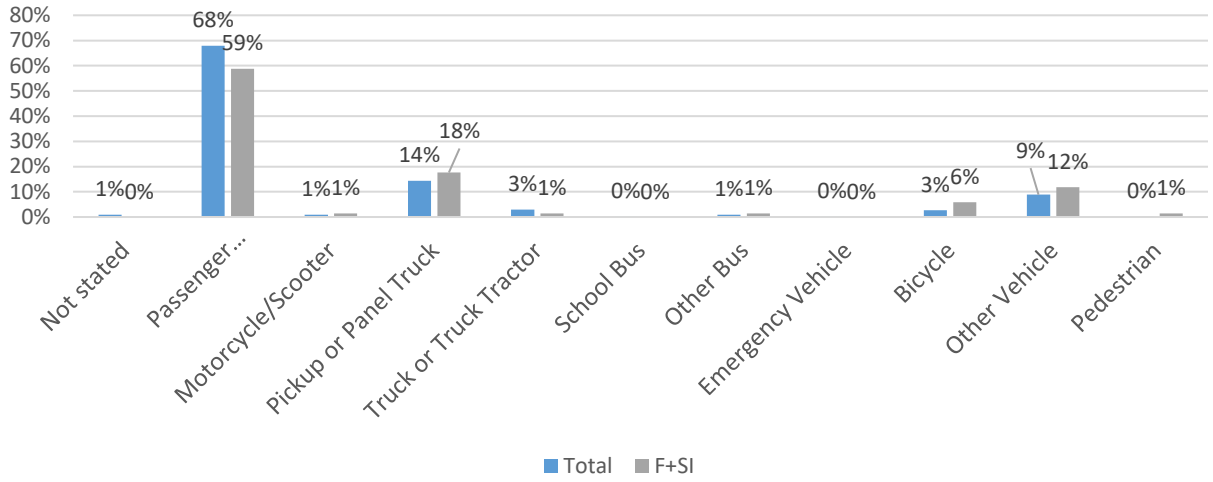


Modes

In addition to motor vehicle involved with, modes include a more detailed breakdown of the vehicle type at fault in the collision, including motorcycles and trucks. For collisions of all severity, the majority were caused by a passenger car (68%), followed by truck or bus (14%). Crashes with passenger car (59%) and pickup truck (18%) also makes up the majority of F+SI collisions.

Figure 9 illustrates the percentage for all collisions as well as F+SI collisions by mode.

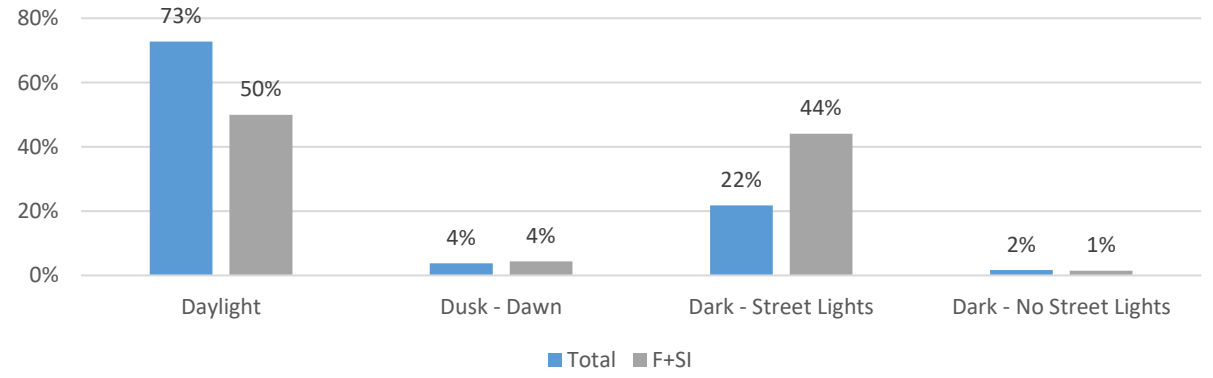
Figure 9. Modes: All Collisions vs F+SI Collisions:



Lighting

For collisions of all severity, 73% of collisions occurred in daylight, while 22% of collisions occurred in the dark on streets with streetlights. For F+SI collisions, a higher percentage of crashes occurred in daytime conditions, with 50% of collisions having occurred in daylight and 44% of collisions occurred in the dark on streets with street lights. **Figure 10** illustrates the lighting condition for all collisions and F+SI collisions.

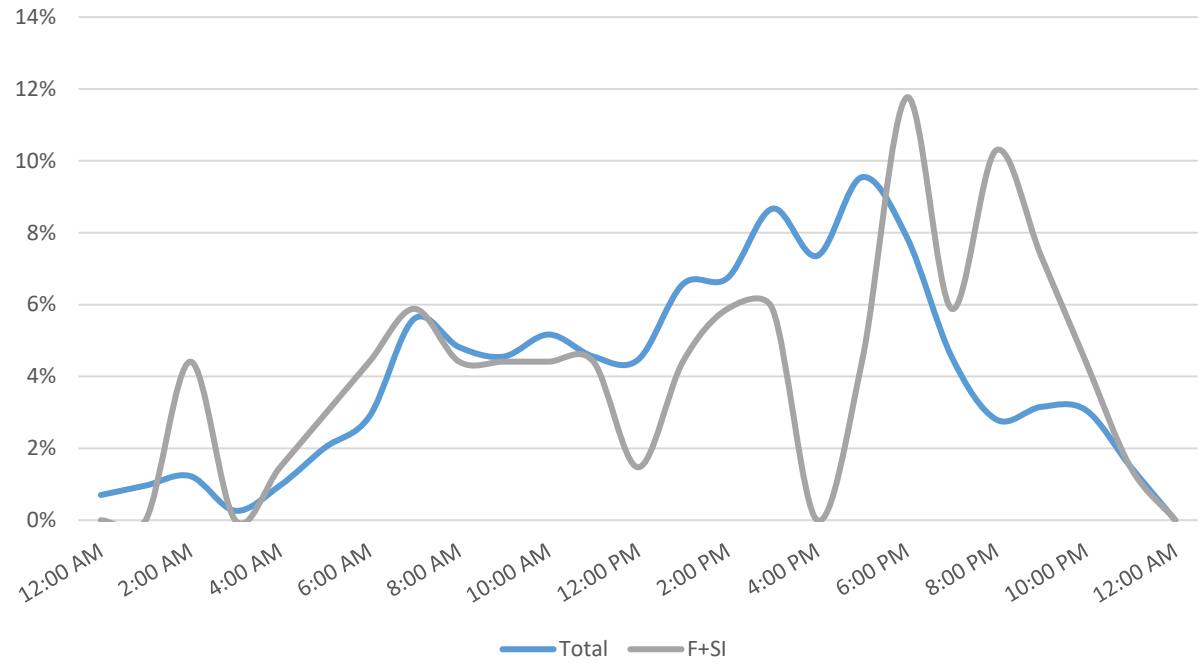
Figure 10. Lighting Conditions: All Collisions vs F+SI Collisions:



Time of the Day

For collisions of all severity, the hour with the most number of collisions was between 5:00 p.m. to 6:00 p.m. (9%), while the hour with the fewest number of collisions was between 3:00 a.m. to 4:00 a.m. (0%). For all F+SI collisions, maximum number of collisions occurred between 5:00 p.m. to 6:00 p.m. (11%). **Figure 11** illustrates the percentage of collisions occurring during each hour of the day for all collisions as well as F+SI collisions.

Figure 11. Time of the Day: All Collisions vs F+SI:



FATAL AND SEVERE INJURY COLLISIONS

This section describes a detailed collision analysis performed for F+SI collisions occurring at roadway segments and intersections in the City of Livermore. Of the total 68 F+SI collisions that occurred during the study period, 13 collisions (19%) occurred on roadway segments and 55 collisions (81%) occurred at intersections. This distribution is illustrated in **Figure 12** below.

Figure 12. Intersection vs. Roadway Segment Collisions: F+SI Collisions:

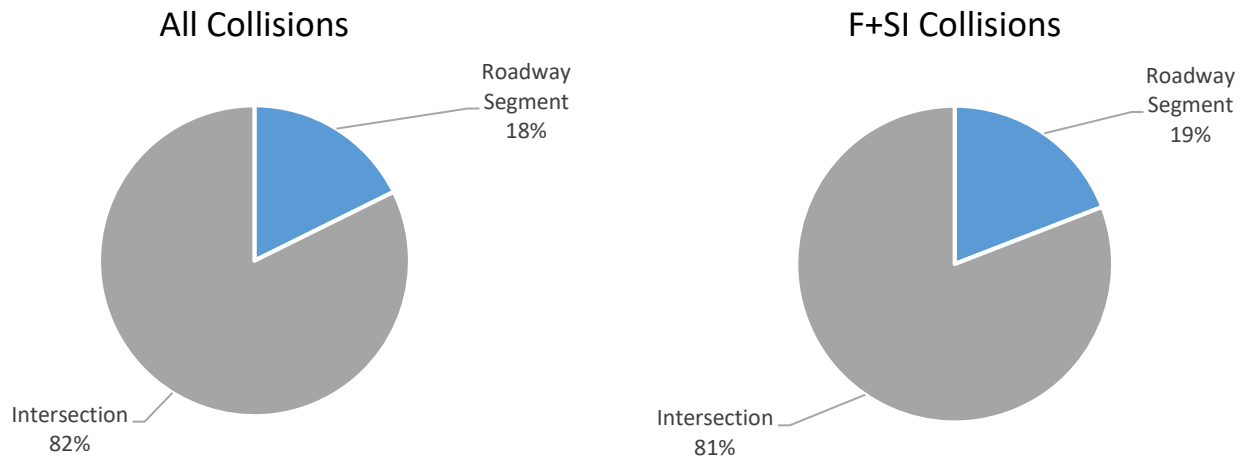
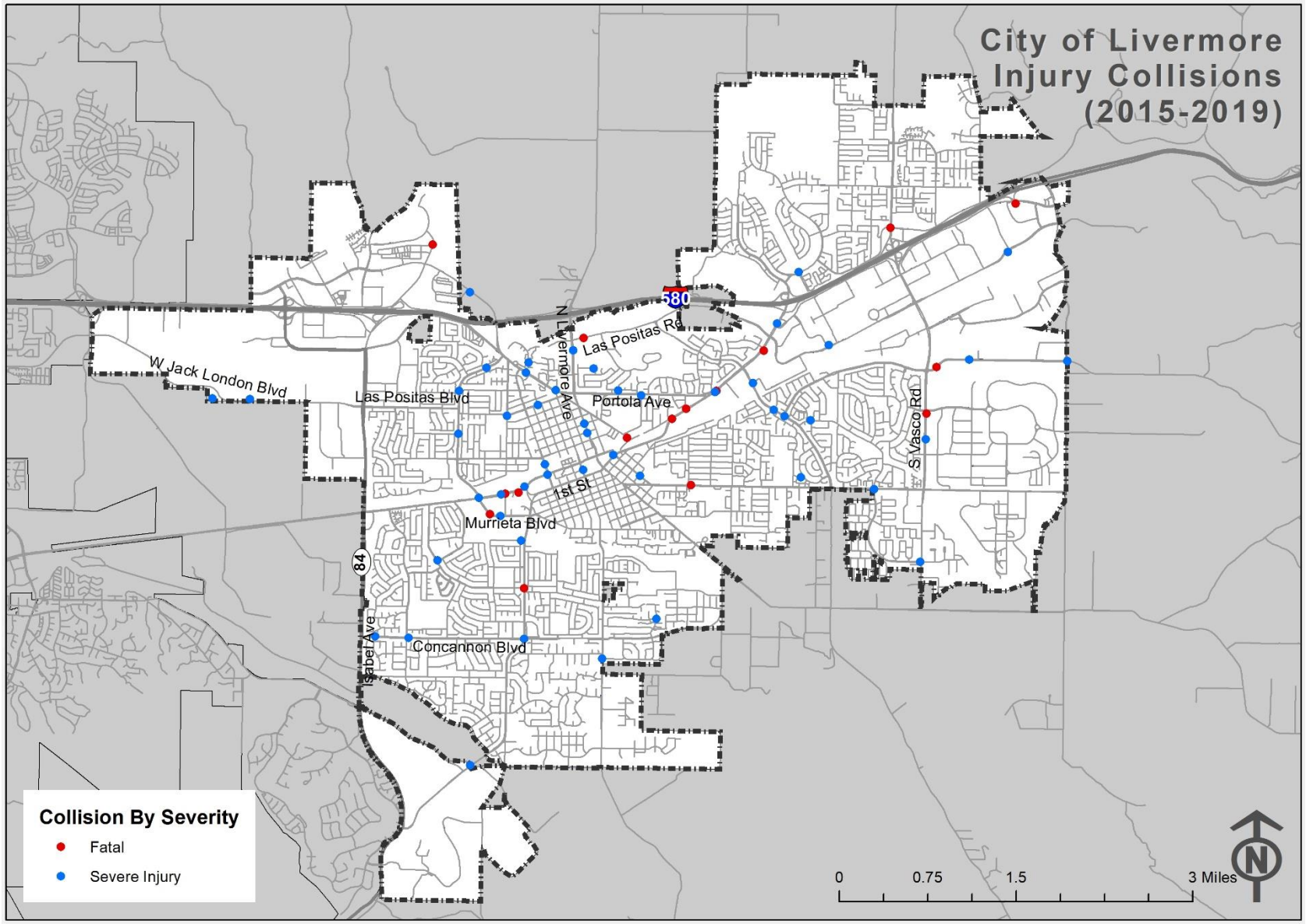


Figure 13 maps the F+SI collisions that occurred the City of Livermore during the study period.

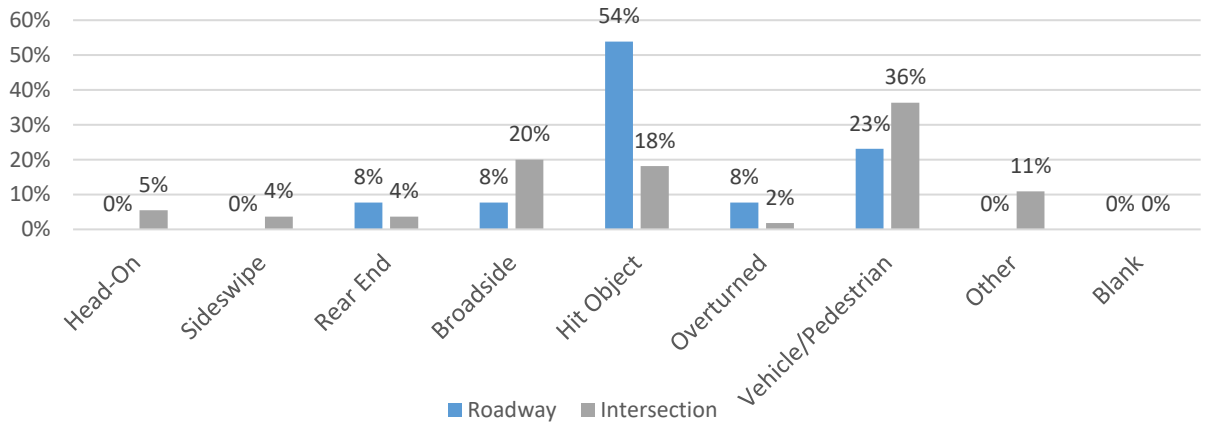
Figure 13. Fatal and Severe Injury Collisions (2015-2019)



Collision Type and Location Type

Higher frequency of F+SI collision type were hit object (54%) and vehicle/pedestrian (23%) type collisions on roadway segments and along with vehicle/pedestrian involved collisions (36%) and broadside collisions (20%) at the intersection. 8% of all F+SI collisions were rear end, broadside and overturned collisions that occurred on roadway segments and 18% of collisions were hit objects occurring at the intersections. **Figure 14** shows fatal and severe injury collisions location type and collision type.

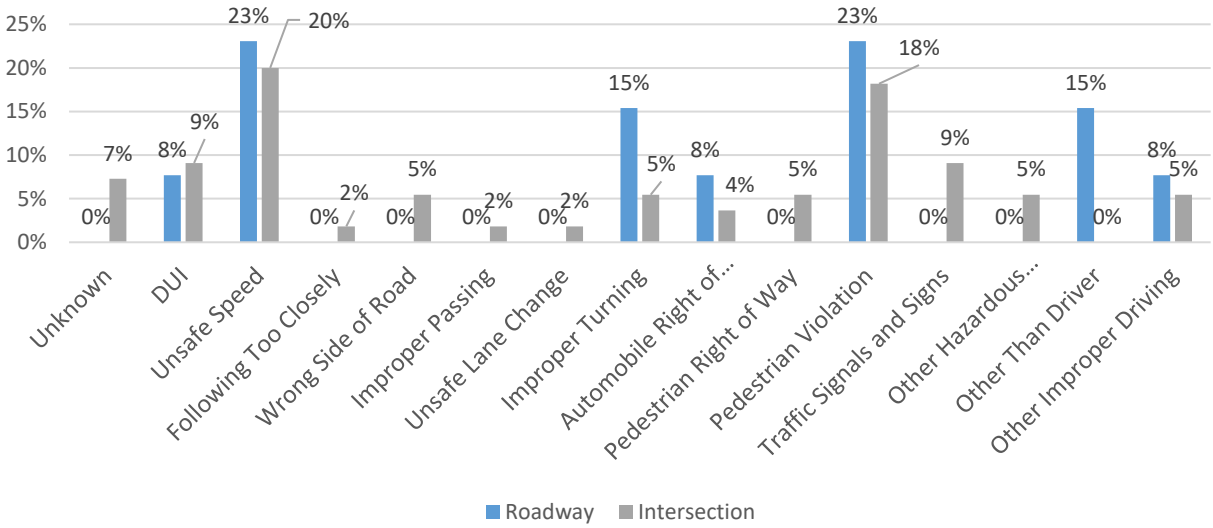
Figure 14. F+SI Collision Type vs Location Type:



Violation Category and Location Type

The most common violation types among F+SI collisions were unsafe speed (23%), pedestrian violation (23%), improper turning (15%) and driving under influence and auto mobile right of way (8%). These F+SI collisions primarily occurred at roadway segments. Unsafe speed and pedestrian violation was the most common violation category along roadway segments, as well as at intersections. **Figure 15** shows fatal and severe injury collisions by location type and violation category.

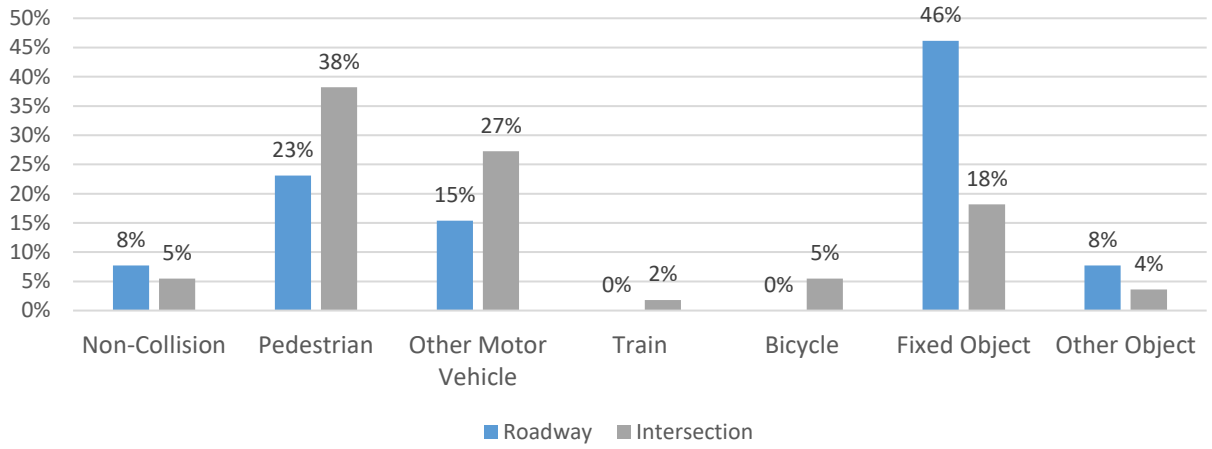
Figure 15. F+SI Collisions: Violation Category vs Location Type:



Motor Vehicle Involved With and Location Type

F+SI collisions involving fixed object and pedestrian was the most common type of collision occurring on roadway segments (46% and 23% of all F+SI collisions). At the intersections, the most common collision was with pedestrian (38% of all F+SI collisions). **Figure 16** shows fatal and severe injury collisions by location type and collision type.

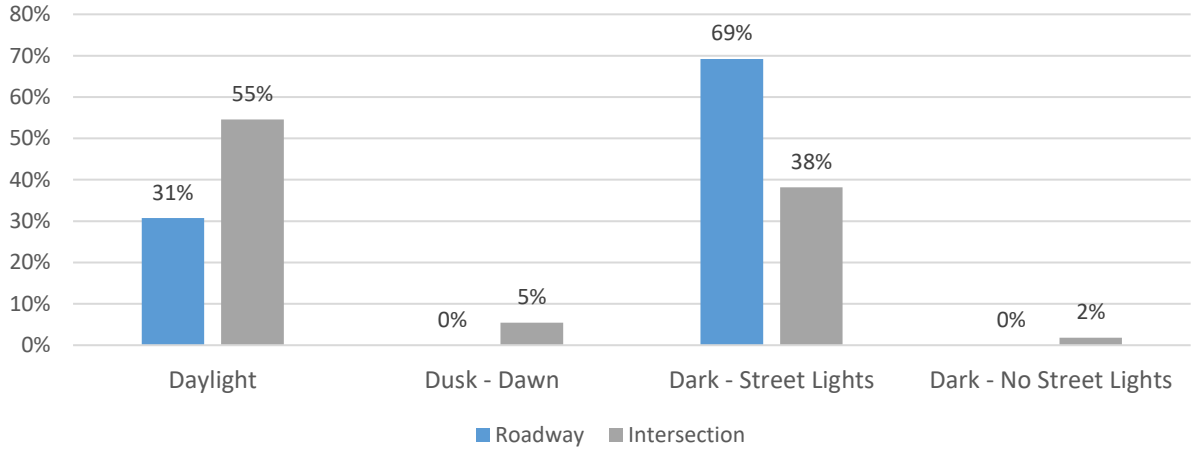
Figure 16. F+SI Collisions: Motor Vehicle Involved With vs Location Type:



Lighting and Location Type

Most F+SI collisions occurred in dark conditions with street lights on roadways (69%) and in daylight conditions (31%) occurring on roadway segments. 55% of F+SI collisions. **Figure 17** shows fatal and severe injury collisions by location type and lighting conditions.

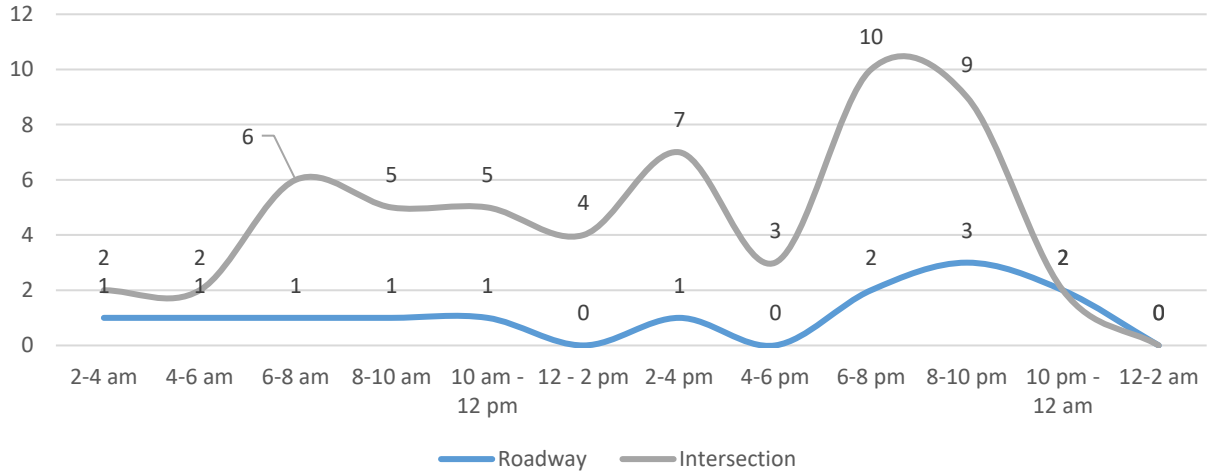
Figure 17. F+SI Collisions: Lighting and Location Type:



Time of the Day and Location Type

The time duration with the most F+SI collisions was during 7:00 p.m. to 10:00 p.m. These primarily occurred at intersections, though the most number of roadway segment F+SI collisions occurred between 8:00 p.m. and 10:00 p.m. and between 10:00 p.m. and 11:00 p.m. **Figure 18** shows fatal and severe injury collisions by location type and time of day.

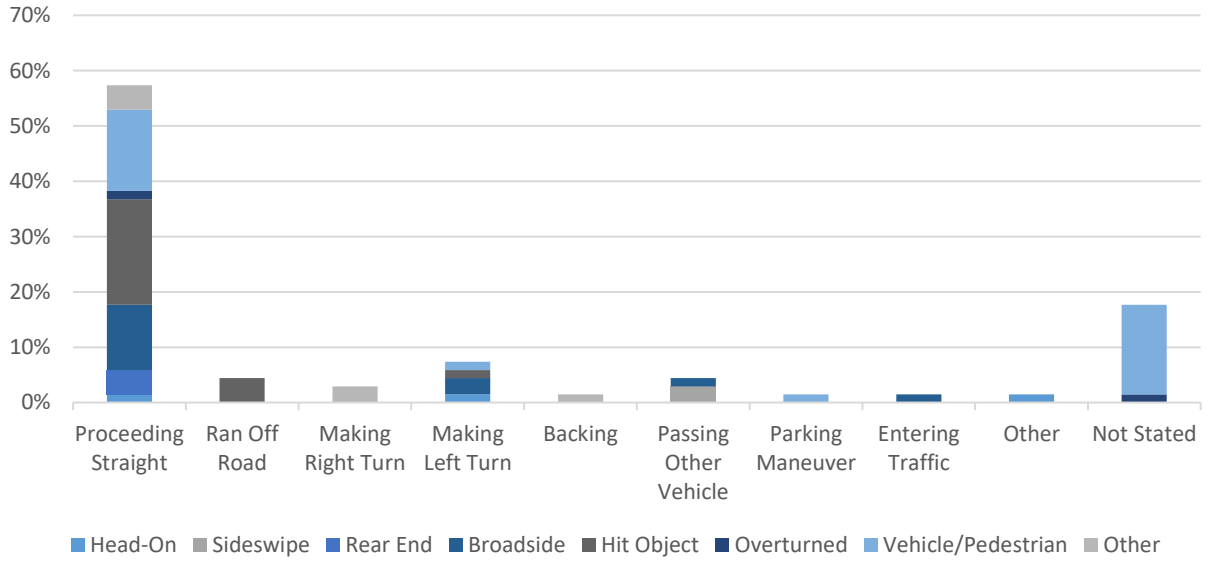
Figure 18. F+SI Collisions: Time of Day vs Location Type:



Collision Type vs. Movement Preceding Collision of Party at Fault

The most common type of collision for F+SI collisions was vehicle/pedestrian collisions. Of these collisions, Proceeding Straight was the most common movement preceding the collision of the party at fault (59% of all F+SI collisions), followed by making left turn (8%). **Figure 19** shows distribution of collision type and the movement by the party at fault preceding the collision.

Figure 19. F+SI Collisions by Collision Type and Movement Preceding Collisions of Party at Fault:



Geographic Collision Analysis

This section describes a detailed geographic collision analysis performed for injury collisions occurring on roadway segments and at intersections in the City of Livermore. The above collision analysis was used to identify five main collision factors that highlight the top trends among collisions in the City of Livermore. These five collision factors were identified to be rear end collisions, broadside collisions, nighttime collisions, unsafe speed violations, and pedestrian collisions.

Rear End Type Collisions

Rear End collisions represented the highest proportion of collisions of all severity (27%), a significant percentage of F+SI collisions (8%). **Figure 20** shows the distribution of rear end collisions throughout the City of Livermore between 2015 and 2019. E Stanley Blvd and North Vasco Rd have a higher concentration of rear end collisions, compared to other Livermore roads.

Broadside Type Collisions

Broadside collisions caused 32% of all injury collisions, 20% when considering only F+SI collisions. It was the most common collision type among F+SI collisions. **Figure 21** shows the distribution of broadside collisions throughout the City of Livermore between 2015 and 2019. Maple St, Third St and Fourth St have a higher concentration of broadside collisions, compared to other Livermore roads.

Nighttime Type Collisions

Collisions occurring at night represented only 22% of all injury collisions, but rose significantly to 38% of F+SI collisions, indicating that lighting may be a factor in those collisions. **Figure 22** shows the distribution of nighttime collisions throughout the City of Livermore between 2015 and 2019. E Stanley Ave and Vallecitos Rd have a higher concentration of nighttime collisions, compared to other roads in the City of Livermore.

Unsafe Speed Violations

26% of all injury collisions, a significant percentage of F+SI collisions (23%) in Livermore were caused by unsafe speed, the highest of any violation type among all injury collisions. **Figure 23** shows the distribution of unsafe speed collisions throughout the City of Livermore between 2015 and 2019. E Stanley Ave have a higher concentration of unsafe speed collisions, compared to other Livermore roads.

Pedestrian Type Collisions

Vehicle/pedestrian collisions accounted for 9% of all F+SI collisions (the most of any category), compared to 36% of all injury collisions. **Figure 24** shows the distribution of pedestrian collisions throughout the City of Livermore between 2015 and 2019, E Stanley Ave, First St and Las Positas Rd have a higher concentration of pedestrian collisions, compared to other Livermore roads.

Figure 20. City of Livermore Rear End Collisions (2015 - 2019)

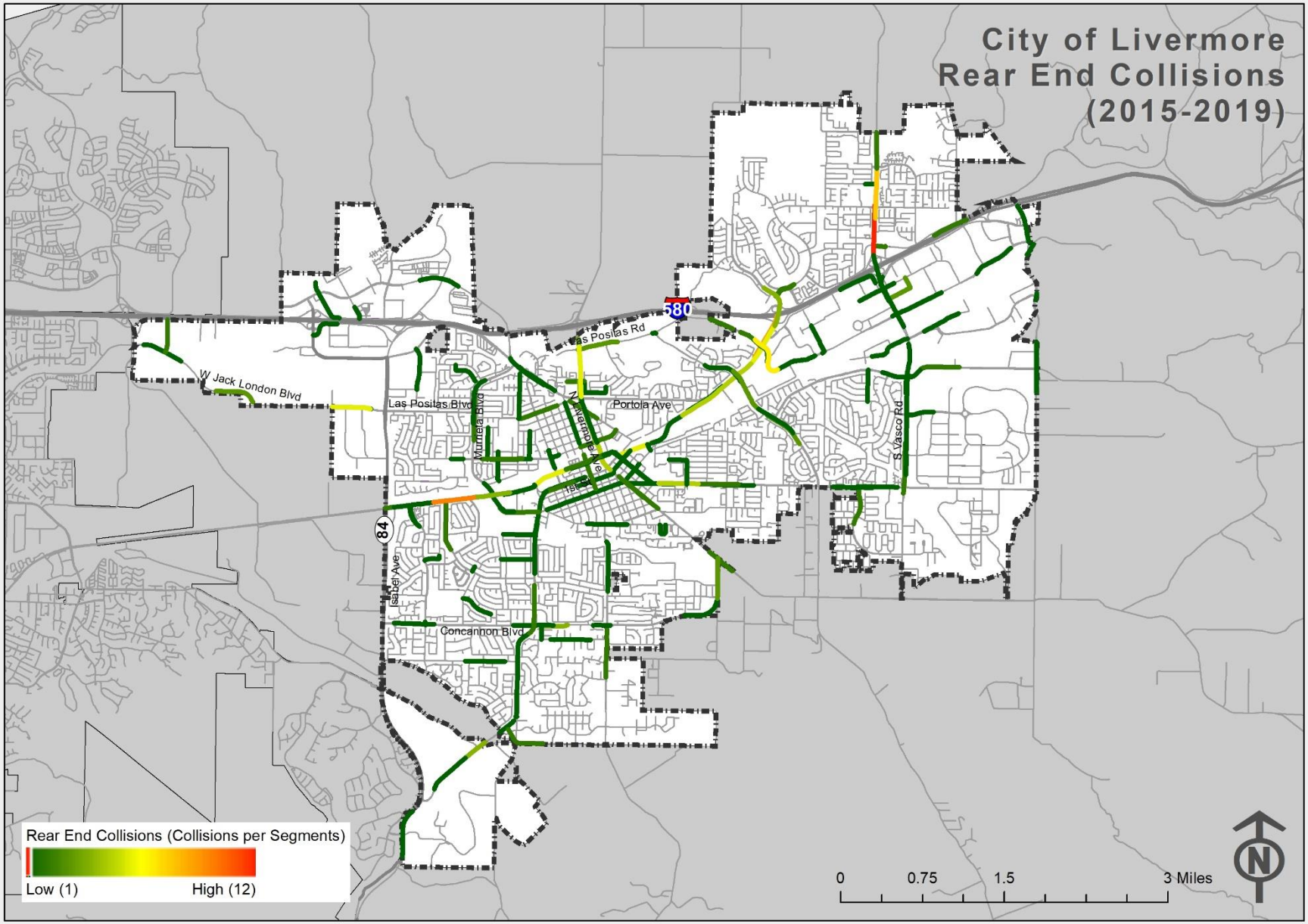


Figure 21. City of Livermore Broadside Collisions (2015 - 2019)

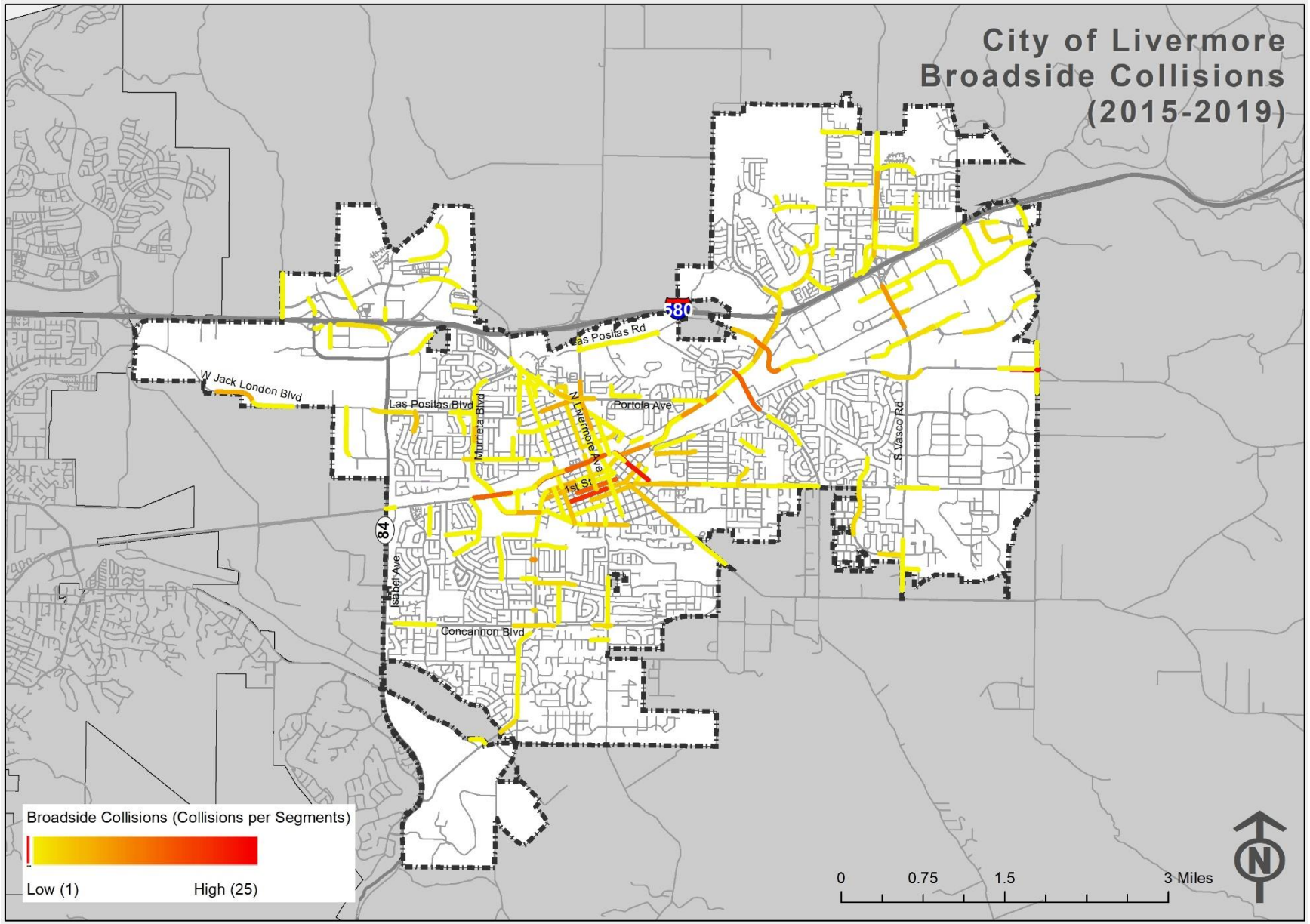


Figure 22. City of Livermore Nighttime Collisions (2015 - 2019)

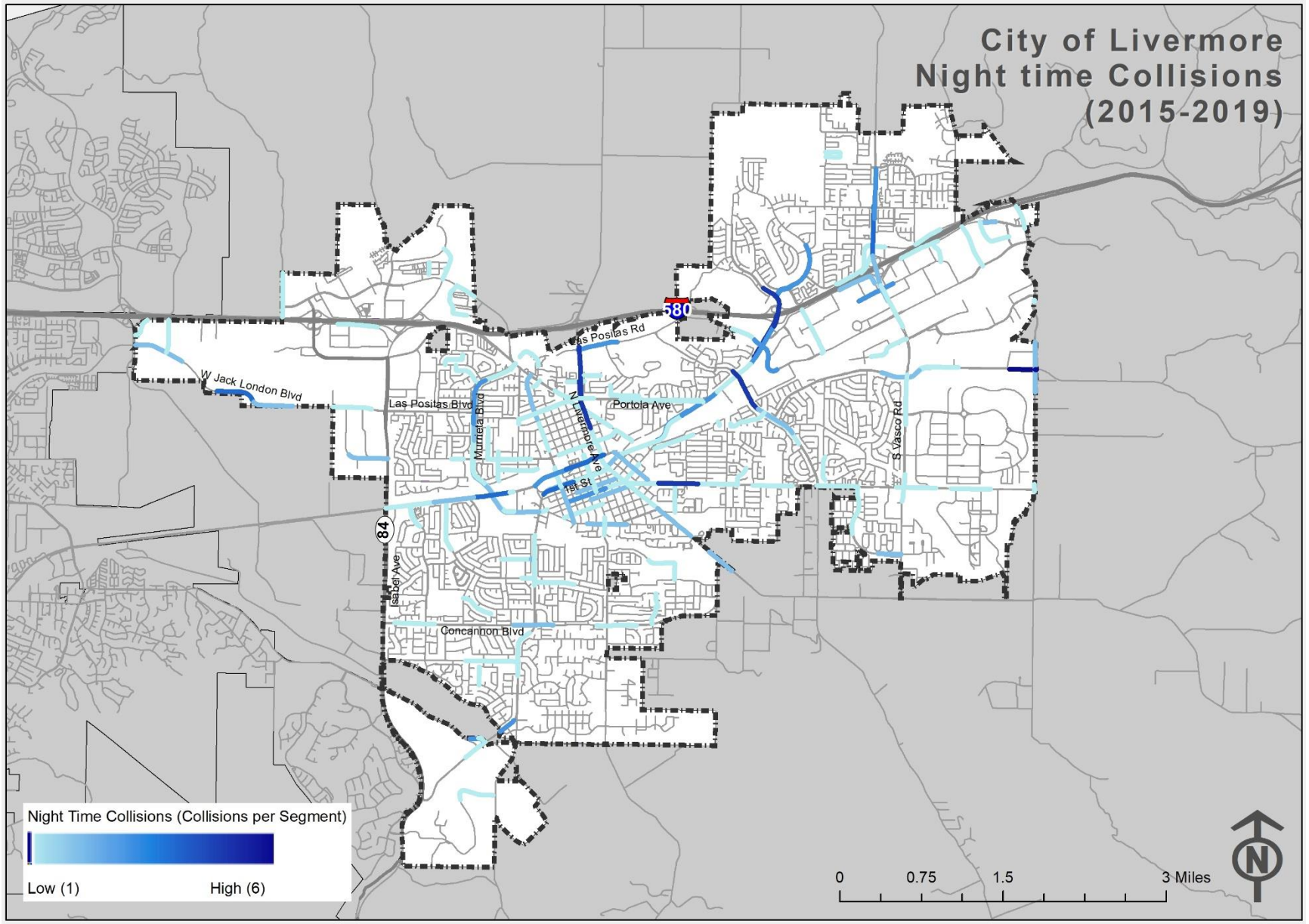


Figure 23. City of Livermore Unsafe Speed Collisions (2015 - 2019)

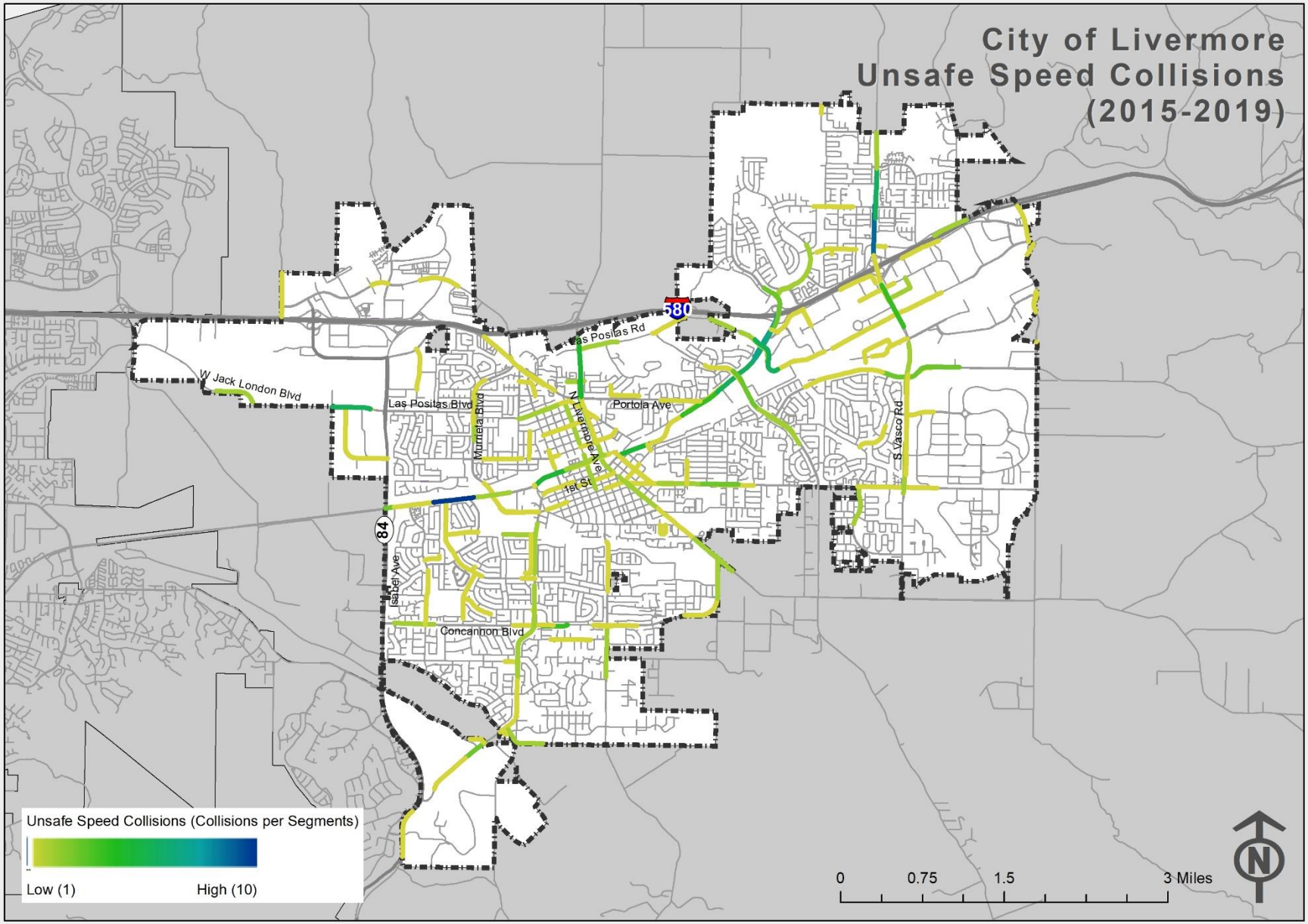
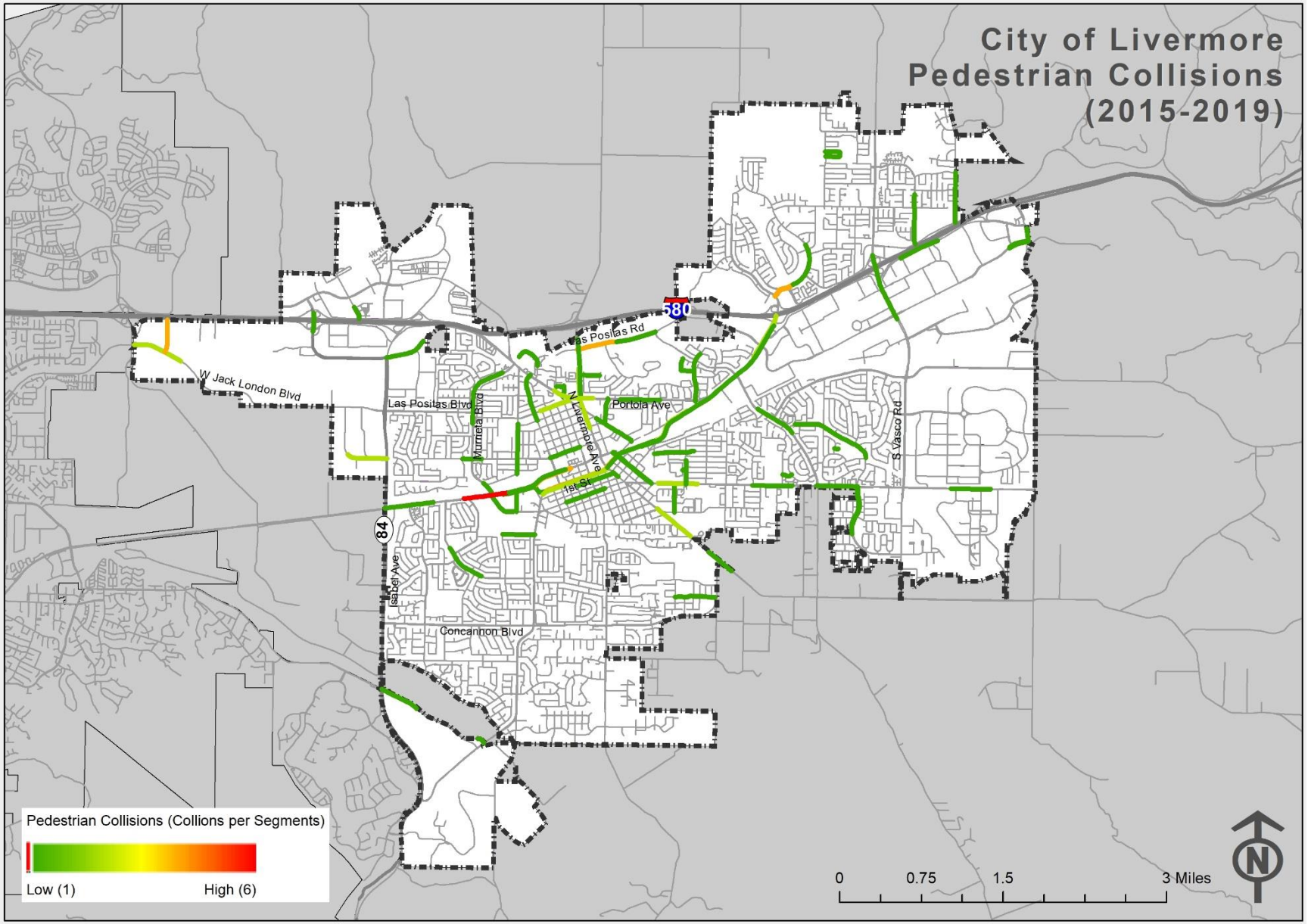


Figure 24. City of Livermore Pedestrian Collisions (2015 – 2019)



Collision trend analysis- pedestrian and bicycle collisions

Collisions on City roads

Out of 1,142 injury collisions, 209 collisions (**18**%) involved pedestrian and bicycle collisions. There were 27 (13%) F+SI (fatal and severe injury) collisions, of which 20 collisions (74%) led to a severe injury and 7 collisions (26%) led to a fatality. **Figure 25** illustrates the classification of pedestrian and bicycle collisions based on severity on city roads.

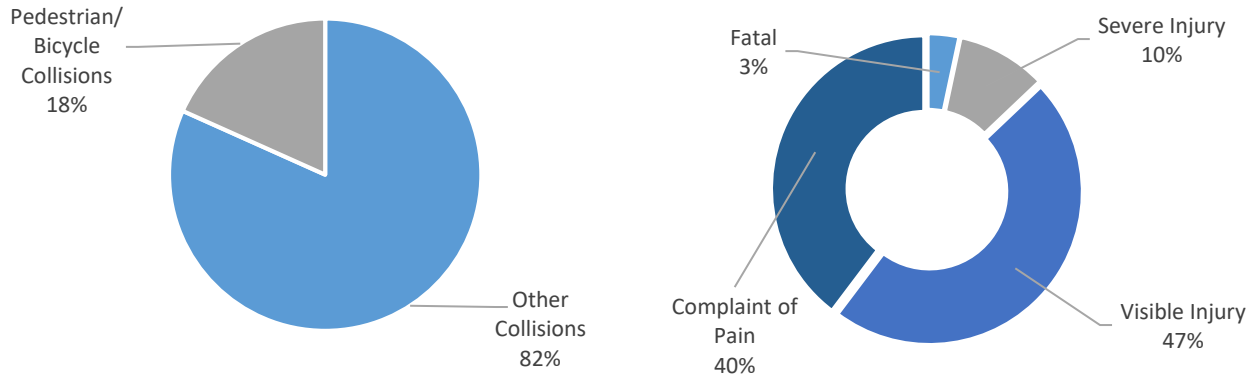


Figure 25: Pedestrian and Bicycle Collisions based on severity (2015-2019)

Table 2. Pedestrian and Bicycle Injury Collision by severity type (2015-2019):

Collision Severity	Roadway Segment	Intersection	Total	Percentage
Fatal	1	6	7	3%
Severe Injury	2	18	20	9.5%
Visible Injury	6	93	99	47%
Complaint of Pain	4	79	83	40%
Total	**13**	**196**	**209**	**100%**

Figure 26 and **Figure 27** illustrates all the pedestrian and bicycle collisions that have occurred in the City of Livermore from 1/1/2015 to 12/31/2019.

Figure 26. City of Livermore Pedestrian Collisions (2015 - 2019)

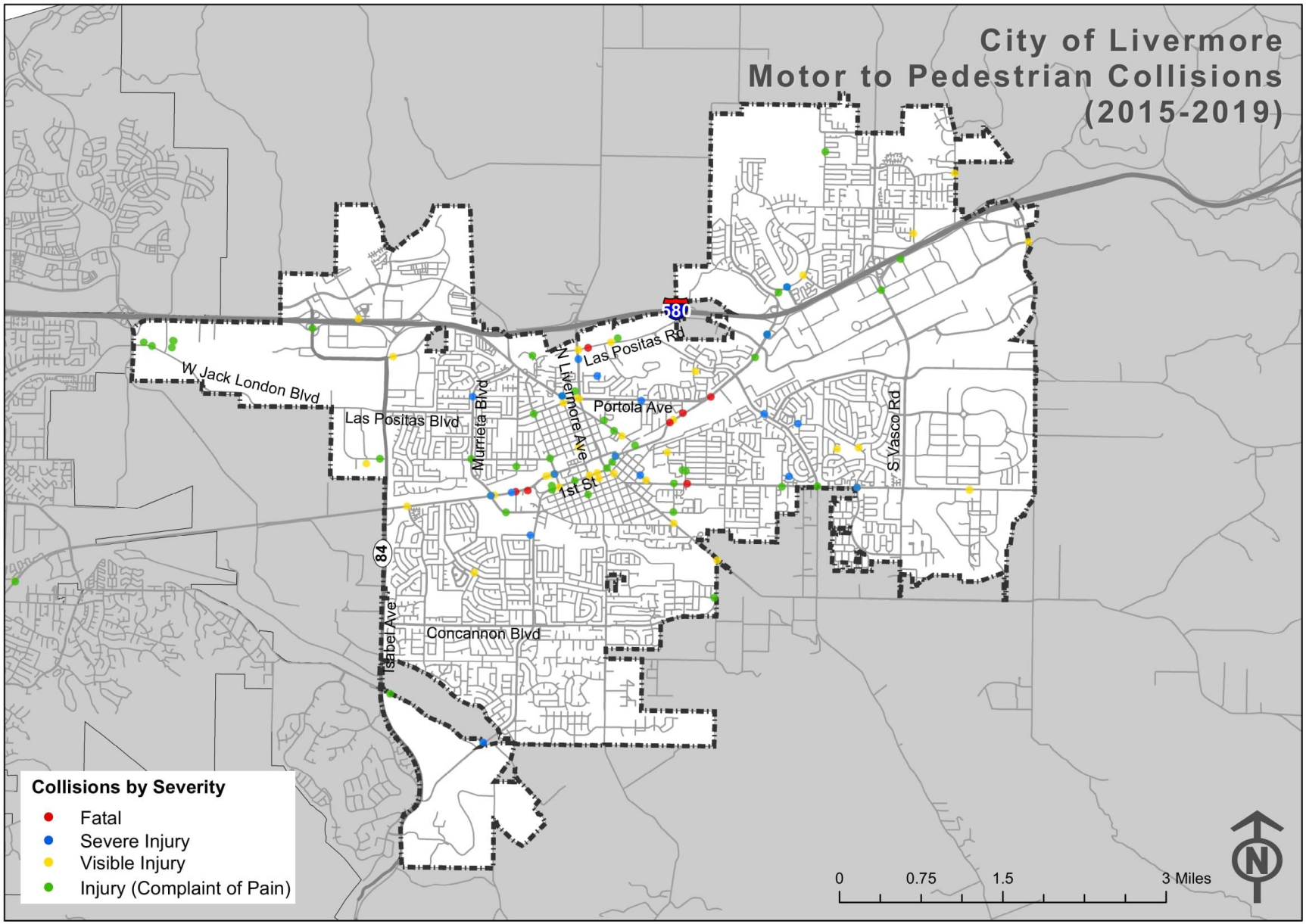
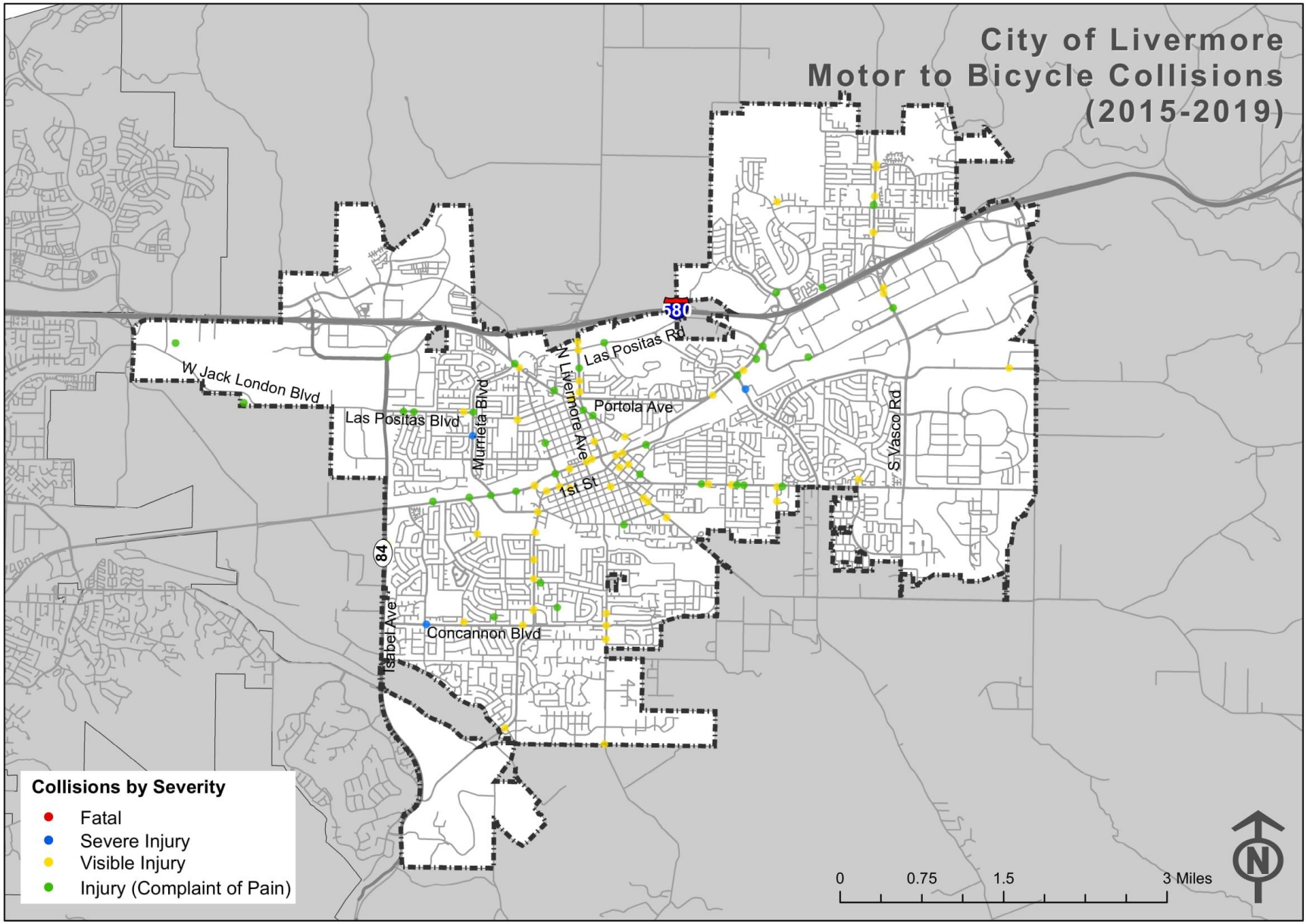


Figure 27. City of Livermore Bicycle Collisions (2015-2019)



COLLISION SEVERITY WEIGHT

Equivalent Property Damage Only (EPDO) method was used to identify the high severity collision network. The EPDO method accounts for both the severity and frequency of collisions by converting each collision to an equivalent number of property damage only (PDO) collisions. The EPDO method assigns a crash cost and score to each collision according to the severity of the crash weighted by the comprehensive crash cost. These EPDO scores are calculated using a simplified version of the comprehensive crash costs per HSIP Cycle 10 application. The weights used in the analysis are shown below in **Table** .

Table 3. EPDO Score used in HSIP Cycle 10

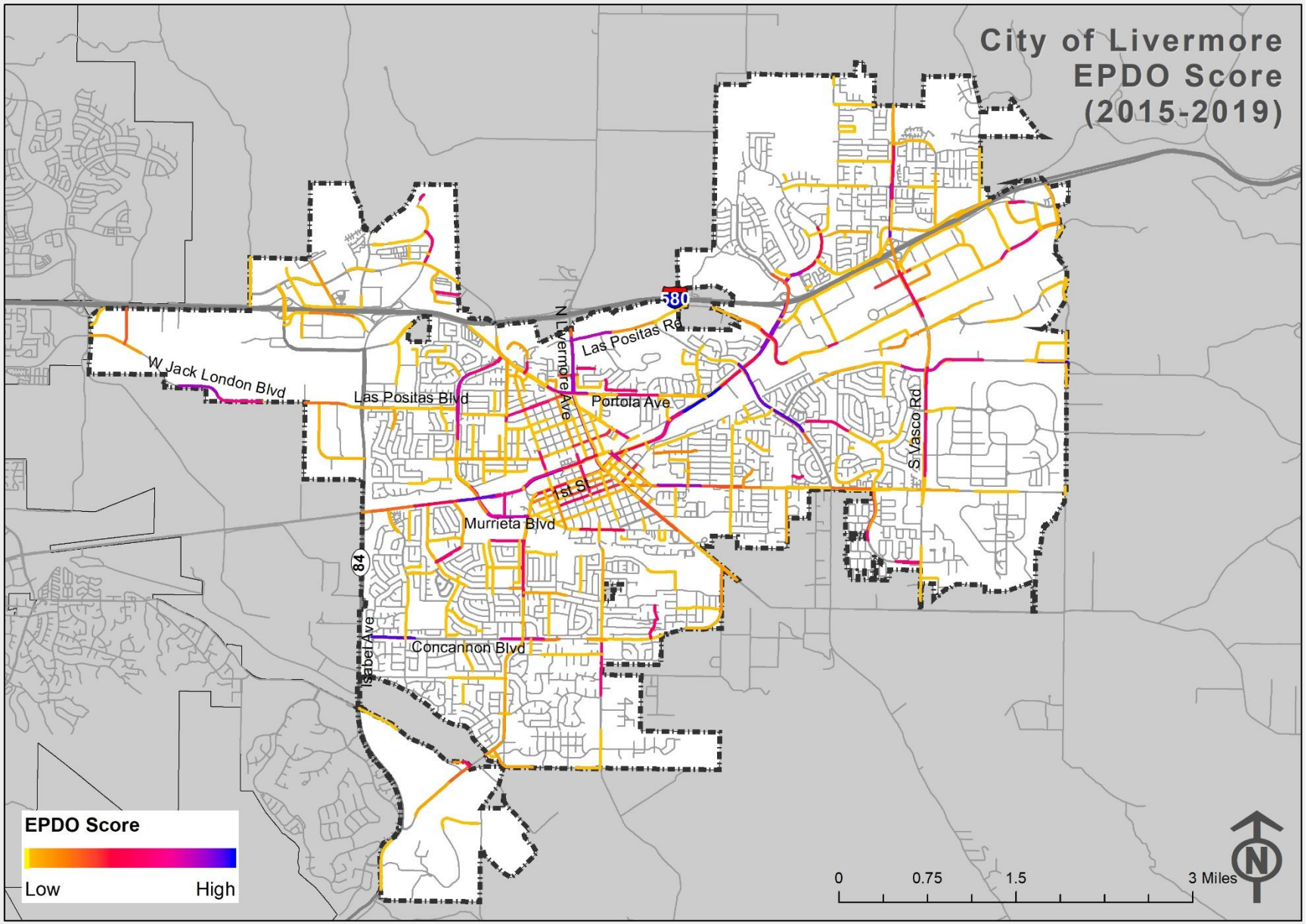
Collision Severity	EPDO Score
Fatal and Severe Injury Combined	165*
Visible Injury	11
Possible Injury	6
PDO	1

*This is the score used in HSIP Cycle 10 for collisions on roadways segments, to simplify the analysis this study uses the same score for all F+SI collisions regardless of location.

EPDO is used because it provides a methodology for the project team to understand the locations in Livermore that are experiencing the most severe crashes. Because of the high score given to fatal and severe injury crashes, locations that have these types of crashes are more likely to receive a higher EPDO score than other locations that may have more collisions, but fewer fatal or severe injury collisions. Locations that have the highest EPDO scores are selected for inclusion in the High Collision Network, shown in the next section. Identified intersections are scored based on collisions occurring at or within 250 feet of the intersection, while roadway segment locations are identified based on collisions that occur along the segment, except directly at an intersection (0 feet from intersection per CROSSROADS data). Identifying the locations with the most severe crashes allows the team to focus recommended solutions and countermeasures at these locations.

The EPDO scores for all injury collisions can then be aggregated in a variety of ways to identify collision patterns, such as location hot-spots. The weighted collisions for the City of Livermore were geolocated onto Livermore's road network. GIS is then used to calculate the EPDO score for each roadway segment and intersection citywide, which is then ranked according to its score. **Figure 28** shows the location and geographic concentration of collisions by their EPDO score.

Figure 28. City of Livermore EPDO Score

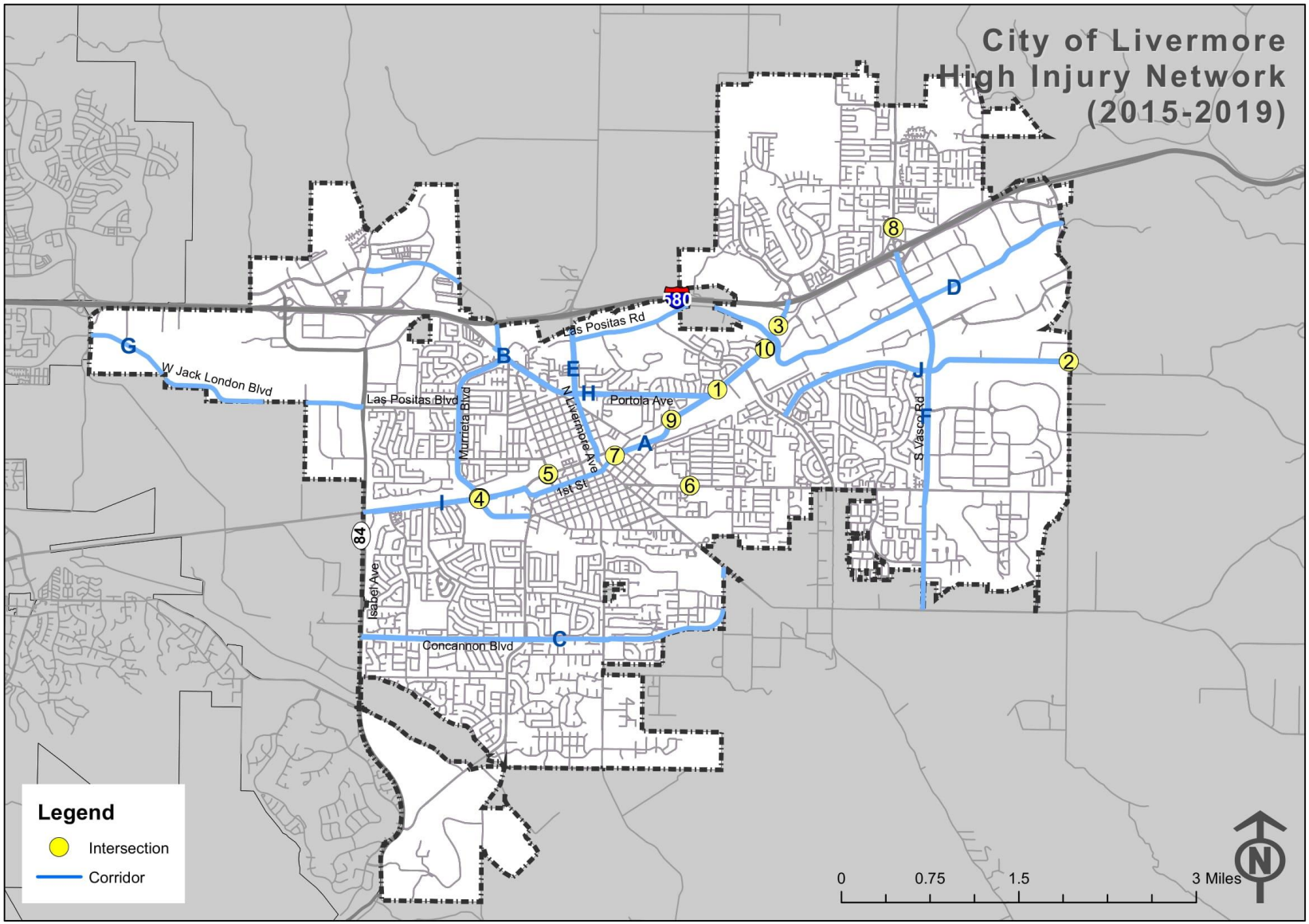


HIGH INJURY NETWORK

Following the detailed collision analysis, the next step was to identify the high-injury roadway segments and intersections in Livermore. The methodology for scoring the high injury locations is the same method as used in the severity weight section. **Figure 29** shows the top 10 high-collision roadway segments, and top 10 high-collision intersections.

For the purposes of the high collision network analysis, intersections include injury collisions that occurred within 250 feet of it and roadways include all collisions that occurred along the roadway except for collisions that occurred directly at an intersection. Such collisions are assigned a 0 value in distance from intersection value column in the CROSSROADS.

Figure 29. City of Livermore High Injury Network (HIN)



Intersections Ranking

10 intersections were identified as high collision intersections. There were a total of 109 collisions and 13 F+SI collisions that occurred at these intersections. The intersection of Patterson Pass Rd & Greenville Rd and First St & Southfrount Rd had the highest number of F+SI collisions with three.

Collisions that occurred on the SR-84 are not part of high injury collisions. Collisions that are recorded on SR-84 from the year 2015-2019 are part of Isabel Avenue from the intersections of Isabel Avenue & Vallecitos Rd and Isabel Avenue & Portola Avenue. (*Data source: Collision data 2015-2019 retrieved from CROSSROADS)

Table lists the collision rate of the top 10 identified high-risk intersections along with their severity weight and the number of F+SI collisions.

Table 4. High Collision Intersections

ID	Intersection	Total Injury Collisions	F+SI Collisions	Severity Weight
1	First St & 360' N of Portola Ave (Signalized)	7	3	534
2	Patterson Pass Rd & Greenville Rd (Signalized)	27	2	530
3	First St and Southfront Rd (Signalized)	12	1	241
4	E Stanley Blvd & Murrieta Blvd (Signalized)	10	1	239
5	Railroad Ave & S P St (Signalized)	9	1	228
6	Jensen St & East Ave (Non-Signalized)	8	1	227
7	First St & Maple St (Signalized)	6	1	187
8	Northfront Road & North Vasco Road (Signalized)	9	1	282
9	First St & Scott St (Non-Signalized)	7	1	437
10	First St & Bellmawr Dr (Non-Signalized)	6	1	215

Note: Intersection#2: Patterson Pass Rd & Greenville Rd

Corridors Ranking

10 corridors were identified as high collision corridors. There was a total 274 injury collisions and 27 F+SI collisions on these corridors. The First St and Murrieta Blvd corridors have the highest number of F+SI collisions with six.

Collisions that occurred on the SR-84 are not part of High Injury Network. Collisions that are recorded on SR-84 from the year 2015-2019 are part of Isabel Avenue from the intersections of Isabel Avenue & Vallecitos Rd and Isabel Avenue & Portola Avenue. (*Data source: Collision data 2015-2019 retrieved from CROSSROADS)

Table lists the collision rate of the top 10 identified high-collision corridors along with the number of F+SI collisions, total collisions, corridor length, and severity weight.

Table 5. High Collision Corridors

ID	Corridors	Total	F+SI	Length (miles)	Severity Weight
A	First St: E Stanley Blvd to I-580/John P Miller Memorial Hwy (Intersection)	74	6	3.5	1518
B	Murrieta Blvd: Holmes St to Portola Avenue	25	5	2.3	995
C	Concannon Blvd: Isabel Avenue (City Limit- West) to S Livermore Avenue (City Limit- East)	19	3	3.5	626
D	Las Positas Rd: N Livermore Ave to Greenville Rd (City Limit- East)	31	2	5.4	544
E	N Livermore Avenue: 400' N (City Limit) to Railroad Avenue	27	2	1.4	510
F	S Vasco Rd: I-580 (City Limit-North) to Tesla Rd (City Limit-South)	18	2	3.1	456
G	W Jack London Blvd: Wolf House Dr to 1900 W' from Discovery Dr	19	2	1.3	447
H	Portola Avenue: First St to Murrieta Blvd	13	2	2.0	426
I	E Stanley Blvd: Rail Road Avenue to Murdell Lane	38	1	1.2	422
J	Patterson Pass Rd: Greenville Rd to N Mines Rd	10	2	2.6	398