Safe Street Design Recommendations for Downtown Los Angeles

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Approval Page

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Date Submitted: March 2016

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Acknowledgement

I would like to express my deepest gratitude to my parents and friends who supported me throughout college. I would not be able to come this far without them.

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Chapter 1: Introduction
Introduction

Transportation is a vital component to everyday lives of people. Taking a trip to work, shopping, home or anywhere requires choosing modes of transportation. All modes of transportation, including driving, biking, and walking, are exposed to the danger of accidents. The wide intersections in Los Angeles are like highways; “cars sped through while vehicles leaving parking lots narrowly zip past children on bikes and old women with wire carts” (Los Angeles Walks, 2015). It is essential to create safe streets for all modes of transportation to minimize accident rates but give opportunities to people to choose their preferred modes of transportation. Therefore, this research is conducted to identify and analyze safety problems at locations with frequent traffic accidents and suggest street design solutions to prevent the traffic crashes in Los Angeles, California. The intent of the study is not to discourage driving but to provide guidelines for Los Angeles City to create safe streets for modes of all types.

Methodology

This research took a step by step approach to analyzing and identifying safe street guidelines for the City of Los Angeles. The steps of the research are explained as follows:

1. Review details of traffic collisions that occurred within the City
2. Identify hot spots of high accident rates in the City
3. Review case studies of similar hot spots and resolutions
4. Propose street designs that can minimize the accidents in the City of Los Angeles
Organization of Report

This first Chapter is an introduction to the study. Chapter 2 reviews overall collision patterns, including locations and causes within the City. Chapter 3 identifies and analyzes the corridors with high occurrences of traffic accidents. Chapter 4 includes a review of similar studies and treatments in other cities. Chapter 5 introduces the appropriate safe street designs for all modes of transportation. Chapter 6 provides conclusion of the study.

Relevance to Planning

Planning is the design of the urban environment to improve communities and the welfare of people. In community development, transportation ensures the efficient and effective movements of people and goods. Providing high levels of safety and mobility is part of transportation planning because it is the pathway to enhance the quality of lives and welfare of people. In the United States, from 2003 to 2007, 16.3% of all roadway vehicle crashes were caused by at least one roadway related factor including poor roadway conditions such as wet and slick surfaces and view obstructions due to street design or objects (U.S. Department of Transportation National Highway Traffic Safety Administration, 2008). The wide streets also have potential to cause traffic incidents; wide intersections may invite speeding and rapid lane changes (Los Angeles Walks, 2015). The purpose of this report is to analyze the current traffic conditions and collision patterns in City of Los Angeles to recommend influential street designs that can minimize these roadway-related accidents as well as traffic fatalities and injuries.
Chapter 2: Existing Conditions and Literature
Background

Current Los Angeles City
Los Angeles is one of the largest cities in the United States with a population of about 3.7 million. Consequently, on average, a vehicle trip in Los Angeles takes 33% longer than the average trip during non-traffic hour and 77% longer during peak traffic hour (TomTom, 2013). Despite the heavily congested traffic, 77% of people still drive to work while 10.9% takes public transportation; 1% of the people bike, and 3.6% walk to their works (United States Census Bureau, 2013). Unfortunately, no mode of transportation in Los Angeles city is considered safe. In 2012, Los Angeles City traffic collision rate ranked 2nd among thirteen cities in California with populations more than 250,000 (OTS, 2012). Approximately 36,000 vehicle collisions occur annually, which equals to 100 collisions every day. In addition, 48% of traffic fatalities involve pedestrians and bicyclists. The pedestrian fatality rates for children under age 4 and seniors over age 70 are double the national average (City of Los Angeles, 2014). This indicates that unacceptable proportion of pedestrians in Los Angeles city is in danger of getting into collisions with automobiles and consequent high potential for fatality and injury.

Current Efforts by Los Angeles City
Los Angeles City adopted a Mobility Plan in 2014 to provide guidelines for creating “a transportation system that balances the needs of all road users” (City of Los Angeles, 2014). The plan has six goals, which are listed as follows (City of Los Angeles, 2014):

1. Safety First
2. World Class Infrastructure
3. Access for All Angelenos
4. Collaboration, Communication, and Informed Choices
5. Clean Environments
6. Smart Investments
The objective under the goal of Safety First is “Vision Zero: Decrease transportation related fatality rate to zero by 2035” (City of Los Angeles, 2014). The Vision Zero Plan adopted by City of Los Angeles in 2015 has two targets: reduce citywide traffic deaths by 20 percent by 2017 and eliminate traffic deaths citywide by 2025 (City of Los Angeles, 2015). Consequently, the plan takes six different approaches to reach its targets (City of Los Angeles, 2015):

1. Engineering and Planning
2. Enforcement
3. Education
4. Evaluation and monitoring
5. Partnerships
6. Equity

The Engineering and Planning approach addresses the provision of street design to increase visibility of vulnerable street users on the high priority intersections and street segments (City of Los Angeles, 2015). At the time of this study, the Vision Zero Plan was adopted and did not have detailed street design guidelines to increase safety. This research parallels with Engineering and Planning approach because it also provides street design recommendations to increase mobility, safety, and visibility of street users. However, this report is based on an independent research and does not represent official policies or standards of Los Angeles City.
Existing Conditions

Introduction
All traffic collisions data was retrieved from the State Integrated Traffic Records System (SWITRS) and for the ten-month period from June 1st, 2014 to March 31st, 2015. This period was selected because it reflected the most recent available traffic collisions data and patterns at the time of the study. The traffic collisions data collected only occurred on city-owned public roads, which are defined as “street or route that is designated by a public authority to accommodate a person or a group of people” (The Free Dictionary, 2016). State highways were not included because the research specifically focused on analyzing and providing accident mitigation solutions for city streets.

Traffic Collisions by Mode
According to data from SWITRS, there were 32,753 traffic collisions over the ten-month period from June 1, 2014 to March 31st, 2015 (2014). As shown in Figure 2-1, 59 percent of motor vehicles collision in the City of Los Angeles involved only vehicles. The second highest group of accidents at 15% included parked and moving vehicles. The third highest group of victims in vehicle collisions was pedestrians at 8% followed by fixed objects, bicycles, and motor vehicles on the other roadway. It was anticipated that the highest collision rates would include only vehicles in motion. However, the second highest rate of accidents between parked and moving vehicles was unexpected. This indicates that when people are parking their cars on the street of Los Angeles City, they are taking the risk of getting their cars hit by other vehicles. Furthermore, the records revealed that fixed objects such as signs, signals, posts, and trees can become obstacles to drivers and cause traffic collisions.
Traffic Collisions Pattern by Severity

The traffic collisions were rated by severity: property damage only (PDO), injury, and fatal. All fatality rates were significantly low for all types of collisions. However, as shown in Table 2-1 and 2-2, pedestrian-involved traffic crashes had the highest fatality rate at 3.1 percent. Furthermore, 83 among a total of 186 fatal collisions involved pedestrians which comprised almost half of all fatal collisions. Clearly, this data reveals that pedestrians are most vulnerable and not protected on the streets of Los Angeles City. Approximately 95 percent of all pedestrian and bicycle involved collisions resulted in injuries whereas collisions with other motor vehicles have injury and fatality rates at 66.8 and 0.3 percent respectively. Lastly, PDO is less likely to occur in vehicle collisions involving pedestrians and bicyclists; PDO rate for traffic accidents with pedestrians and bicycles were at 1.5 and 4.1 percent respectively. The overall patterns from the data showed that walkers and bikers particularly are not safe on streets compared to drivers.
Table 2-1: Traffic Collision Severity by Percentage

<table>
<thead>
<tr>
<th>Motor Vehicle involved with</th>
<th>PDO</th>
<th>Injury</th>
<th>Fatal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Motor Vehicle</td>
<td>32.9%</td>
<td>66.8%</td>
<td>0.3%</td>
<td>100%</td>
</tr>
<tr>
<td>Parked Motor Vehicle</td>
<td>80.0%</td>
<td>19.9%</td>
<td>0.1%</td>
<td>100%</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>1.5%</td>
<td>95.4%</td>
<td>3.1%</td>
<td>100%</td>
</tr>
<tr>
<td>Fixed Object</td>
<td>68.7%</td>
<td>30.4%</td>
<td>0.9%</td>
<td>100%</td>
</tr>
<tr>
<td>Bicycle</td>
<td>4.1%</td>
<td>95.3%</td>
<td>0.6%</td>
<td>100%</td>
</tr>
<tr>
<td>Motor Vehicles on Other Roadway</td>
<td>39.1%</td>
<td>60.9%</td>
<td>0.0%</td>
<td>100%</td>
</tr>
<tr>
<td>Other Object</td>
<td>50.9%</td>
<td>48.0%</td>
<td>1.1%</td>
<td>100%</td>
</tr>
<tr>
<td>Non-Collision</td>
<td>27.8%</td>
<td>71.7%</td>
<td>0.5%</td>
<td>100%</td>
</tr>
<tr>
<td>Animal</td>
<td>69.6%</td>
<td>30.4%</td>
<td>0.0%</td>
<td>100%</td>
</tr>
<tr>
<td>Train</td>
<td>36.4%</td>
<td>63.6%</td>
<td>0.0%</td>
<td>100%</td>
</tr>
<tr>
<td>Not Stated</td>
<td>44.6%</td>
<td>55.4%</td>
<td>0.0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

(Source: SWITRS, 2008)

Table 2-2: Traffic Collision Severity by Count

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>PDO</th>
<th>Injury</th>
<th>Fatal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Motor Vehicle</td>
<td>6369</td>
<td>12938</td>
<td>61</td>
<td>19368</td>
</tr>
<tr>
<td>Parked Motor Vehicle</td>
<td>3969</td>
<td>989</td>
<td>3</td>
<td>4961</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>41</td>
<td>2557</td>
<td>83</td>
<td>2681</td>
</tr>
<tr>
<td>Fixed Object</td>
<td>1816</td>
<td>802</td>
<td>24</td>
<td>2642</td>
</tr>
<tr>
<td>Bicycle</td>
<td>82</td>
<td>1890</td>
<td>11</td>
<td>1983</td>
</tr>
<tr>
<td>Motor Vehicles on Other Roadway</td>
<td>126</td>
<td>196</td>
<td>0</td>
<td>322</td>
</tr>
<tr>
<td>Other Object</td>
<td>140</td>
<td>132</td>
<td>3</td>
<td>275</td>
</tr>
<tr>
<td>Non-Collision</td>
<td>55</td>
<td>142</td>
<td>1</td>
<td>198</td>
</tr>
<tr>
<td>Animal</td>
<td>16</td>
<td>7</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Train</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Not Stated</td>
<td>129</td>
<td>160</td>
<td>0</td>
<td>289</td>
</tr>
<tr>
<td>Total</td>
<td>12747</td>
<td>19820</td>
<td>186</td>
<td>32753</td>
</tr>
</tbody>
</table>

(Source: SWITRS, 2008)

Traffic Collision Patterns by Causes

As shown in Figure 2-2, the most common Primary Collision Factors (PCF) are unsafe speed and automobile right-of-way and each factors caused more than 6000 traffic collisions over the ten-month study period in Los Angeles City. The other common PCFs include improper turning, traffic signals and signs, and alcohol/drug use, unsafe lane change, unsafe starting of backing, following too closely, and pedestrian right-of-way. It is assumed that the PCFs are not only caused by inappropriate driving behaviors
but also poor street designs, which can cause confusion and conflicts among street users. Therefore, except for alcohol/drug use and vehicle operation related PCFs, there are opportunities to prevent other PCFs including speeding and automobile right-of-way and reduce significant number of traffic crashes through appropriate street design solutions.

Figure 2-2: Primary Collision Factors

(Source: SWITRS, 2008)
Traffic Collision Patterns by Type

Traffic collision types include sideswipe, rear end, head-on, broadside, overturned, automobile/pedestrian, and hit object. As shown in Figure 2-3, sideswipe, broadside, and rear end collisions are most common in Los Angeles city. The broadside collisions, which have the highest rate of 27.6%, are most likely to occur in intersections due to factors like automobile right-of-way and speeding. Similarly, sideswipe collision can take place due to unsafe speeding, inappropriate turn, and lane change. Real-end collision can be caused by unsafe speeding and following too closely. Despite the low number of pedestrians trips in Los Angeles City, automobile/pedestrian collisions at 7.9 percent ranked as the 5th highest collision type, indicating the high risk of pedestrians getting in collisions with motor vehicles.

Figure 2-3: Traffic Collision Types

(Source: SWITRS, 2008)
Traffic Collision Patterns by Time of the Day and Day of Week

Figure 2-4 shows overall pattern of traffic collisions by time of day and day of week. Crashes occurred in afternoon than morning and during the peak traffic hours than non-traffic hours. The morning peak traffic collision hour was between 8-9am, and afternoon was between 5-6pm; both of these hours are considered rush hour in LA because many people are going to or leaving from their workplaces around this time. The day of week with the highest traffic accidents was Friday; over the ten-month period, 3399 traffic collisions occurred on Friday whereas Monday had the lowest of 2877 traffic collisions. At dawn between 4-6am, significantly low traffic collisions occurred because less people are driving at this time of the day. Therefore, it is important to consider the street design that can support safety and mobility during specific traffic times for all road users.

Figure 2-4: Traffic Collisions by Time and Day of Week

(Source: SWITRS, 2008)
Traffic Collision Patterns by Drivers at Fault by Age and Sex

As shown in Figure 2-5, the patterns of drivers at fault were similar for both genders; the percentage of drivers at fault were above 50% on average for male and female teenage drivers; it is assumed that there are high percentages of teenage drivers at fault because they are new drivers. On the other hand, approximately 40% of drivers in their 30s to 50s were at fault, which is the lowest among all age groups. The percentage of drivers at fault bounced back to above 50% and peaked around 70% for elders aged from 75 and over. There were only slight differences in percentage between male and female drivers at fault for most age groups, which indicates that gender does not make much difference in driving abilities. However, for drivers aged from 75-84, female drivers at fault were about 10% higher than male. It is expected that there are higher percentage of driver at fault among elderly drivers because they are losing their driving capability due to the aging of the senses of sight and hearing (U.S. Library of Medicine, 2016). Therefore, to prevent traffic collisions, it would be important to simplify street design and increase visibility especially for new and elderly drivers to promote safe driving.

Figure 2-5: Drivers at Fault in Traffic Collisions by Sex and Gender

(Source, SWITRS, 2008)
Chapter 3: Traffic Collision Hot Spot Analysis
Introduction

This chapter focuses on analyzing the causes and results of traffic collisions as well as current conditions and design of the corridors. The first step of the analysis is identifying traffic collision hot spots within Los Angeles City. The details of traffic collisions that occurred over ten months from June 1st, 2014 to March 31st, 2015 were retrieved in Excel spreadsheet format from SWITRS (2008). Then, as shown in Figure 3-1, collisions were pinpointed on Google My Map, using the crossing streets of traffic crashes identified in the data. The map shows numerous collision hot spots within Los Angeles City. In this study, it was decided to focus on one hot spot, which is Downtown Los Angeles (DTLA) because it is the site where large numbers of people from within and outside the City visit for work, entertainment, and other purposes, which means the street users not only include Los Angeles City residents but also visitors. In order to provide a street that is safe and comprehensible for anyone, DTLA is chosen for site analysis.
Analysis

Corridors with High Traffic Collisions Occurrences

The collision data map shows that DTLA area has the most traffic collisions. The four DTLA streets shown in Figure 3-2 that are found to have repeated collisions are: Flower St, Broadway, 8th Street, and Olympic Boulevard. Each identified street, within a mile range, has more than 6 accidents occurrences between 06/2014 and 03/2015. The collisions due to alcohol consumption, drug use, sleep driving, and animal trespassing were not counted because they were caused by drivers’ misjudgment or unexpected disruption. The primary causes and street conditions for each street are explained in the following sections. Table 3-1 shows a summary of traffic collisions that occurred in those four corridors in DTLA. The most common PCFs among the traffic collisions were unsafe speeding followed by unsafe lane change, traffic signal and signal violation, and
improper turning. In the following sections, the details of street conditions and traffic collision are analyzed to identify the problems that triggered traffic collisions.

Figure 3-2: Corridors with High Traffic Collision Occurrences in Downtown Los Angeles

(Source: Google Maps, 2016)

*Corridors were identified using traffic collision records retrieved from SWITRS, 2008

Table 3-1: Summary of Traffic Collisions by Primary Collision Factors

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>Broadway</th>
<th>Olympic Blvd</th>
<th>Flower St.</th>
<th>8th St.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsafe speeding</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Unsafe lane change</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Automobile right-of-way</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Pedestrian right-of-way</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Improper passing</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Traffic Signal and sign violation</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Following too closely</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Wrong side of road</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Improper turning</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Pedestrian Violation</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>
Other than driver (or pedestrian) | 1 | 0 | 0 | 0 | 1  
Other Hazardous Violation     | 0 | 1 | 0 | 1 | 2  
Unsafe starting or backing    | 0 | 1 | 1 | 1 | 3  
Unknown                        | 0 | 0 | 2 | 0 | 2  
**Total**                      | **16**|** 10**|** 9**|** 8**|** 43**  
(Source: SWITRS, 2008)

Broadway Traffic Collision Analysis

Broadway is a two-way street with two lanes north bound and one lane on south bound. There are on-street parking spaces and plant buffers south bound. As shown in Table 3-1, during 10 months from 06/2014 to 03/2015, 16 traffic collisions occurred on Broadway St. within DTLA. The most common causes are found to be unsafe speeding, improper turning, and unsafe lane change; each collision factor caused three collisions which resulted in sideswipe, hit object, head-on, and rear-end.

Traffic signal and sign violation and pedestrian right-of-way each caused two collisions. As shown in the table, pedestrians were crossing at intersections at the time of the accidents. It is assumed that collisions occurred due to the absence of protected left turn for motor vehicles. On the busy streets of DTLA, it is likely that the drivers may have rushed to make a turn and hit the pedestrians crossing at the crosswalks.

Lastly, automobile right-of-way and following too closely each triggered one traffic accidents, which involve bicycle and other vehicle. Currently, bicyclists share lanes with motorists, and this increases the chance of collisions. It is essential to create safe bike lanes in order to separate drivers and protect bicyclists.

Table 3-2 shows details of collisions along Broadway over the ten-month study period. In the location of the collision 3, which involved a parked vehicle, there are no available on-street parking spaces; the only available on-street parking spaces are by the fire lane. Google street view shows the cars parked on the fire lanes. The design solution to mitigate these illegal parking is providing designated on-street parking spaces.
<table>
<thead>
<tr>
<th>Collision</th>
<th>Date</th>
<th>Primary Collision Factor</th>
<th>Collision Type</th>
<th>Collided with</th>
<th>Ped Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/13/2015</td>
<td>Improper turning</td>
<td>Sideswipe</td>
<td>Parked vehicle</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1/15/2015</td>
<td>Unsafe speeding</td>
<td>Hit Object</td>
<td>Other object</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>8/17/2014</td>
<td>Improper Turning</td>
<td>Head On</td>
<td>Parked Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>9/30/2014</td>
<td>Traffic signal and sign violation</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>3/4/2015</td>
<td>Improper turning</td>
<td>Rear end</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>6/12/2016</td>
<td>Other than driver (or pedestrian)</td>
<td>Sideswipe</td>
<td>Bicycle</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>6/12/2014</td>
<td>Pedestrian right-of-way</td>
<td>Vehicle/Pedestrian</td>
<td>Pedestrian</td>
<td>Crossing at Intersection</td>
</tr>
<tr>
<td>8</td>
<td>1/7/2015</td>
<td>Pedestrian right-of-way</td>
<td>Vehicle/Pedestrian</td>
<td>Pedestrian</td>
<td>Crossing at Intersection</td>
</tr>
<tr>
<td>9</td>
<td>6/25/2014</td>
<td>Unsafe lane change</td>
<td>Sideswipe</td>
<td>Bicycle</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>8/16/2014</td>
<td>Unsafe lane change</td>
<td>Sideswipe</td>
<td>Non-collision</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>2/12/2015</td>
<td>Unsafe lane change</td>
<td>Sideswipe</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>3/7/2015</td>
<td>Unsafe speeding</td>
<td>Rear end</td>
<td>Parked vehicle</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>1/26/2015</td>
<td>Following too closely</td>
<td>Rear end</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>1/6/2015</td>
<td>Traffic signal and sign violation</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>1/2/2015</td>
<td>Automobile right-of-way</td>
<td>Sideswipe</td>
<td>Bicycle</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>12/6/2015</td>
<td>Unsafe speeding</td>
<td>Overturned</td>
<td>Non-collision</td>
<td>-</td>
</tr>
</tbody>
</table>

(Source: SWITRS, 2008)
Flower Street Traffic Collision Analysis

Flower Street is a south bound, one way street; it has three lanes with on-street parking on each side. Unlike clustered pattern on Broadway, as shown in Figure 3-3, the collision locations are spread out on Flower Street. Table 3-2 shows that four out of the nine collisions occurred due to traffic signal and sign violations and unsafe speeding. It is possible that the one-way street treatment may have triggered those crashes. The intent of a one-way street is to ease the flow of traffic along busy urban streets like those in Los Angeles. Consequently, drivers stops less frequently, which makes it harder for bicyclists and pedestrians to share the roads (Jaffe, 2013). The speed also tends to be higher on one-way streets because drivers pay less attention to their speeds (Jaffe,
2013). For collision 1 and 3, the PCFs are unknown but the types are broadside and sideswipe. The possible PCFs are traffic signal and sign violation, unsafe speeding, and improper turning, which may have derived from the one-way street conditions. This reveals that the one-way street decreases traffic congestion but can increase danger for all modes of transportation. Two automobile/pedestrian collisions occurred at the intersection and in the street without crosswalks. This indicates pedestrian crosswalks need to be better protected and increased in number to prevent illegal crossings.

Table 3-3: Flower Street Traffic Collision Details

<table>
<thead>
<tr>
<th>Collision</th>
<th>Date</th>
<th>Primary Collision Factor</th>
<th>Collision Type</th>
<th>Collided with</th>
<th>Ped Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2/12/2015</td>
<td>Unknown</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1/9/2015</td>
<td>Unsafe speeding</td>
<td>Rear end</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>1/13/2015</td>
<td>Unknown</td>
<td>Sideswipe</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>8/27/2014</td>
<td>Traffic signal and sign violation</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>12/21/2014</td>
<td>Pedestrian violation</td>
<td>Vehicle/Pedestrian</td>
<td>Pedestrian</td>
<td>Crossing at Intersection</td>
</tr>
<tr>
<td>6</td>
<td>3/1/2015</td>
<td>Traffic signal and sign violation</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>2/21/2015</td>
<td>Unsafe starting or backing</td>
<td>Other</td>
<td>Parked vehicle</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>3/3/2015</td>
<td>Pedestrian violation</td>
<td>Vehicle/Pedestrian</td>
<td>Pedestrian</td>
<td>Crossing not at crosswalk</td>
</tr>
<tr>
<td>9</td>
<td>2/4/2015</td>
<td>Unsafe speeding</td>
<td>Rear end</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
</tbody>
</table>

(Source: SWITRS, 2008)
Olympic Boulevard Traffic Collision Analysis

On Olympic Boulevard, 10 collisions occurred within a mile range in DTLA; As shown in Table 3-4, four collisions were due to automobile-right-way and involved pedestrians, bicyclist, and other vehicles on the same and other side of roadway. Olympic Blvd. is a large street with two lanes and on-street parking on each side. However, just like previously analyzed streets, street views in Figure 3-4 show that there are no designated bike lanes. Furthermore, most intersections do not have protected left turn signals. Consequently, the cars rush to make turns which can resulted in traffic accidents. This indicates the lack of defined right of way for drivers, pedestrians, and bicyclists. In addition, five out of ten collisions ended up as sideswipe; the causes are unsafe lane change, improper passing, wrong side of road, and automobile right-of-way. These accidents are most likely to happen to drivers in a hurry. It will be a challenge to provide street design guidelines that can increase safety and mobility altogether to support urban lives of people.
Table 3-4: Olympic Boulevard Traffic Collision Details

<table>
<thead>
<tr>
<th>Collision</th>
<th>Date</th>
<th>Primary Collision Factor</th>
<th>Collision Type</th>
<th>Collided with</th>
<th>Ped Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/30/2015</td>
<td>Pedestrian Violation</td>
<td>Head On</td>
<td>Pedestrian Crossing at Intersection</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1/20/2015</td>
<td>Automobile right-of-way</td>
<td>Broadside</td>
<td>Bicycle</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>1/9/2015</td>
<td>Unsafe speeding</td>
<td>Rear end</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>12/19/2014</td>
<td>Unsafe lane change</td>
<td>Sideswipe</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>12/13/2014</td>
<td>Unsafe starting or backing</td>
<td>Other type</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>8/20/2014</td>
<td>Improper passing</td>
<td>Sideswipe</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>1/1/2015</td>
<td>Wrong side of road</td>
<td>Sideswipe</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>8/5/2014</td>
<td>Other Hazardous Violation</td>
<td>Rear end</td>
<td>Parked Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>1/5/2015</td>
<td>Automobile right-of-way</td>
<td>Sideswipe</td>
<td>Other Vehicle</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>3/24/2015</td>
<td>Automobile right-of-way</td>
<td>Sideswipe</td>
<td>Other vehicle on other roadway</td>
<td>-</td>
</tr>
</tbody>
</table>

(Source: SWITRS, 2008)
Figure 3-5: Street Views and Locations of Collision that Occurred on Olympic Boulevard

(Source: Google Maps, 2016)
*Collision Locations retrieved from traffic collision records from SWITRS, 2008
*Collision numbers in the figure corresponds with collision numbers on Table 3-3
8th Street Traffic Collision Analysis

As shown in street views from Figure 3-6, 8th street is a west bound one-way street with three lanes and on-street parking on each side. There were a variety of PCFs as shown in Table 3-5 including other hazardous violation, traffic signal and sign violation, improper passing, improper turning, unsafe lane change, unsafe starting or backing, and unsafe speeding. Half of the collision types are sideswipe which involved other vehicles and a bicycle. As previously mentioned, the causes of sideswipe collisions such as improper passing, turning, and unsafe lane change may occur when drivers are in a hurry and pay less attention to signals, signs, other drivers, bicyclists, and pedestrians. It is essential to have easily noticeable traffic signs and separated right of way to increase road safety. In collision 1, a pedestrian was in the road at the time of the accident. If it is due to conditions of the road, there may be objects or factors like construction that caused them to walk on roads instead of sidewalks.

Table 3-5: 8th Street Traffic Collision Details

<table>
<thead>
<tr>
<th>Collision</th>
<th>Date</th>
<th>Primary Collision Factor</th>
<th>Collision Type</th>
<th>Collided with</th>
<th>Ped Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/26/2014</td>
<td>Other Hazardous Violation</td>
<td>Vehicle/Pedestrian</td>
<td>Pedestrian</td>
<td>In road, including shoulder</td>
</tr>
<tr>
<td>2</td>
<td>8/27/2014</td>
<td>Traffic signal and sign violation</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>10/7/2014</td>
<td>Improper passing</td>
<td>Sideswipe</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>6/11/2014</td>
<td>Improper turning</td>
<td>Broadside</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>3/4/2015</td>
<td>Improper turning</td>
<td>Rear end</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>8/4/2014</td>
<td>Unsafe lane change</td>
<td>Sideswipe</td>
<td>Bicycle</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>12/21/2014</td>
<td>Unsafe starting or backing</td>
<td>Sideswipe</td>
<td>Other vehicle</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>1/21/2015</td>
<td>Unsafe speeding</td>
<td>Sideswipe</td>
<td>Parked vehicle</td>
<td>-</td>
</tr>
</tbody>
</table>

(Source: SWITRS, 2008)
Figure 3-6: Street Views and Locations of Collision that Occurred on 8th Street

(Source: Google Maps, 2016)
*Collision Locations retrieved from traffic collision records from SWITRS, 2008
*Collision numbers in the figure corresponds with collision numbers on Table 3-5
Chapter 4: Case Studies
Vision Zero New York

Background
New York City adopted the Vision Zero Plan in 2014 on the premise that all traffic fatalities cannot be accepted. “Traffic collision is the leading cause of injury related death for children under 14, and the second leading cause for seniors” (City of New York, 2014). Since 1990, the City has decreased its traffic fatality rate. After making major engineering changes in 2005, the fatality decreased even more by 34% (City of New York, 2014). Despite reduction in traffic fatality rate, the plan is adopted because all the traffic fatalities are unacceptable and can be prevented. The plan not only provides guideline for safe street design but also defines the steps to reduce death or serious injuries on streets for other public entities including City Police and Transportation Department, and Department of Health and Mental Hygiene. However, in this research, only street safety design related strategies are reviewed.

New York City has one of the lowest traffic fatality rates among cities in the U.S.; the pedestrian fatality rate for New York is 1.9 per 100,000 residents while San Antonio, the city with the highest traffic fatality rate, has 10.7 (Drum Major Institute, 2011). However, the traffic fatality rate of New York City is significantly high when compared to the cities in developed countries in Europe. Consequently, NY adopted this Vision Zero Plan to prevent wasting any lives on streets. With this plan, New York City envisioned to provide environments for New Yorkers to live lives of health and opportunities without any interruptions caused by preventable traffic incidence (City of New York, 2014).
Problems Associated with Traffic Collisions

Traffic Fatality Rate
The Department of Transportation (DOT) reported that the primary cause of pedestrian fatalities is dangerous driver choices, which include inattention, speeding, and failure to yield (City of New York, 2014). The overall traffic collision trend shows 46 percent decrease in motorist and passenger fatalities in 2001. 53 percent of the total pedestrian fatalities were due to bad driver choices while the remaining 47 percent was caused by poor pedestrian choices such as crossing against traffic signals or crossing at midblock. The bicycle fatalities remained constant from 2001 to 2010 despite increase in transit and bicycle users and decline in motorists (Drum Major Institute, 2011). Overall, only traffic fatalities of motorists decreased significantly while pedestrian and bicyclists had small or no reductions.

Unsafe Road Design
The highways are successfully safe when they are wide, straight, flat, and more open. Consequently, the traffic engineers implemented similar design on the non-highway streets of New York. However, the study found that applying this highway safety design in urban arterial roadways is unsafe for pedestrians and bicyclists. In urban areas, this design encourages motorists to drive above speed limits. As more drivers speed, the street becomes more dangerous for vulnerable street users like pedestrians and bicyclists.

Primary Collision Factors
In 2009, driving at unsafe speed caused 63 fatal traffic crashes while drunk driving and distracted driving caused 22 and 39 crashes (Drum Major Institute, 2011). Speeding is one of the most dangerous factors of roadway fatalities because high speed decreases the survival rate of pedestrians colliding with vehicles. The second most common collision factor is distracted driving; often times, many drivers are using cell phones while driving. It is dangerous to perform non-driving activities while on the wheel because it slows down the drivers’ reaction time.
*Culture of Non-Compliance*

Other problems that caused traffic crashes were non-compliance behaviors of drivers, pedestrian, and bicyclists. On busy urban streets of New York, many people did not follow laws. Drivers often violated traffic laws and speeded over the limit. About one-third of bicyclists failed to stop at red lights. In addition, bicyclists frequently rode on the wrong side of roads. Lastly, Pedestrians often crossed the streets against traffic lights (Drum Major Institute, 2011). These risky behaviors increased over time because more people are likely to violate traffic laws when they see others doing so.

**Design Solutions**

*Design Guideline*

After identifying problems associated with traffic crashes, New York City proposed the following design solutions (2014):

1. Designate lanes
2. Clear Merges and transitions
3. Add crosswalks
4. Open up Intersections to improve visibility
5. Widen the parking lane
6. Add bike paths and lanes
7. Create new left turn lanes
8. Left turn phases
9. Eliminate unsafe turn movements
10. Leading pedestrian intervals
11. Leading bus interval
12. Install speed bumps
13. Time traffic signals for “green waves”:
14. Reduce night-time speeding with signal timing:
15. Arterial Slow Zones
a. The arterial zones of NY City had the majority of pedestrian fatalities. Therefore, DOT reduced the speed limit to 25 mph but maintained mobility by adjusting the signal timing (City of New York, 2015).

Currently Implemented

In 2014, New York City installed new design in 50 corridors and intersections, five miles of protected bike paths, 400 new speed bumps, and 45 leading pedestrian interval signals. The improved street designs are shown in the following figures.

The Figure 4-1 shows how street design changed after implementation of the treatments. In order to reduce speeding, the new intersection design includes pedestrian safety island, curb extensions, new pedestrian ramps, and new crosswalks. In addition, the crosswalk distances became shorter, and turns became simpler in order to calm the traffic and increase the pedestrian safety. As shown in Figure 4-1 & 4-2, other strategies to reduce speeding and unsafe turns are raising center medians and narrowing the travel lanes. In this way, the motorists are less likely to speed or make unsafe turns.

Figure 4-1: Street View of Before and After Implementation of the Plan

(Source: City of New York, 2015)
Figure 4-2: Pedestrian Safety Improvement Before and After

(Source: City of New York, 2015)

Figure 4-3: Speeding and Unsafe Turn Prevention Street Design

(Source: City of New York, 2015)
Results after One Year

In 2015, a year after implementation of Vision Zero, New York City published a progress report that showed mixed results for different street users.

The Vision Zero Plan for pedestrian safety showed positive results where pedestrian fatalities went down from 180 in 2013 to 138 in 2014; this is even lower than average fatalities of 155 for the previous three years (New York City, 2015). Unfortunately, bicyclist fatalities increased from 12 in 2013 to 20 in 2014 despite implementing five miles of protected bike lanes (New York City, 2015). One needs to view the apparent increase in bicycle crashes against the explosion in bicycle use in the implementation of protected bike lanes. Motorist fatalities decreased from 42 in 2013 to 37 in 2014. The analysis of vehicle crashes by DOT was not yet released. However, it was assumed that the speed and unsafe turning mitigations helped prevent some traffic incidents.
San Francisco Better Street Plan

Background
San Francisco County Transportation Authority (SFCTA) adopted the Better Street Plan in 2010, a citywide policy document, to provide street design guidelines that create balance between all users of street and built environments. The plan focuses on improving pedestrian environments of the streets “where people walk, shop, sit, play or interact” (SFCTA, 2010). The plan not only considers transportation but also social, recreation, and ecology in the design. This plan is chosen to be reviewed in order to provide designs that successfully protect pedestrians, the most vulnerable group in traffic crashes. This research only reviews safety related design methods and guidelines in order to be consistent with the purpose of this research, which is providing traffic incidents prevention designs to support modes of all types.

Existing Conditions & Problems
San Francisco (SF) is an urbanized city with busy streets filled with cars, buses, pedestrians, and bicyclists. On average, 62 percent of people drove to work while 20 percent and 17 percent walked and took transit. Only one percent of the people biked to work (SFCTA, 2010). Consequently, a high number of pedestrians were injured or killed in traffic accidents; however, the high numbers were due to the large total volume of people walking in the city. The analyzed patterns revealed that most pedestrian and automobile collisions occurred at intersections with traffic signals. In addition, the study indicates that elder populations were “at a higher risk of dying in collisions than any other age group” (SFCTA, 2010). Consequently the most common PCF of pedestrian involved traffic collisions from 2002 to 2006 were found to be pedestrian right-of-way (37.97%) and pedestrian violation (SFCTA, 2000).

SFMTA started installing pedestrian signals at traffic signals in the City. Currently, 65 percent of all traffic signals have pedestrian signals. At some of the remaining traffic signals, pedestrian signals will be installed in next few years.
Proposed Design Guidelines
SFCTA provides design guidelines to increase safety and security of pedestrians; the various street elements such as crosswalk markings, curb radii, median, and pedestrian islands are covered. The plan provides detailed guidelines on appropriate street element sizes for different types of streets.

The guidelines provide principles of designing effective crosswalk markings in order to alert motorists to the presence of pedestrians on the streets; crosswalks should be highly visible and installed on all intersections with traffic signals. In addition, midblock crosswalks should be implemented in long blocks to increase accessibility and prevent illegal crossings. Figure 4-4 demonstrates different type of crosswalk markings. Continental crosswalk marking is recommended at all intersections with traffic signals because a study found that it increases the yielding of drivers.

Figure 4-4: Visible Crosswalk Designs

(Source: ITE Professional Development Complete Streets)
In addition to crosswalk markings, SF recommends the use of warning signs, stop and yield lines, flashing lights and flashing beacons in order to increase driver awareness. The stop and yield lines can be effective in preventing vehicle encroachments and in impeding speed of vehicles at pedestrian crossings. Signs and lights inform drivers of the presence of pedestrian crosswalks.

Different pedestrian signals are also proposed to reduce conflict between pedestrians and automobiles. At intersection with high pedestrian volumes, a pedestrian scramble signal, which gives “exclusive pedestrian phases,” is suggested (SFCTA, 2010). Pedestrian head-start signals give crossing right-of-way to pedestrians before the light turns green for motorists.

Curb Radii is the curb radius defined by two sidewalks meeting at the intersection. The successful curb radii design accommodates pedestrian volume and vehicle turns. Figure 4-5 shows that small curb radii sizes can be safer for both pedestrians and motorists because they shorten crossing distances and slow the vehicle turns. The curb radii design varies depending on types of vehicles that are frequently using the street. In the street frequently used by large vehicles, painted median and advanced stop can be implemented. Large vehicles may cross over painted medians while making turns. Similarly, advanced stop in the opposing lanes give extra space for large vehicles to turn.

Figure 4-5: Curb Radii and Crossing Distance

(Source: SFCTA, 2010)
Another strategy by SF to increase pedestrian safety is providing medians and pedestrian islands. Medians separate opposing traffic and provide pedestrian refuge in wide crosswalks. Furthermore, medians become useful by providing space for emergency stops and out-of-control vehicles. The design guidelines recommend medians to be as wide as possible. They can also be combined with pedestrian islands, bulb out, and other traffic calming measures. Pedestrian islands can be provided in the long or un-signalized crosswalks. Slowly moving pedestrians can rest in pedestrian islands to cross the street with safety and comfort.
Chapter 5: Safe Street Design Recommendations
Introduction

This chapter provides design recommendations for creating safe streets after analyzing the existing conditions of the streets and past traffic collision records to mitigate sources of traffic crashes. The street design related causes of collisions are lack of defined right-of-way, protected turns, crossings, lane designations, and presence of confusion and conflicts arising from street configurations. The design recommendations intend to provide safe streets with the principles of creating accommodating mobility, comprehensible and visible street, and promoting space utilizations. These include, but are not limited to split phasing, accommodation for bicyclists, visible crosswalks, comprehensible lanes, pedestrian islands and medians, curb extensions, and conversion of underutilized spaces. The implementation of the treatments needs traffic engineering judgement and modifications to better suit the road conditions. The conceptual diagrams of street designs after implementation of the treatments are included at the end of the section. The following is the outline of the Design Recommendations Section:

1. Accommodate Mobility for All Street User
   1.1. Split Phasing
      1.1.2. Split Phase with Protected Left Turns
      1.1.3. Pedestrian Crossing Priority
   1.2. Accommodation for Bicyclists
      1.2.2. Separated Bicycle Lane
      1.2.3. Bicycle Crossing Markings
2. Create Comprehensible and Visible Street
   2.1. Visible Crosswalks
      2.1.2. Raised Midblock Crossings
      2.1.3. Continental Crosswalk Marking
      2.1.4. Bright Yellow Color Crosswalk Markings
   2.2. Comprehensible Lanes
      2.2.2. Colored Bike Lane
      2.2.3. Lane Designations
   2.3. Pedestrian islands and medians
Design Recommendations

1. Accommodate mobility for all street users

Often times, mobility is described as fast movement of the automobiles. However, the correct definition of mobility is “movement of people in a population, as from place to place” (Lewyn, 2009). Thus, the term “people” does not only indicate the drivers but all the street users including pedestrians, drivers, and bicyclists. Therefore, accommodating mobility provides protection of all street users on the roadways and enhances the flow of traffics for modes of all types. Under this principle, in order to accommodate mobility, the treatments emphasize providing designated spaces for each mode and efficiently sharing with crossing traffics.

1.1. Split Phasing

Split phasing controls signal phasing by separating the two opposing approaches and reducing conflicts between street users (NACTO, 2000). Currently, most intersections in the DTLA do not have protected left turns but permitted left turns, which allows vehicles to turn after yielding to vehicles in the opposing lanes. Through the site analysis, it was determined that most drivers would make turns when signals were about to turn red due to the large volume of opposing traffic. The traffic collision records in Chapter 2 reveal that most of pedestrian vs. automobile crashes occur when pedestrians are crossing in intersections and automobiles are making turns. Split phasing is needed in order to define the right-of-way and eliminate confusion when the street users are sharing the roads.
1.1.1. Split Phase with Protected Left Turns

The protected left turns allows vehicles to make safe turns at the intersections. The benefits of the protected left turn include minimized conflicts with pedestrians crossing and improved operational efficiency due to single-phased pedestrian crossings (NACTO, 2000). It is recommended to install protected left turn signals in all the intersections with large volumes of left turning vehicles. The major concern about the protected left turn is that vehicles can be trapped within the road after yielding to large volume of pedestrians. Therefore, the strategy to prevent trapping of vehicles is explained in the following treatment.

1.1.2. Pedestrian Crossing Priority

Trapping of vehicles making left turns is caused when there are high numbers of pedestrians crossing at intersections, making the drivers to yield for long periods of time until the light turns red. In order to prevent trapping, it is recommended to give pedestrians head start in the crossing before vehicles make turns. This can be utilized at intersections with high numbers of pedestrians.

1.2. Accommodation for Bicyclists

Currently, the selected corridors from Chapter 3, which are Broadway, Olympic Boulevard, Flower Street, and 8th Street, do not have separate bike lanes. This requires that bicyclists share lanes with automobiles. In addition, bicycle turning and crossing are not supported in the roadway, and the risk of bicyclists colliding with vehicles is increased. Therefore, the following treatments are proposed to promote safe and comfortable bicycling. Extended bicycle infrastructure can expand the transportation mode choices for people, which can result in increased number of bicyclists in Los Angeles city.

1.2.1. Separated Bicycle Lane

It is recommended that separate bicycle lanes are installed in all the corridors with available spaces. On the streets with designated street parking, the bike lane can be installed between street parking and the travel lanes. If the space allows, buffered bike lanes can be implemented. On the one-way streets, bike lanes on the left side can
accommodate mobility of bicyclists since the right-side bicycles are more likely to confront conflicts with street parking, buses, and vehicle turnovers (NACTO, n.d.)

1.2.2. Bicycle Crossing Markings

Across intersections, bicycle paths can be ambiguous to many bicyclists, which can result in conflicts with motor vehicles. Installing bicycle crossing markings can help finding the clear path for bicyclists. The marking can be dotted lines with filled color or arrows with bicycle signs (NACTO, n.d.). In this way, bicyclists can safely cross the intersections without encroaching on to travel lanes.

2. Create Comprehensible and Visible Street

Streets that are visibly and physically easy to use can reduce traffic collisions and provide great experience to street users. On the other hand, poor street design can cause confusion and conflict between the street users. In addition to comprehensibility of the streets, visibility is considered because it can largely impact drivers; the study reveals that when people are driving in an interval and can no longer see obstacles on the road, the possibilities of collisions increased as the estimated arrival times are longer (Groeger and Comte, 1999). Therefore, treatments are proposed to provide clear paths that eliminate confusion and are understandable for anyone. The purposes of the treatments are simplifying the street and clearly defining the right-of-way for all modes of transportation to ease traffic flow and create easy access.

2.1. Visible Crosswalks

Effective crosswalk designs can enhance the understanding not only for pedestrians but also drivers and cyclists; the presence of pedestrians can be informed through visible crosswalk designs. However, before considering the design treatments to enhance crosswalks, it has to be ensured that crosswalks are installed in the locations that are desired for pedestrians to provide the clear paths. The crosswalk design treatments include speed table, markings, and use of visible color.
2.1.1. Raised Midblock Crossings

Raised Midblock Crossing is visually appealing and promotes safe crossing of pedestrian by increasing yielding to pedestrians by motorists. In addition, even without the presence of pedestrians, raised crossings can slow down speeds of vehicles because they are also traffic calming devices that “raise the entire wheelbase of a vehicle to reduce its traffic speed” (NACTO, n.d.).

2.1.2. Continental Crosswalk Marking

As explained in Chapter 3, San Francisco Better Street guideline recommends continental crosswalk markings because it has proven to be most efficient in increasing number of drivers yielding to pedestrians. Due to the same reason, utilization of continental crosswalk markings is suggested for Los Angeles City to accommodate pedestrian networks.

2.1.3. Bright Yellow Color Crosswalk Markings

Pure bright lemon yellow color is found to be the most fatiguing color because of its excessive stimulation to the eyes, which makes the color eye irritant (Color Matters, 2016). Therefore, utilization of the bright yellow color in the crosswalks especially in highly congested intersections can increase the visibility of pedestrian crossings.

2.2. Comprehensible Lanes

According to Figure 2-2, the second highest PCF was automobile right-of-way, which can be caused by ambiguous or confusing lane designs. It is essential to inform street users of their right-of-way or required yielding to others. Therefore, the treatments are proposed to simplify the lanes and minimize the conflicts and confusion as much as possible. Drivers and bicyclists are mostly focused in the treatments because they share the core of roadways together.

2.2.1. Colored Bike Lane

The colored bike lane can increase visibility and reduce potential areas of conflicts with illegal on-street parking (NACTO, n.d.). The coloring of the bike lanes can be applied consistently throughout the corridor with gaps. The green color bike lane is
recommended because the green paint treatment has proven to lower vehicle encroachments to bike lanes to 7 percent as opposed to 16 percent of vehicle encroachment to non-painted bike lanes in New York City (NYCDOT, 2011, p.8).

2.2.2. Lane Designations

Lane Designation can be accommodated by large signs and clear lane markings especially in the intersections with one-way streets, which can confuse the drivers who visited the site for the first time. The traffic collision records described in Chapter 2 revealed that one of the traffic crashes that occurred at the intersection between Olympic Boulevard and Midway Street, a one-way street, was due to driving on the wrong side of the road. To prevent confusion to drivers, the signage and marking has to be modified to grab their attention. Current signs and markings can be improved to be larger with text markings that inform of the upcoming one-way streets.

2.3. Pedestrian islands and medians

Pedestrian islands and medians can visually and physically accommodate understanding and safe use of street users. Pedestrians can make safe crossings, and opposing traffic can be efficiently separated. The sizes and types of pedestrian islands and medians can be modified depending on the street conditions and sizes.

2.3.1. Raised and Paved Medians

Raised medians can be utilized as physical barriers that prevent cars from driving on the wrong side of the roads whereas paved medians can provide space for refugee or emergency stops for drivers. On wide streets, raised medians can be combined with the paved medians; paved medians can be installed in the gaps between raised medians to provide spaces for vehicles to make turns, emergency stops, or evacuations.

2.3.2. Pedestrian Islands

Pedestrian islands can be utilized in long crosswalks. They can be combined with the signalized crosswalks to increase safety of pedestrians; it can be useful especially for seniors and disabled persons who may not cross the street within the signalized time. In this way, they can take a rest in the pedestrian islands while crossing the streets.
2.4. **Curb Extensions**

The SF Better Street Plan explains that the benefits of curb extensions are increased pedestrian visibility through improved sight lines and decreased pedestrian exposure to vehicles by shortening the crossing distance (SFCTA, 2010). In addition to increased visibility, they reduce vehicle turn speeds through the visually and physically narrowed streets and increase pedestrian waiting space (SFCTA, 2010). The type of curb extensions includes gateway curb and mid-block curb.

2.4.1. **Gateway Curb Extensions**

Gateway curb extensions can be implemented in the intersections with frequent traffic collisions caused by improper turning. It is recommended to align the bulb-outs with the street parking lanes in order to increase the visibility of pedestrians (NACTO, n.d.). The intersection has to be analyzed for suitability for curb extensions because the construction cost is high, and they can become obstacles when changing bus routes and lane layout (SFCTA, 2010).

2.4.2. **Mid-Block (Pinchpoint) Curb Extensions**

Mid-block curb extensions can be applied along with mid-block crossings. Different pavements can be used to differentiate them from vehicle lanes and provide resting areas for pedestrians. Landscape and buffer areas can also be implemented to further increase the visibility and promote aesthetic of streetscapes (SFCTA, 2010). Mid-block curb extensions can be combined with raised mid-block crosswalks explained in the treatment 2.1.1., which shortens the crosswalks, making it safer for pedestrians.

3. **Promote Utilization of Spaces**

Through the site analysis, opportunities to expand the street systems were found. Because Los Angeles is one of the largest cities, street expansion can increase its capacity to better serve the growing population. The treatments are proposed after analyzing what is underutilized and what is needed for the current street systems.
3.1. Conversion of Underutilized Spaces

As shown in the Figure 5-1 and 5-2, the underutilized spaces identified from the site analysis are planting strips and fire lanes located within Broadway in DTLA. They are determined to be underutilized space because it is not raised to provide extra space for pedestrians and implemented next to fire lane, which brings ambiguity to its users. Figure 5-2 shows wide emergency vehicle designated area next to the fire lanes. Drivers frequently park in these areas because they are empty most of the time. Therefore, treatment in the area is needed to prevent illegal parking. The area can accommodated other uses while it still serves as emergency vehicle parking.

Figure 5-1: Planting Strips on South Broadway near intersection with West 6th Street

(Source: Google Maps, 2016)
3.1.1. Planting Strip and Designated Fire Lane Conversion

Both the planting strips and fire designated lane are large enough to become another lane. However, to accommodate use of all street users, it is recommended to utilize these spaces to implement bike lanes. In addition, curbs also can be extended if the space allows, making the streets more pedestrian-friendly. The fire lane can still serve its purpose with installation of the bike lanes; in the event of emergency, fire trucks and other emergency vehicles can park in the bicycle lanes.
Conceptual Diagrams of the Streets

This section includes diagrams of the streets before and after implementing the recommended treatments. The diagrams include the two intersections between Flower Street and Hope Street, and Broadway and Olympic Boulevard, and a midblock crossing on Broadway. The following diagrams are only conceptual to show how street safety can be improved through appropriate designs. The recommended treatments can also be applied to other streets with similar conditions in Los Angeles City.

Flower Street and Hope Street
In DTLA, Flower Street is a southbound one-way street. At the intersection with Hope Street shown in Figure 5-3, there are no bike lanes or enough crosswalks to become accessible for pedestrians. After seeing that there is enough space for bike lanes and to widen the sidewalks, a conceptual diagram was created to demonstrate the street design after implementing the treatment. Figure 5-4 and 5-5 show top and bird-eye view of the conceptual diagram. The applied treatments include bike lanes, additional crosswalks, and widened sidewalks. Continental crosswalk markings and green bicycle lanes are used to increase visibility. To accommodate left turning bicyclists, exclusive bike left turn lane is proposed as well as a bike box which can be utilized while waiting for the signal.

Figure 5-3: Flower Street and Hope Street before Treatments
(Source: Google Maps, 2016)
Figure 5-4: Top View of Flower Street and Hope Street after Treatments

(Source: Google Maps, 2016)
*SketchUp and Vray are utilized for the rendering

Figure 5-5: Bird-Eye View of Flower Street and Hope Street after Treatment

(Source: Google Maps, 2016)
*SketchUp and Vray are utilized for the rendering
Broadway and Olympic Boulevard

The intersection between Broadway and Olympic Boulevard shown in Figure 5-6 was analyzed to be an automobile oriented intersections due to the absence of bike lanes, narrow sidewalks, and visible crosswalk markings. Therefore, in the conceptual diagram, Figure 5-7 and 5-8, treatments are applied to increase comprehensibility and mobility for all street users. First of all, since there are multiple lanes on each street, arrow markings are applied in each lane to simplify the street configurations for motorists. Protected left turn signals are proposed for all four approaches. Additionally, separate bike lanes are applied on each side. As demonstrated in Figure 5-7 and 5-8, to minimize conflicts between through bicyclists and right turning automobiles, it is proposed to implement the exclusive right turn lanes next to through bicycle lanes. Bicycle crossing markings are also included to promote safe crossing of bicyclists and vehicles. Lastly, because the current crosswalk marking is determined as lacking in visibility, it is replaced by continental crosswalk markings in the diagram to efficiently alert others of the presence of pedestrians. In the larger intersections with available spaces, medians and pedestrian islands can be implemented in order for people to cross the streets safely and comfortably.
Figure 5-6: Broadway and Olympic Boulevard before Treatments

(Source: Google Maps, 2016)

Figure 5-7: Top View of Broadway and Olympic Boulevard after Treatments

(Source: Google Maps, 2016)

*SketchUp and Vray are utilized for the rendering*
Midblock Crossing on Broadway

This midblock crossing is located on the north of the intersection between 6th Street and Broadway. Although there are traffic signals currently, the traffic collision details from Chapter 3 have revealed that over the ten-month period two pedestrian/automobile collisions occurred in this area when pedestrians were crossing. Figure 5-9 shows the view of current midblock crossing. To promote safe crossing of pedestrians, the proposed treatment shown in Figure 5-10 is a speed table combined with a crosswalk. By implementing this treatment, it is expected that pedestrians can safely cross the street due to increased visibility and shortened crosswalk. Motorists are likely to reduce the speed when they see the raised crosswalk, which can increase yielding to pedestrians. Furthermore, separate bicycle lanes are proposed on each side because the collision data showed that three bicycle/automobile collisions occurred on Broadway over the ten-month period. As explained in treatment 3.1.1., planting strip and emergency vehicle parking area are replaced by bicycle lanes because they are found to be underutilized.
Figure 5-9: Midblock Crossing on Broadway before Treatments

(Source: Google Maps, 2016)

Figure 5-10: Bird-Eye View of Midblock Crossing on Broadway after Treatments

(Source: Google Maps, 2016)

*SketchUp and Vray are used for the rendering*
Chapter 6: Conclusion
Conclusion

Through this research I realized that traffic collisions should not be considered as an acceptable cause of deaths rather it is a preventable death with appropriate design treatments. My primary purpose for this research is to find ways to give everyone an opportunity to choose preferential mode of transportation without being limited by safety related issues. As I researched more about the topic, I learned that in order to promote mobility of all roadway users including drivers, bicyclists, and pedestrians, there are many challenges and constraints after promoting one thing after another. It is a great challenge to design streets that can eliminate all the traffic fatality. My design recommendations can increase the safety of the streets, but it is not guaranteed that it can result in zero traffic fatality if implemented. Therefore, it is important to monitor and update the streets after identifying the problems and solutions in order to support urban lives of people.
References


Google Maps. (2016). [South Broadway, Los Angeles] [Street View]. Retrieved from https://www.google.com/maps/@34.0469935,-118.2517496,3a,75y,235.21h,80.04t/data=!3m6!1e1!3m4!1sZxRo8U8CGou3_ETwFkON9w!2e0!7i13312!8i6656


Appendix
Collision Map A1

(Source: Google Maps, 2016)
Collision Map A2

(Source: Google Maps, 2016)
Collision Map A3

(Source: Google Maps, 2016)
Collision Map A4

(Source: Google Maps, 2016)
Collision Map A5

(Source: Google Maps, 2016)
Collision Map A6

(Source: Google Maps, 2016)
Figure 2-8: Collision Map A7

(Source: Google Maps, 2016)
Collision Map A8

(Source: Google Maps, 2016)
Collision Map A9

(Source: Google Maps, 2016)
Collision Map A10

(Source: Google Maps, 2016)
Collision Map A11

(Source: Google Maps, 2016)
Collision Map A12

(Source: Google Maps, 2016)
Collision Map A13

(Source: Google Maps, 2016)
Collision Map A14

(Source: Google Maps, 2016)
Collision Map A15

(Source: Google Maps, 2016)
Collision Map A16

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Collision Map A17

(Source: Google Maps, 2016)
Collision Map A18

(Source: Google Maps, 2016)
Collision Map A19

(Source: Google Maps, 2016)
Collision Map A20

(Source: Google Maps, 2016)
Collision Map A21

(Source: Google Maps, 2016)
Figure 2-24: Collision Map A23

(Source: Google Maps, 2016)
Figure 2-25: Collision Map A24

(Source: Google Maps, 2016)