ATTACHMENT A

Metro Blue Line Safety Improvement Study For Wardlow Crossing

Final Reports

Los Angeles County Metropolitan Transit Authority

July 24, 2017

FINAL

Baseline Tasks

Task 1. –	Safety Analysis Report
Task 2. –	Traffic Analysis Report
Task 3. –	Grade Separation Priority Report

Wardlow Station and At-Grade Crossing Safety Evaluation

TASK 1- Safety Analysis Report

Los Angeles County Metropolitan Transit Authority

July 24, 2017

FINAL

Quality information

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1. INTRODUCTION

The Los Angeles County Metropolitan Transportation Authority (Metro) has implemented on-going significant investments in safety measures over the last 25 years. Notable safety enhancements at selected crossings, such as four-quadrant gates, photo enforcement technology, enhanced passive and active signage, pedestrian gates, swing gates, and in-pavement lights have contributed toward a downward trend in incidents, however, Metro is committed to making further improvements and advancing safety efforts for their patrons, the public and Metro employees. An indication of this commitment is highlighted by a $33 million investment last fiscal year for upgrading all 27 gated at-grade intersections along the Metro Blue Line (MBL) to the current practice by installing pedestrian/swing gates.

As part of Metro's ongoing program to evaluate safety improvements, the Metro Board approved a Motion in May 2016 directing the CEO to undertake various actions. One of the actions was to initiate this feasibility study to improve safety at the Wardlow grade crossing. This report focuses on the safety analysis of the Wardlow crossing and the identification of potential enhancements to improve transit, pedestrian, and vehicle operations and safety.

2. EXISTING CONDITIONS AND POTENTIAL ENHANCEMENTS

A field visit was conducted May 4th, 2017 from 1:00 PM to 3:00 PM with Metro Operations and the City of Long Beach to observe and discuss current operations. A history of current roadway improvements was provided by the City and potential future operations of the MBL and roadway system were discussed.

The Wardlow Light Rail Transit (LRT) Station is in the northeast quadrant of the Wardlow Road and Pacific Place signalized intersection. The traffic signal provides an eight (8) phase operation with protected left turn movements for all four legs. Vehicles can make 'U' turns at the intersection from all four directions. Pedestrian crosswalks are on all four legs with standard pedestrian signal heads for control.

2.1 Roadway

2.1.1 Wardlow Road

As shown in **Figure 2**, Wardlow Road is two lanes westbound (WB) and three lanes eastbound (EB) with a center raised median island and is posted 40 mph. There is a single left turn lane for EB and WB with a WB right turn lane at the intersection of North Pacific Place. All pockets have arrow markings. At the time the project team conducted the initial site visit, the team saw temporary markings for what appeared to be a future "protected" on-street bicycle lanes. If constructed, the bicycle lanes will reduce the traffic capacity of the roadway. There is an EB mid-block left turn pocket for access to the development north of Wardlow Road and east of the Wardlow Station between Cedar Ave and Pacific Avenue. The frontage road between Wardlow Road and the development on the north is one-way from Pacific Avenue to the mid-block driveway. The frontage road becomes two-way west of the mid-block driveway. See **Figure 1** below.

Figure 1. - Frontage road along Wardlow Road and mid-block pocket.

Cedar Ave, a north-south directional street in the development has a southbound (SB) right turn only onto Wardlow Road approximately 100 feet east of the at-grade crossing. Motorists can travel east from Cedar Ave along the frontage road to the existing mid-block driveway that allows left turns onto Wardlow Road.

There is on-street parking (restricted from 4:00AM to 8:00AM on Wednesday) on the north side of Wardlow Road from Pacific Avenue to the right turn only driveway from Cedar Avenue. There is 2-hour parking allowed on the north side of Wardlow Road from Pacific Place west to Magnolia Avenue with restriction from 4:00AM to 6:00AM on Wednesday and no parking from 2:00AM to 4:00AM every day.

The EB lanes have railroad markings in two of the three lanes. There is a W82 trolley warning sign 60 feet downstream from the EB markings, but there is no W10-1 railroad warning sign. The EB railroad markings are approximately 420 feet from the nearest track and 220 feet from the intersection limit line. The WB railroad markings are approximately 345 feet from the nearest track, exceeding the 125-feet (Condition B) distance suggested in Table 2C-4 of the California Manual on Uniform Traffic Control Devices (CAMUTCD). However, Wardlow Road experiences heavy traffic volumes in the peak hours, which would suggest the 345 feet is appropriate for the advance warning sign. Finally, the WB direction does not have the W10-1 railroad warning sign.

2.1.1.1 Potential Enhancements

a. Depending on other potential enhancements that might be installed, the closure of Cedar Ave. access to Wardlow Rd. right-out only may be beneficial to the overall safety of the at-grade crossing. This proposal adds another level of safety to the rail crossing and it is especially important to Westbound traffic flow that is in close proximity to the Westbound rail gates. Any mitigation that involves the roadway must be approved by the City of Long Beach.

b. In accordance with CAMUTCD Section 8B.102, the Light Rail Transit (Trolley) Crossing sign W82 (CA) may be used in advance of a highway-LRT grade crossing controlled by traffic signals or stop signs. Wardlow is an at-grade railroad crossing controlled by the railroad warning system, therefore, the existing W82 trolley warning sign 60 feet downstream from the EB markings should be removed.

c. CAMUTCD, Section 8B-27, states that identical (RXR) markings shall be placed in each approach lane on all paved approaches to grade crossings where Crossbuck (R15-1) signs, flashing light signals, or automatic gates are located. Therefore, RXR markings should be placed in the EB curb lane in alignment with the two existing RXR markings.

d. Appropriate W10-1 with a W48 (2) number of tracks should be installed at the EB railroad pavement markings in accordance with CAMUTCD Section 8B.06 and Figure 8B-6 for additional enhancement for safety.

e. Appropriate W10-1 with a W48 (2) number of tracks should be installed at the WB railroad pavement markings in accordance with CAMUTCD Section 8B.06 and Figure 8B-6 for additional enhancement for safety.

2.1.2 Pacific Place

As shown in **Figure 2** Pacific Place is two lanes southbound (SB) and two lanes northbound (NB) and is posted 40 mph. There is a single NB left turn lane and a dedicated NB right turn lane at the intersection of Wardlow Road. The south leg of the intersection has a two-way-left-turn (2WLT) lane south of the NB single left turn pocket. The north leg has a raised median from the 405 Freeway to the beginning of the double left turn pocket with a break at the Wardlow park-n-ride lot's northern driveway. The double left turn lanes are striped from the end of the raised median to the intersection. All pockets have arrow markings. There are three designated bus stops along Pacific Place for transfers to the LRT.

Parking is allowed on the west side of Pacific Place from the I-405 off-ramp transition to the SB right turn lane transition at Wardlow Road. Parking is restricted between 4:00 PM to 6:00 AM on Tuesdays. Parking is allowed on the east side of Pacific Place from Wardlow Power substation driveway to the I-405 Bridge with restrictions from 4:00 PM to 6:00 AM on Tuesdays.

2.1.2.1 Potential Enhancements

a. The CAMUTCD Standard recommendation for parallel roadways where the distance from the edge of the parallel roadway to the edge of the railroad track is less than 100 feet is to place a W10-2 sign and W48 sign with railroad pavement markings in accordance with CAMUTCD Figure 8B-6. The NB right turn lane and the SB left turn lanes should have the W10-2 and W48 signs in accordance with CAMUTCD Figure 8B-6.

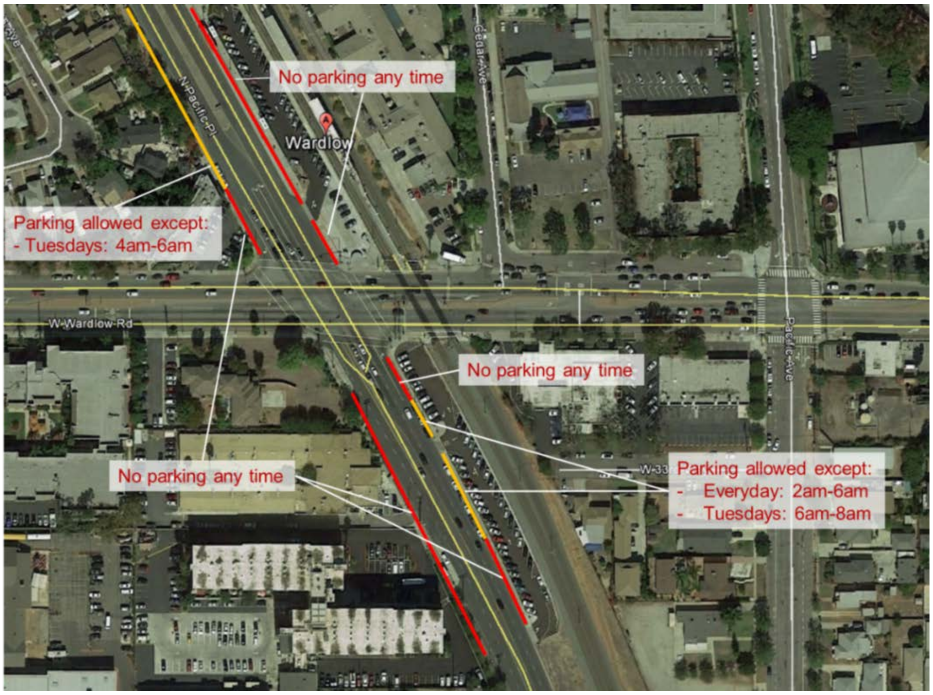

Figure 2. - Wardlow Road & Pacific Place Configuration and Parking Restrictions.

2.2 At-Grade Crossing

Figure 3 presents the two track at-grade crossing of Wardlow Road. The center of the southbound track is approximately 65 feet east of the east leg crosswalk line and the center of northbound track is 26 feet from the center of the SB track. The minimum track clearance distance is 80 feet measured along the greatest possible distance (right turn lane) from the crossing gate “stop bar” (at-grade crossing limit line) to six (6) feet past the furthest rail and the clear storage area measured from six (6) feet past the furthest rail to the intersection limit line is 55 feet.

The at-grade crossing is controlled by an active railroad traffic control system consisting of flashing lights, gates, and bells. There are automatic gates with flashing lights on the right side of the roadway with cantilevers for both EB and WB approaches and in the median islands for approaching vehicles.

2.2.1 Potential Enhancements

a. See potential enhancements under Operational Observations.

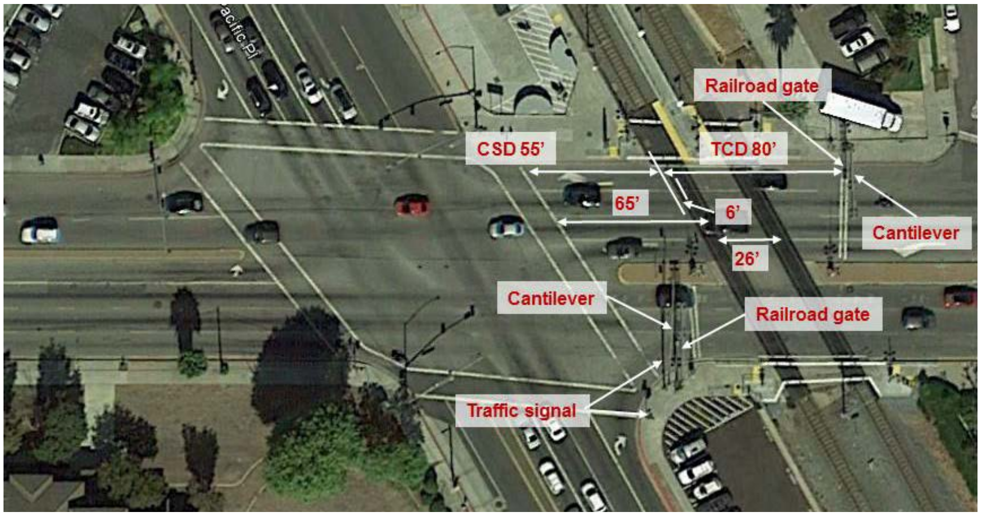

Figure 3. - Wardlow at-grade crossing.

2.2.2 Vehicle Control

The EB approach has three through lanes, therefore a cantilever with two pairs of flashing lights over the lane lines have been installed along with the side and median island mechanisms. Each pair of approach flashing lights has back flashers associated with them. The R15-1 Crossbuck and R15-2P number of tracks signs are mounted on the cantilever and the island mechanism. There is a non-standard “Watch for Trains” sign posted on the center median island. There is an I-13 “Report Emergency or Problem” Sign on the EB vehicle gate mechanism. There are no R8-8 “Do Not Stop On Tracks” signs.

The WB approach has two through lanes with a left turn and right turn lane that starts upstream from the crossing. Therefore the approach has a cantilever with flashing lights over the through lane lines and the right turn lane along with the side and median island mechanisms. Each pair of approach flashing lights has back flashers associated with them. The R15-1 Crossbuck and R15-2P number of tracks signs are mounted on the cantilever and the island mechanism. There is an I-13 “Report Emergency or Problem” sign on WB vehicle gate mechanism. The WB left turn pocket has a left turn arrow pavement marking upstream and downstream from the crossing. There are no R8-8 “Do Not Stop On Tracks” signs.

On Pacific Place, the NB right turn lane has no railroad pavement markings, but does have a W10-7 active blank-out sign on the near side and far side traffic signal poles. There is no NB advance W10-2(R) warning sign.

The SB dual left turn lanes have no railroad pavement markings or SB advance W10-2(L) warning sign.

2.2.2.1 Potential Enhancements

a. The non-standard “Watch for Trains” sign posted on the center median island should be removed. It has a potential of being a distraction more than an enhancement.

b. The WB left turn arrow pavement marking upstream from the crossing should be removed. It has been observed at other facilities that motorists upon seeing the upstream left turn arrow have confused the trackway opening as the roadway and have made left turns onto the trackway during the evening hours.

c. Install R8-8 “Do Not Stop On Tracks” signs on cantilevers and side mounts if possible.

2.2.3 Pedestrian Control

The south sidewalk pedestrian crossing is controlled by automatic gates with flashing lights and emergency swing gates on both the east and west side of the trackway. There is Type 1 pedestrian channelization against Wardlow Road curb guiding the pedestrian to the automatic pedestrian gates and reducing potential risk behavior by walk arounds. The emergency swing gates have W82-1 Trolley “Look Both Ways” warning signs on both sides of the gate. The automatic pedestrian gate has, on the inside of the arm, an “EXIT” sign with an arrow pointing towards the emergency swing gate, when the arm is lowered, to direct any pedestrian that might get caught inside the automatic gate to the emergency exit. There are back-flashers on both mechanisms and the R15-1 Crossbuck and R15-2P number of tracks signs are mounted on the mechanism pole. The pedestrian crossing of the trackway is delineated with six inch white lines. There are “WARNING Do Not Enter while lights and bells are active” signs (dual language) at both the east and west pedestrian entrance to the crossing. There are tactile warning strips in front of the west and east pedestrian entrances and the emergency swing gates. See **Figure 4** below.

Pedestrian gate arm “Exit” sign

Figure 4. - Pedestrian gate arm “Exit” sign pointing to the pedestrian exit gate.

The north pedestrian sidewalk crossing is controlled by automatic gates with flashing lights and emergency swing gates on both the east and west side of the trackway. There is Type 1 pedestrian channelization against Wardlow Road curb guiding the pedestrian to the automatic pedestrian gates and reducing potential risk behavior by walk arounds. The emergency swing gates have W82-1 Trolley “Look Both Ways” warning signs on both sides of the gate. There are back-flashers on both mechanisms and the R15-1 Crossbuck and R15-2P number of tracks signs are mounted on the mechanism pole. The pedestrian crossing of the trackway is delineated with six inch white lines.

The southern access ramp to the Wardlow Station is between the NB and SB tracks from the north side Wardlow Road pedestrian crossing. Type I pedestrian barriers are placed along the Wardlow Road curb to prevent pedestrians from walking down the ramp and into the street. There are “WARNING Do Not Enter while lights and bells are active” signs (dual language) at both the east and west pedestrian entrance to the crossing. There are tactile warning strips in front of the west and east pedestrian entrances and the emergency swing gates. See **Figure 5**.

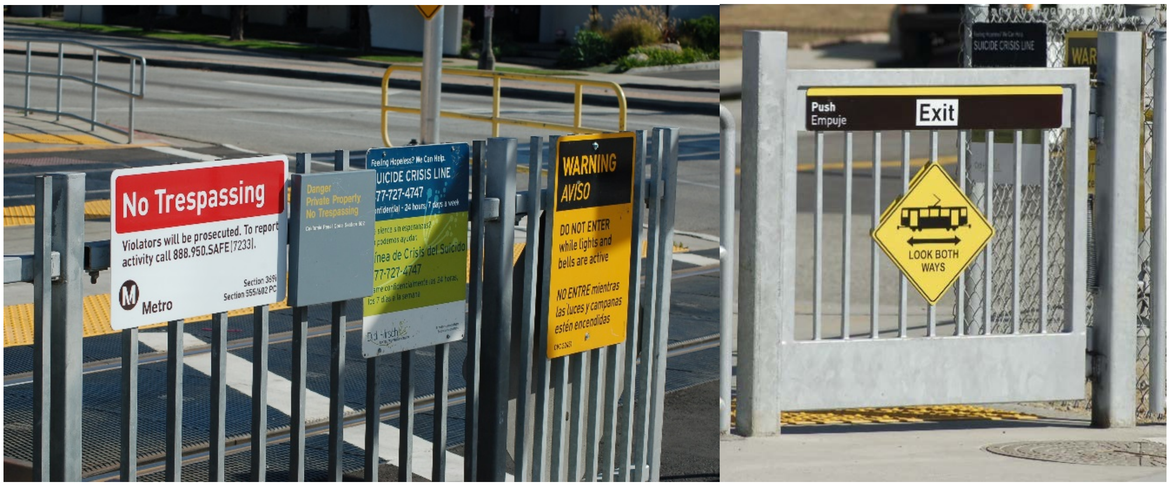

Figure 5. - Wardlow pedestrian gates and signs.

2.2.3.1 Potential Enhancements

a. None at this time.

The Wardlow Station (**Figure 6**) is a center platform with accesses from the north and south ends of the station. The station platform is approximately 150 feet north of Wardlow Road.

2.2.4 North Station Entrance

The north ramp is accessed through the park-n-ride lot, which is west of the station. Pedestrians entering or exiting the north ramp only cross the SB track. There is a set of flashing lights with a bell between the tracks facing the platform and a set of back-to-back flashing lights for the patrons exiting/entering the station to/from the park-n-ride lot and need to cross the SB track. There is a "WARNING Do Not Enter while lights and bells are active" sign (dual language) at the pedestrian entrance to the crossing. There are 3-foot wide tactile strips on both sides of the SB track with a 1-foot yellow strip alongside the tactile (further from the track). It appears the tactile edge closest to the trackway is approximately 1-foot outside the dynamic envelope. The yellow strip has words "WAIT HERE" in three different locations along the strip.

2.2.4.1 Potential Enhancements

a. The edge of the tactile does not follow the recommendation in CPUC's May 2008 Pedestrian-Rail Crossing in California - Detectable Warning, which suggest "for light rail crossings the detectable warning is typically placed no closer than 30 inches from the light rail vehicle's dynamic envelope, pursuant to General Order 143." G.O. 143-B Subsection 9.06C-1 states "on station platforms, in yards and along shop aisles, and other locations, including emergency walkways, where passengers, employees, or other persons are permitted or required to be while trains are in motion, the minimum clearances shall be thirty (30) inches." It has been observed that passengers stand on the tactile strip located on the station platforms waiting for a train arrival. Because of this standard practice, CPUC has strongly suggested that the tactile warning strip be placed 30 inches from the dynamic envelope. It is understood that pedestrians approaching the at-grade crossing will likewise stand on the tactile strip. However the 1-foot yellow strip alongside the tactile (further from the track), which has words "WAIT HERE" in three different locations along the strip does meet CPUC's suggestion. Therefore to relocate the tactile warning strip would be an option, but not necessary.

2.2.5 South Station Entrance

The south ramp access is between the NB and SB tracks from the Wardlow Road pedestrian crossing. The ramp is fully channelized from the station platform to the Wardlow Road pedestrian crossing. Type I pedestrian barriers are placed along the Wardlow Road curb to prevent pedestrians from walking down the ramp and into the street. There is a set of flashing lights with a bell, an R15-1 Crossbuck, an R15-2P "2 Tracks" sign and a W82-1 Trolley "Look Both Ways" warning sign facing the patrons leaving the station.

2.2.5.1 Potential Enhancements

a. None at this time.

Figure 6. - Wardlow station.

3. OPERATIONAL OBSERVATIONS AND POTENTIAL ENHANCEMENTS

The observation was not conducted during any peak hour traffic operation, but was long enough to see possible concerns and provided a medium for discussion of future possibilities. The traffic and pedestrian volumes were probably moderate to semi-heavy at times. For the most part, the railroad warning system for the at-grade crossing provides appropriate control of the crossing.

3.1 General Discussions

3.1.1 Bike Lanes

The City of Long Beach has installed bike lanes on Wardlow Road since the inception of this study, which has adjusted the lane configuration with minimal operating issues along Wardlow Road. The City of Long Beach is open to suggestions that will enhance safety and improve efficiency for both the vehicle and train operations if necessary.

Even though the safety related improvements outlined in this report may not impact roadway capacity on Wardlow Rd, it is important that any changes to Wardlow Rd that may be initiated due to these conclusions, are thoroughly investigated with the current striping and/or parking requirements.

Therefore, any mitigation that involve the roadway must be approved by the City.

3.1.1.1 Potential Enhancements

a. Traffic patterns and capacity of Wardlow Road could change with the implementation of bike lanes on Wardlow Road. A second field visit did not notice any impacts to the at-grade operation, but suggest that Metro should review, periodically the interaction of the bike lane with the at-grade crossing.

3.1.2 Preemption

Signal preemption was discussed in the field and during the team field review with City of Long Beach staff, it was confirmed that simultaneous preemption is provided for the traffic signal transition from normal operation to the preempt routine. Copies of the latest traffic signal timing sheets were provided when the traffic signal controller cabinet was opened by City staff during the field visit and reveals a 13-second railroad clearance time, which is sufficient for the track clearance distance. As far as future preemption adjustments, it is recommended that Metro and City of Long Operations are thoroughly involved in the process.

3.1.2.1 Potential Enhancements

a. None at this time.

3.2 Traffic

The following describes specific traffic observations that may need further evaluation and/or potential mitigation enhancements:

1. During a SB train preempt, it appeared that the time for a SB left turn vehicle to clear the entrance upon gate activation is too short. A panel truck barely missed clipping the descending gate. The distance a vehicle must travel from the SB left turn limit line to the railroad entrance gate is approximately 180 feet for the inside lane and 200 feet for the outside lane. The track clearance distance is approximately 80 feet (not including clear storage area of 56-feet).
    - The traffic signal controller does not stay in the NB train preempt Hold (limited service) when a SB train approaches the station during the NB trains activation of the railroad warning system.
    - The SB trains TWC activation does not provide a track clearance interval, but introduces a simultaneous preempt, truncating the current phase.
    - The traffic signal controller preempt sequence has enough time for the WB track clearance (56 feet), but does not have enough additional time for SB left turn movement (180-200 feet) to completely clear the entrance gate.
2. Two WB passenger car vehicles could safely store in the clear storage area between the intersection limit line and the point 6-feet west of the SB track (but not enough room to accommodate a semi-trailer truck). It was observed that frequently three vehicles tried to occupy the space, leaving the rear end of the third vehicle within the dynamic envelope of the SB train. The preempt clearance interval seems to always clear the trackway.

3. Although the traffic signal is interconnected, there were instances where the EB through vehicles were given a short green only to be stopped by the descending railroad gates in which case the second stopped vehicle would block the pedestrian crossing. Although this condition did not interfere with the NB vehicle movement, this operation is somewhat risky.
4. Often times the NB right turning vehicles on Pacific Pl would stack up behind the horizontal railroad gate. As the field crew determined that there were two functioning W10-7 blank-out "NO RIGHT TURN" signs in proper operation, this was due to driver non-compliance with the regulatory device. Regardless of the presence of the active warning sign, the crossing gates prevent vehicles from entering the trackway during train passage.
5. The Cedar Ave SB right only exit lane is approximately 50 feet from the at-grade crossing stop bar. A motorist was trying to exit Cedar Avenue and access the Wardlow WB left turn pocket. Even though the traffic was moderate the motorist could not make the maneuver, therefore the motorist backed up and drove east on the frontage road to use the mid-block driveway.
6. Visibility is restricted for the left turn from the mid-block driveway to see the EB vehicles on Wardlow Road by the vehicles parked on Wardlow Road between the mid-block driveway and Cedar Ave.

3.2.1.1 Potential Enhancements

a. There is a short term and long term recommendation for the SB train preemption:

   1) Short Term - Provide a minimum of 4-seconds delay between the termination of the current traffic signal phase and the railroad warning system activation and,

   2) Long Term - The approach of the SB train should place a hold on the NB train limited service.

   However, precise rail preempt phasing should be coordinated with Metro Operations so that both the City of Long Beach and Metro requirements and priorities can be met.

b. A short term and long term control scenarios should be considered for the WB approach:

   1) Short Term - Passive control using the R10-6 "Stop Here on Red" sign with "KEEP CLEAR" pavement markings should be installed per **Figure 7**. Typically an at-grade crossing limit line would have a R8-10 "Stop Here When Flashing" sign, but the intent would be to keep the area between the at-grade crossing limit line and intersection crosswalk clear of vehicles. Therefore a R10-6 "Stop Her on Red" sign should be placed at the railroad limit line with "KEEP CLEAR" pavement marks in the track clearance and clear storage areas. An option would be to place diagonal striping between the tracks and the intersection as shown in **Figure 8.**

   2) Long Term - If Short Term improvements do not control traffic from queuing in the track clear distance area, then a pre-signal (**Figure 9**) for the at-grade crossing should be considered. Installation of a pre-signal would require the closure of Cedar Ave. because it would then be inside the controlled crossing and must be coordinated with the City of Long Beach.

c. Parking on the north side of Wardlow Road from the midblock driveway towards the crossing should be removed to provide sufficient visibility for the left turning vehicles from the midblock driveway.

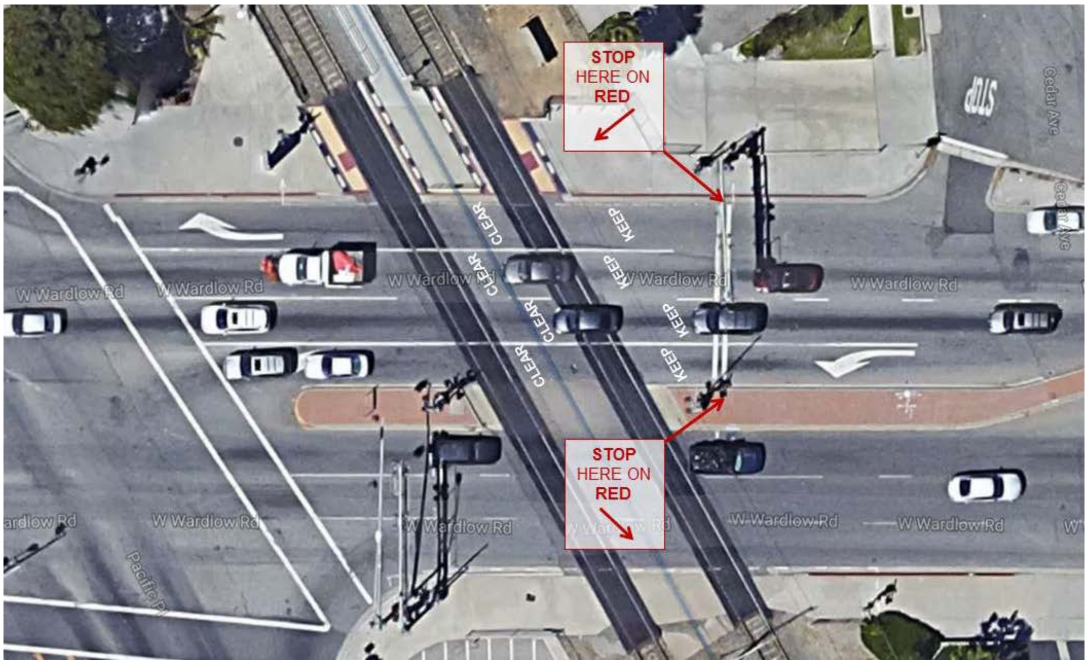

Figure 7. - "KEEP CLEAR" pavement markings.

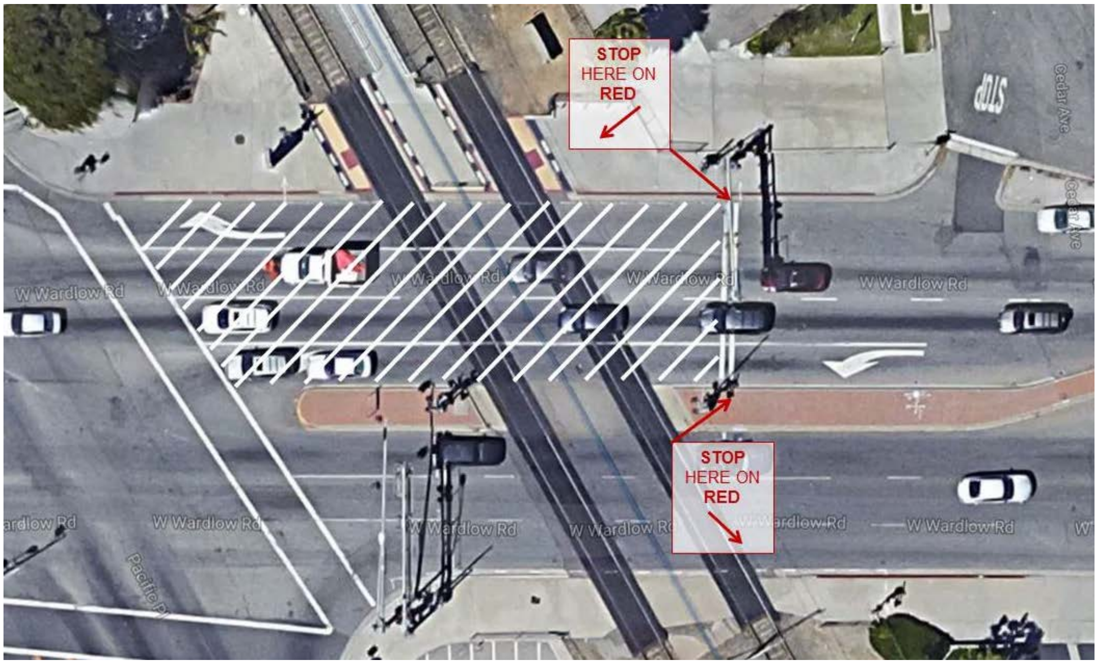

Figure 8. - Diagonal stripping in clear area.

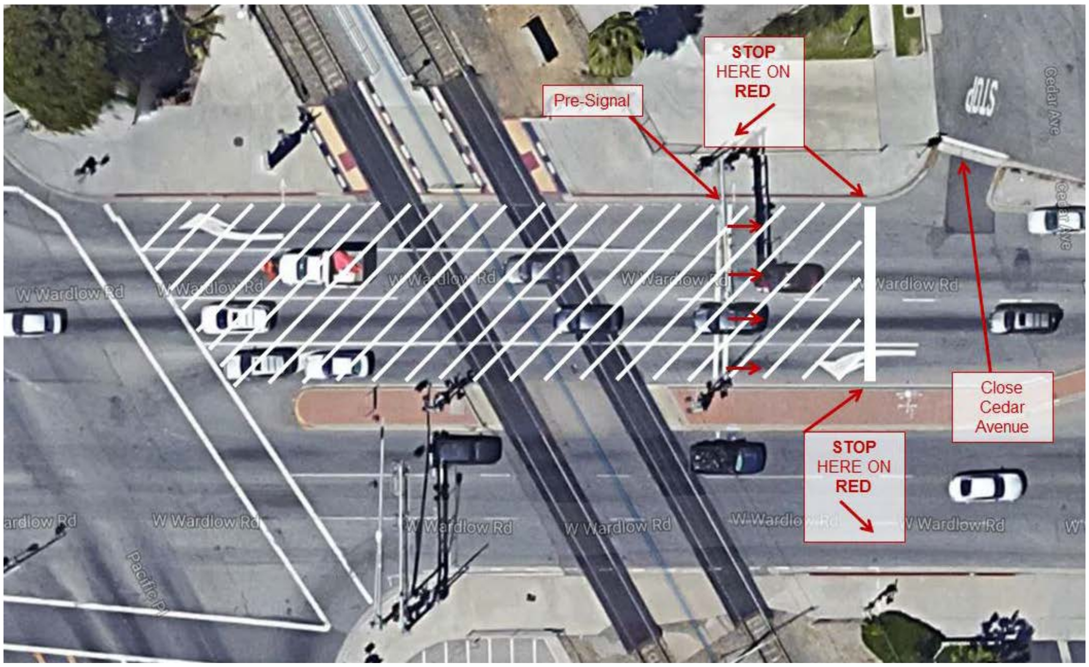

Figure 9. - Pre-signal.

3.3 Pedestrians

The following describes specific pedestrian observations that may need further evaluation and/or potential mitigation enhancements:

1. There were a few individuals in motorized wheelchairs that crossed the trackway. These individuals could be from the assisted living care center on Pacific Place south of Wardlow Road.
2. An eastbound pedestrian walked under the automatic pedestrian gate as it was descending.
3. We observed a pedestrian traveling from the southwest quadrant of the at-grade crossing (southeast corner of the intersection) walk between the 6 foot gap between the pedestrian channelization and the railroads EB vehicle gate to cross Wardlow Road in the trackway to reach the north curb near the station access ramp.
4. We observed an EB pedestrian who had to wait in the 30' area between the automatic pedestrian gate and the vehicle gate. The vehicle gate does not have an emergency swing gate, therefore the pedestrian waited for the vehicle gate to ascend before proceeding eastbound.

3.3.1.1 Potential Enhancements

a. Extend the pedestrian channelization in the southwest quadrant closer to the EB railroad vehicle gate mechanism to reduce the possibility of a risky behavior by the pedestrians.

b. Extend the pedestrian channelization on the northwest quadrant to the intersection crosswalk.

c. Install pedestrian channelization on the median island and if possible between the tracks.

d. An optional enhancement, but not seen as being necessary, is the installation of an emergency swing gate adjacent to the railroad vehicle gate in the northeast quadrant of the crossing.

3.4 Railroad Warning System

The following describes specific observations related to the railroad warnings system and current improvements that may need further evaluation and/or potential mitigation enhancements:

1. A NB train activated the railroad warning system, and appeared to initiate a clearance phase for the WB vehicles. We noticed a SB train under the I-405 approaching the station while the NB train was still in the island circuitry. Upon the NB train leaving the island circuitry it appeared the preemption was released and the railroad warning was energized

(deactivated) while the SB train was still approaching the station. In response to a query regarding advance preemption, the City of Long Beach indicated the at-grade crossing has simultaneous preemption. Observation reveals simultaneous activation of the railroad warning system for the southbound train and advance preemption for the northbound train as presented on the railroad plans. In response to a query regarding advance gate pumping detection for the railroad warning system, Metro staff indicated that the MBL has train to wayside control (TWC) and the operator of the SB train must push the TWC button after the train has stopped at the station to activate a preempt call. It was not clear if the call from the SB train provided a track clearance interval.

3.4.1.1 Potential Enhancements

a. The preempt systems and their parameters should be analyzed more closely with Metro Operations to ensure sufficient timing parameters are met.There is a short term and long term recommendation for the SB train preemption:

    1. Short Term - Provide a minimum of 4-seconds delay between the termination of the current traffic signal phase and the railroad warning system activation, and

    2. Long Term - The approach of the SB train should place a hold on the NB train limited service.

4. COLLISION AND RIDERSHIP

4.1 Introduction

MBL has a total of 103 at-grade crossings, 27 of which are equipped with flashing lights, gates, and bells. The maximum operating speeds through these 27 crossings is 55 mph. The MBL was the first LRT line constructed in Los Angeles County and over the years Los Angeles Metropolitan Transportation Authority (LA Metro) and its predecessor Los Angeles County Transportation Commission have made a series of safety-related improvements to mitigate identified safety concerns regarding train-vehicle collisions at roadway crossings as well as pedestrian safety improvements at sidewalk crossings and station access points. These have included:

- Four-quadrant gates – The installation at 124th Street was a pilot for LA Metro and four-quadrant gates are now provided at all locations where there is a concern for vehicles driving around lowered crossing gates.
- Photo-enforcement – Metro has installed photo-enforcement at various locations; as with the four-quadrant gates, photo enforcement technology was also piloted on the MBL.
- Pedestrian swing gates – Originally installed at the Rosa Parks/Willowbrook station to improve safety at a combined LRT and freight rail pedestrian crossing between the platform and the adjacent bus transfer center, swing gates were subsequently used extensively on the Pasadena Gold Line and Exposition Line.
- Pedestrian gates – Metro is currently installing pedestrian automatic gates at the mid-corridor gated crossings. The current standard is to include both an automatic gate as well as a swing gate which is used to allow persons to exit the crossing should the gates descend while a person is in the crossing area.

4.2 Collision History

4.2.1 10-Year History

The analysis covers Metro’s collision data for the 10-year period July 2006 to December 2016 for all 27 at-grade crossings located within the Cab Signal territory with maximum speeds of 55 mph, beginning at Spring Street in Long Beach and extending to 20th Street in Los Angeles. All occurrences are classified based on type of collision, contributing factor, and fatalities. The task also takes into consideration the year and time of day of the collisions. It is important to note that suicide cases are analyzed and shared but excluded from the analysis as these occurrences are not applicable for this study. Finally, a 10-Year Collision History Technical Memorandum was produced and is currently supporting this study with findings to identify potential risky behaviors.

4.2.2 Collision Data

Metro’s collision data was entered into the master database. All 27 at-grade crossings were listed starting with Spring St. in Long Beach (South) and ending with 20th St. in Los Angeles (North). Aside from the name of the crossings, the master database also includes the following information; location number, type of collision, contributing factors, fatalities, schools within 1 mile and stations within 1 mile. Finally, the data was cataloged for fiscal year and time of day, including a morning peak (6:30AM-8:30AM, a mid-day peak (1:30PM-3:30PM), an evening peak (4:30PM-6:30PM) and other times (remaining time gaps).

Aside from the 27 at-grade crossings in this corridor's segment, there are total of ten (10) stations between at-grade and aerial. Vernon, Slauson, Florence, Firestone, 103rd St/Watts Towers, Willowbrook (old Imperial), Compton, Artesia, Del Amo and Wardlow stations, are all at-grade stations while Firestone, Del Amo and Slauson, are all aerial stations.

Among all seven (7) at-grade stations, just six (6) stations have had collisions during the 10-year period, including Vernon, Florence, Willowbrook, Compton, Artesia and Wardlow. Furthermore, Vernon, Florence and Wardlow are the only three (3) stations being considered in this study due to the fact that the collisions occurred there are located adjacent to the at-grade crossings. Finally, the stations of Willowbrook, Compton and Artesia, on the other hand, are excluded due to the fact that the collisions there occurred either at dedicated pedestrian-only crossings or within the platforms.

From this point on, the stations being analyzed will only include Vernon, Florence and Wardlow.

4.2.3 General Findings

The summary obtained from the 27 at-grade crossing collision data indicates a total of 14 train vs vehicle collisions and 39 train vs pedestrian collisions for the 10-year period. Within the same period, there are a total of 19 fatalities as a result of the 39 train vs. pedestrian collisions (excluding-suicide related collisions & fatalities).

Metro's collision data indicates that six (6) locations experienced three (3) to six (6) collisions over the 10-year period. There were 13 locations with one (1) or two (2) collisions. Locations with more than three (3) collisions or fatalities included Wilmington Ave., 103rd St, and Gage St. Eight (8) of the 27 crossings had no train-pedestrian collisions in the 10-year period.

Finally, there were relatively fewer train-vehicle collisions except at 41st St. where there were four (4) collisions. **Table 1** and **Figure 10** below are summaries of all 27 crossings including collisions and fatalities between train vs vehicle and train vs pedestrian (suicides excluded from the summary).

	Train vs Vehicle Collisions	**Train vs Pedestrian Collisions**	**Train vs Vehicle Fatalities**	**Train vs Pedestrian Fatalities**
Spring St.	1	0	0	0
Wardlow Rd.	0	0	0	0
Manville Rd.	0	0	0	0
Greenleaf Blvd.	0	0	0	0
Alondra Blvd.	0	3	0	0
Myrrh St.	0	0	0	0
Compton Blvd.	0	0	0	0
Elm St.	0	1	0	1
Stockwell St.	0	2	0	1
130th St.	1	1	0	1
El Segundo Blvd.	0	2	0	1
124th St.	0	1	0	1
119th St.	2	1	0	1
Wilmington Ave.	1	6	0	1
108th St.	0	0	0	0
103rd St.	2	4	0	2
Century Blvd.	0	3	0	2
92nd St.	0	1	0	1
Nadeau St.	1	3	0	1
Florence Ave.	0	0	0	0
Gage Ave.	1	4	0	3
55th St.	1	1	0	0
48th Pl.	0	2	0	1
Vernon Ave.	0	1	0	1
41st St.	4	1	0	0
24th St.	0	1	0	1
20th St.	0	1	0	0
	14	**39**	**0**	**19**

Table 1. - Summary table for all 27 crossings including collisions and fatalities between train vs vehicle and train vs pedestrian.

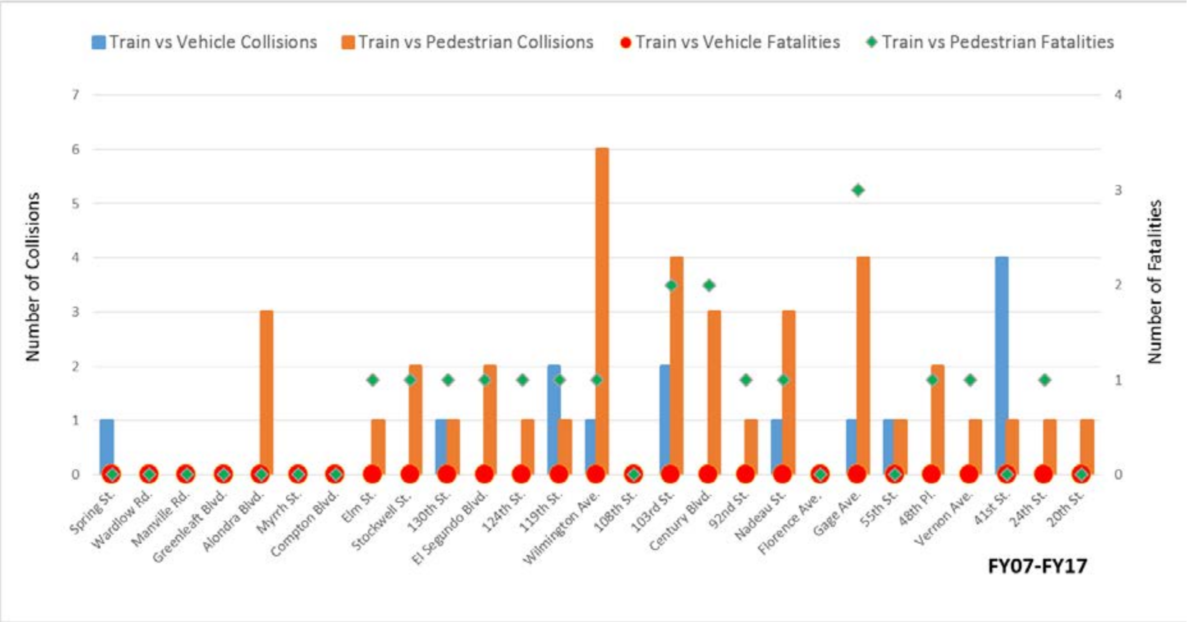

Figure 10. - Summary chart for collisions/fatalities at all 27 at-grade crossings.

Table 2 and **Figure 11** are summaries of the collisions and/or fatalities occurred during the last 10 years between train-vehicle and/or train-pedestrians at the three (3) stations previously identified in this study. The total number of collisions occurred as following; Vernon and Wardlow Stations had three (3) collisions each, while Florence Station had two (2) collisions. Finally, total number of fatalities for the 10-year period was three (3). (Suicides excluded from the summary).

	Train vs Vehicle Collisions	Train vs Pedestrian Collisions	Train vs Vehicle Fatalities	Train vs Pedestrian Fatalities
Vernon	0	3	0	2
Florence	1	2	0	0
Wardlow	0	3	0	1
	1	**8**	**0**	**3**

Table 2 - Stations collision and fatality data summary.

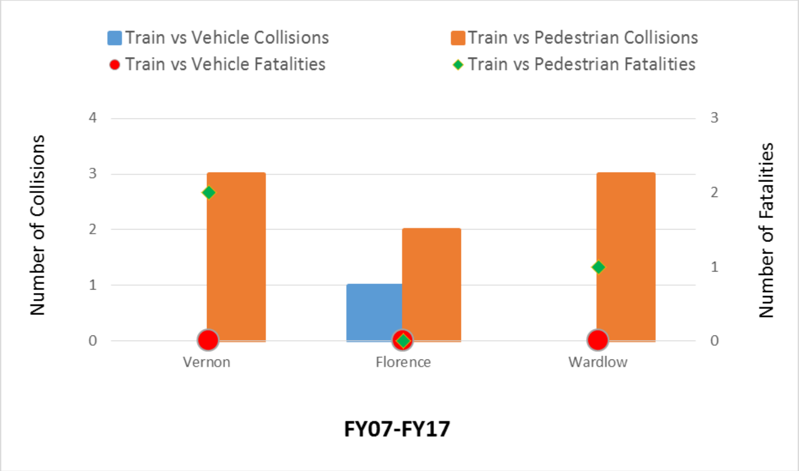

Figure 11. - Summary chart of stations collision/fatalities data.

4.2.3.1 Further Analysis

Collision data from at-grade crossings and stations was combined in order to understand the overall number of collisions at all these locations.

All 27 at-grade crossings and three (3) stations, including Wardlow, Florence and Vernon, were analyzed.

In summary, the results show a total of 15 train-vehicle collisions and 47 train-pedestrian collisions with 22 train-pedestrian fatalities. No train vs vehicle fatalities occurred. **Table 3** and **Figure 12** combined collisions from adjacent at-grade crossings and stations.

	At-Grade Stations Nearby	**Train vs Vehicle Collisions**	**Train vs Pedestrian Collisions**	**Train vs Vehicle Fatalities**	**Train vs Pedestrian Fatalities**
Spring St.	NO	1	0	0	0
Wardlow	YES	0	3	0	1
Manville	NO	0	0	0	0
Greenleaf	NO	0	0	0	0
Alondra	NO	0	3	0	0
Myrrh St.	NO	0	0	0	0
Compton	YES	0	0	0	0
Elm St.	NO	0	1	0	1
Stockwell	NO	0	2	0	1
130th St.	NO	1	1	0	1
El Segundo	NO	0	2	0	1
124th St.	NO	0	1	0	1
119th St.	NO	2	1	0	1
Wilmington	NO	1	6	0	1
108th St.	NO	0	0	0	0
103rd St.	YES	2	4	0	2
Century	NO	0	3	0	2
92nd St.	NO	0	1	0	1
Nadeau St.	NO	1	3	0	1
Florence	YES	1	2	0	0
Gage Ave.	NO	1	4	0	3
55th St.	NO	1	1	0	0
48th Pl.	NO	0	2	0	1
Vernon	YES	0	4	0	3
41st St.	NO	4	1	0	0
24th St.	NO	0	1	0	1
20th St.	NO	0	1	0	0
		15	**47**	**0**	**22**

Table 3 - Combined collisions from adjacent at-grade crossings and stations

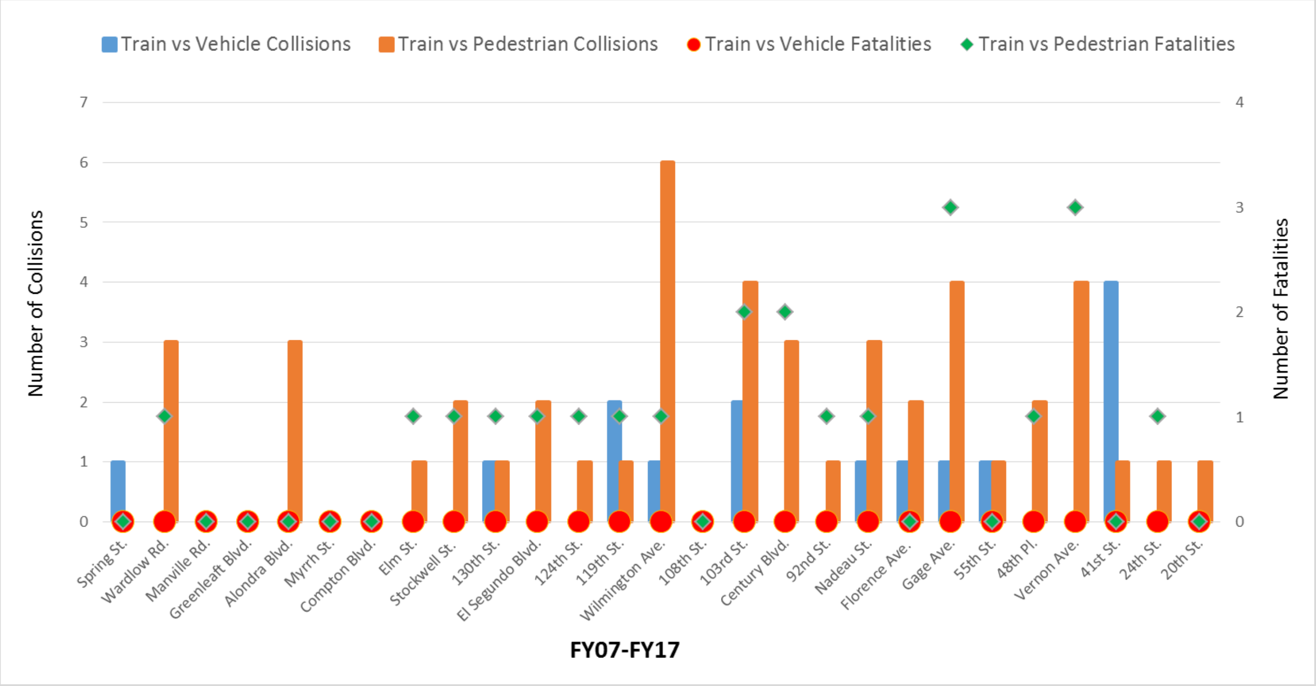

Figure 12. - Summary chart with combined collisions from adjacent at-grade crossings and stations.

4.2.4 Findings by Fiscal Year

This analysis also takes into consideration information such as collisions by fiscal year (FY). As mentioned above, Metro's collision data report covers 9.5 years of data, from July 01, 2006 through December 31, 2016 or FY2007 - FY2017. In order to further understand these collisions, we observed collision patterns year by year.

At-grade crossing collisions within this period were higher among train-pedestrian. It appears that recent train-pedestrian collision frequency has increased from 1-3 per year to 3 to 5 collisions per year since FY11. There were 3 and 4 train-vehicle collisions in 2015 and 2016 respectively; with no train-vehicle collisions in FY14 or FY17. The overall average number of train-vehicle collisions is fairly constant from 2007 to 2013 at about 1 to 2 per year. See **Table 4** and **Figure 13.**

Station collision data shows that train-pedestrian collisions at studied stations have decreased slightly over the past 10 years, observing five (5) collisions within the first five (5) years, as well as another three (3) train-pedestrian collisions and only one (1) train-vehicle collision within the most recent five (5) years. See **Table 5** and **Figure 14**.

	At-grade crossing collisions (excluding suicides)	
	Train vs Vehicle	**Train vs Pedestrians**
FY 07	1	3
FY 08	0	3
FY 09	0	1
FY 10	2	3
FY 11	2	4
FY 12	1	5
FY 13	1	4
FY 14	0	3
FY 15	3	5
FY 16	4	3
FY 17	0	5
	14	**39**

Table 4. - At-grade crossing collision data by fiscal year.

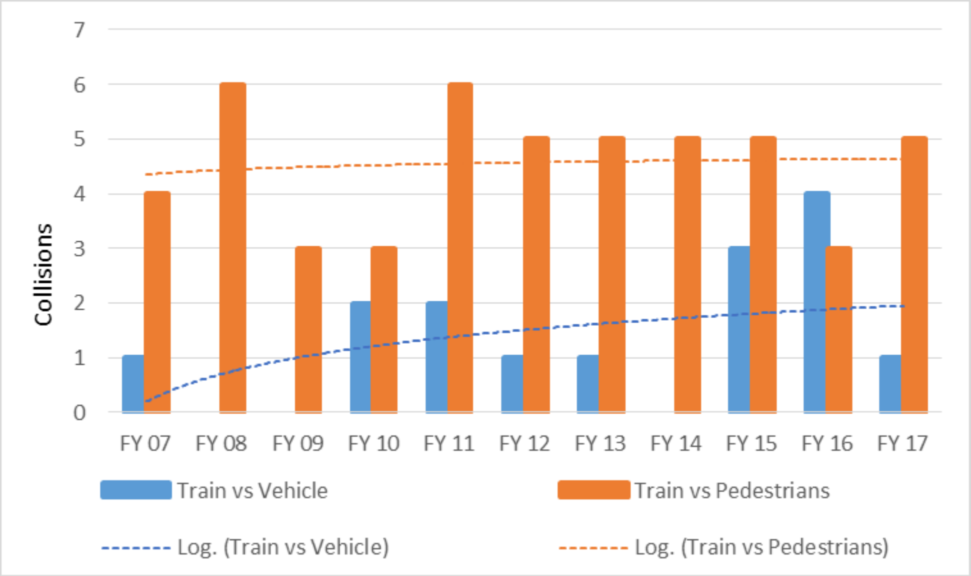

Figure 13. - At-grade crossings collision data by fiscal year (suicides excluded from the summary). FY07-FY17.

	Station collisions (excluding suicides)	
	Train vs Vehicle	Train vs Pedestrians
FY 07	0	0
FY 08	0	1
FY 09	0	2
FY 10	0	0
FY 11	0	2
FY 12	0	0
FY 13	0	1
FY 14	0	2
FY 15	0	0
FY 16	0	0
FY 17	1	0
	1	**8**

Table 5. - Station collision data by fiscal year. FY07-FY17.

Figure 14. - Station collision data by fiscal year. (Suicides excluded from the summary).

4.2.4.1 Further Analysis

Train-pedestrian and train-vehicle collisions from all three (3) stations, Wardlow, Florence and Vernon, were combined with all 27 at-grade crossings presenting the following distribution of collisions by fiscal year; FY 11 (12 collisions), FY 12 thru FY 15 and FY 17 (ten collisions each), FY 08 (eight collisions), and FY 07, FY 09, FY 10 and FY 16 (six collisions each).

4.2.5 Findings by Time of Day

In addition to analyzing collisions by fiscal year, we looked at them by time of day as well. Based on standard practices in the LA region, the collision data was cataloged by time of day, including a morning peak (6:30AM-8:30AM, a mid-day peak (1:30PM-3:30PM), an evening peak (4:30PM-6:30PM) and Others (remaining time gaps). As in all previous analysis, collision data observed for the last ten years include 27 at-grade crossings as well as three (3) stations.

The largest number of at-grade crossing train-vehicle and train-pedestrian collisions (39 combined), were observed during times other than AM, MIDDAY or PM. Following that, there were a total of ten (10 combined) train-vehicle and train-pedestrian collisions that occurred during the PM peak.

At stations, the highest number, at three (3) train-pedestrian collisions, occurred during MIDDAY and PM peaks, with two (2) collisions occurring during OTHERS (one related to train-pedestrian and another one to train-vehicle), and finally a single (1) train-pedestrian collision taking place during AM peak. See **Table 6**, and **Figure 15** & **Figure 16** for summaries of at-grade crossing and station collisions by time of day.

At-grade crossing collisions
(excluding suicides)

	Train vs Vehicle	Train vs Pedestrians
AM	1	1
MIDDAY	0	2
PM	1	9
OTHERS	12	27
	14	**39**

Stations collisions
(excluding suicides)

	Train vs Vehicle	Train vs Pedestrians
AM	0	1
MIDDAY	0	3
PM	0	3
OTHERS	1	1
	1	**8**

Table 6. - At-grade (top table) and station (bottom table) collision data by time of day (FY07-FY17).

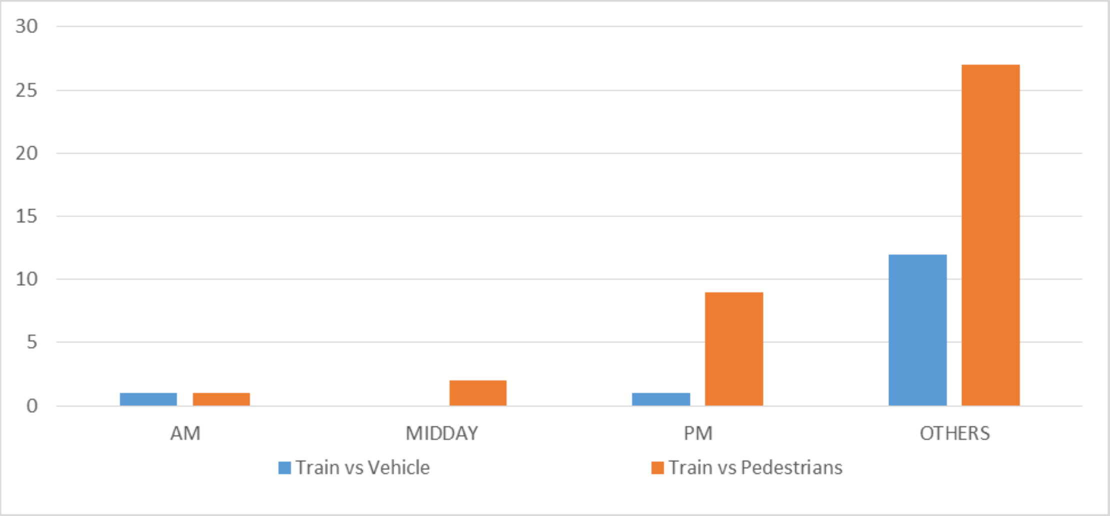

Figure 15. - At-grade collision data by time of day (FY07-FY17).

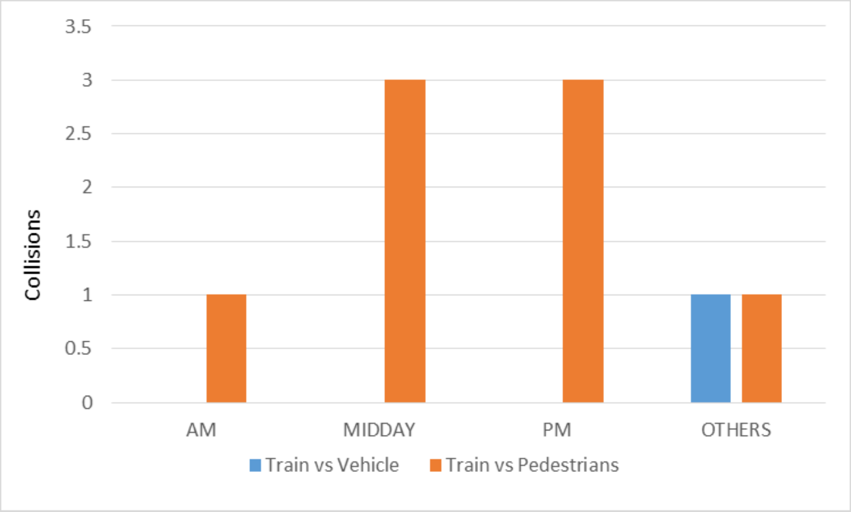

Figure 16. - Station collision data by time of day FY07-FY17.

4.2.5.1 Further Analysis

Similarly to section 4.2.3.1 and 4.2.4.1, train-pedestrian and train-vehicle collisions from all three (3) stations, Wardlow, Florence and Vernon were combined with all 27 at-grade crossings presenting the following distribution of collisions by time of day; a total of 40 collisions occurred during OTHERS (time window outside of the AM, MIDDAY and PM peaks), with another 13 collisions during the PM peak, six (6) collisions during the MIDDAY peak, and finally three (3) collisions during the AM peak. All values combine both train-pedestrian and train-vehicle collisions.

4.3 Ridership

Boarding ridership data along the entire Metro Blue Line (MBL) for the period July 2006 through March 2017 shows a bumpy trendline with a minimum of 68,843 boarding recorded in December 2007 and a maximum of 93,201 in November 2012. Some of the peaks in ridership (values above 85,000 boarding) occurred in July 2008, July 2011, March 2012, September 2013 and July 2014. Some of the lowest points (values below 71,000 boarding), on the other hand, occurred in December 2007, January 2010 and December 2010. Surprisingly, the majority of low points in ridership year after year occurred around November-January, with the exception of the November 2012 - January 2013 period where the MBL achieved a maximum in ridership (see above). See **Figure 17** for a summary of boarding on the MBL.

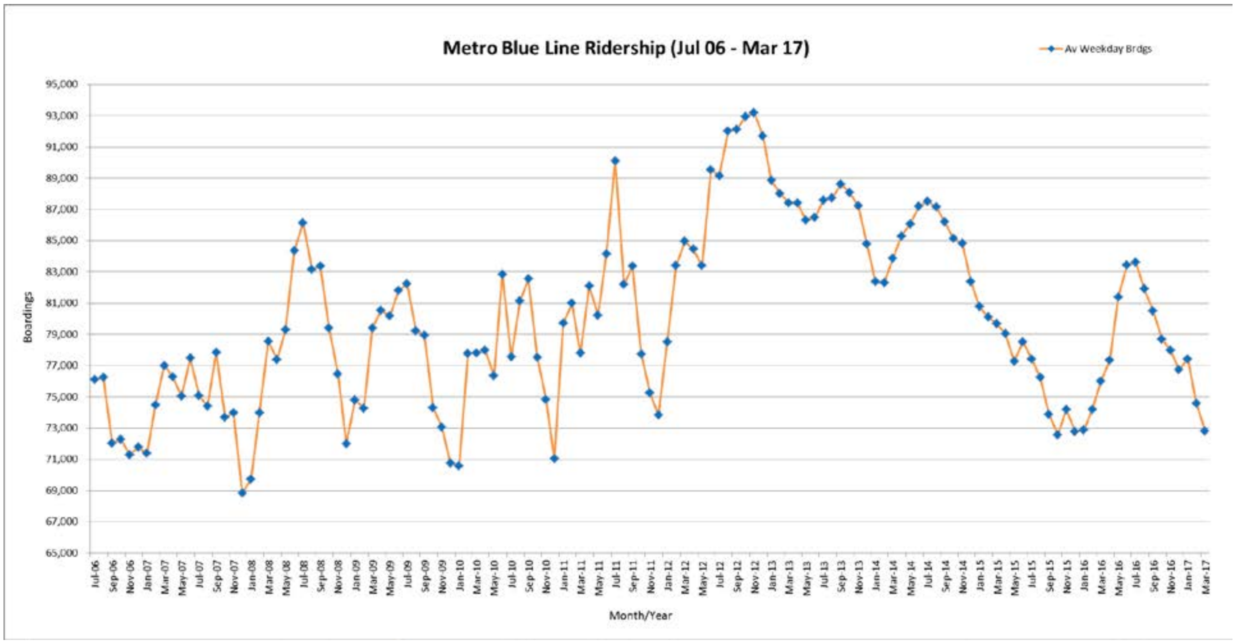

Figure 17. - Summary of boarding ridership on the MBL. Jul 06- Mar 17.

4.3.1 Ridership vs. Collisions

A total of 8 collisions (all vehicle-pedestrian) occurred at the three (3) stations during the last 10 years. Among them, one (1) collision in FY 08 and two (2) collisions in FY 09, another two (2) collisions in FY 11, one (1) in FY 13 and two (2) in FY 14, concluding with a single one (1) in FY 17 (this one being the only train-vehicle collision). Overall, a downward trend in train-pedestrian collision within the 10-year period has been observed. Therefore, no clear relationship seems to exist between ridership during the period of Jul 2006 through Mar 2017 for the entire MBL and all nine (9) collisions at the three (3) stations.

Average daily boarding were obtained from FY 16 for the three (3) stations. Florence Station has the highest boarding ridership during weekdays, weekends, as well as the entire week, followed by Vernon Station and Wardlow Station. On the contrary, the number of combined collisions at each of the three (3) stations is constant at three (3). Therefore, it is not possible to relate ridership and collisions at these three (3) stations.

See **Table 7** and **Figure 18** with data on boarding, collisions and fatalities.

	Vernon	**Florence**	**Wardlow**
Average Weekday Daily Boarding (FY16)	2,336	3,866	1,559
Average Weekend Daily Boarding (FY16)	1,854	2,644	742
Average Entire Week Daily Boarding (FY16)	2,198	3,517	1,326
Total Collisions (FY07-FY17)	3	3	3
Total Fatalities (FY07-FY17)	2	0	1

Table 7. - Boarding, collision and fatalities at stations.

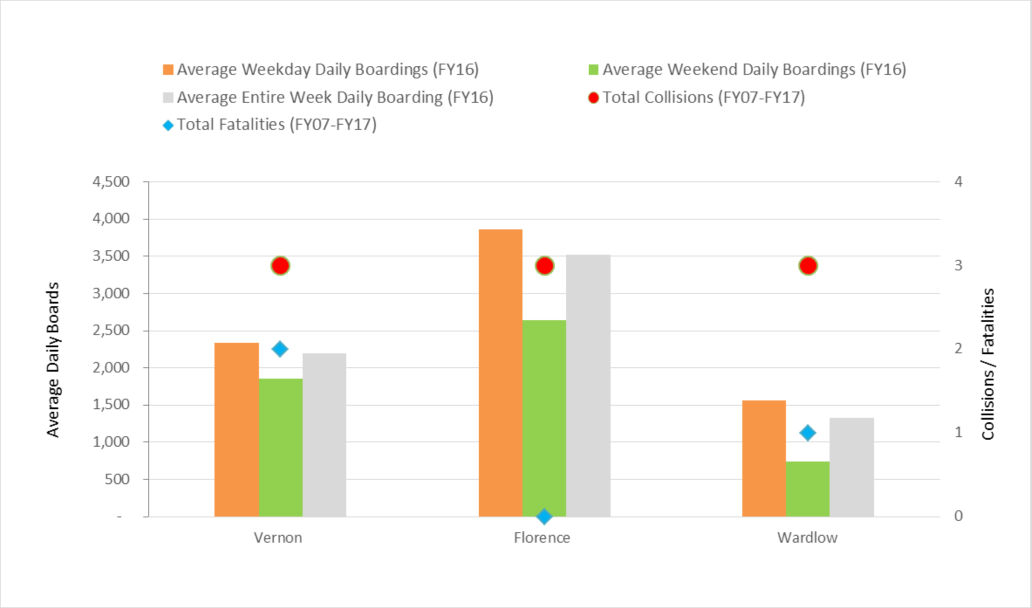

Figure 18. - Boarding, collision and fatalities at stations.

Finally, we analyzed the relationship between collisions and at-grade crossings by segregating crossings by proximity to any of the at-grade MBL stations located within the Cab Signal Route Segment. This process identified 22 at-grade crossings nowhere near a station area and only five (5) at-grade crossings within close proximity to a station area. See **Table 8** and **Figure 19** below with more detailed information.

The result of this analysis showed that the ratio of pedestrian collisions at crossings near a station area is barely higher (1.80) than those at crossings away from a station area (1.73), concluding that there is no clear indication that the at-grade crossings adjacent to stations have significantly higher chances for pedestrian collisions to occur.

Contrarily, the ratio of total collisions (combined pedestrian & vehicle) at crossings near a station area is approximately 20 percent lower than the ratio at crossings away from a station area.

	Crossings away from station area	Crossings near station area	Total
No. of at-grade crossings	22	5	27
No. of pedestrian collisions (excluding suicides)	38	9	47
No. of vehicle collisions	14	1	15
No. total collisions	52	10	62
Ratio (pedestrian collisions/No. of at-grade crossings)	1.73	1.80	1.74
Ratio (vehicle collisions/No.at-grade crossings)	0.64	0.20	0.56
Ratio (total collisions/No.at-grade crossings)	2.36	2.00	2.30

Table 8. - Ratio of Collisions per crossing based on proximity to a station.

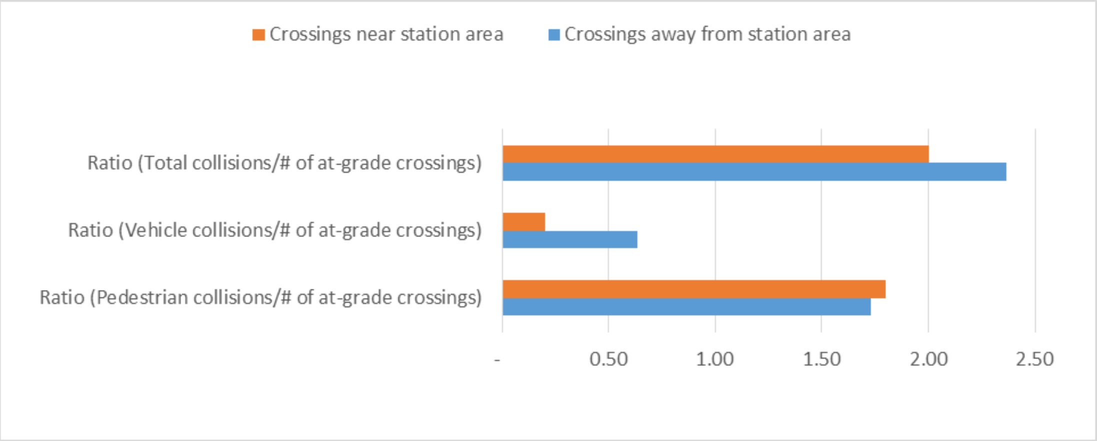

Figure 19. - Bar graph displaying ratio of collisions per crossing based on proximity to a station along CAB Signal Route Segment.

5. SUMMARY OF POTENTIAL ENHANCEMENTS

The following is a summary of potential enhancements that may provide additional safety for the Wardlow At-Grade crossing.

1. Roadway Enhancements

- Close Cedar Avenue right only (2.1.1.1a).
- Remove EB Wardlow Road W82 sign (2.1.1.1b).
- Place RXR markings in the EB curb lane on Wardlow Road (2.1.1.1c).
- Install W10-1 and W48 railroad warning signs for EB Wardlow Road (2.1.1.1d).
- Install W10-1 and W48 railroad warning signs for WB Wardlow Road (2.1.1.1e).
- Install W10-2 and W48 railroad warning signs for NB Pacific Place right turn lane and SB Pacific Place Left turn lanes. The SB Left turn signs would need to be placed on the raised median island. Railroad pavement markings should be installed (2.1.2.1a).

2. At-Grade Crossing Enhancements

- Remove Non-Standard “watch for Trains” sign on median-island (2.2.2.1a).
- Remove WB left turn arrow pavement marking upstream from crossing (2.2.2.1b).

- Place R8-8 Signs on the cantilevers for both EB and WB directions (2.2.2.1c).

3. Station Enhancements

- Relocating tactile strip at North station entrance is optional and not necessary because of “WAIT HERE” strip (2.3.1.1a).

4. General Discussion “Enhancements”

- Coordinate with City of Long Beach on bike lane installation (3.1.1.1a)

5. Traffic Enhancements

- Short Term - Provide a minimum of 4-seconds delay between the termination of the current traffic signal phase and the railroad warning system activation and, (3.2.1.1a).
- Long Term - The approach of the SB train should place a hold on the NB train limited service (3.2.1.1a).
- Short Term - Install passive control R10-6 “Stop Her on Red” with KEEP CLEAR pavement markings in the track clearance and clear storage areas. Long Term - If passive does not mitigate concerns consider installation of a pre-signal to manage WB traffic queuing onto the trackway (3.2.1.1b, and 2.1.1.1a for additional information on pre-signal).
- Consider removing parking on Wardlow Road between the mid-block driveway to Cedar Avenue right only driveway to enhance visibility for left turning vehicles at the mid-block driveway, Observation 5.1.6. (3.2.1.1c).

6. Pedestrian Enhancements

- Close the gap between railroad mechanisms and channelization in the southwest quadrant to reduce the ability of pedestrians performing risky behaviors (3.3.1.1a).
- Extend the pedestrian channelization on the northwest quadrant to the intersection crosswalk (3.3.1.1b).
- Install pedestrian channelization on the median island and if possible between the tracks (3.3.1.1c).
- Consider the placement of an emergency swing gate at the railroad vehicle gate in the northeast quadrant. This would reduce unwanted delay and potential anxieties for the pedestrian (3.3.1.1d).

7. Railroad Warning System Enhancements

- Preempt parameters programmed into the traffic signal controller should be analyzed more closely with Metro to ensure sufficient timing parameters are met (3.4.1.1a).
- There is a short term and long term recommendation for the SB train preemption: (3.4.1.1a).
    - Short Term - Provide a minimum of 4-seconds delay between the termination of the current traffic signal phase and the railroad warning system activation, and
    - Long Term - The approach of the SB train should place a hold on the NB train limited service

Wardlow Station and At-Grade Crossing Safety Evaluation

TASK 2- Traffic Analysis Report

Los Angeles County Metropolitan Transit Authority

August 25, 2017

FINAL

Quality information

Prepared by	Checked by	Approved by
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Revision	Revision date	Details	Authorized	Name	Position
No. 1	06/27/2017	Response to Metro Comments			
No. 2	08/23/2017	Response to City of Long Beach Comments			

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1. INTRODUCTION

The purpose of this traffic study is to evaluate and assess the traffic operating conditions at the intersection of Wardlow Road and Pacific Place adjacent to the Metro Blue Line (MBL) Wardlow Station. This traffic study is being conducted as part of the overall feasibility study to improve safety at the Wardlow grade crossing. The focus of this task is to perform an independent traffic analysis at the intersection of Wardlow Road and Pacific Place during the peak and off peak hours to identify existing traffic impacts and vehicular delays resulting from the gate down time at the adjacent MBL at-grade crossing.

2. BACKGROUND

The Metro Blue Line is a 22.0-mile light rail line running north-south between the City of Long Beach and Downtown Los Angeles, passing through the downtown area, South Los Angeles, Watts, Willowbrook, Compton, and Long Beach in Los Angeles County. This rail line opened in 1990 and is the oldest in the Metro Rail System. The line's northern terminus is at 7th Street/Metro Center, from which it runs south along Flower Street, sharing tracks with the Expo Line. The two lines diverge at Flower Street and Washington Boulevard just south of downtown Los Angeles. The Blue Line turns east on Washington Boulevard before turning south on Long Beach Avenue to join the Southern Pacific right-of-way to Willow Station which runs as far as Long Beach where the line follows Long Beach Boulevard to the Long Beach Transit Mall, which is a loop involving Long Beach Boulevard, 1st Street, Pacific Avenue and 8th Street. There are 22 stations on the MBL, and trains operate, at speeds up to 55 mph, in various alignments ranging from at-grade street running, to at-grade cab signal, tunnel, and aerial. The trains consist of three 90-foot long articulated cars running at 6-minute headways during the AM and PM peak periods (ten trains per hour per direction) and 12-minute headways during the midday period (five trains per hour per direction).

The Wardlow Station is an at-grade light rail station along the MBL alignment. It is located at the north east corner of the intersection of Wardlow Road and Pacific Place in the City of Long Beach. It consists of a center island platform with two tracks; one on either side of the platform. The station is considered a park-and-ride station due to its close proximity to the I-405 and I-710 freeway entrances and it provides 25 parking spaces. The station also has 10 bicycle lockers as well as bicycle racks. In addition, Long Beach Transit provides bus connections to the station.

3. TRAFFIC EVALUATION METHODOLOGY

In order to evaluate traffic operating conditions at the intersection of Wardlow Road and Pacific Place, intersection turning movement traffic counts were collected on a typical non-holiday weekday (Tuesday, Wednesday, or Thursday) when school is in session during the morning (AM), Midday, and evening (PM) peak periods. The traffic counts were collected May 18th, 2017 and are presentenced in **Appendix A**. In addition, field site visits were conducted in conjunction with City of Long Beach traffic engineering staff to observe the operation of the intersection, including signal phasing, pedestrian activity, and vehicular queue formation, during normal operating conditions and during periods when the rail crossing gates are activated. The existing intersection lane configuration is presented in **Figure 1** and the peak hour intersection turning movement traffic volumes for the AM, Midday, and PM are presented in **Figure 2**.

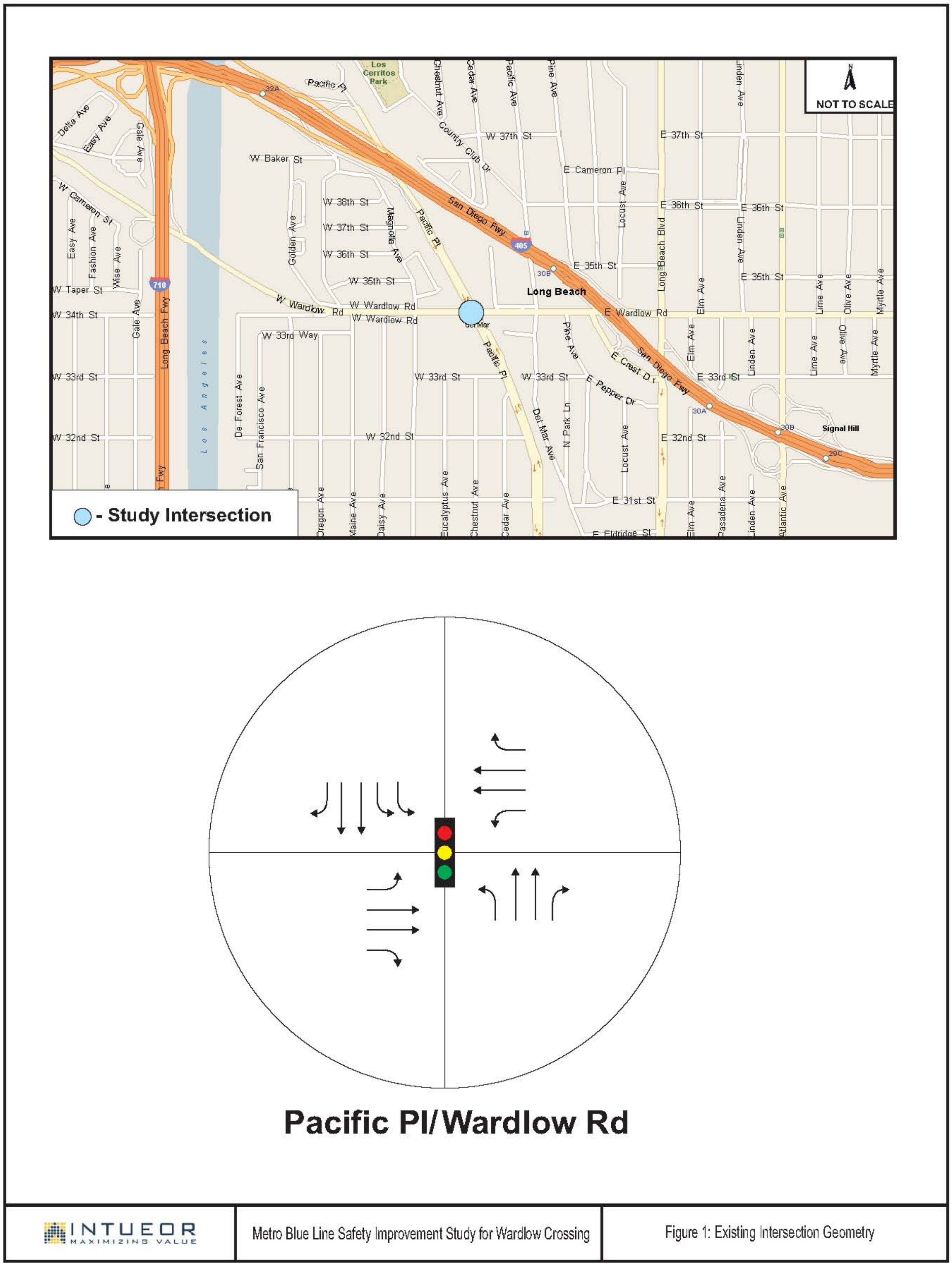
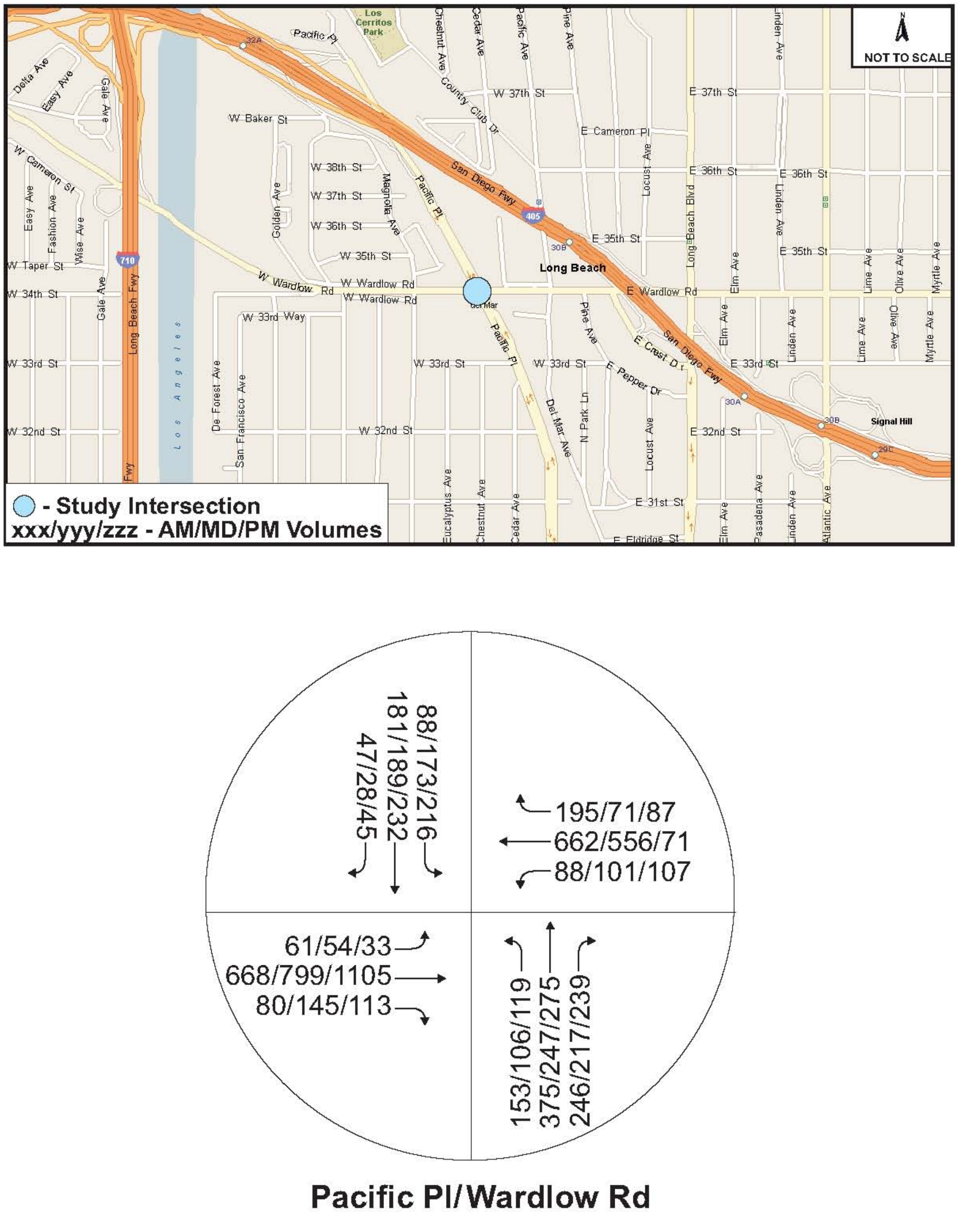


Figure 1. – Existing Intersection Lane Configuration.



INTUEOR MAXIMIZING VALUE

Metro Blue Line Safety Improvement Study for Wardlow Crossing

Figure 2: Existing (2017) AM/MD/PM Peak Hour Traffic Volumes

Figure 2. – Peak Hour Intersection Turning Movement Traffic Volumes for the AM, Midday, and PM

The existing intersection peak hour evaluation was performed using the level of service (LOS) analysis procedures outlined in the *Highway Capacity Manual* (2010). The LOS for signalized intersections is calculated using the average delay (in seconds) per approaching vehicle. **Table 1** presents the LOS definition for signalized intersections. The Synchro software version 8.0 was used to analyze intersection traffic operating conditions for each peak hour. This is a widely accepted tool used to calculate level of service based on the delay methodology presented in the Highway Capacity Manual (2010), which is the industry standard for analyzing traffic intersection operating conditions. However, there are limitations to this methodology such that signal pre-emption and traffic operations during the gate down time period is not adequately replicated. To approximate the signal pre-emption operating conditions, the crossing gates were modeled as an isolated mock traffic signal. The Synchro computed delays for this mock intersection were then added to the delays calculated for the intersection of Wardlow Road and Pacific Place when operating under normal (no gate actuation) operating conditions.

Level of Service	Average Vehicle Delay (Seconds)	Definition
A	≤ 10.0	EXCELLENT. No vehicle waits longer than one red light and none of the approach signal phases are fully used.
B	> 10.0 and ≤ 20.0	VERY GOOD. An occasional approach phase is fully utilized; many drivers begin to feel somewhat restricted within groups of vehicles.
C	> 20.0 and ≤ 35.0	GOOD. Occasionally drivers may have to wait through more than one red light; backups may develop behind turning vehicles.
D	> 35.0 and ≤ 55.0	FAIR. Delays may be substantial during portions of the peak hours, but enough lower volume periods occur to permit clearing of developing lines, preventing excessive backups.
E	> 55.0 and ≤ 80.0	POOR. Represents the most vehicles intersection approaches can accommodate; may be long lines of waiting vehicles through several signal cycles.
F	> 80	FAILURE. Backups from nearby locations or on cross streets may restrict or prevent movement of vehicles out of the intersection approaches. Tremendous delays with continuously increasing queue lengths.
Source: Transportation Research Board, *Interim materials on Highway Capacity,* Transportation Research Circular No. 212, January 1980; and *Highway Capacity Manual (2010).*		

Table 1. – LOS Definitions for Signalized Intersections**.**

4. EXISTING TRAFFIC CONDITIONS

A level of service analysis using the previously described methodology was conducted to evaluate existing operating conditions at the study intersection. The results of the AM, Midday, and PM peak hour intersection level of service analysis are summarized in **Table 2**. The Wardlow Road and Pacific Place intersection is operating at LOS C during all three peak hours. The detailed LOS worksheets are presented in **Appendix B.**

Intersection	Control Type	AM Peak Hour		MD Peak Hour		PM Peak Hour	
		Delay[1]	LOS	Delay[1]	LOS	Delay[1]	LOS
Pacific Pl/ Wardlow Rd	Signalized	27.3	C	27.5	C	31.2	C
[1] Average vehicle delay in seconds (combined delay with gate actuation)							

Table 2. – Existing Intersection Peak Hour Level of Service Analysis**.**

During the site visit, the gate down time was observed for several cycles and it was timed between 45 and 50 seconds. The traffic signal timing plans were obtained from the City of Long Beach and it was found that the overall signal cycle length was 110 seconds with 55 seconds allocated to all the north/south movements and 55 seconds allocated to all the east/west movements. Consequently, when a train triggers the crossing gates, a clearance period is initiated so that the westbound through and left turn movements clear the crossing area. This clearance phase is followed by the normal north/south phase where the northbound left turns operate in a lead position followed by the north/south through movements, then followed by a lagging southbound left turn movement once the crossing gates are raised. Due to the limitation of the HCM methodology, this exact phasing sequence cannot be exactly replicated in the Synchro software.

For evaluation purposes, the closest condition is to assume that the Wardlow Road and Pacific Place intersection and the crossing gates operate as two separate traffic signals.

- The Wardlow Road and Pacific Place intersection operating conditions were modeled under normal operating (no gate actuating) condition with a cycle length of 110 seconds during all three peak hours.
- The crossing gates intersection was modeled as having 2 phases with a total cycle length of 180 seconds for the AM and PM peak hours and 360 seconds for the MD peak hour. The cycle length represents the occurrence of the train crossing during the analyzed peak periods. The north/south phase will extend 50 seconds to replicate the gate down time during all three peak hours. The east/west phase servicing vehicular traffic will extend the remaining time of the cycle length, which is 130 seconds during the AM and PM peak hours and 310 seconds during the MD peak hour.

The calculated delays for both intersections were then added to represent the closest delay estimation of the operating conditions at the intersection of Wardlow Road and Pacific Place.

Additionally, as part of the traffic signal operations evaluation, the vehicular queue lengths formed due to the red signal indication were reported and reviewed and are presented in **Table 3**. The queue analysis show that the eastbound queue lengths extend for about 385 feet in the PM peak hour and the westbound queue lengths extend for approximately 220 feet in the AM peak hour. The detailed queue worksheets are presented in **Appendix C**. These results are similar to what was observed in the field during the site visit for normal operations, however, it was also observed that vehicular queues in the westbound direction extend back to the Pacific Avenue intersection when the crossing gates are down. The increase in queue lengths due to the activation of the crossing gate was also observed in the eastbound direction. These observations, which show an increase in queue lengths when the crossing gates are down. These observed queue lengths translate to an increase in the vehicular delay that was not quantified by the HCM analysis methodology. Consequently, field observations confirm that traffic operations at the intersection of Wardlow Road and Pacific Place are impacted during the period when the crossing gates are down. Due to the higher traffic volumes on Wardlow Road and the fact that the north/south direction can continue to operate while the train is passing through the crossing, an increase in east/west vehicular delays is anticipated.

Intersection	Movement	Available Storage (ft)	AM Peak Hour		MD Peak Hour		PM Peak Hour	
			95th Percentile Queue (ft)	Adequate Storage? (Yes or No)	95th Percentile Queue (ft)	Adequate Storage? (Yes or No)	95th Percentile Queue (ft)	Adequate Storage? (Yes or No)
Pacific Pl/ Wardlow Rd	EBL	155	76	Yes	66	Yes	49	Yes
	EBT	520	228	Yes	257	Yes	384	Yes
	EBR	100	0	Yes	33	Yes	15	Yes
	WBL	160	99	Yes	107	Yes	115	Yes
	EBT	280	217	Yes	165	Yes	164	Yes
	WBR	50	67	No	0	Yes	6	Yes
	NBL	100	182	No	128	No	144	No
	NBR	90	62	Yes	61	Yes	70	Yes
	SBL	120	51	Yes	80	Yes	103	Yes
	SBR	90	0	Yes	0	Yes	0	Yes

Table 3. – Existing Intersection Peak Hour Queues vs. Storage**.**

5. EXISTING TRANSIT

Wardlow Station is currently being served by Long Beach Transit, which operates a fixed bus route service adjacent to the station. The Long Beach Transit bus lines serving the vicinity of the Wardlow Road and Pacific Place intersection are described below.

- **Route 131 (Redondo Ave/Belmont Shore/Seal Beach)** – This route provides bus service between Wardlow Station in Long Beach and Electric Avenue & Main Street in Seal Beach. Route 131 operates on a 45 minutes headway during weekdays and on a 60 minutes headway during weekends.
- **Route 181/182 (Magnolia/Pacific)** – This route provides bus service between Wardlow Station in Long Beach and the Transit Gallery near downtown Long Beach. Route 181/182 operates on a 20 to 30 minutes headway during weekdays and on a 30 minutes headway during weekends.

6. EXISTING SCHOOL BUS ACTIVITY

Wardlow Road is designated as a school bus route, with approximately 50 daily school buses using this route in both directions combined. There is no student drop-off or pick-up zone within 200 feet of the crossing. In this area, Wardlow Road is currently not designated as a safe route to school.

7. EXISTING PEDESTRIAN AND BICYCLE ACTIVITY

Existing pedestrian and bicycle activity at the Wardlow Road and Pacific Place crosswalks were recorded during the AM, Midday, and PM peak period traffic counts. Most of the pedestrian activity was focused towards the station coming from the north approach crosswalk (east-west pedestrian movement) and from the east approach crosswalk (north-south pedestrian movement). The east approach crosswalk activity is due to the use of the overflow station parking area located on the southeast quadrant of the intersection. A total of 66 pedestrians were counted during the AM peak hour, 65 were counted during the Midday peak hour, and 61 were counted during the PM peak hour. Bicycle activity was also recorded with 11 counted in the AM peak hour, 12 counted in the Midday peak hour, and 17 counted in the PM peak hour.

8. EXISTING SIGNAL PREEMPTION

Signal preemption was discussed in the field and during the team field review with City of Long Beach staff, it was confirmed that simultaneous preemption is provided for the traffic signal transition from normal operation to the preempt routine. Copies of the latest traffic signal timing sheets were provided when the traffic signal controller cabinet was opened by City staff during the field visit and reveals a 13-second railroad clearance time, which is sufficient for the track clearance distance. Potential enhancements to the signal preemption operations are described in Section 9 below.

9. EXISTING TRAFFIC OPERATIONS OBSERVATIONS AND ENHANCEMENTS

Consistent with the *Wardlow Station and At-Grade Crossing Safety Evaluation Task 1 – Safety Analysis Report,* the existing traffic observations and potential enhancements are described below:

9.1 Traffic Observations

The following describes specific traffic observations that may need further evaluation and/or potential mitigation enhancements:

1. During a SB train preempt, it appeared that the time for a SB left turn vehicle to clear the entrance upon gate activation is too short. A panel truck barely missed clipping the descending gate. The distance a vehicle must travel from the SB left turn limit line to the railroad entrance gate is approximately 180 feet for the inside lane and

200 feet for the outside lane. The track clearance distance is approximately 80 feet (not including clear storage area of 56-feet).

- The traffic signal controller does not stay in the NB train preempt Hold (limited service) when a SB train approaches the station during the NB trains activation of the railroad warning system.
- The SB trains TWC activation does not provide a track clearance interval, but introduces a simultaneous preempt, truncating the current phase.
- The traffic signal controller preempt sequence has enough time for the WB track clearance (56 feet), but does not have enough additional time for SB left turn movement (180-200 feet) to completely clear the entrance gate.

2. Two WB passenger car vehicles could safely store in the clear storage area between the intersection limit line and the point 6-feet west of SB track (but not enough room to accommodate a semi-trailer truck). It was observed that frequently three vehicles tried to occupy the space, leaving the rear end of the third vehicle within the dynamic envelope of the SB train. The preempt clearance interval seems to always clear the trackway.
3. Although the traffic signal is interconnected, there were instances where the EB through vehicles were given a short green only to be stopped by the descending railroad gates in which case the second stopped vehicle would block the pedestrian crossing. Although this condition did not interfere with the NB train movement, this operation of having vehicles queued between the eastbound gate and the Pacific Place roadway is somewhat risky.
4. Often times the NB right turning vehicles on Pacific Pl would stack up behind the horizontal railroad gate. As the field crew determined that there were two functioning W10-7 blank-out “NO RIGHT TURN” signs in proper operation, this was due to driver non-compliance with the regulatory device. Regardless of the presence of the active warning sign, the crossing gates prevent vehicles from entering the trackway during train passage.
5. The Cedar Ave SB right only exit lane is approximately 50 feet from the at-grade crossing stop bar. A motorist was trying to exit Cedar Avenue and access the Wardlow WB left turn pocket. Even though the traffic was moderate the motorist could not make the maneuver, therefore the motorist backed up and drove east on the frontage road to use the mid-block driveway.
6. Visibility is restricted for the left turn from the mid-block driveway to see the EB vehicles on Wardlow Road by the vehicles parked on Wardlow Road between the mid-block driveway and Cedar Ave.

9.2 Potential Enhancements

1. There are short term and long term recommendation for the SB train preemption:
    - Short Term - Provide a minimum of 4-seconds delay between the termination of the current traffic signal phase and the railroad warning system activation and;
    - Long Term - The approach of the SB train should place a hold on the NB train limited service.

2. A short term and long term scenario should be considered for the WB approach:
    - Short Term - Passive control using the R10-6 “Stop Here on Red” sign with “KEEP CLEAR” pavement markings should be installed as shown in **Figure 3**. Typically an at-grade crossing limit line would have a R8-10 “Stop Here When Flashing” sign, but the intent would be to keep the area between the at-grade crossing limit line and intersection crosswalk clear of vehicles. Therefore a R10-6 “Stop Her on Red” sign should be placed at the railroad limit line with “KEEP CLEAR” pavement marks in the track clearance and clear storage areas. An option would be to place diagonal striping between the tracks and the intersection as shown in **Figure 4.**
    - Long Term - A pre-signal, as shown in **Figure 5** for the at-grade crossing would be installed to the westbound approach and would be placed prior to the location of the crossing gates. This treatment would be advantageous in keeping vehicles off the trackway. Installation of a pre-signal would require the closure of Cedar Avenue intersection because it would then be inside the controlled crossing.

3. Parking on the north side of Wardlow Road from the midblock driveway towards the crossing should be removed to provide sufficient visibility for the left turning vehicles from the midblock driveway.

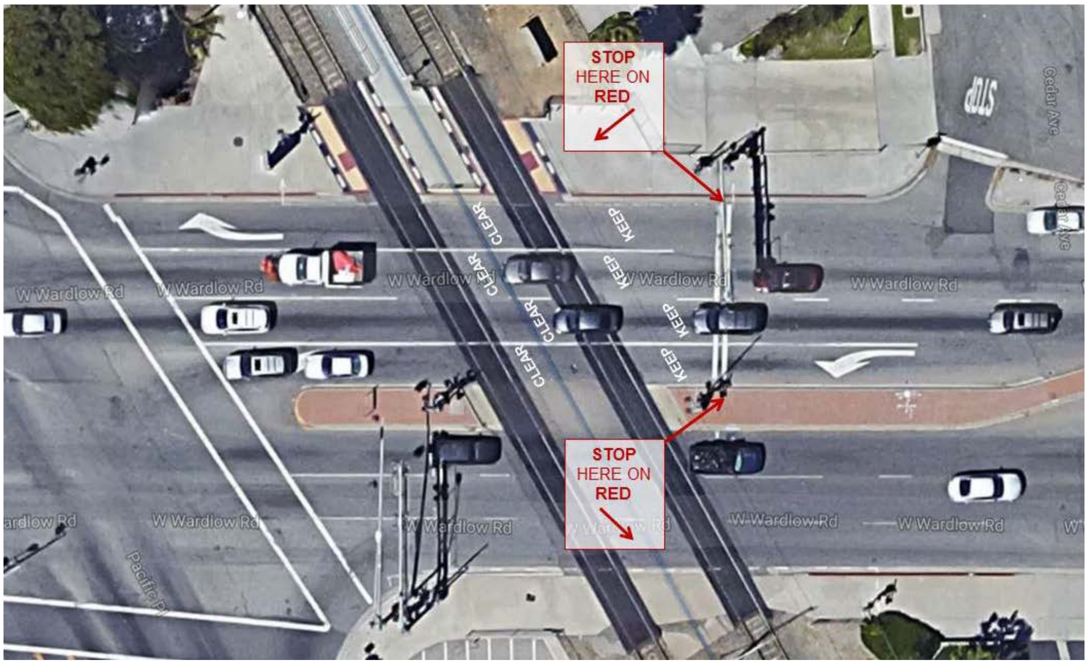


Figure 3. – “KEEP CLEAR” pavement markings.

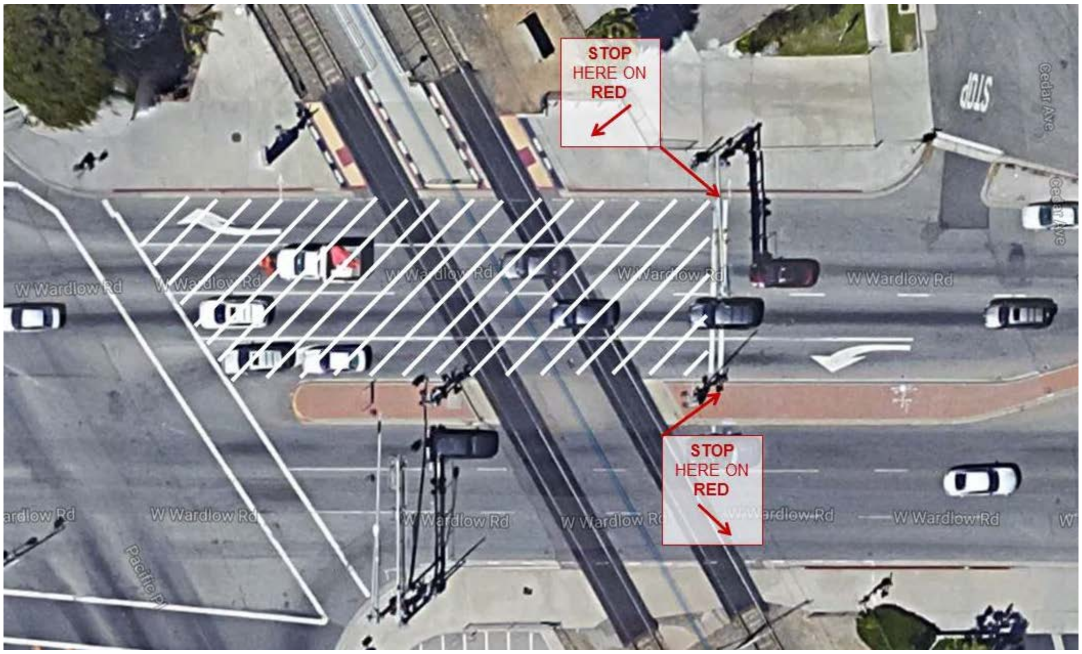


Figure 4. – Diagonal stripping in clear area.

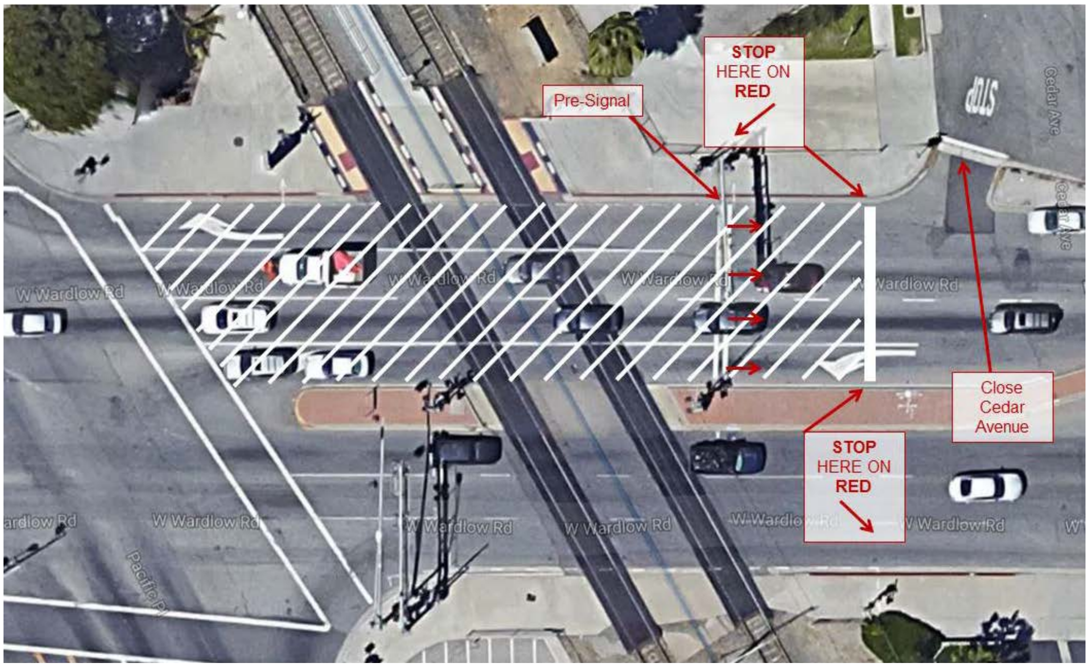


Figure 5. – Pre-signal.

10. FINDINGS AND CONCLUSIONS

Based on the traffic evaluation performed and described in this report, the Wardlow Road and Pacific Place intersection is anticipated to operate at LOS C during all three peak hours. Vehicles traveling in the westbound direction of Wardlow Road were observed to stop on the tracks when the signal indication is red and in order to mitigate this potential safety concern, the installation of pre-signals is a recommended countermeasure. Other safety measures that can be considered include in-pavement markings to define stay clear areas and further reinforced by special signage clearly identifying spots where vehicles need to stop ahead of the crossing gates.

In an effort to improve operations and queue management at the study intersection, the traffic evaluation assessed existing signal timing during all three peak hours. The evaluation also included the creation of a mock intersection to replicate operations of the at-grade crossing. An additional delay adjustment was manually added to the level of service delay results of the Wardlow Road and Pacific Place intersection to reflect the outcome of adjacent mock intersection. Based on this quantitative analysis, it was concluded that the existing signal timing during all three peak hours are optimized and no timing adjustments are recommended. However, from a qualitative perspective, an assessment was performed using other physical and operational factors to support the conditions that were observed during the site visits. This assessment resulted in the development of the safety enhancements that are presented in Section 9 in addition to those that were proposed and presented in the Task 1 – Safety Analysis Report. It should be noted that these safety enhancement, which are detailed in the Task 1 – Safety Analysis Report, are also considered as a qualitative evaluation of the at-grade crossing and are therefore applicable to this report too.

Existing public transit, school bus, pedestrian, and bicycle activity was observed to be light and operated normally with and without the crossing gate being activated.

Appendix A

Intersection Turning Movement Counts

Intersection Turning Movement

Prepared by:

National Data & Surveying Services

Project ID: 17-5338-021

Day: Thursday

City: Long Beach

Date: 5/18/2017

AM

NS/EW Streets:	Pacific Pl			Pacific Pl			Wardlow Rd			Wardlow Rd			
	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	0	0	0	0	0	0	0	0	0	0	0	
6:30 AM	29	85	24	18	50	6	17	89	21	15	93	35	482
6:45 AM	29	75	35	38	51	3	15	99	27	17	123	43	555
7:00 AM	19	68	35	41	50	10	22	137	21	12	117	50	582
7:15 AM	41	78	57	26	42	11	15	164	15	20	149	40	658
7:30 AM	41	103	64	12	37	12	14	161	19	20	185	56	724
7:45 AM	44	104	60	20	53	12	16	160	25	20	162	47	723
8:00 AM	27	90	65	30	49	12	16	183	21	28	166	52	739
8:15 AM	27	51	64	24	52	15	12	167	21	26	141	33	633

	UTURNS			
	NB	SB	EB	WB
6:30 AM	0	1	2	0
6:45 AM	0	0	3	0
7:00 AM	0	2	1	0
7:15 AM	0	0	3	0
7:30 AM	0	0	0	0
7:45 AM	0	1	1	0
8:00 AM	0	0	0	0
8:15 AM	0	0	0	0

	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
TOTAL VOLUMES :	257	654	404	209	384	81	127	1160	170	158	1136	356	5096
APPROACH %'s :	19.54%	49.73%	30.72%	31.01%	56.97%	12.02%	8.72%	79.62%	11.67%	9.58%	68.85%	21.58%	

NB	SB	EB	WB
0	4	10	0

PEAK HR START TIME :	715 AM												TOTAL
PEAK HR VOL :	153	375	246	88	181	47	61	668	80	88	662	195	2844
PEAK HR FACTOR :		0.930			0.868			0.919			0.905		0.962

CONTROL : 0

Intersection Turning Movement

Prepared by:

National Data & Surveying Services

Project ID: 17-5338-021

City: Long Beach

Day: Thursday

Date: 5/18/2017

PM

NS/EW Streets:	Pacific Pl			Pacific Pl			Wardlow Rd			Wardlow Rd			
	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	0	0	0	0	0	0	0	0	0	0	0	
4:30 PM	19	57	54	48	59	9	6	259	30	23	155	28	747
4:45 PM	25	69	60	38	51	10	8	283	34	30	140	20	768
5:00 PM	27	79	67	56	52	11	12	274	24	23	168	12	805
5:15 PM	41	62	66	55	71	13	5	273	16	32	133	28	795
5:30 PM	26	65	46	67	58	11	8	275	39	22	151	27	795
5:45 PM	22	57	55	48	54	10	10	281	18	26	145	19	745
6:00 PM	22	61	72	43	64	9	11	241	35	24	144	30	756
6:15 PM	18	45	41	46	47	12	14	216	33	24	152	30	678
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
TOTAL VOLUMES :	200	495	461	401	456	85	74	2102	229	204	1188	194	6089
APPROACH %'s :	17.30%	42.82%	39.88%	42.57%	48.41%	9.02%	3.08%	87.40%	9.52%	12.86%	74.91%	12.23%	
PEAK HR START TIME :	445 PM												TOTAL
PEAK HR VOL :	119	275	239	216	232	45	33	1105	113	107	592	87	3163
PEAK HR FACTOR :		0.915			0.887			0.962			0.968		0.982

UTURNS			
NB	SB	EB	WB
0	0	0	1
0	0	0	1
0	1	1	1
0	2	3	0
0	2	1	0
0	0	1	0
0	1	1	2
0	0	0	1
NB	SB	EB	WB
0	6	7	6

CONTROL : 0

Intersection Turning Movement

Prepared by:

National Data & Surveying Services

Project ID: 17-5338-021 **Day:** Thursday

City: Long Beach **Date:** 5/18/2017

NOON

NS/EW Streets:	Pacific Pl			Pacific Pl			Wardlow Rd			Wardlow Rd				UTURNS			
	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND							
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL	NB	SB	EB	WB
LANES:	0	0	0	0	0	0	0	0	0	0	0	0					
1:30 PM	29	46	36	30	43	17	12	158	27	29	88	13	528	0	1	2	1
1:45 PM	24	60	60	50	66	8	7	130	27	27	130	21	610	0	1	1	1
2:00 PM	22	70	52	36	41	12	21	180	28	20	163	14	659	0	1	0	0
2:15 PM	35	56	53	28	48	6	17	180	21	17	127	19	607	0	0	2	0
2:30 PM	21	68	63	36	46	5	14	176	24	22	143	14	632	0	0	2	1
2:45 PM	25	62	33	45	38	11	17	230	38	29	144	19	691	0	0	3	1
3:00 PM	23	60	66	43	54	6	13	188	35	19	132	20	659	0	0	0	0
3:15 PM	37	57	55	49	51	6	10	205	48	31	137	18	704	0	2	1	0

	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL	NB	SB	EB	WB
TOTAL VOLUMES :	216	479	418	317	387	71	111	1447	248	194	1064	138	5090	0	5	11	4
APPROACH %'s :	19.41%	43.04%	37.56%	40.90%	49.94%	9.16%	6.15%	80.12%	13.73%	13.90%	76.22%	9.89%					

PEAK HR START TIME :	230 PM												TOTAL
PEAK HR VOL :	106	247	217	173	189	28	54	799	145	101	556	71	2686
PEAK HR FACTOR :		0.938			0.920			0.875			0.948		0.954

CONTROL : 0

ITM Peak Hour Summary

Prepared by:

National Data & Surveying Services

Pacific Pl and Wardlow Rd , Long Beach

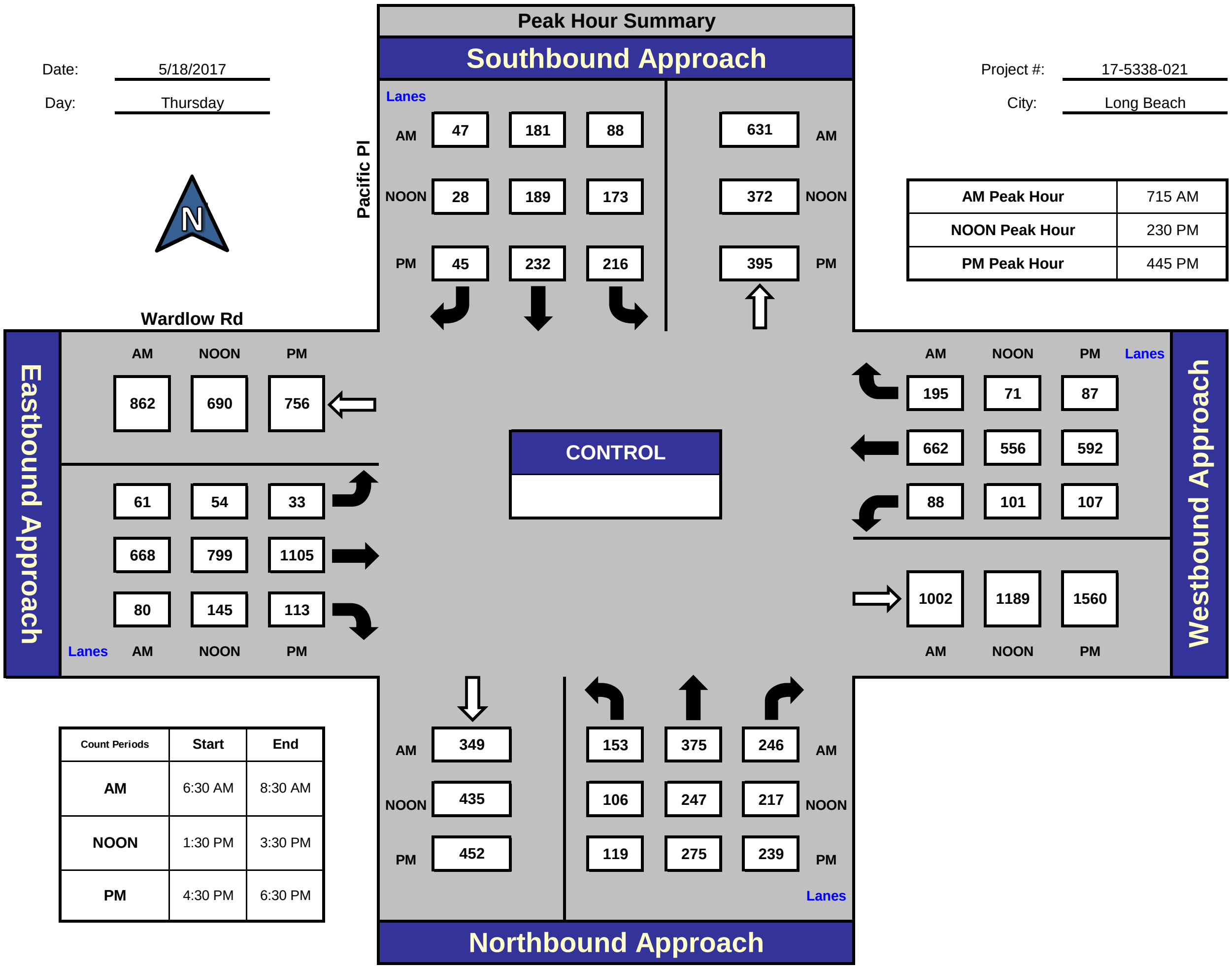
Date: 5/18/2017

Day: Thursday

Project #: 17-5338-021

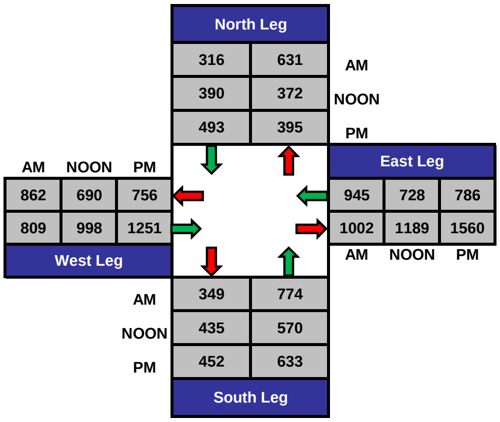
City: Long Beach

AM Peak Hour	715 AM
NOON Peak Hour	230 PM
PM Peak Hour	445 PM

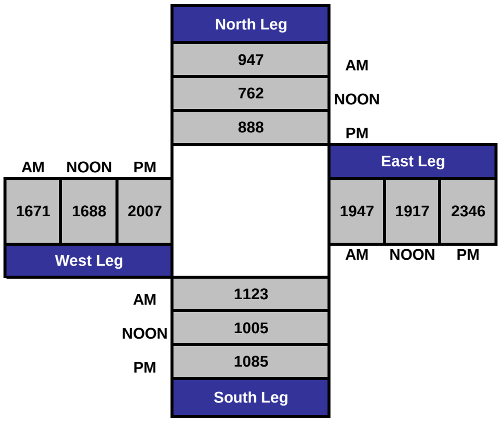


Count Periods	Start	End
AM	6:30 AM	8:30 AM
NOON	1:30 PM	3:30 PM
PM	4:30 PM	6:30 PM

Total Ins & Outs



Total Volume Per Leg



PREPARED BY NATIONAL DATA & SURVEYING SERVICES

PROJECT#: 17-5338-021
N/S Street: Pacific Pl
E/W Street: Wardlow Rd
DATE: 5/18/2017 DAY: Thursday
CITY: Long Beach

AM

PEDESTRIANS

TIME	NORTH LEG		SOUTH LEG		EAST LEG		WEST LEG	
	EB	WB	EB	WB	NB	SB	NB	SB
6:30 AM	3	2	0	0	4	0	0	0
6:45 AM	3	1	0	1	6	0	0	0
7:00 AM	3	3	2	0	7	0	1	0
7:15 AM	5	2	0	2	8	1	2	1
7:30 AM	2	4	1	0	4	0	0	5
7:45 AM	3	1	0	1	6	0	1	1
8:00 AM	2	1	3	0	4	0	0	0
8:15 AM	4	1	1	1	1	0	4	0
TOTALS	**25**	**15**	**7**	**5**	**40**	**1**	**8**	**7**

BIKES

TIME	NB			SB			EB			WB		
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR
6:30 AM	0	2	0	0	0	0	0	2	0	0	1	0
6:45 AM	0	0	0	0	0	0	0	0	0	0	2	0
7:00 AM	0	0	0	0	0	0	0	1	0	0	1	0
7:15 AM	0	0	0	0	0	0	0	1	1	0	0	0
7:30 AM	0	0	0	0	0	0	0	0	1	0	1	0
7:45 AM	0	0	0	1	0	0	0	1	0	0	0	0
8:00 AM	0	0	0	0	0	0	0	1	0	0	3	0
8:15 AM	0	0	0	0	0	0	0	2	0	0	1	0
TOTALS	**0**	**2**	**0**	**1**	**0**	**0**	**0**	**8**	**2**	**0**	**9**	**0**

NOON

PEDESTRIANS

TIME	NORTH LEG		SOUTH LEG		EAST LEG		WEST LEG	
	EB	WB	EB	WB	NB	SB	NB	SB
1:30 PM	1	8	1	2	1	3	0	4
1:45 PM	0	5	2	0	2	1	0	2
2:00 PM	3	2	1	0	1	2	0	0
2:15 PM	2	5	0	0	0	0	0	1
2:30 PM	3	5	1	1	1	1	2	2
2:45 PM	1	2	3	3	3	0	0	1
3:00 PM	5	4	2	0	2	0	1	1
3:15 PM	1	9	0	4	1	2	1	3
TOTALS	**16**	**40**	**10**	**10**	**11**	**9**	**4**	**14**

BIKES

TIME	NB			SB			EB			WB		
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR
1:30 PM	0	0	0	0	0	0	0	2	0	0	1	0
1:45 PM	0	0	0	0	0	0	0	0	0	0	2	0
2:00 PM	0	0	0	0	0	0	0	3	0	0	0	0
2:15 PM	0	0	0	0	0	0	0	2	0	0	1	0
2:30 PM	0	0	0	0	1	0	0	0	0	0	1	0
2:45 PM	0	0	0	0	0	0	0	0	0	1	0	0
3:00 PM	1	0	0	0	0	0	0	0	1	0	2	0
3:15 PM	1	0	0	0	0	0	0	1	0	0	3	0
TOTALS	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**8**	**1**	**1**	**10**	**0**

PM

PEDESTRIANS

TIME	NORTH LEG		SOUTH LEG		EAST LEG		WEST LEG	
	EB	WB	EB	WB	NB	SB	NB	SB
4:30 PM	1	6	5	2	1	6	0	2
4:45 PM	1	4	0	0	0	1	0	0
5:00 PM	2	4	3	1	5	2	1	4
5:15 PM	0	2	1	1	0	1	0	0
5:30 PM	2	5	1	0	0	4	1	0
5:45 PM	2	8	0	1	1	5	1	2
6:00 PM	5	2	0	2	0	7	1	2
6:15 PM	0	1	0	1	1	3	0	2
TOTALS	**13**	**32**	**10**	**8**	**8**	**29**	**4**	**12**

BIKES

TIME	NB			SB			EB			WB		
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR
4:30 PM	0	1	1	0	0	0	0	0	0	0	1	0
4:45 PM	0	0	0	0	0	0	0	0	0	0	1	0
5:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
5:15 PM	0	0	0	0	0	0	1	2	0	0	1	0
5:30 PM	1	0	0	0	0	0	0	1	0	0	4	0
5:45 PM	0	0	0	0	0	0	0	4	0	0	1	0
6:00 PM	0	0	0	0	0	0	0	1	0	0	1	0
6:15 PM	0	0	0	0	0	0	0	2	0	0	0	0
TOTALS	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**10**	**0**	**0**	**9**	**0**

Appendix B

Synchro LOS Output

HCM 2010 Signalized Intersection Summary
3: Pacific Place & Wardlow Road

Existing (2017) Conditions
AM Peak Hour

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↑	↱	↰	↑↑	↱	↰	↑↑	↱	↰↰	↑↑	↱
Volume (veh/h)	61	668	80	88	662	195	153	375	246	88	181	47
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.96	1.00		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863
Adj Flow Rate, veh/h	64	696	83	92	690	203	159	391	256	92	189	49
Adj No. of Lanes	1	2	1	1	2	1	1	2	1	2	2	1
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	82	1393	620	116	1501	662	193	913	392	178	751	326
Arrive On Green	0.05	0.39	0.39	0.07	0.42	0.42	0.11	0.26	0.26	0.05	0.21	0.21
Sat Flow, veh/h	1774	3539	1575	1774	3539	1561	1774	3539	1519	3442	3539	1536
Grp Volume(v), veh/h	64	696	83	92	690	203	159	391	256	92	189	49
Grp Sat Flow(s),veh/h/ln	1774	1770	1575	1774	1770	1561	1774	1770	1519	1721	1770	1536
Q Serve(g_s), s	3.1	12.8	1.9	4.4	12.0	5.3	7.6	8.0	13.0	2.3	3.8	2.2
Cycle Q Clear(g_c), s	3.1	12.8	1.9	4.4	12.0	5.3	7.6	8.0	13.0	2.3	3.8	2.2
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	82	1393	620	116	1501	662	193	913	392	178	751	326
V/C Ratio(X)	0.78	0.50	0.13	0.79	0.46	0.31	0.82	0.43	0.65	0.52	0.25	0.15
Avail Cap(c_a), veh/h	267	1393	620	267	1501	662	246	1311	563	518	1352	587
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	40.7	19.8	7.1	39.8	17.8	8.3	37.7	26.7	28.6	39.9	28.3	27.7
Incr Delay (d2), s/veh	5.8	1.3	0.4	4.5	1.0	1.2	12.9	0.2	1.4	0.9	0.1	0.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.6	6.4	1.3	2.3	6.1	2.9	4.4	3.9	5.6	1.1	1.9	1.0
LnGrp Delay(d),s/veh	46.5	21.1	7.5	44.3	18.8	9.5	50.6	27.0	30.0	40.8	28.5	27.9
LnGrp LOS	D	C	A	D	B	A	D	C	C	D	C	C
Approach Vol, veh/h		843			985			806			330	
Approach Delay, s/veh		21.7			19.3			32.6			31.8	
Approach LOS		C			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	10.6	39.0	13.4	23.3	8.0	41.6	9.5	27.3
Change Period (Y+Rc), s	5.0	* 5	4.0	5.0	4.0	5.0	5.0	* 5
Max Green Setting (Gmax), s	13.0	* 34	12.0	33.0	13.0	34.0	13.0	* 32
Max Q Clear Time (g_c+I1), s	6.4	14.8	9.6	5.8	5.1	14.0	4.3	15.0
Green Ext Time (p_c), s	0.3	5.5	0.0	1.1	0.0	6.1	0.8	2.4

Intersection Summary	
HCM 2010 Ctrl Delay	25.0
HCM 2010 LOS	C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑↑			↑↑			↑			↑	
Volume (veh/h)	0	1002	0	0	945	0	0	10	0	0	10	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	0	1863	0	0	1863	0	0	950	0	0	950	0
Adj Flow Rate, veh/h	0	1044	0	0	984	0	0	10	0	0	10	0
Adj No. of Lanes	0	2	0	0	2	0	0	1	0	0	1	0
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	0	2	0	0	2	0	0	100	0	0	100	0
Cap, veh/h	0	2712	0	0	2712	0	0	74	0	0	74	0
Arrive On Green	0.00	0.77	0.00	0.00	0.77	0.00	0.00	0.08	0.00	0.00	0.08	0.00
Sat Flow, veh/h	0	3725	0	0	3725	0	0	950	0	0	950	0
Grp Volume(v), veh/h	0	1044	0	0	984	0	0	10	0	0	10	0
Grp Sat Flow(s),veh/h/ln	0	1770	0	0	1770	0	0	950	0	0	950	0
Q Serve(g_s), s	0.0	5.0	0.0	0.0	4.6	0.0	0.0	0.5	0.0	0.0	0.5	0.0
Cycle Q Clear(g_c), s	0.0	5.0	0.0	0.0	4.6	0.0	0.0	0.5	0.0	0.0	0.5	0.0
Prop In Lane	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Lane Grp Cap(c), veh/h	0	2712	0	0	2712	0	0	74	0	0	74	0
V/C Ratio(X)	0.00	0.38	0.00	0.00	0.36	0.00	0.00	0.14	0.00	0.00	0.14	0.00
Avail Cap(c_a), veh/h	0	8686	0	0	8686	0	0	851	0	0	851	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
Uniform Delay (d), s/veh	0.0	2.0	0.0	0.0	1.9	0.0	0.0	22.1	0.0	0.0	22.1	0.0
Incr Delay (d2), s/veh	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.8	0.0	0.0	0.8	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	2.4	0.0	0.0	2.2	0.0	0.0	0.1	0.0	0.0	0.1	0.0
LnGrp Delay(d),s/veh	0.0	2.1	0.0	0.0	2.0	0.0	0.0	22.9	0.0	0.0	22.9	0.0
LnGrp LOS		A			A			C			C	
Approach Vol, veh/h		1044			984			10			10	
Approach Delay, s/veh		2.1			2.0			22.9			22.9	
Approach LOS		A			A			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		8.0		43.3		8.0		43.3
Change Period (Y+Rc), s		4.0		4.0		4.0		4.0
Max Green Setting (Gmax), s		46.0		126.0		46.0		126.0
Max Q Clear Time (g_c+I1), s		2.5		7.0		2.5		6.6
Green Ext Time (p_c), s		0.1		32.3		0.1		32.3

Intersection Summary	
HCM 2010 Ctrl Delay	2.3
HCM 2010 LOS	A

3: Pacific Place & Wardlow Road

MD Peak Hour

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↑	↱	↰	↑↑	↱	↰	↑↑	↱	↰↰	↑↑	↱
Volume (veh/h)	54	799	145	101	556	71	106	247	217	173	189	28
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.98	1.00		0.97	1.00		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863
Adj Flow Rate, veh/h	56	832	151	105	579	74	110	257	226	180	197	29
Adj No. of Lanes	1	2	1	1	2	1	1	2	1	2	2	1
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	72	1394	617	134	1560	684	139	770	335	281	822	356
Arrive On Green	0.04	0.39	0.39	0.08	0.44	0.44	0.08	0.22	0.22	0.08	0.23	0.23
Sat Flow, veh/h	1774	3539	1566	1774	3539	1551	1774	3539	1541	3442	3539	1533
Grp Volume(v), veh/h	56	832	151	105	579	74	110	257	226	180	197	29
Grp Sat Flow(s),veh/h/ln	1774	1770	1566	1774	1770	1551	1774	1770	1541	1721	1770	1533
Q Serve(g_s), s	2.7	16.1	3.9	5.0	9.4	1.6	5.3	5.3	11.6	4.4	3.9	1.3
Cycle Q Clear(g_c), s	2.7	16.1	3.9	5.0	9.4	1.6	5.3	5.3	11.6	4.4	3.9	1.3
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	72	1394	617	134	1560	684	139	770	335	281	822	356
V/C Ratio(X)	0.78	0.60	0.24	0.78	0.37	0.11	0.79	0.33	0.67	0.64	0.24	0.08
Avail Cap(c_a), veh/h	226	1394	617	226	1560	684	185	1312	571	598	1557	675
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	41.1	20.7	8.6	39.2	16.1	5.9	39.1	28.5	31.0	38.4	26.9	25.9
Incr Delay (d2), s/veh	6.8	1.9	0.9	3.7	0.7	0.3	11.2	0.1	0.9	0.9	0.1	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.5	8.2	2.3	2.6	4.7	1.0	3.0	2.6	5.0	2.1	1.9	0.5
LnGrp Delay(d),s/veh	47.8	22.6	9.5	42.9	16.8	6.3	50.3	28.6	31.9	39.3	27.0	26.0
LnGrp LOS	D	C	A	D	B	A	D	C	C	D	C	C
Approach Vol, veh/h		1039			758			593			406	
Approach Delay, s/veh		22.1			19.4			33.9			32.4	
Approach LOS		C			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	11.5	39.0	10.8	25.1	7.5	43.1	12.0	23.8
Change Period (Y+Rc), s	5.0	* 5	4.0	5.0	4.0	5.0	5.0	* 5
Max Green Setting (Gmax), s	11.0	* 34	9.0	38.0	11.0	34.0	15.0	* 32
Max Q Clear Time (g_c+I1), s	7.0	18.1	7.3	5.9	4.7	11.4	6.4	13.6
Green Ext Time (p_c), s	0.2	7.2	0.0	1.1	0.0	3.9	0.8	1.3

Intersection Summary	
HCM 2010 Ctrl Delay	25.4
HCM 2010 LOS	C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑↑			↑↑			↑			↑	
Volume (veh/h)	0	1189	0	0	728	0	0	5	0	0	5	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	0	1863	0	0	1863	0	0	950	0	0	950	0
Adj Flow Rate, veh/h	0	1239	0	0	758	0	0	5	0	0	5	0
Adj No. of Lanes	0	2	0	0	2	0	0	1	0	0	1	0
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	0	2	0	0	2	0	0	100	0	0	100	0
Cap, veh/h	0	2743	0	0	2743	0	0	71	0	0	71	0
Arrive On Green	0.00	0.78	0.00	0.00	0.78	0.00	0.00	0.07	0.00	0.00	0.07	0.00
Sat Flow, veh/h	0	3725	0	0	3725	0	0	950	0	0	950	0
Grp Volume(v), veh/h	0	1239	0	0	758	0	0	5	0	0	5	0
Grp Sat Flow(s),veh/h/ln	0	1770	0	0	1770	0	0	950	0	0	950	0
Q Serve(g_s), s	0.0	6.5	0.0	0.0	3.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0
Cycle Q Clear(g_c), s	0.0	6.5	0.0	0.0	3.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0
Prop In Lane	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Lane Grp Cap(c), veh/h	0	2743	0	0	2743	0	0	71	0	0	71	0
V/C Ratio(X)	0.00	0.45	0.00	0.00	0.28	0.00	0.00	0.07	0.00	0.00	0.07	0.00
Avail Cap(c_a), veh/h	0	20306	0	0	20306	0	0	819	0	0	819	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
Uniform Delay (d), s/veh	0.0	2.1	0.0	0.0	1.7	0.0	0.0	22.9	0.0	0.0	22.9	0.0
Incr Delay (d2), s/veh	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.0	0.4	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	3.0	0.0	0.0	1.5	0.0	0.0	0.1	0.0	0.0	0.1	0.0
LnGrp Delay(d),s/veh	0.0	2.2	0.0	0.0	1.8	0.0	0.0	23.3	0.0	0.0	23.3	0.0
LnGrp LOS		A			A			C			C	
Approach Vol, veh/h		1239			758			5			5	
Approach Delay, s/veh		2.2			1.8			23.3			23.3	
Approach LOS		A			A			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		8.0		45.3		8.0		45.3
Change Period (Y+Rc), s		4.0		4.0		4.0		4.0
Max Green Setting (Gmax), s		46.0		306.0		46.0		306.0
Max Q Clear Time (g_c+I1), s		2.3		8.5		2.3		5.3
Green Ext Time (p_c), s		0.0		32.9		0.0		32.9

Intersection Summary	
HCM 2010 Ctrl Delay	2.1
HCM 2010 LOS	A

3: Pacific Place & Wardlow Road

PM Peak Hour

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↑	↱	↰	↑↑	↱	↰	↑↑	↱	↰↰	↑↑	↱
Volume (veh/h)	33	1105	113	107	592	87	119	275	239	216	232	45
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.97	1.00		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863
Adj Flow Rate, veh/h	34	1128	115	109	604	89	121	281	244	220	237	46
Adj No. of Lanes	1	2	1	1	2	1	1	2	1	2	2	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	42	1428	636	139	1658	732	150	774	335	300	821	358
Arrive On Green	0.02	0.40	0.40	0.08	0.47	0.47	0.08	0.22	0.22	0.09	0.23	0.23
Sat Flow, veh/h	1774	3539	1575	1774	3539	1563	1774	3539	1532	3442	3539	1543
Grp Volume(v), veh/h	34	1128	115	109	604	89	121	281	244	220	237	46
Grp Sat Flow(s),veh/h/ln	1774	1770	1575	1774	1770	1563	1774	1770	1532	1721	1770	1543
Q Serve(g_s), s	1.8	26.3	3.1	5.7	10.3	1.9	6.3	6.3	13.9	5.9	5.2	2.2
Cycle Q Clear(g_c), s	1.8	26.3	3.1	5.7	10.3	1.9	6.3	6.3	13.9	5.9	5.2	2.2
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	42	1428	636	139	1658	732	150	774	335	300	821	358
V/C Ratio(X)	0.81	0.79	0.18	0.79	0.36	0.12	0.81	0.36	0.73	0.73	0.29	0.13
Avail Cap(c_a), veh/h	226	1428	636	226	1658	732	188	1203	521	365	1203	524
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	45.8	24.6	8.8	42.6	16.0	5.7	42.3	31.2	34.2	41.9	29.8	28.6
Incr Delay (d2), s/veh	12.4	4.5	0.6	3.7	0.6	0.3	14.5	0.1	1.1	4.3	0.1	0.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.0	13.7	1.9	2.9	5.2	1.3	3.7	3.1	6.0	3.0	2.5	1.0
LnGrp Delay(d),s/veh	58.1	29.1	9.4	46.3	16.7	6.1	56.9	31.3	35.3	46.2	29.9	28.7
LnGrp LOS	E	C	A	D	B	A	E	C	D	D	C	C
Approach Vol, veh/h		1277			802			646			503	
Approach Delay, s/veh		28.1			19.5			37.6			36.9	
Approach LOS		C			B			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	12.4	43.0	12.0	26.8	6.2	49.1	13.2	25.6
Change Period (Y+Rc), s	5.0	* 5	4.0	5.0	4.0	5.0	5.0	* 5
Max Green Setting (Gmax), s	12.0	* 38	10.0	32.0	12.0	38.0	10.0	* 32
Max Q Clear Time (g_c+I1), s	7.7	28.3	8.3	7.2	3.8	12.3	7.9	15.9
Green Ext Time (p_c), s	0.2	6.5	0.0	1.3	0.0	4.2	0.4	1.4

Intersection Summary	
HCM 2010 Ctrl Delay	29.2
HCM 2010 LOS	C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑↑			↑↑			↑			↑	
Volume (veh/h)	0	1560	0	0	786	0	0	10	0	0	10	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	0	1863	0	0	1863	0	0	950	0	0	950	0
Adj Flow Rate, veh/h	0	1592	0	0	802	0	0	10	0	0	10	0
Adj No. of Lanes	0	2	0	0	2	0	0	1	0	0	1	0
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	0	2	0	0	2	0	0	100	0	0	100	0
Cap, veh/h	0	2958	0	0	2958	0	0	52	0	0	52	0
Arrive On Green	0.00	0.84	0.00	0.00	0.84	0.00	0.00	0.05	0.00	0.00	0.05	0.00
Sat Flow, veh/h	0	3725	0	0	3725	0	0	950	0	0	950	0
Grp Volume(v), veh/h	0	1592	0	0	802	0	0	10	0	0	10	0
Grp Sat Flow(s),veh/h/ln	0	1770	0	0	1770	0	0	950	0	0	950	0
Q Serve(g_s), s	0.0	9.8	0.0	0.0	3.5	0.0	0.0	0.7	0.0	0.0	0.7	0.0
Cycle Q Clear(g_c), s	0.0	9.8	0.0	0.0	3.5	0.0	0.0	0.7	0.0	0.0	0.7	0.0
Prop In Lane	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Lane Grp Cap(c), veh/h	0	2958	0	0	2958	0	0	52	0	0	52	0
V/C Ratio(X)	0.00	0.54	0.00	0.00	0.27	0.00	0.00	0.19	0.00	0.00	0.19	0.00
Avail Cap(c_a), veh/h	0	6107	0	0	6107	0	0	598	0	0	598	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
Uniform Delay (d), s/veh	0.0	1.8	0.0	0.0	1.3	0.0	0.0	33.0	0.0	0.0	33.0	0.0
Incr Delay (d2), s/veh	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	1.8	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	4.5	0.0	0.0	1.7	0.0	0.0	0.2	0.0	0.0	0.2	0.0
LnGrp Delay(d),s/veh	0.0	1.9	0.0	0.0	1.3	0.0	0.0	34.7	0.0	0.0	34.7	0.0
LnGrp LOS		A			A			C			C	
Approach Vol, veh/h		1592			802			10			10	
Approach Delay, s/veh		1.9			1.3			34.7			34.7	
Approach LOS		A			A			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		8.0		65.0		8.0		65.0
Change Period (Y+Rc), s		4.0		4.0		4.0		4.0
Max Green Setting (Gmax), s		46.0		126.0		46.0		126.0
Max Q Clear Time (g_c+I1), s		2.7		11.8		2.7		5.5
Green Ext Time (p_c), s		0.1		49.2		0.1		50.1

Intersection Summary	
HCM 2010 Ctrl Delay	2.0
HCM 2010 LOS	A

Appendix C

Synchro Queues Output

3: Pacific Place & Wardlow Road

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Group Flow (vph)	64	696	83	92	690	203	159	391	256	92	189	49
v/c Ratio	0.40	0.46	0.11	0.49	0.44	0.27	0.66	0.53	0.49	0.32	0.41	0.15
Control Delay	44.6	19.6	0.3	45.3	18.5	6.8	50.2	33.2	7.8	40.6	36.1	1.0
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	44.6	19.6	0.3	45.3	18.5	6.8	50.2	33.2	7.8	40.6	36.1	1.0
Queue Length 50th (ft)	32	133	0	45	127	16	78	98	0	23	48	0
Queue Length 95th (ft)	76	228	0	99	217	67	#182	154	62	51	83	0
Internal Link Dist (ft)		740			1155			511			433	
Turn Bay Length (ft)	155		100	160		52	100		90	120		90
Base Capacity (vph)	290	1520	758	290	1568	763	268	1431	768	564	1475	730
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.22	0.46	0.11	0.32	0.44	0.27	0.59	0.27	0.33	0.16	0.13	0.07

Intersection Summary

\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Group Flow (vph)	56	832	151	105	579	74	110	257	226	180	197	29
v/c Ratio	0.38	0.53	0.20	0.55	0.33	0.09	0.58	0.54	0.56	0.48	0.41	0.09
Control Delay	43.8	19.1	3.6	46.5	14.8	0.2	48.9	37.2	10.9	38.7	34.4	0.5
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	43.8	19.1	3.6	46.5	14.8	0.2	48.9	37.2	10.9	38.7	34.4	0.5
Queue Length 50th (ft)	27	156	0	50	94	0	53	64	0	44	48	0
Queue Length 95th (ft)	66	257	33	107	165	0	#128	107	61	80	82	0
Internal Link Dist (ft)		740			1155			511			433	
Turn Bay Length (ft)	155		100	160		52	100		90	120		90
Base Capacity (vph)	254	1571	773	254	1732	819	207	1479	777	672	1756	839
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.22	0.53	0.20	0.41	0.33	0.09	0.53	0.17	0.29	0.27	0.11	0.03

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Group Flow (vph)	34	1128	115	109	604	89	121	281	244	220	237	46
v/c Ratio	0.28	0.69	0.14	0.58	0.33	0.10	0.63	0.59	0.59	0.59	0.50	0.14
Control Delay	45.7	22.6	1.6	50.5	14.0	0.7	53.3	40.2	11.9	44.3	38.4	0.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	45.7	22.6	1.6	50.5	14.0	0.7	53.3	40.2	11.9	44.3	38.4	0.8
Queue Length 50th (ft)	18	256	0	58	103	0	64	77	3	59	64	0
Queue Length 95th (ft)	49	384	15	115	164	6	#144	121	70	103	103	0
Internal Link Dist (ft)		740			1155			511			433	
Turn Bay Length (ft)	155		100	160		52	100		90	120		90
Base Capacity (vph)	257	1628	800	257	1823	862	214	1371	742	415	1371	691
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.13	0.69	0.14	0.42	0.33	0.10	0.57	0.20	0.33	0.53	0.17	0.07

Intersection Summary

\#   95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

TASK 3 - Grade Separation Priority Report

Final Report

Los Angeles County Metropolitan Transit Authority

July 24, 2018

Quality information

Prepared by	Checked by	Approved by
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Revision History

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1	6/30/2017	Comments on Approach	✓	Vijay Khawani	Metro PM
2	8/10/2017	Comments on Draft	✓	Vijay Khawani	Metro PM
3	8/23/2017	Comments on Revised Draft	✓	Vijay Khawani	Metro PM
4	8/29/2017	Comments on Final	✓	Vijay Khawani	Metro PM
5	9/6/2017	Additional comments on Final	✓	Vijay Khawani	Metro PM
6	9/8/2017	Additional comments on Final	✓	Vijay Khawani	Metro PM
7	9/16/2017	Additional comments on Final	✓	Vijay Khawani	Metro PM
8	12/11/2017	Typo revised on page 14	✓	Vijay Khawani	Metro PM
9	07/24/2018	Ranking updated due to 4QG at Greenleaf Blvd.	✓	Vijay Khawani	Metro PM

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Appendices

1. Introduction

This report presents the results of a Grade Separation Priority study which has been prepared as part of the Los Angeles *Metro Blue Line Safety Improvement Study for Wardlow Crossing*. This report satisfies the Task 3 requirement which is to develop a recommended grade separation priority for Wardlow Road in relation to the 26 other road crossings along the Metro Blue Line cab-signaled mid-corridor between 20th Street in Los Angeles (just south of the Washington station and Spring Street in Long Beach (just north of the Willow Street station). Prior deliverables have included a *Grade Crossing Safety Study* for the grade crossing along West Wardlow Boulevard in the City of Long Beach (adjacent to the Wardlow Metro Blue Line station) and a *Traffic Study* of the operations along Wardlow Road near the grade crossing.

MBL has 103 at-grade crossings with varying levels of safety treatments (refer to **Figure 1**). The Metro Board has made significant investments to improve the safety of the MBL because of the number of collisions with vehicles and pedestrians associated with light rail systems. This has included “photo enforcement” of traffic signal violations, installation of “four-quadrant” road crossing gates, installation of “swing gates” to increase pedestrian awareness at crossings, and the current ongoing installation of pedestrian automatic gates and swing gates along the mid-corridor segment. Many of these improvements have been implemented recently and are expected to make an immediate impact on the safety of the users, especially the installation of pedestrian gates. However, several years of “after” data will be required to verify a reduction in the collision rate since collisions are a relatively rare occurrence.

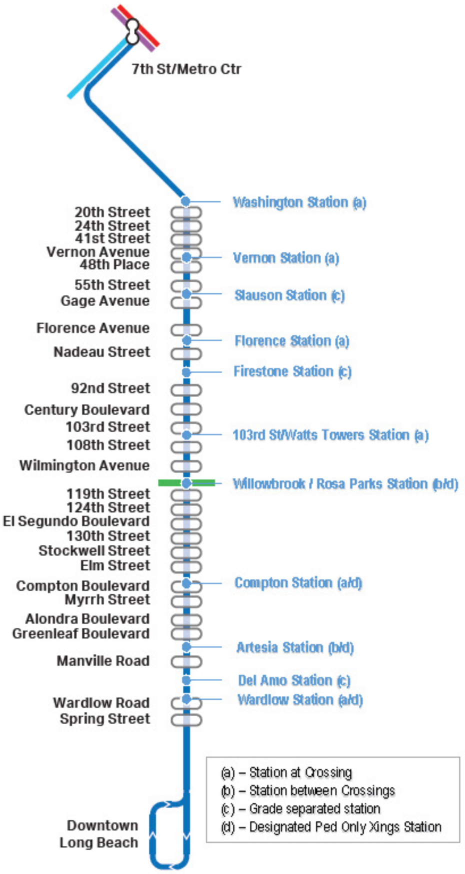


Figure 2 indicates the crossings and stations within the study segment. There are 27 cross streets with crossing gates. There are eleven stations within the study area however three of these are already grade-separated (Slauson, Firestone and Del Amo). There are pedestrian-only crossings at Compton Station, Willowbrook Station, Wardlow Station, and Artesia Station, with adjacent roadway grade crossings at Washington Station, Florence Station, 103rd Street Station, Vernon Station, Compton Station, and Wardlow Station along with 21 grade crossings with no adjacent station.

Figure 1. – Project vicinity map.

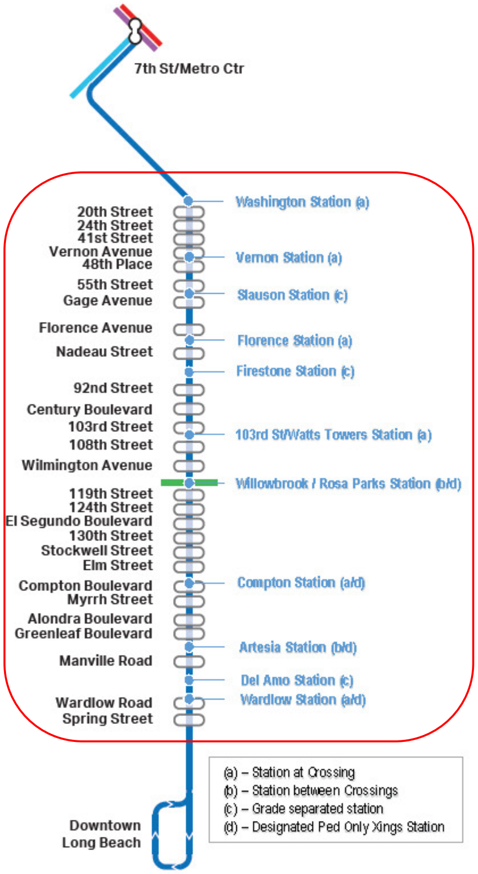


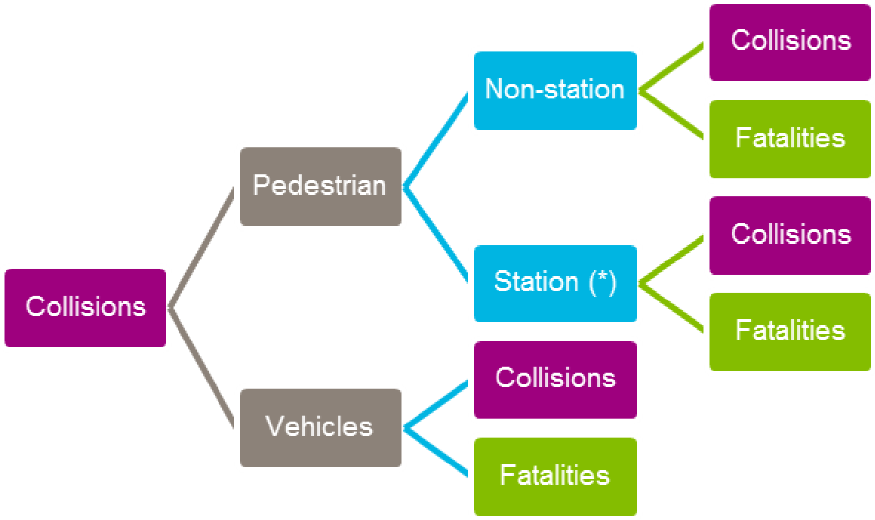
Figure 2. – Study Area map.

This memorandum describes the methodology used to prioritize light rail grade separation for the MBL. The factors used in the prioritization consider safety, traffic, and operational aspects along with consideration for the level of benefit which could potentially be derived by constructing a grade separation. The formula which has been derived reflects all these factors. The resulting recommended priority list reflects the relative score developed for each potential grade separation location. It is important to note that currently there is no formula that can be used by rail transit agencies to prioritize grade separations for existing at-grade crossings on a light rail transit system. The formula developed in this study however is based on a combination of elements from Metro's grade crossing safety policy, the California Public Utilities Commission's Section 190 formula, MBL-specific accident data and characteristics of the 27 gated crossings, engineering judgment, and experience.

2. Priority Assessment Methodology

2.1 Collision Categorization

The foundation of the priority formula is data obtained from 10-years of collision history for the MBL grade crossings. The collisions were classified as shown in **Figure 3.**



(*) A station location is a crossing where there is a nearside or farside station located in immediate proximity of the vehicle-pedestrian at grade crossing.

Figure 3. - Collision Categorization

The purpose of disaggregating the collisions is to allow for computation of potential weighting factors for all collisions vs. those resulting in fatalities as well as to associate each type of collision with likely relevant factors such as the exposure (e.g., number of vehicles or pedestrian count). The categorizations were also used to identify trends in locations of collisions vs. fatalities to correlate them with specific traffic operations conditions, such as time of day or unusual roadway geometries. Suicides (e.g., "intentional deaths") were not considered for grade separation analysis. Also excluded were minor incidents at station platforms such as accidents where a train mirror may have grazed a patron standing too close the platform edge. The collision data has been analyzed to determine patterns in data including potential correlations with traffic volumes and pedestrian counts. In keeping with the data stratification shown in **Figure 3**, collisions recorded at the pedestrian-only crossings at the 4 stations mentioned above were not included as part of this analysis because they were not one of the 27 at-grade gated crossings under review. Furthermore, from an engineering standpoint, a decision to grade separate the gated crossing upstream or downstream from one of these stations would also likely result in a grade separation of the pedestrian-only crossing at that station.

2.2 Prioritization Factors

The grade separation prioritization factors were determined based on the traffic and safety analyses specific to the MBL and factors which might result in higher collision rates at the crossings. The list of factors was refined by assessing the correlation between the factors and the occurrence of collisions. (E.g., the collision data showed higher average collisions per crossing “with” the specified characteristic compared to the average collision rate at crossings “without” the same characteristic.) If a factor was highly correlated with collisions, it was included in the analysis; if there was no correlation, it was excluded.

The final factors used in the prioritization analysis are:

- **Collisions** – The primary collision data which was considered was pedestrian fatalities (excluding suicides) with injury-only collisions as a secondary consideration. It should be noted that there were no vehicular collisions resulting in fatalities and there were far fewer vehicular collisions compared to pedestrian collisions (15 vs. 47).

Given the significantly lower frequency and severity of vehicular collisions, and the fact that there were no strong quantifiable correlations between crossing characteristics and vehicular collisions, the recommended prioritization formula considers cross street traffic as a measure of benefit for grade separation but does not explicitly consider vehicular collisions.

- **Accident History (AH)** – the number of recorded fatalities in the ten-year history was found to correlate with locations with higher collision rates in general and there were some locations where the proportion of fatalities was higher compared to the typical mid-corridor crossing. Therefore a AH factor, defined as the number of fatalities plus 0.2 times the number of no-fatal collisions over the ten year period, was added to the raw crossing safety score. See section **2.3.1** for more details about this factor.
- **Traffic Volumes** – Crossings with higher traffic volume are subject to higher vehicular delays. In addition, should a grade separation be provided, separations at locations with higher volumes would benefit more road users compared to locations with lower traffic levels. To maintain consistency with the approach used in the *LA Metro Grade Crossing Safety Policy* the analysis considered the highest directional per-lane peak hour volume at each location. (Peak hour volumes were found to be closely correlated with the total Average Daily Traffic (ADT) which was also collected.)
- **Warning Devices** – Crossings where four-quadrant crossing gates have been installed did not have any vehicular collisions in the ten-year accident history (there are five such locations.) Should these locations be grade-separated, road users would be benefitted with a reduction in traffic delay and congestion but may not receive significant safety benefits. Accordingly, a “warning devices” factor was included in the priority formula to take into account the reduced total benefit of providing a grade separation at these locations.
- **Pedestrian Counts** – The analysis considered the total daily pedestrian traffic through the crossing area. This number was developed from counts taken at the adjacent intersection(s) with adjustments to discount movements not made through the adjacent grade crossing. Raw data collection included both peak and off-peak pedestrian traffic, however, analysis of the data indicated poor correlation between collisions and peak period pedestrian movements so the total pedestrian utilization was considered. (Similar to the approach taken with respect to traffic utilization, pedestrian utilization also reflects a measure of benefit to pedestrians should a crossing be grade separated.)
- **Stations** – The presence of a station adjacent to an at-grade gated crossing was found to correlate with higher collision rates compared to “non-station” crossings. Cross streets with station access pedestrian traffic require more pedestrian attention to avoid risky behavior at the grade crossing and patrons concerned with transfers and/or station access/egress can become distracted while attempting to cross. In addition, there is the possibility of “another train coming” collision in which a parked train blocks view of the far track or patrons boarding or de-boarding a train may not consider a train arriving from the opposite direction.
- **Presence of Freight Tracks** – Grade crossings that include adjacent freight tracks (along the UPRR Wilmington Subdivision) were found to have higher average collision rates compared to crossings with only LRT tracks. The presence of freight tracks requires pedestrians to negotiate multiple track crossings to traverse the crossing or use the station and are another source of “another train coming” type of collisions.
- **Intersection Geometry** – Skewed crossings have longer clearance distance requiring more crossing time. Highly skewed crossings also present sight distance concerns because a train may be coming from behind relative to the pedestrian direction. Both minor and major skew angles (defined as less than or more than 45 degrees, respectively) were considered. The team did not identify a relationship between minor skew and the collision history. The Wilmington crossing is highly skewed (acute angle of about 22 degrees) and four pedestrian collisions were recorded (more than average). However, since this was the only severely skewed crossing, and since collisions were already included in the formula, there was a concern with validating a skew factor in the priority formula based upon a sample of one crossing. Therefore, the formula does not include a factor for the geometry/skew angle.
- **Bus Stops** – Bus stops adjacent to the LRT could be associated with higher collision rates in the event patrons attempting to make a transfer are distracted while crossing the track or exhibit risky behavior such as attempting to beat a train to the crossing.

- **Proximity to Schools** – Locations within in 0.25 miles of schools were given higher priority due to higher pedestrian volumes of school-age children utilizing the crossing.
- **Nearby/Adjacent Intersection** – Adjacent signalized intersections could potentially result in vehicles queuing on the tracks or diving under lowering crossing gates to traverse the intersection. The presence of adjacent intersections may correlate with higher incidences of pedestrian collisions as well because of diverting attention away from the act of crossing the tracks.
- **Sight Distance Restriction** – Crossings with restricted sight distance at one or both tracks may not allow a train operator to see an approaching vehicle or pedestrian until it is too late to bring the train to a stop.

The specific process used to incorporate these factors into the recommended priority formula is described in the following sections.

2.3 Prioritization Formula

2.3.1 Factor Correlation

The preliminary investigation into the prioritization factors using the available data shows that some factors are highly correlated, some have a more moderate effect, and others only marginally correlated, but still potentially worth considering in ranking grade separation priorities.

It should be noted that the results of this analysis are specific to the data for these 27 grade crossings on the MBL as they are operationally similar in that the crossings are gated and trains travel at up to 55 mph in this segment.

The safety component of the prioritization formula was developed by reviewing data at each of the potential grade crossing locations to determine correlations between candidate prioritization factors and the collision data. The weighting was established using an approach that takes into account the magnitude of correlation as further described below.

After the collision data was tabulated and the crossing characteristics were identified for each crossing, an aggregate “crossing safety score” was established in which the weight assigned to each characteristic was based upon the average collision rate “with” versus “without” the characteristic. The crossing safety score was then weighted together with other factors reflecting the benefits based upon crossing utilization (by both pedestrians and vehicles) and potential congestion relief (for roadway users) to develop an overall score which was used to create the recommended priority list as described in the next section.

One of the factors that is highly correlated with pedestrian collisions is the pedestrian volume. For this analysis, a composite “Accident History factor (AH)” was established by weighting injury-only collisions with those resulting in fatalities. The AH was computed as Number of Fatalities + 0.2 X Number of No-Fatal Collisions. This weighting is based upon actuarial values established by the Federal Railroad Administration (FRA) with an approximate 50% discount applied to injuries. (The FRA data reflects freight and commuter rail crossing casualties in which the train typically cannot slow significantly to avoid or reduce the impact of a collision whereas a light rail train often can[1].)

See Master Spreadsheet **Appendix A** for calculation of the Accident History Factor (AH) for each location.

Figure 4 shows the correlation between pedestrian volume and pedestrian Accident History (fatalities vs no-fatal collisions). The pedestrian AH factor trendline follows the pedestrian volume graph very closely

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[1] Per 49 CFR 222, Appendix C, the FRA has determined the value of a life to be $3,000,000 vs. $1,167,000 for an injury collision involving a conventional train involved in a grade crossing collision. Therefore, with a score of 1 corresponding to a 3M$ fatality the proportionate raw score of an injury would be approximately 0.4. This was discounted by 50% (adjusted score of 0.2) to account for the ability of a light rail train to slow down or stop to avoid a collision.

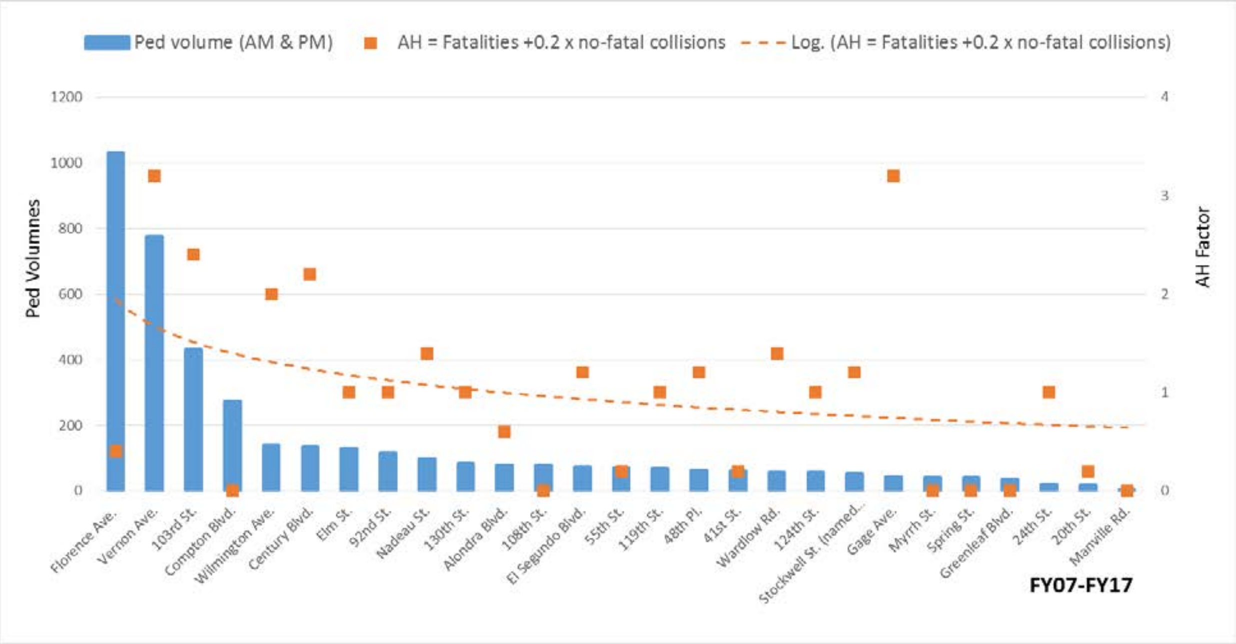

Figure 4. – Pedestrian volume vs Pedestrian Collisions.

Another factor which was identified was restricted sight distance. Crossings with restricted sight distance at one or both tracks may not allow a train operator to see an approaching vehicle or pedestrian until it is too late to bring the train to a stop. The most challenging quadrants are the northwest (eastbound crossing user vs. southbound train) and southeast (westbound crossing user vs. northbound train). Very few crossings were found to have full sight distance restrictions but several locations had partially obstructed sight distance and these crossings as a group had a higher average collision rate. **Figure 5** shows the correlation between the AH factor and locations where there is a sight distance restriction. As shown in the graph, there is a high correlation between the AH factor and locations with restricted sight distance.

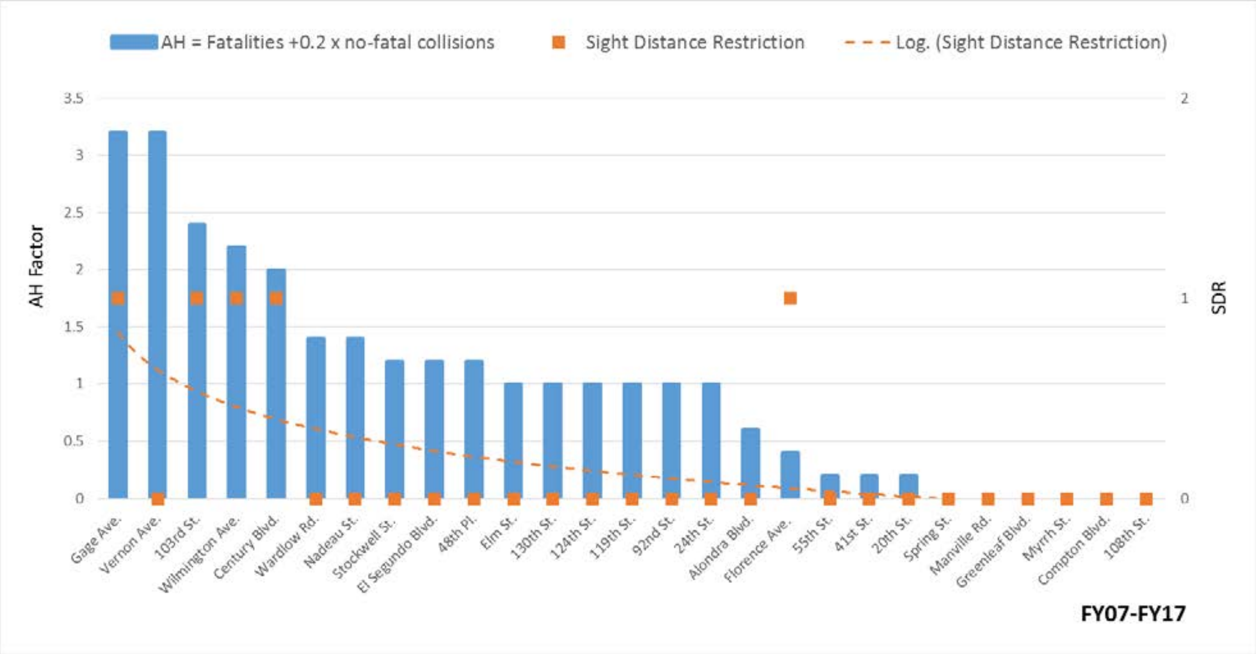

Figure 5. – Sight Distance Restriction vs pedestrian collisions.

2.3.2 Prioritization Formula

The final prioritization formula considers both safety and pedestrian and vehicle exposure. The safety portion of the formula is based on the correlation of the factors previously discussed. The safety factors use the pedestrian collisions to determine the coefficients.

There were no significant safety factors that were found to predict the likelihood of a vehicular collisions because of the relatively small number of vehicular collisions over the last ten years and no recorded fatalities due to vehicular collisions. However, vehicular volume was included in the recommended priority formula for two reasons: (1) locations with higher roadway volumes are subject to more vehicle-hours of delay, and (2) locations with higher volumes would benefit more highway users should a grade separation be provided.

Similarly, as the pedestrian volumes were roughly correlated with the AH factor, and because locations with higher total pedestrian volumes would derive greater total benefit should a grade separation be provided, a term for total pedestrian volume was also included in the aggregate prioritization formula.

The prioritization formula is shown below.

$$P = S_{SF} + V_{P} + f_{WD} \times V_{V}$$

The ranges assigned to each of the three factors were established so that the “safety” portion of the aggregate score would represent 50% of the weight, with the pedestrian volume and vehicular volumes each contributing 25% to the total score, as shown below:

$S_{SF}=$ Safety Score (1-12)

$$S_{SF}= [F_{ST}\times ST+ F_{SDR}\times SDR + F_{FR}\times FR + F_{ADJ}\times ADJ + F_{BS}\times BS + F_{SC}\times SC + AH]$$

$ST=$ Station located nearby the crossing

$SDR=$ Sight distance restriction

$FR=$ Freight (presence of freight tracks)

$ADJ=$ Adjacent signalized intersection

$BS=$ Bus Stops

$SC=$ Schools

$AH=$ Accident History Factor (No. of Fatalities + 0.2 x No. of non-fatal collisions)

$V_{P}=$ Pedestrian volume score at the crossing (1-6)

$V_{V}=$ Vehicular volume score (1-6)

$f_{WD}=$ Warning Device factor (0.5-1)

2.3.3 Factor Calculation

The prioritization formula includes weighting coefficients for each of the variables that were determined based on the relative importance of the factor to predict collisions and fatalities. The following calculations explain how the coefficients were calculated for each of the variables. The AH factor was used to determine the average number of collisions in all cases.

Stations

The Station coefficient was calculated by determined the average AH factor occurring at crossings with a station nearby and comparing that to the average AH factor that occurred at non-station locations. The average AH factor occurring at stations is 1.3, and the average number of pedestrian collisions occurring at non-station locations is 0.9.

The ratio of the two yields a coefficient of 1.4. This means a collision is 40% more likely to occur at a crossing where there is a station compared to a crossing where there is no station.

Sight Distance Restriction

Recognizing that all crossings include active warning devices to alert drivers, pedestrians, bicyclists and other road users of the impending arrival of a train, nevertheless there were some locations where the train operator would not have sight distance to slow the train in response to observing potentially risky behavior by highway users approaching the crossing. A correlation between higher collision frequency (for pedestrian – LRT collisions) was found at locations flagged with sight distance impairments in one or both approach quadrants. Because the particular type of sight distance impairment was varied and site-specific, this criteria was scored in a binary fashion – locations where sight distance restrictions where identified were scored as 1 vs 0 for locations with clear sight lines (500-800 feet up the track depending upon the train speed).

Table 1 shows the sight distance restriction scores for each intersection and the AH factor that occurred at each intersection. ST denotes there is a Station adjacent to the crossing.

		AH Factor	**Sight Distance Restriction**
1	*Spring St.*	0	0
2	*Wardlow Rd. (ST)*	1.4	0
3	*Manville Rd.*	0	0
4	*Greenleaf Blvd.*	0	0
5	*Alondra Blvd.*	0.6	0
6	*Myrrh St.*	0	0
7	*Compton Blvd. (ST)*	0	0
8	*Elm St.*	1	0
9	*Stockwell St.*	1.2	0
10	*130th St.*	1	0
11	*El Segundo Blvd.*	1.2	0
12	*124th St.*	1	0
13	*119th St.*	1	0
14	*Wilmington Ave.*	2	1
15	*108th St.*	0	0
16	*103rd St. (ST)*	2.4	1
17	*Century Blvd.*	2.2	1
18	*92nd St.*	1	0
19	*Nadeau St.*	1.4	0
20	*Florence Ave. (ST)*	0.4	1
21	*Gage Ave.*	3.2	1
22	*55th St.*	0.2	0
23	*48th Pl.*	1.2	0
24	*Vernon Ave. (ST)*	3.2	0
25	*41st St.*	0.2	0
26	*24th St.*	1	0
27	*20th St. (ST)*	0.2	0

Table 1. - Sight Distance Restriction.

The average AH factor for locations with and without sight distance restriction is shown in the **Table 2**.

	Average AH Factor
No Sight Distance Restriction (0)	0.8

	Average AH Factor
Sight Distance Restriction	2.0

Table 2. - Average number of collisions per Sight Distance score

The ratio of the major to the “no” sight distance **yields a coefficient of 2.7 for sight distance restriction.**

Freight

The Spring Street, Wardlow Road, 24th Street and 20th Street intersections do not have a freight track adjacent to the light rail. The average AH factor at the locations with a freight track is 1.1 and without freight is 0.7. The coefficient for the freight variable 1.1/0.7, which is 1.6.

Adjacent Signalized Intersections

Candidate intersections with an adjacent signalized intersections averaged 1.1 pedestrian AH factor. Candidate intersections without adjacent signalized intersections averaged 0.8 pedestrian AH factor. The ratio of collisions at signalized to unsignalized intersections is 1.3.

Proximity to Bus Stops

The average AH factor that occurred at intersections near bus stops is 1.0, while the average number of pedestrian AH factor that occurred at intersections without bus stops is 0.9. The coefficient for proximity to bus stops is 1.2.

Schools

The average pedestrian AH factor at intersections within 0.25 mi of a school is 1.0 and the average pedestrian AH factor at intersections that are not close to a school is 1.0. The ratio for the two values is 1.0.

Accident History Factor

The number of pedestrian fatalities plus 20% of the no-fatal collisions is used as the final factor for the safety portion of the formula.

Pedestrian Volumes (V_P)

The pedestrian volumes were calculated by adding the peak and off-peak period pedestrian volumes. The pedestrian volumes were ranked by determining six ranges with the highest volumes given a score of 6 and the lowest 1. **Table 3** shows the pedestrian volumes and scores and **Table 4** shows the calculation.

		Ped Volume	**Ped Score (V_P)**
1	*Spring St.*	40	1
2	*Wardlow Rd.*	59	1
3	*Manville Rd.*	4	1
4	*Greenleaf Blvd.*	36	1
5	*Alondra Blvd.*	79	1
6	*Myrrh St.*	41	1
7	*Compton Blvd.*	273	3
8	*Elm St.*	130	2
9	*Stockwell St.*	54	1
10	*130th St.*	82	1
11	*El Segundo Blvd.*	73	1
12	*124th St.*	59	1
13	*119th St.*	67	1
14	*Wilmington Ave.*	140	2
15	*108th St.*	79	1
16	*103rd St.*	430	4
17	*Century Blvd.*	135	2
18	*92nd St.*	117	2
19	*Nadeau St.*	99	1
20	*Florence Ave.*	1032	6
21	*Gage Ave.*	43	1
22	*55th St.*	70	1
23	*48th Pl.*	64	1
24	*Vernon Ave.*	776	4
25	*41st St.*	60	1
26	*24th St.*	20	1
27	*20th St.*	17	1

Table 3. - Pedestrian Volumes and Scores.

Maximum Pedestrian Volume	1,032
Minimum Pedestrian Volume	4
(Max-Min)	1,028
Range 1 Pedestrian Volume	<100
Range 2 Pedestrian Volume	100 - 200
Range 3 Pedestrian Volume	201 - 400
Range 4 Pedestrian Volume	401 - 800
Range 5 Pedestrian Volume	801 - 1,000
Range 6 Pedestrian Volume	>1,000

Table 4. - Pedestrian Volume Calculation.

Vehicular Volumes (V_V)

The vehicular volumes were calculated by dividing the peak hour directional volume by the number of lanes across the train tracks.

The volumes were ranked by determining six equal ranges with the highest volumes given a score of 6 and the lowest 1. **Table 5** shows the vehicular volumes and scores and **Table 6** shows the calculation.

		Highest Peak Volume per lane on xing	**Volume Score (V_V)**
1	*Spring St.*	780	6
2	*Wardlow Rd.*	616	5
3	*Manville Rd.*	382	2
4	*Greenleaf Blvd.*	957	6
5	*Alondra Blvd.*	576	4
6	*Myrrh St.*	403	3
7	*Compton Blvd.*	531	4
8	*Elm St.*	252	2
9	*Stockwell St.*	235	2
10	*130th St.*	138	1
11	*El Segundo Blvd.*	541	4
12	*124th St.*	217	2
13	*119th St.*	527	4
14	*Wilmington Ave.*	829	6
15	*108th St.*	320	2
16	*103rd St.*	311	2
17	*Century Blvd.*	302	2
18	*92nd St.*	467	3
19	*Nadeau St.*	612	5
20	*Florence Ave.*	510	4
21	*Gage Ave.*	640	5
22	*55th St.*	290	2
23	*48th Pl.*	243	2
24	*Vernon Ave.*	404	3
25	*41st St.*	428	3
26	*24th St.*	326	2
27	*20th St.*	151	1

Table 5. - Vehicular Volume and Scores.

Max peak volume per lane	957
Min peak volume per lane	138
(Max-Min)	819
Range 1 Vehicular Volume	<200
Range 2 Vehicular Volume	200 - 400
Range 3 Vehicular Volume	401 - 500
Range 4 Vehicular Volume	501 - 600
Range 5 Vehicular Volume	601 - 700
Range 6 Vehicular Volume	>700

Table 6. - Vehicular Volume Calculation.

Warning Device Factor (f_{WD})

The vehicular volume score of the crossings that have four quadrant gates in place has been multiplied by warning device factor 0.5 vs the rest of the crossings where that factor is considered as 1. **Table 7** shows the warning devices factors considered at each location. This factor was applied to the vehicle volume factor to in effect “credit” out the safety benefit of four-quadrant gates such that the vehicular volume-driven portion of the priority score would only reflect the highway delay benefit resulting from a potential grade separation.

		Warning Device Factor (f_{WD})
1	*Spring St.*	1.0
2	*Wardlow Rd.*	1.0
3	*Manville Rd.*	1.0
4	*Greenleaf Blvd. (4OG)*	0.5
5	*Alondra Blvd. (4OG)*	0.5
6	*Myrrh St. (4OG)*	0.5
7	*Compton Blvd. (4OG)*	0.5
8	*Elm St. (4OG)*	0.5
9	*Stockwell St.*	1.0
10	*130th St.*	1.0
11	*El Segundo Blvd.*	1.0
12	*124th St. (4OG)*	0.5
13	*119th St.*	1.0
14	*Wilmington Ave.*	1.0
15	*108th St.*	1.0
16	*103rd St.*	1.0
17	*Century Blvd.*	1.0
18	*92nd St.*	1.0
19	*Nadeau St.*	1.0
20	*Florence Ave.*	1.0
21	*Gage Ave.*	1.0
22	*55th St.*	1.0
23	*48th Pl.*	1.0
24	*Vernon Ave.*	1.0
25	*41st St.*	1.0
26	*24th St.*	1.0
27	*20th St.*	1.0

Table 7. – Warning Device Factor.

3. Prioritization Results

The proposed prioritization formula is shown below. The coefficients for each variable are shown in **Table 8.**

$$P = S_{SF} + V_P + f_{WD} \times V_V$$

$$P = [1.4\times ST + 2.7\times SDR + 1.6\times FR + 1.3\times ADJ + 1.2\times BS + 1.0\times SC + AH] + V_P + f_{WD} \times V_V$$

$\mathrm{ST} =$ Station located nearby the crossing

$\mathrm{SDR} =$ Sight distance restriction

$\mathrm{FR} =$ Freight (presence of freight tracks)

$\mathrm{ADJ} =$ Adjacent signalized intersection

$\mathrm{BS} =$ Bus Stops

$\mathrm{SC} =$ Schools

$\mathrm{AH} =$ Accident History (No. of Fatalities + 0.2 x No. of non-fatal collisions)

$V_P =$ Pedestrian volume score at the crossing (1-6)

$V_V =$ Vehicular volume score (1-6)

$f_{WD}=$ Warning Device factor (0.5-1)

Coefficient	**Value**
F_{ST}	1.4
F_{SDR}	2.7
F_{FR}	1.6
F_{ADJ}	1.3
F_{BS}	1.2
F_{SC}	1.0

Table 8. - Coefficient Values

Based on this formula the resulting scores and corresponding rankings are shown in **Table 9.**

Ranking	**Location**	**Safety Score**	**Pedestrian Volume Score**	**Warning Device factor**	**Vehicular Volume Score**	**Total Score**
1	*Florence Ave.*	8.2	6	1.0	4	18.2
2	*103rd St.*	11.5	4	1.0	2	17.5
3	*Wilmington Ave.*	8.4	2	1.0	6	16.4
4	*Vernon Ave.*	8.7	4	1.0	3	15.7
5	*Century Blvd.*	10.0	2	1.0	2	14.0
6	*Gage Ave.*	7.5	1	1.0	5	13.5
7	*Wardlow Rd.*	6.2	1	1.0	5	12.2
8	*Nadeau St.*	5.2	1	1.0	5	11.2
9	*Compton Blvd.*	5.5	3	0.5	4	10.5
10	*El Segundo Blvd.*	5.3	1	1.0	4	10.3
11	*119th St.*	5.1	1	1.0	4	10.1
12	*92nd St.*	4.8	2	1.0	3	9.8

Ranking	Location	Safety Score	Pedestrian Volume Score	Warning Device factor	Vehicular Volume Score	Total Score
13	*Stockwell St.*	6.3	1	1.0	2	9.3
14	*Alondra Blvd.*	5.7	1	0.5	4	8.7
15	*48th Pl.*	5.3	1	1.0	2	8.3
16	*41st St.*	4.3	1	1.0	3	8.3
17	*Spring St.*	1.2	1	1.0	6	8.2
18	*Myrrh St.*	5.1	1	0.5	3	7.6
19	*130th St.*	5.1	1	1.0	1	7.1
20	*124th St.*	5.1	1	0.5	2	7.1
21	*55th St.*	4.0	1	1.0	2	7.0
22	*Greenleaf Blvd.*	2.8	1	0.5	6	6.8
23	*Elm St.*	3.8	2	0.5	2	6.8
24	*Manville Rd.*	2.6	1	1.0	2	5.6
25	*108th St.*	2.6	1	1.0	2	5.6
26	*24th St.*	2.3	1	1.0	2	5.3
27	*20th St.*	2.9	1	1.0	1	4.9

Table 9. - Final Grade Separation Prioritization

Florence Ave., 103rd, Wilmington Ave., and Vernon Ave are the top four locations recommended for grade separation. Florence Ave. has a restricted sight distance and very high pedestrian volumes and moderate vehicular volumes, which contribute to increased exposure. 103rd St. also has a high number of pedestrian fatalities, sight distance restriction, and moderate pedestrian volumes. Wilmington Ave. has the highest number of collisions and a severe skew angle that contributes to its unsafe condition. Vernon Ave has a very high number of pedestrian fatalities and high pedestrian volumes. The four locations are the highest priority locations for grade separation.

4. Conclusions

It is clear from the final scoring of the crossings that there are four crossings at the top of the list with similar scores and a second group of relatively higher scores comprised of 7 additional crossings. (It should be noted that Wardlow Road is at the middle of the second-tier group and ranked number 7.) All the remaining crossings had scores that were below average.

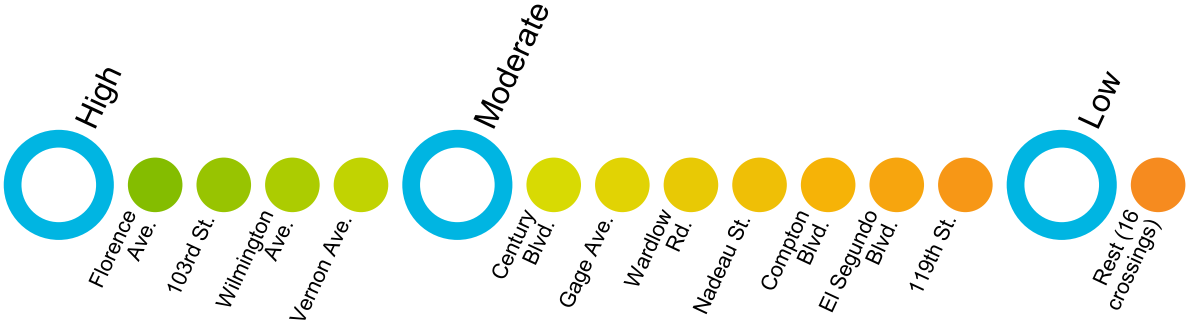

Figure 6. – Groups of crossings with High, Moderate & Low Scores.

Before any of the crossings are grade separated, the full range of appropriate at-grade mitigation should be implemented. This includes completion of the pedestrian crossing gate installations currently underway along with potentially wider deployment of four-quadrant road crossing gates, if warranted, to address vehicular collisions.

There were no vehicular collision at crossings with four quadrant gates, so implementation of this treatment would be expected to significantly reduce this type of collision.

Following application of the above retrofits to the MBL crossings a multi-year post-treatment accident history should be reviewed to determine the benefits of these improvements (especially with respect to pedestrian collisions).

Grade separations could then be considered at high priority locations where collisions are found to be recurring despite application of all available safety treatments.

As part of this study, rough order of magnitude estimates were prepared for two representative grade separations to determine a range of costs that could be expected for typical grade separations. The Gage Avenue Crossing was selected as a representative crossing for an aerial guideway crossing over a roadway. The Florence Avenue Crossing was selected as a representative crossing for an aerial guideway and aerial station over a roadway.

Using these representative crossings and unit costs from similar Metro projects, the ROM estimates results in a total project cost of $80 to $110 Million (2017 value) for a grade separation involving an aerial guideway over the roadway and $120 to $160 Million (2017 value) for a grade separation involving an aerial guideway and new aerial station over the roadway.

Before significant planning can be performed to prioritize and identify specific crossings for implementation, an analysis of the effectiveness of recent pedestrian improvements implemented should be performed. It would be premature to consider grade separation until these improvements have been implemented and the benefits evaluated. Subsequent phases of analysis should take into account the effectiveness of these new pedestrian improvements into the grade separation prioritization.

Appendix A. – Master Spreadsheet

Item No.	Location description	Total Observed Ped Collisions (*)	Total Observed Ped Fatalities (*)	Total Observed Vehicular Collisions (*)	Total Vehicular Fatalities (*)	Total Collisions (*)	Skew Angle (0- no 1- skew)	Sight Distance Restriction (0- no 1- yes)	Freight track (Yes/No)	Adj. Signalized intersection (Yes/No)	Peak period (AM+PM) Ped Volume	Bus Stop (0- Stops no adj to Station 1- Stops adj station 2- Transfer Center)	Schools within 0.25mile	Stations nearby (0-no 1-yes)
1	Spring St.	0	0	1	0	1	0	0	No	No	40	1	Yes	0
2	Wardlow Rd.	3	1	0	0	3	0	0	No	Yes	59	1	Yes	1
3	Manville Rd.	0	0	0	0	0	0	0	Yes	No	4	0	Yes	0
4	Greenleaf Blvd.	0	0	0	0	0	0	0	Yes	No	36	1	No	0
5	Alondra Blvd.	3	0	0	0	3	0	0	Yes	Yes	79	1	Yes	0
6	Myrrh St.	0	0	0	0	0	0	0	Yes	Yes	41	1	Yes	0
7	Compton Blvd.	0	0	0	0	0	0	0	Yes	Yes	273	1	No	1
8	Elm St.	1	1	0	0	1	0	0	Yes	No	130	1	No	0
9	Stockwell St.	2	1	0	0	2	0	0	Yes	Yes	54	1	Yes	0
10	130th St.	1	1	1	0	2	0	0	Yes	Yes	82	1	No	0
11	El Segundo Blvd.	2	1	0	0	2	0	0	Yes	Yes	73	1	No	0
12	124th St.	1	1	0	0	1	0	0	Yes	Yes	59	1	No	0
13	119th St.	1	1	2	0	3	0	0	Yes	Yes	67	1	No	0
14	Wilmington Ave.	6	1	1	0	7	1	1	Yes	No	140	1	Yes	0
15	108th St.	0	0	0	0	0	0	0	Yes	No	79	0	Yes	0
16	103rd St.	4	2	2	0	6	0	1	Yes	Yes	430	1	Yes	1
17	Century Blvd.	3	2	0	0	3	0	1	Yes	Yes	135	1	Yes	0
18	92nd St.	1	1	0	0	1	0	0	Yes	No	117	1	Yes	0
19	Nadeau St.	3	1	1	0	4	0	0	Yes	No	99	1	Yes	0
20	Florence Ave.	2	0	1	0	3	0	1	Yes	No	1032	1	Yes	1
21	Gage Ave.	4	3	1	0	5	0	1	Yes	No	43	0	No	0
22	55th St.	1	0	1	0	2	0	0	Yes	No	70	1	Yes	0
23	48th Pl.	2	1	0	0	2	0	0	Yes	Yes	64	1	No	0
24	Vernon Ave.	4	3	0	0	4	0	0	Yes	Yes	776	1	No	1
25	41st St.	1	0	4	0	5	0	0	Yes	Yes	60	1	No	0
26	24th St.	1	1	0	0	1	0	0	No	Yes	20	0	No	0
27	20th St.	1	0	0	0	1	0	0	No	Yes	17	0	No	1
		47	**22**	**15**	**0**	**62**								

(*) The collisions do not include suicides.

Item No.	Location description	Number of Lanes		ADT Volume		ADT	Highest AM Peak Hour Volume		Highest PM Peak Hour Volume		Highest Peak Hour Volume		Peak Vol per lane on xing	Four quad gates	Warning Devices 4QG (0-no 1-yes)
		EB/NB	WB/SB	EB/NB	WB/SB		EB/NB	WB/SB	EB/NB	WB/SB	EB/NB	WB/SB			
1	Spring St.	1	1	8570	8529	17,099	728	636	780	647	780	647	780	No	0
2	Wardlow Rd.	2	2	12716	10553	23,269	841	842	1231	776	1231	842	616	No	0
3	Manville Rd.	2	2	4628	4219	8,847	207	546	763	305	763	546	382	No	0
4	Greenleaf Blvd.	1	1	8519	7490	16,009	504	678	957	549	957	678	957	No	1
5	Alondra Blvd.	2	2	10449	9086	19,535	704	934	1152	672	1152	934	576	Yes	1
6	Myrrh St.	1	1	3197	3219	6,416	247	403	398	249	398	403	403	Yes	1
7	Compton Blvd.	2	2	11125	10018	21,143	691	768	1062	773	1062	773	531	Yes	1
8	Elm St.	1	1	2426	2143	4,569	213	168	252	202	252	202	252	Yes	1
9	Stockwell St.	1	1	2311	2429	4,740	235	211	202	210	235	211	235	No	0
10	130th St.	1	1	1111	1205	2,316	138	136	120	119	138	136	138	No	0
11	El Segundo Blvd.	2	2	9494	750	10,244	609	736	1081	509	1081	736	541	No	0
12	124th St.	1	1	1729	1651	3,380	168	217	191	134	191	217	217	Yes	1
13	119th St.	1	1	5339	5200	10,539	306	527	484	408	484	527	527	No	0
14	Wilmington Ave.	1	1	10985	10410	21,395	763	829	819	661	819	829	829	No	0
15	108th St.	1	1	2126	2268	4,394	164	320	232	209	232	320	320	No	0
16	103rd St.	2	2	5514	6956	12,470	357	622	498	460	498	622	311	No	0
17	Century Blvd.	2	2	5880	5714	11,594	423	554	604	394	604	554	302	No	0
18	92nd St.	2	2	10369	9640	20,009	786	856	934	686	934	856	467	No	0
19	Nadeau St.	2	2	11781	11460	23,241	896	1031	1223	887	1223	1031	612	No	0
20	Florence Ave.	2	2	14886	14067	28,953	852	800	970	1020	970	1020	510	No	0
21	Gage Ave.	2	2	15544	14977	30,521	1115	1125	1280	1096	1280	1125	640	No	0
22	55th St.	1	1	3313	3026	6,339	290	224	269	268	290	268	290	No	0
23	48th Pl.	1	1	1859	1614	3,473	243	84	168	218	243	218	243	No	0
24	Vernon Ave.	2	2	8689	9554	18,243	572	581	570	808	572	808	404	No	0
25	41st St.	1	1	4672	4392	9,064	413	296	315	428	413	428	428	No	0
26	24th St.	1	1	1902	2772	4,674	183	206	193	326	193	326	326	No	0
27	20th St.	1	1	1016	1059	2,075	143	68	94	151	143	151	151	No	0