
TCRP
Web-Only Document 53:
Operation of Light Rail Transit through Ungated Crossings at Speeds over 35 MPH

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DETAILS

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AUTHORS

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CONTENTS

CHAPTER 1: INTRODUCTION

TCRP Web-Only Document 53 presents the findings and results of the investigation conducted in support of TCRP Project A-32, “Operation of Light Rail Transit through Ungated Crossings at Speeds over 35 MPH.” In addition, this report presents the findings of the micro-simulation modeling conducted as an alternative to an evaluation of the impacts of higher LRV speeds on selected locations in San Jose. The project panel agreed that the modeling was a feasible and valid alternative to a field test, necessitated by the City of San Jose’s decision to not participate in a field test. In addition, other municipalities/systems that were contacted to participate were not able to do so during the project schedule.

TCRP Web-Only Document 53 is organized as follows:

- Chapter 2: Identification of Participating LRT Agency and Potential Study Crossings;
- Chapter 3: Assessment of the Operational and Safety Aspects of Existing, Alternative, and Possible Supplemental Traffic Control Devices;
- Chapter 4: Modeling/Simulation of Light Rail Operating Conditions: North First Street from East Brokaw Road to Trimble Road;
- Chapter 5: Risk Analysis;
- Appendix A: Summary of Crash Data at the Intersections of North First Street and Brokaw Road, Charcot Avenue, and Trimble Road;
- Appendix B: VTA *Draft* Letter to FHWA Requesting Permission to Experiment with an Increase in LRV Speeds to 40 MPH through Three Ungated Crossings;
- Appendix C: Conflict Data (a tabular presentation of the micro-simulation results);
- Appendix D: Testing Plan (developed initially for the test in San Jose, but could be used as a test plan template if another municipality decides to participate in the future); and
- Appendix E: Evaluation Plan.

Chapter 2 provides a summary of interviews conducted with four transit agencies operating LRT, lists the primary criteria used to select a corridor with crossings suitable for study under the TCRP A-32 project, presents characteristics of the candidate study corridor resulting from the interviews, and recommends three crossings along the North First St. corridor in San Jose, CA, as test sites for the demonstration project.

Chapter 3 provides an in-depth look at the recommended test sites along North First St. in San Jose. Existing data, including crossing geometry, traffic volumes, pedestrian and bicycle volumes, LRT operational data, historical crash and near-miss data, and traffic signal timings, are summarized. In addition, the results of focus groups conducted with 30 local San Jose drivers regarding their comprehension and perceptions of a variety of different traffic control devices are presented. Finally, recommended traffic control devices, along with preliminary cost estimates of the devices, are presented.

Chapter 4 describes the methodology and results of the micro-simulation study. The objective of this study was to develop a micro-simulation model for the Light Rail corridor on North Frist St. from East Brokaw Road to Trimble Road in San Jose, California in order to analyze the simulated intersection safety under existing and suggested conditions (increasing LRV operating speed from 35 mph to 45 mph).

Chapter 5 presents the risk analysis conducted for the TCRP A-32 project. The risk analysis considers the probability that a crash (or crashes) will occur during the testing period, the types of crashes that are likely to occur, and the severity of the crashes. The analysis is a frequency-based analysis of historical safety-related data and recent observations of behaviors at the study intersections. The analysis considers the changes that will take place during the testing period and their potential future impacts on crash rates and severity.

Supporting documentation for the project can be found in the appendices at the end of the report.

CHAPTER 2: IDENTIFICATION OF PARTICIPATING LRT AGENCY AND POTENTIAL STUDY CROSSINGS

This chapter summarizes the approach used for identifying both the participating LRT agency as well as the potential study crossings.

The objectives of Task 1 were to survey LRT agencies and to identify potential highway-rail crossings suitable for further study. Task 1 was composed of the following two subtasks:

→ Task 1-1: Identify, select, and survey LRT agencies in North America that are candidates for LRV operation speeds exceeding 35 mph; and

→ Task 1-2: Identify potential crossings suitable for further study.

Figure 1 illustrates the flow of the Task 1 subtasks, as well as the Task 1 output that will feed into Task 2. The findings from both of the Task 1 subtasks are discussed in more detail below.

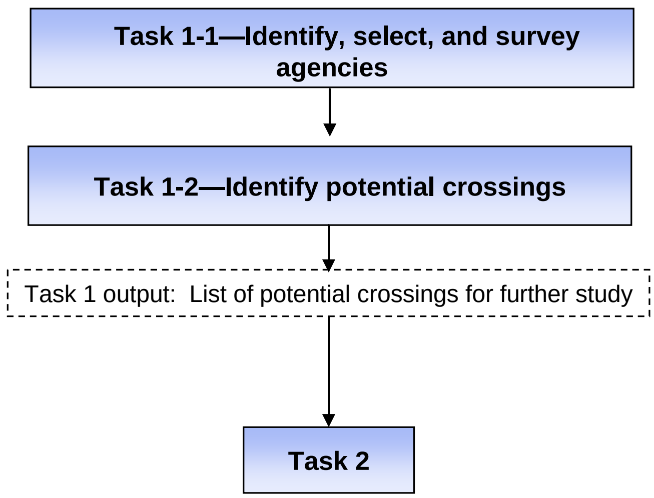

Figure 1. Subtask Flow Diagram for Task 1

Each of these subtasks is described in more detail below.

IDENTIFY, SELECT, AND SURVEY LRT AGENCIES IN NORTH AMERICA THAT ARE CANDIDATES FOR LRV OPERATION SPEEDS EXCEEDING 35 MPH

Immediately following kick-off of this research effort, the SAIC team participated in a teleconference with the panel and the Transportation Research Board Systems Planning Office (TRB SPO). One major topic of discussion during this teleconference was which transit agencies might be good candidates and be interested in participating in the study. As a result of the conversation, the panel recommended that the research team start Task 1 by contacting the following four transit agencies:

1. Utah Transit Authority (UTA) in Salt Lake City, UT;
2. Santa Clara Valley Transportation Authority (VTA) in Santa Clara / San Jose, CA;

3. New Jersey Transit (Hudson-Bergen Line) in Jersey City, NJ; and
4. Dallas Area Rapid Transit (DART) in Dallas, TX.

Utah Transit Authority

Staff at UTA said they would be willing to participate in the study, but suggested that North First St. in San Jose or Lancaster Rd. in Dallas would potentially make better test beds for the project. The location suggested in Salt Lake City was 1725 E and Campus Drive; however, this segment is short, and by the time the trains get to the intersection, their speeds are coming down to 35 mph. Further, it is not certain that speeds in excess of 35 mph would be appropriate at this site regardless of the crossing control method.

If UTA were selected as the test site, the agency would be willing to help facilitate the data collection effort, but would have to get the local jurisdiction's agreement. The transit agency would be willing to change out tapes and batteries during video data collection as necessary.

As an aside, UTA suggested that perhaps one reason there are so many left-turn collisions is the slower train speeds relative to the parallel traffic (drivers pass the train and then don't give it much thought). So by increasing the train speeds, he thinks a corresponding decrease in left-turn collisions would result.

Santa Clara Valley Transportation Authority

The team also spoke with the General Manager of the VTA, as well as the Assistant Director of Maintenance and Security of the VTA who expressed interest in participating in TCRP A-32 and believed that North First St. would be an ideal area for the study. This segment of the LRT line comprises tracks set in rock ballast (not embedded in paving) and situated in the median of North First St. The portion of the right-of-way within the median is owned by the VTA. At most intersections the signalization is owned and operated by the City of San Jose, although a few are under the jurisdiction of Santa Clara County. Train movements at these intersections are given some degree of signal preference over conflicting movement, but they do not preempt the operation in all circumstances. These movements receive what might be called "predictive priority," a system by which, when an approaching train is detected, the normal signal cycle is altered in various ways to reduce, and in some cases completely avoid, signal delay of train movements without seriously disrupting other vehicle movements. At present, the signal controllers at Trimble Rd. and Brokaw Rd. operate independently of any other intersections, but the city is planning to coordinate the signal controllers along North First St. in the near future to provide a progression for through traffic along North First St. Since these through movements are concurrent with the train movements and utilize the same phase in the cycle, this programming can be expected to be complementary.

The VTA also indicated that it was engaged in a number of improvements to mitigate left-turn collisions along North First St. and other intersections. Construction of Phase I of the agency's improvement project was scheduled for summer 2009, with construction of Phase II of the project scheduled for spring 2010. While the VTA did express concern about the cost of making the improvements, the fact that they are already making some improvements to the intersections in an effort to improve safety may reduce or minimize the costs of participating in the project.

New Jersey Transit (Hudson-Bergen Line)

The SAIC team also spoke with staff at New Jersey Transit (Hudson-Bergen Line). They could not identify any locations where they could increase speeds above 35 mph on the Hudson-Bergen, as the distance between stations is not long enough.

Dallas Area Rapid Transit (DART)

The SAIC Team spoke with DART staff. DART was interested in the project; however, they were not certain that DART would be willing to or could increase the operating speed. The one potential corridor would be along Lancaster Road between Illinois Ave. and Ledbetter Dr., where stations are spaced approximately 1 mile apart. The current operating speed for LRVs and auto traffic is 35 mph. The major issue with this system is that DART has an agreement with the City not to operate faster than the adjacent roadway; if the speed of the trains were to increase, so would the adjacent roadway speeds.

Recommendation

Based on the information obtained through the interviews, the research team recommended the VTA as the agency to participate in the study. The VTA was willing and had a corridor that would allow for an increase in train speed.

IDENTIFY POTENTIAL CROSSINGS SUITABLE FOR FURTHER STUDY

The primary criteria used to select a corridor with crossings suitable for study under the TCRP A-32 project included:

- LRT operates in semi-exclusive right-of-way (Types b.2, b.3, or b.4);
- Posted speed limit on parallel roadway is more than 35 mph;
- Crossings are not currently equipped with flashing lights or automatic gates; and
- Distance between stations and adjacent crossings are sufficient to allow LRVs to accelerate from the station to the higher speeds by the crossings and decelerate from the higher speeds through the crossings to the stations.

Further discussions with staff at the VTA were conducted to identify potential crossings suitable for study. It was suggested that the North First St. corridor, between Gish and Tasman, may be a good study area. Within this segment, the LRT tracks are situated in a semi-exclusive right-of-way, and there are no flashing lights or automatic gates installed at any of the crossings. The posted speed limit along North First St. within this segment ranges from 35 to 45 mph. Station-to-station spacing averages about 0.5 miles in both the northbound and southbound directions, and maximum train speeds are 35 mph in both directions within the corridor.

Finally, the distance from a crossing to the nearest LRT station needs to be sufficient to allow LRVs to either accelerate from the station up to the higher speeds prior to entering the crossing (where the nearest station is upstream of the crossing) or to decelerate from the higher speeds at the crossing to the station (where the nearest station is downstream of the crossing). Where the nearest LRT station is upstream of the crossing, the LRV will need to accelerate from a stopped position at the station to 40 mph prior to entering the crossing. Assuming an LRV service acceleration rate of 2.75 mph per second, a minimum distance of approximately 425 feet is required. Where the nearest LRT station is downstream of the crossing, the LRV will need to decelerate from 40 mph at the crossing to a stopped position at the station. Assuming an LRV service deceleration rate of approximately 3 mph per second, a minimum distance of approximately 400 feet is required. The distances between the crossings and the nearest stations are shown in Table 1 and Table 2 for the northbound and southbound directions, respectively. The shaded rows indicate the distances that meet the minimum requirements for the 40 mph test.

Table 1. Distances from Crossings to Nearest Station: Northbound Guadalupe Line
(Gish Rd. to Tasman Dr.)

Crossing	Nearest Station(s)	Distance to Nearest Station(s)	
		Station South of Crossing (~425' required to accelerate to 40 mph before crossing)[1]	Station North of Crossing (~400' required to decelerate from 40 mph to station)[2]
Gish Rd.	Gish Station	Station at crossing	
Sonora Ave.	Gish Station	654' south of crossing	
Skyport Dr.	Metro Airport Station	--	1220' north of crossing
Metro Dr.	Metro Airport Station	Station at crossing	
Old Bayshore Hwy.	Metro Airport Station	240' south of crossing	--
Brokaw Rd.	Karina Court Station	--	1080' north of crossing
Karina Ct.	Karina Court Station	Station at crossing	
Charcot Ave.	Karina Court Station	1150' south of crossing	--
Component Dr.	Component Station	Station at crossing	
Trimble Rd.	Component Station	930' south of crossing	--
Bonaventura Dr.	Bonaventura Station	Station at crossing	
Plumeria Dr.	Bonaventura Station	960' south of crossing	--
Orchard Pkwy.	Orchard Pkwy Station	Station at crossing	
Montague Expy.	Orchard Pkwy Station	610' south of crossing	--
River Oaks Pkwy.	River Oaks Station	Station at crossing	
Rio Robles	Tasman Station	--	910' north of crossing
Tasman Dr.	Tasman Station	130' south of crossing	--

[1] Acceleration rate assumed to be 2.75 miles per hour per second. Acceleration distances were measured from the north end of the station to the stop bar on the northbound approach to the intersection.

[2] Deceleration rate assumed to be 3 miles per hour per second. Deceleration distances were measured from the stop bar on the southbound approach to the intersection to the mid-point of the station.

Note: Shaded rows represent those distances that are sufficient to allow for acceleration to or deceleration from 40 mph.

Table 2. Distances from Crossings to Nearest Station: Southbound Guadalupe Line (Tasman Dr. to Gish Rd.)

Crossing	Nearest Station	Distance to Nearest Station	
		Station North of Crossing (~425' required to accelerate to 40 mph before crossing) [1]	Station South of Crossing (~400' required to decelerate from 40 mph to station) [2]
Tasman Dr.	Tasman Station	--	290' south of crossing
Rio Robles	Tasman Station	760' north of crossing	--
River Oaks Pkwy	River Oaks Station	Station at crossing	
Montague Expy.	Orchard Pkwy Station	--	1170' south of crossing
Orchard Pkwy.	Orchard Pkwy Station	Station at crossing	
Plumeria Dr.	Orchard Pkwy Station	1130' north of crossing	--
Bonaventura Dr.	Bonaventura Station	Station at crossing	
Trimble Rd.	Bonaventura Station	440' north of crossing	--
Component Dr.	Component Station	Station at crossing	
Charcot Ave.	Component Station	1110' north of crossing	--
Karina Ct.	Karina Court Station	Station at crossing	
Brokaw Rd.	Karina Court Station	500' north of crossing	--
Old Bayshore Hwy.	Metro Airport Station	--	830' south of crossing
Metro Dr.	Metro Airport Station	Station at crossing	
Skyport Dr.	Metro Airport Station	660' north of crossing	--
Sonora Ave.	Gish Station		1206' south of crossing
Gish Rd.	Gish Station	Station at crossing	

[1] Acceleration rate assumed to be 2.75 miles per hour per second. Acceleration distances were measured from the south end of the station to the stop bar on the southbound approach to the intersection.

[2] Deceleration rate assumed to be 3 miles per hour per second. Deceleration distances were measured from the stop bar on the northbound approach to the intersection to the mid-point of the station.

Note: Shaded rows represent those distances that are sufficient to allow for acceleration to or deceleration from 40 mph.

In further conversations with the VTA, the research team learned that the VTA had just released a bid for a left-turn and track intrusion mitigation project, which created an interesting and unique opportunity for the TCRP A-32 project. Currently, there are active warning signs that indicate a train is approaching for the North First St. left-turn movements at each intersection, but there are no gates and no indicators other than traffic signals for perpendicular traffic on the North First St. segment. An analysis of historical collision rates showed that left-turn and track-intrusion incidents are the predominant types of incidents on the VTA system. The VTA's safety improvement project involves the implementation of strategies to reduce left-turn collisions and track intrusions at high-incident locations, several of which are situated along the North First St. corridor under investigation. Specifically, the following intersections are included in the first phase of work:

- North First St. and Brokaw Rd.
- Capitol Ave. and McKee Rd.
- North First St. and Tasman
- North First St. and Burton
- North First St. and Charcot Ave.
- Hostetter Rd. and Capitol Ave.

- Lawrence Expy. and Tasman Dr.
- North First Street and Karina Court
- Woz Way and San Carlos Street

As can be seen in the list of intersections, four of the intersections that will be improved in Phase I of the VTA's project are located along the North First Street corridor between Gish Road and Tasman Road.

Work planned at these locations includes the following:

- Install recessed stop bars 20 ft from crosswalk with "KEEP CLEAR" markings downstream of each stop bar;
- Install additional signage, including:
  - Signs that read "Do Not Drive on Tracks" (R15-6 or R15-6a) placed between tracks at crosswalk and oriented towards cross-street left turning traffic;
- Install additional pavement markings, including:
  - Painted "bull nose" with double yellow stripe and two-way yellow retro-reflective raised pavement markers;
  - Lane line and center line extensions through intersections for cross-street left turn movements;
- Replace existing single flash active Train Approaching Sign (W10-7) with a dual flash sign that adds a No Left Turn icon and alternates between the Train icon and the No Left Turn icon;
- Install three Caltrans Type Q "markers" / bollards between left-turn lane and trackway between stop bar and crosswalk; and
- Install Caltrans Type K-1 "markers" / reflectors between tracks at crosswalk.

Phase I design has been reviewed by the California Public Utilities Commission (CPUC), the City of San Jose, and other jurisdictions, with review comments being included in the final design. Phase I is expected to be complete by the end of September 2009, and Phase II construction is projected to begin in spring 2010.

As noted in the amplified work plan for this TCRP A-32 project, one of the challenges of the project was to identify a transit agency that was willing to participate not only by increasing the speeds of the trains, but also by implementing safety countermeasures as part of the test of increased speeds. With no financial resources offered to the participating agency to procure and install the safety measures for the TCRP demonstration test, it was recognized that it may be difficult to identify an agency willing to absorb the costs of participation. Therefore, the timing of the VTA improvement project was serendipitous in that the VTA had already gone through the process of determining the most common types of collisions along their LRT line (namely left-turn and track-intrusion); identifying countermeasures to mitigate these incidents; and conducting the planning, reviewing, and approval process for the countermeasures. In many ways, this finding simplified the TCRP A-32 project.

Task 2 of the project involved identifying promising safety countermeasures, analyzing the safety and operational aspects of the countermeasures, matching safety measures to specific sites/intersections, and doing a preliminary cost estimate. For the VTA's particular set of improvements, these steps have been largely taken; however, it should be noted that considering the VTA's safety improvement project did not replace the research that would be conducted for TCRP A-32, rather it complemented it. In moving forward with Task 2, the study team focused on identifying countermeasures that could supplement and/or complement the VTA's countermeasures. For example, emphasis was placed on identifying countermeasures to mitigate cross-street and pedestrian collisions.

Recognizing the benefits of building on the VTA's improvements, the TCRP A-32 research team considered, as an additional criterion, the intersections that would be improved as part of the VTA's project. Selecting crossings as test locations that were going to be improved would encourage the VTA's participation in the TCRP demonstration project. Further, with the high number of intersections being improved, it did not necessarily limit the TCRP A-32 research team from selecting appropriate and representative test sites, rather, it helped the team focus on which ones should be selected.

Tables 3 and 4 summarize the crossings along the North First Street corridor (northbound and southbound directions, respectively). Checkmarks indicate which crossings meet each of the criteria specified for selection as a test site, with consideration for the crossings being improved by the VTA. The shaded rows indicate the crossings that met all four of the TCRP A-32 criteria. Five crossings met the criteria in both the northbound and southbound directions:

- Brokaw Rd.;
- Charcot Ave.;
- Trimble Rd.;
- Plumeria Dr.; and
- Montague Expy.

Considering exclusively those crossings that are also VTA improvement sites leaves Brokaw Rd., Charcot Ave., and Trimble Rd. in both the northbound and southbound directions.

Table 3. Northbound North First Street Crossings Meeting Selection Criteria (Including VTA Improvements)

Crossing	Original Selection Criteria				Additional Criterion
	Semi-exclusive ROW	Posted speed limit >35 mph	No flashing lights / gates	Sufficient distance between crossing and nearby station(s)	VTA Improvements
Gish Rd.	√		√		
Sonora Ave.	√		√	√	
Skyport Dr.	√		√	√	
Metro Dr.	√		√		
Old Bayshore Hwy.	√	√	√		
Brokaw Rd.	√	√	√	√	√
Karina Ct.	√	√	√		√
Charcot Ave.	√	√	√	√	√
Component Dr.	√	√	√		
Trimble Rd.	√	√	√	√	√[1]
Bonaventura Dr.	√	√	√		
Plumeria Dr.	√	√	√	√	
Orchard Pkwy.	√	√	√		
Montague Expy.	√	√	√	√	
River Oaks Pkwy	√	√	√		
Rio Robles	√	√	√		
Tasman Drive	√	√	√	√	√

[1]To be improved during Phase II of the VTA's improvement project (Spring 2010)

Note: Rows with lighter shading indicate crossings that meet the four original criteria for possible test sites. Rows with darker shading indicate crossings that meet the four original criteria for possible test sites and are also receiving VTA safety improvements.

Table 4. Southbound North First Street Crossings Meeting Selection Criteria (Including VTA Improvements)

Crossing	Original Selection Criteria				Additional Criterion
	Semi-exclusive ROW	Posted speed limit >35 mph	No flashing lights / gates	Sufficient distance between crossing and nearby station(s)	VTA Improvements
Tasman Drive	√	√	√		√
Rio Robles	√	√	√	√	
River Oaks Pkwy	√	√	√		
Montague Expy.	√	√	√	√	
Orchard Pkwy	√	√	√		
Plumeria Dr.	√	√	√	√	
Bonaventura Dr.	√	√	√		
Trimble Rd.	√	√	√	√	√[1]
Component Dr.	√	√	√		
Charcot Ave.	√	√	√	√	√
Karina Ct.	√	√	√		√
Brokaw Rd.	√	√	√	√	√
Old Bayshore Hwy.	√	√	√		
Metro Dr.	√		√		
Skyport Dr.	√		√	√	
Sonora Ave.	√		√	√	
Gish Rd.	√		√		

[1]To be improved during Phase II of the VTA's improvement project (Spring 2010)

Note: Rows with lighter shading indicate crossings that meet the four original criteria for possible test sites. Rows with darker shading indicate crossings that meet the four original criteria for possible test sites and are also receiving VTA safety improvements.

Recommendation

Considering the criteria specified for test site selection, as well as the VTA improvement sites, the research team selected the following three crossings as test sites in both the northbound and southbound directions:

- Brokaw Rd.;
- Charcot Ave.; and
- Trimble Rd.

The research team did discuss the intersection of North First St. and Montague Expy. with the VTA as a potential test site. This is the sole intersection in the corridor that is not controlled by the City of San Jose; rather, this intersection is controlled by Santa Clara County. However, including this crossing as a test site was potentially problematic for two reasons. First, from a jurisdictional standpoint, selection of this site would require buy-in, approvals, and cooperation from a third agency. Further, the Montague Expressway is a major thoroughfare on which the county wants to keep traffic moving. Therefore, the priority at the intersection of North First St. and Montague Expy. is given to the Montague Expy. Knowing that the priority is not given to North First St. or the LRT, from a technical standpoint, it will be difficult to test higher speeds through this crossing.

The only other crossing that met all of the TCRP A-32 criteria for selection of a test site was the intersection of North First St. and Plumeria Dr. This intersection is the next four-way intersection to the north of the crossing at Trimble. Due to the similarity and proximity of these two intersections, it seemed more prudent to select the crossing at Trimble Rd. as a test site simply because it is one of the VTA's improvement sites. If the Plumeria crossing had been selected, the VTA would have then had to improve that intersection as well.

Summary of Study Segment and General Intersection Design and Operational Characteristics

The "study segment" stretches from Brokaw Rd. north to Trimble Rd., a distance of about 1 mile, and traverses five signalized intersections: Brokaw Rd., Karina Ct., Charcot Ave., Component Dr., and Trimble Rd. Figure 2 shows the study segment as it relates to the larger San Jose area, and Figure 3 shows the specific study intersections within the study segment as well as their relation to the other two signalized intersections within the study segment.

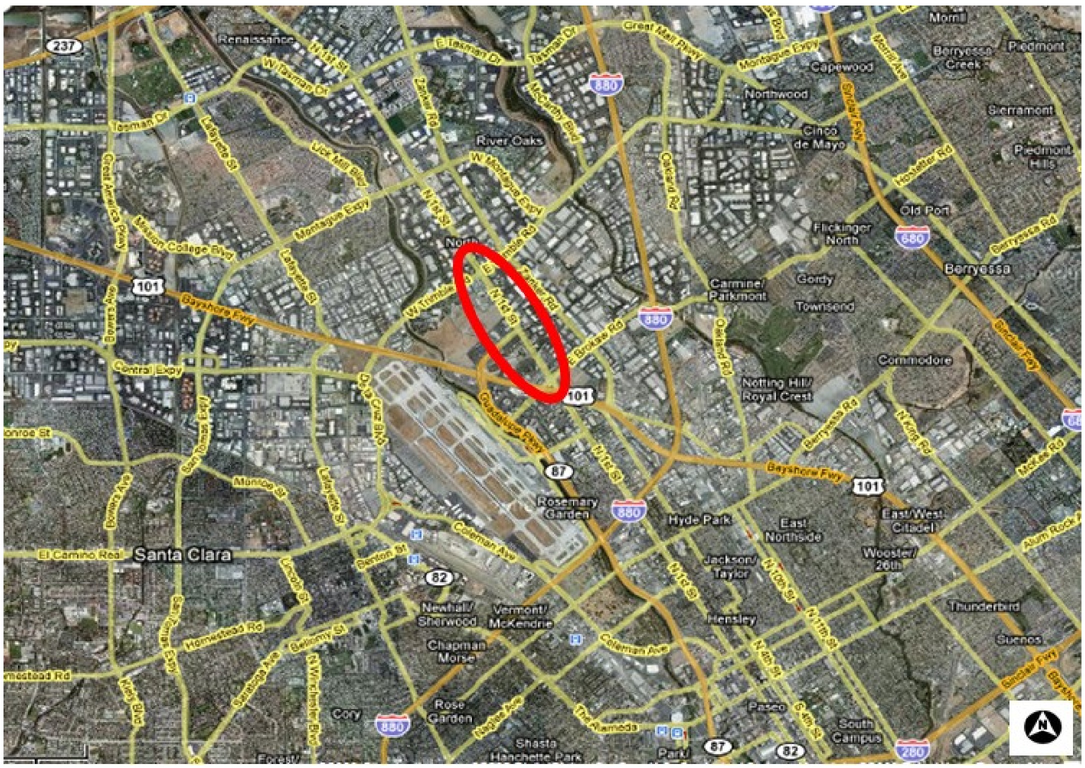

Figure 2. Study Area Location

Figure 3. Study Intersections

Intersection Geometrics

Figure 4, Figure 5, and Figure 6 show the geometry of the three study sites using aerial imagery.

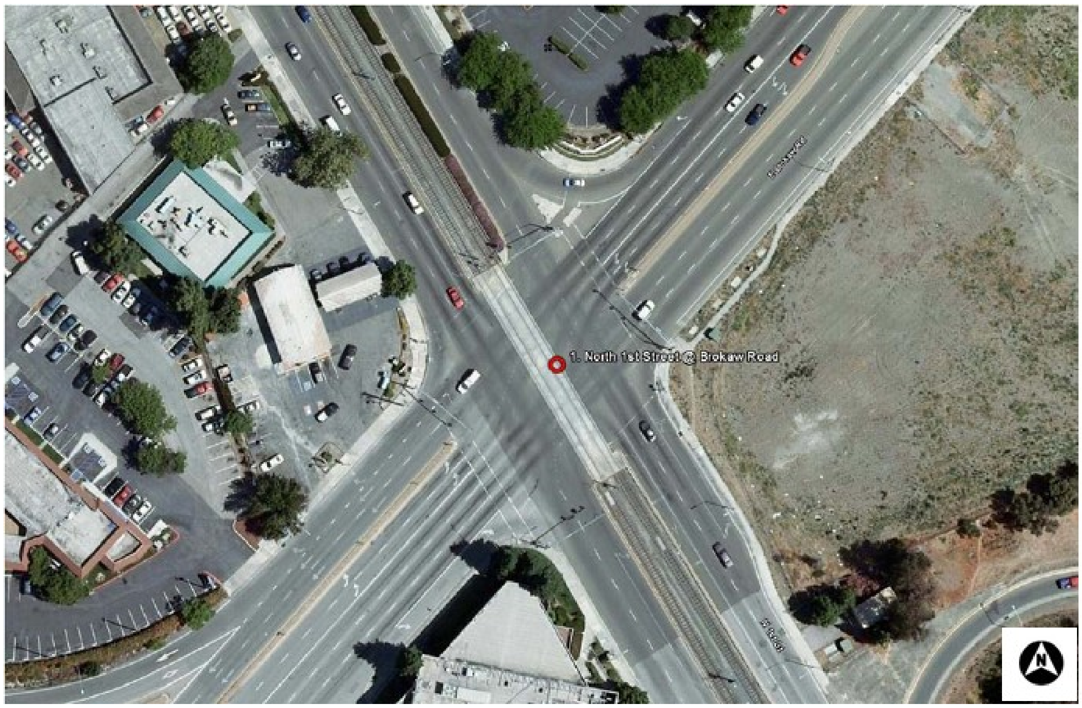

Figure 4. Aerial View of North First Street and Brokaw Rd.

Figure 5. Aerial View of North First Street and Charcot Ave.

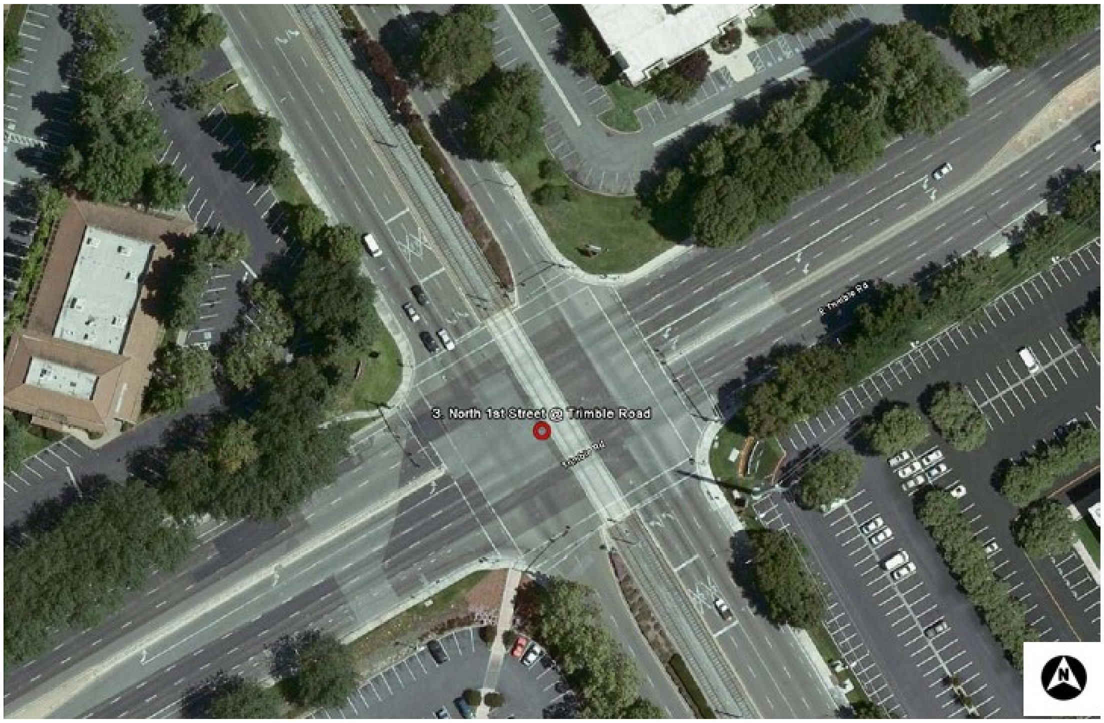

Figure 6. Aerial View of North First Street and Trimble Rd.

Table 5 summarizes the general geometric characteristics of the three study intersections. The designs of the study intersections, in general, provide separate lanes for the different movements (left-turn, through, right-turn). Two of the intersections are at right angles, with the intersection at Brokaw Rd. being at a slight skew (approximately 75 degrees). The intersection designs provide sufficient sight distance for all four approaches to each of the three intersections.

Table 5. Summary of Geometric Characteristics of Intersections within the Study Segment

	Brokaw	Charcot	Trimble
Total # of Major Street NB lanes	4	4	4
LT	1	2	2
(Length of LT bay)	300'	300'	300'
THRU........	2	2	2
RT........	1	shared	shared
Crosswalk........	no	yes	yes
Bike lane........	no	yes	yes
Total # of Major Street SB lanes	3	3	4
LT	1	1	2
(Length of LT bay)	275'	300'	300'
THRU........	2	2	2
RT........	narrow area	narrow area	shared
Crosswalk........	yes	yes	yes
Bike lane........	yes	yes	yes
Total # of Minor Street EB lanes	6	4	5
LT	2	2	1
(Length of LT bay)	300'	450'	300'
THRU........	3	2	3
RT........	1	narrow area	1
Crosswalk........	yes	yes	yes
Bike lane........	yes	no	yes
Total # of Minor Street WB lanes	4	4	5
LT	2	2	2
(Length of LT bay)	240'	250'	300'
THRU........	2	2	3
RT........	1	narrow area	1
Crosswalk........	yes	yes	yes
Bike lane........	yes	no	yes
Distance to nearest NB station	1080' N of intersection	1150' S of intersection	930' S of intersection
Distance to nearest SB station	500' N of intersection	1110' N of intersection	440' N of intersection
Approximate intersection angle	75 degrees	90 degrees	90 degrees
	4-way	4-way	4-way

Traffic Volumes

Table 6 shows the traffic volumes by turning movement. Traffic volumes were collected in 2008 and 2009, and according to the City of San Jose, traffic volumes have not changed by any noticeable margin since they collected these data. Peak hourly traffic volumes in the northbound direction along North First St. alone range from 533 vehicles per hour (vph) to 1,416 vph. The southbound peak hourly volumes range from a low of 400 vph to a high of 1,420 vph. On the cross-streets, the highest peak hourly volume, 1,786 vph between the hours of 8:00 a.m. and 9:00 a.m., occurs on the westbound Brokaw Rd. approach to North First St. The volumes of left-turn movements from North First St. across the track way ranged from a low of 46 vph on the southbound approach at Charcot Ave. to a high of 256 vph on the northbound approach at Trimble Rd.

Table 6. Traffic Volumes at Study Intersections on North First Street

Intersection of North First St. @	Northbound AM (PM)			Southbound AM (PM)			Eastbound AM (PM)			Westbound AM (PM)			Date Counted and Total Peak Hourly Volume AM (PM)	Peak Hours
	RT	THR	LT	RT	THR	LT	RT	THR	LT	RT	THR	LT		
Brokaw Rd.	309 (295)	660 (330)	106 (53)	120 (255)	231 (930)	85 (224)	83 (60)	672 (840)	542 (314)	385 (186)	1072 (918)	329 (463)	9/23/08 4616 (4919)	8:00-9:00 AM 5:00-6:00 PM
Charcot Ave.	100 (58)	564 (354)	75 (121)	205 (527)	289 (601)	46 (93)	11 (81)	602 (216)	532 (203)	55 (37)	166 (593)	45 (107)	3/24/09 2699 (3000)	7:45-8:45 AM 5:00-6:00 PM
Trimble Rd.	165 (71)	988 (519)	256 (252)	23 (121)	303 (923)	61 (130)	140 (119)	701 (984)	194 (117)	43 (36)	958 (767)	305 (241)	9/23/08 4165 (4285)	8:00-9:00 AM 4:45-5:45 PM

Source: City of San Jose Department of Streets and Traffic.

Pedestrian and Bicycle Volumes

All intersections have crosswalks and pedestrian signal displays. The pedestrian signals are timed to allow pedestrians to cross and clear the total width of North First St. from curb to curb in a signal pedestrian phase. Walk indications are displayed for at least 7 seconds before the Flashing Don’t Walk signal indication is displayed. None of the pedestrian signals have countdown displays. The number of pedestrians crossing at any of the intersection approaches ranges from 5 to 15 per hour. It is worth noting that the east-west, i.e., conflicting movements with light rail, pedestrian volumes at the intersections during the peak hours varied from 2 to 11 pedestrians per hour. Bicyclists are very few as well. Bicycle lanes are provided throughout the corridor, but less than 5 bicyclists per hour are usually observed during the peak period.

LRT Operational Data

Light rail operates at up to 35 miles per hour (mph) in the study section. The posted speed limit on North First St. at the study sites is 45 mph. Light rail operates with approximately 7 to 8 minute headways in both the north and south direction during the peak hours.

Traffic Signal Timing

The current operations at all three intersections include an eight-phase sequence with protected left-turn phasing for both North First St. and the cross-streets. All intersections have exclusive left-turn lanes. All left turns on the cross-streets have a lead-lead left-turn phase sequence. On North First St., the left-turn phase sequence is all lead-lead with the exception at Charcot Ave., which operates in a lag-phase sequence. All signals use Model 2070 controllers and special software by Fourth Dimension™ for transit signal priority (TSP). The TSP function in the software allows the controller to change left-turn phasing, skip phases, and also shorten phase timing in order to accommodate signal priority request by the VTA light rail vehicles.

CHAPTER 3: ASSESSMENT OF THE OPERATIONAL AND SAFETY ASPECTS OF EXISTING, ALTERNATIVE, AND POSSIBLE SUPPLEMENTAL TRAFFIC CONTROL DEVICES

The next step in the project was to analyze the operational and safety aspects of existing traffic control devices, as well as alternative and possible supplemental traffic control devices that could be used at the intersections identified for study, namely:

- North First Street and Brokaw Rd.;
- North First Street and Charcot Ave.; and
- North First Street and Trimble Rd.

The general approach to this analysis was to gather and analyze a variety of data that would indicate how well the intersections currently operate and the existing level of safety at the intersections. Specifically, the approach to the analysis was three-fold as is presented in Table 7.

Table 7. Approach to the Assessment of Existing, Alternative, and Possible Supplemental Traffic Control Devices

Approach	For the Assessment of:	
	Existing Traffic Control Devices	Alternative and Possible Supplemental Traffic Control Deices
(1) Gather and analyze historical safety-related data provided by the local agencies.	✓	
(2) Observe and analyze operations and driver behavior through field video data collection.	✓	
(3) Examine qualitative data collected through focus groups with local drivers.	✓	✓

The data and results are presented below.

ASSESSMENT OF THE OPERATIONAL AND SAFETY ASPECTS OF EXISTING TRAFFIC CONTROL DEVICES

The primary means for assessing the operational and safety aspects of existing traffic control devices were (a) to gather and analyze historical safety-related data and (b) observe and analyze operations and driver behavior through field video data collection. This section of the report presents a synthesis of the data and findings from the analyses. Qualitative data collected through focus groups with local drivers was also examined, and these results are presented in the subsequent section.

Analysis of Safety-Related Data

The team requested and examined the following safety-related data:

- Historical crash data; and
- Historical near miss data.

These data are presented for the three study locations below.

Historical Crash Data

The research team gathered crash data from both the City of San Jose and the VTA. Both data sets represented 3 years worth of crashes. The city reported motor vehicle crashes that occurred between May 10, 2006 and May 10, 2009. The VTA reported LRV-motor vehicle crashes that occurred between May 19, 2006 and April 22, 2009.

Tables 8 and 9 present a high-level summary of the city-reported motor vehicle crashes. Table 8 shows the total number of motor vehicle crashes that occurred at each of the study intersections along with the total number of fatal crashes and total number of injury crashes. Table 9 highlights the crash types of particular interest when considering LRT operation through an intersection: those crashes involving pedestrians, bicycles, and LRVs, as well as those crashes involving red-light running or right-angle crashes. The data shown in Table 9 are not meant to provide a complete categorization of the crashes but rather to point out the types of motor vehicle crashes that are potentially of higher risk at intersections with LRT.

In all, there were 109 reported motor vehicle crashes at the three intersections over the 3-year period. There were no fatalities, and less than one-third of the crashes involved minor injuries. Six crashes (6 percent) involved LRVs, and four crashes (4 percent) involved pedestrians. A total of 17 crashes (16 percent) were a result of vehicles running red lights.

Table 8. Total, Fatal, and Injury City-Reported Motor Vehicle Crashes at Study Intersections

Intersection of North First St. @..	Total Crashes	Total Fatal Crashes	Total Injury Crashes
Brokaw Rd.	64	0	15
Charcot Ave.	14	0	7
Trimble Rd.	31	0	10
Total	109	0	32

Source: City of San Jose Department of Streets and Traffic.

Table 9. Critical Crashes at Study Intersections

Intersection of North First St. @..	Number of Crashes Involving:				
	Ped	Bike	LRV	Vehicle Running Red Light	Right Angle Crash
Brokaw Rd.	2	2	4	9	9
Charcot Ave.	1	1	1	4	5
Trimble Rd.	1	1	1	4	5
Total	4	4	6	17	19

Source: City of San Jose Department of Streets and Traffic.

Appendix A presents a more detailed breakdown of the city-reported crashes in terms of a number of factors, including crash type, probable cause, direction of movements, day of week, time of day, weather conditions, lighting conditions, and surface conditions at the three intersections. The following discussion summarizes the issues identified as being most relevant to this project:

- Intersection of North First Street and Brokaw Rd.—During the 3-year period, there were 64 reported crashes at this intersection, by far the highest crash rate of the three study intersections; however, there were no fatalities, and only 23 percent of the crashes resulted in injuries. A large majority of crashes (over 80 percent) occurred during daylight hours, clear conditions, and on dry pavement. Rear-end crashes were the predominate type of crash (39 percent). Right-angle crashes accounted for about 14 percent of the crashes. Five of the right-angle crashes were between southbound and westbound vehicles, and four were between southbound and eastbound vehicles. In four of the nine right-angle crashes, red-light running was cited as the cause of the crash, and in one of these cases it was the cross-street vehicle that was cited for the red-light violation.

  In the 3 years, there were four LRV-motor vehicle crashes. Two of these were a result of a northbound left-turn violation, one involved unsafe backing, and one involved an unsafe lane change. The two left-turn related LRV crashes resulted in injuries; three people suffered minor injuries in these crashes.

  While there was a large number of crashes at this intersection over the past 3 years, red-light running on North First St. (in particular, the southbound through movement and the northbound left-turn movement) appears to be the biggest concern at this intersection.

- Intersection of North First Street and Charcot Ave.— Over the 3-year period, there were 14 reported crashes at this intersection, the lowest crash rate of the three study intersections. There were no fatalities, and eight people were reported to have been injured in seven of the crashes. The predominant crash type was right-angle crashes (36 percent). Of the five right-angle crashes, two drivers were cited for running a red light (one southbound on North First St. and one eastbound on Charcot Ave.) In two of the crashes the cause was "unknown." In the other, a driver on Charcot Ave. made a right turn on red and was hit by a northbound vehicle.

  In the 3 years, there was one LRV-motor vehicle crash. This crash was a result of a northbound left-turn violation. One person suffered a minor injury.

  There is not a clear crash pattern at Charcot Ave. that would indicate a particular operational or safety concern or problem. In fact, the overall low crash rate at this intersection, as compared to the others, indicates that it is the safest of the three intersections.

- Intersection of North First Street and Trimble Rd.— Over the 3-year period, there were 31 reported crashes at this intersection. None of the crashes resulted in a fatality, and injuries were reported in about one-third of the crashes. As with the other intersections, the large majority of the crashes occurred during daylight hours and under clear, dry conditions. Five (16 percent) of the crashes at Trimble Rd. were classified as right-angle crashes. Three of the right-angle crashes were a result of red light running (two on North First St. and one on Trimble Rd.). In the other two crashes the cause was "unknown."

  In the 3-year period, there was one LRV-motor vehicle crash. This crash involved a motor vehicle making a southbound U-turn. The cause for this crash was recorded as "unknown."

  As with the other intersections, there is not a clear crash pattern at Trimble Rd. that would indicate a particular operational or safety concern or problem.

For this project, it is important to characterize and assess the LRV-related crashes at the three study intersections. Table 10 characterizes the six LRV-related crashes, as reported by the City of San Jose Department of Streets and Traffic.

Table 10. Summary of Crashes at the Study Intersections Involving LRVs

Intersection of North First St. @	Total Crashes	Total LRV Fatal Crashes	Total LRV Injury Crashes	Number of Crashes Involving LRV and:					
				Ped	Bike	Left-turn Vehicle Running Red Light from North First St.	Vehicle Making Unsafe Backing Maneuver	Vehicle Making Unsafe Lane Change	Unknown
Brokaw Rd.	4	0	0	0	0	2	1	1	0
Charcot Ave.	1	0	0	0	0	1	0	0	0
Trimble Rd.	1	0	0	0	0	0	0	0	1

Source: Data were provided by the City of San Jose Department of Streets and Traffic.

As stated previously, the city data show six LRV-related crashes in the past 3 years at the three study intersections. Four of the six crashes (67 percent) occurred at Brokaw Rd. One LRV-related crash was reported at each of the other two intersections in the past 3 years. Of the LRV-related crashes, none involved pedestrians or bicyclists. One-half of the crashes (two of the four) involved vehicles making left turns from North First St. onto the cross-streets.

The team also received crash data from the VTA. Table 11 characterizes the LRV-related crashes as reported by the VTA. It is not surprising that the data obtained from the VTA are not completely consistent with the city-reported data, because crashes that occur within the track right-of-way may be reported solely by the VTA. In addition, the VTA data are somewhat more descriptive of the LRV-motor vehicle collisions than the city-reported data.

The VTA data show 11 total LRV-related crashes over the 3-year period (as opposed to 6 crashes in the City-reported data). Six of the 11 (55 percent) crashes occurred at Brokaw Rd. There were two LRV-related crashes reported at Charcot Ave. and three LRV-related crashes reported at Trimble Rd. in the past 3 years. Of the LRV-related crashes reported by the VTA, none involved pedestrians or bicyclists. Nearly all of the crashes (10 of the 11 crashes, or 91 percent) involved vehicles making left turns from North First St. onto the cross-streets.

Table 11. Summary of Crashes Involving LRVs within VTA Right-of-Way

Intersection of North First St. @	Total Crashes	Total LRV Fatal Crashes	Total LRV Injury Crashes	Number of Crashes involving LRV and:				
				Ped	Bike	Left-Turn Vehicle Running Red Light from North First St.	Left-Turn Vehicle Violation	LRV Signal Violation
Brokaw Rd.	6	0	2	0	0	5	1	0
Charcot Ave.	2	0	1	0	0	1	1	0
Trimble Rd.	3	0	0	0	0	1	1	1

Source: Data were provided by the VTA.

Historical Near Miss Data

In addition to the actual crash data, the VTA provided information on near-miss incidents. These data are generated through reports filed by the LRV operators. The reports are based on specific actions taken by the operators, such as applying emergency brakes or slowing down to avoid a vehicle making an illegal movement, pedestrian(s) standing on the tracks, vehicles stopped on tracks, etc. While they do not represent actual crashes, these data provide excellent surrogate safety measures by identifying high-risk behaviors that could potentially lead to actual crashes. Table 12 categorizes the near-miss incidents reported at the three study intersections for the same 3-year period from 2006 to 2009. The categories shown in the table were taken from the VTA data. It is important to note that the categories are not mutually exclusive, as some crashes are reported in multiple categories.

In all, there were 29 near-miss incidents reported by train operators at the three study intersections during the 3-year period. Seventeen (57 percent) of these were reported at Brokaw Rd., while six (21 percent) were reported at each of the other two intersections. A majority of the near-miss incidents (21, or 72 percent) involved left- or U-turning vehicles, many of which were classified as a “left-turn violation.” There were two near-miss incidents, both at Brokaw Rd., involving a pedestrian crossing in front of the train. Twelve (41 percent) of the near-miss incidents involved the LRV operator applying the maximum brake, and an additional two (7 percent) involved the LRV operator applying the Level 5 brake (non-emergency service braking).

Table 12. Summary of Reported Light Rail Near Miss Incidents (5/22/06 to 4/21/2009) at Study Intersections on North First Street

Intersection of North First St. @	Total Reported Near-miss Incidents	Number of Near-miss Incidents Involving:							
		Left-turning Vehicle (including U- turns)	Vehicles with Left-turn Violation	Red-Light Running Vehicles (Direction Unknown)	Pedestrian Crossing in front of LRV	Bike Crossing in front of LRV	Track Intrusion	LRV Applying Maximum Brake (MB)	LRV Applying Level 5 Brake (B5)
Brokaw Rd.	17	14	7	2	2	0	0	5	1
Charcot Ave.	6	3	2	5	0	0	0	4	0
Trimble Rd.	6	4	0	0	0	1	1	3	1

Source: Data were provided by the VTA

Summary of Historical Safety-Related Data

Motor vehicle crash experience at the three study intersections included a range of crash types, a range of vehicle movements (i.e., vehicle direction of travel and movement at intersections), and a range of probable causes. As a result, it is difficult to identify specific motor vehicle crash patterns in the data that would be suggestive of any particular operational or safety problems or concerns, particularly as they related to LRT. Two discernable patterns were identified. First, at the intersection of North First St. and Brokaw Rd., southbound vehicles were involved in all nine of the right-angle crashes, and the drivers appear to have been at fault in at least five of the crashes (three were cited for running a red-light, one was hit while making a right turn on red, and one left the scene of the crash) and possibly in as many as seven (in two of the crashes, no fault or violation was identified). Southbound vehicles also appear to be over-represented in right-angle motor vehicle crashes at Trimble Rd., although in only one case was the driver cited for running a red light (the other two are unknown). However, with regard to the LRT, this is not a major concern.

The other issue of concern identified in the crash data, and one that is of more concern as it relates to LRT, is the left-turn violations at all three intersections. There were 11 LRV-motor vehicle crashes over the 3-year period at the 3 study intersections, 6 of which occurred at Brokaw Rd. Nearly all of these crashes (10 of the 11 crashes) involved vehicles making left turns from North First St. onto the cross-streets. In addition to the 11 crashes, there were 29 left-turn near-miss incidents reported by train operators, about 60 percent of which occurred at Brokaw Road. As with the crash data, left-turn violations make up the majority of the near-miss incidents. This pattern of left-turn violations is of obvious concern as it relates to LRT. This is the primary reason for VTA's ongoing left-turn improvement project.

It is encouraging that in only three of the 19 right-angle crashes reported in the 3-year period (one at each of the three intersections) was the cross-street driver cited for running a red light, a potential high-risk incident with regard to the LRT. Red-light running on the cross-street was also not something predominate in the near-miss data.

Observation of Operations and Driver Behaviors (Field Video Data)

In addition to the historical safety data, the team conducted field observational studies as a means of assessing the operational and safety aspects of the existing traffic control devices. This section of the report summarizes the methodology for the field video data collection and the results of the analysis.

Field Video Data Collection Methodology

Cameras were set up at approximately 200-250 feet in advance of the curb line of the intersection. This allowed the camera to capture all vehicular, pedestrian and light rail movements on the North First St. approaches, as well as observing the cross-street movements. At Brokaw Rd. and Trimble Rd., cameras were set up to on the northbound approaches to the intersections. At Charcot Ave., cameras were set up on both the northbound and southbound approaches to the intersection. Cameras were also positioned to capture the through and left-turn signal indications. Figures 7 through 9 show the placement, orientation, and capture area of the cameras at Brokaw Rd., Charcot Ave., and Trimble Rd., respectively.

Figure 7. North First Street at Brokaw Road

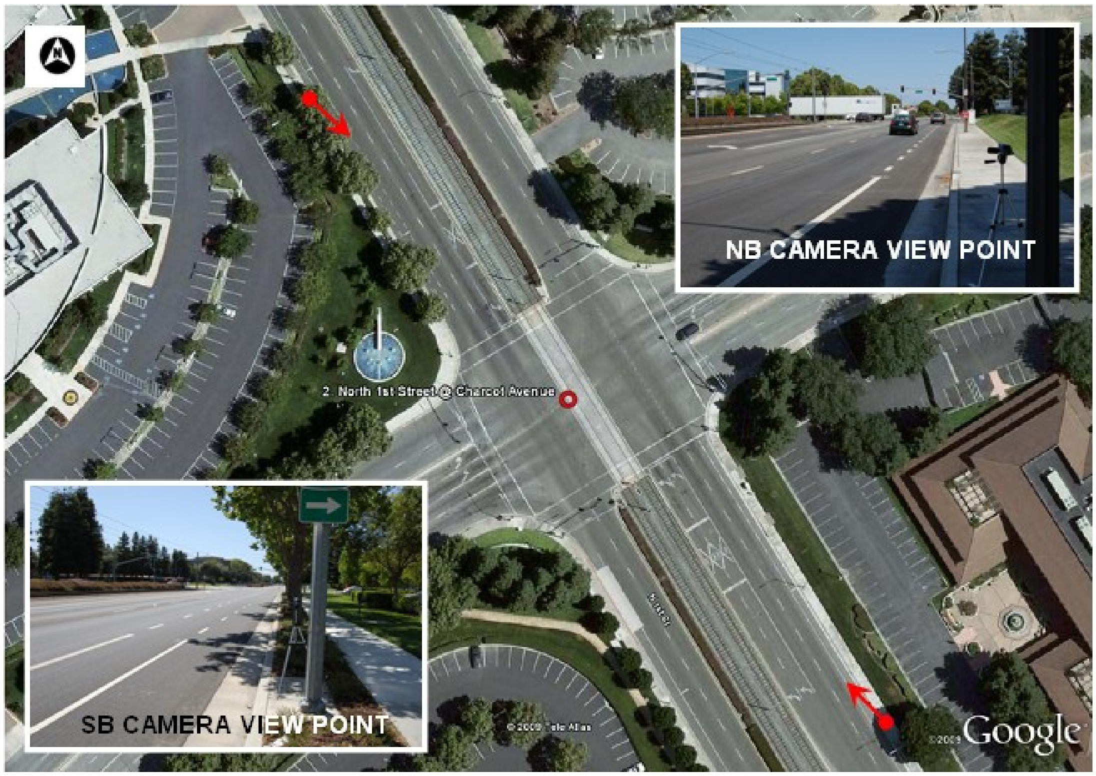

Figure 8. North First Street at Charcot Avenue

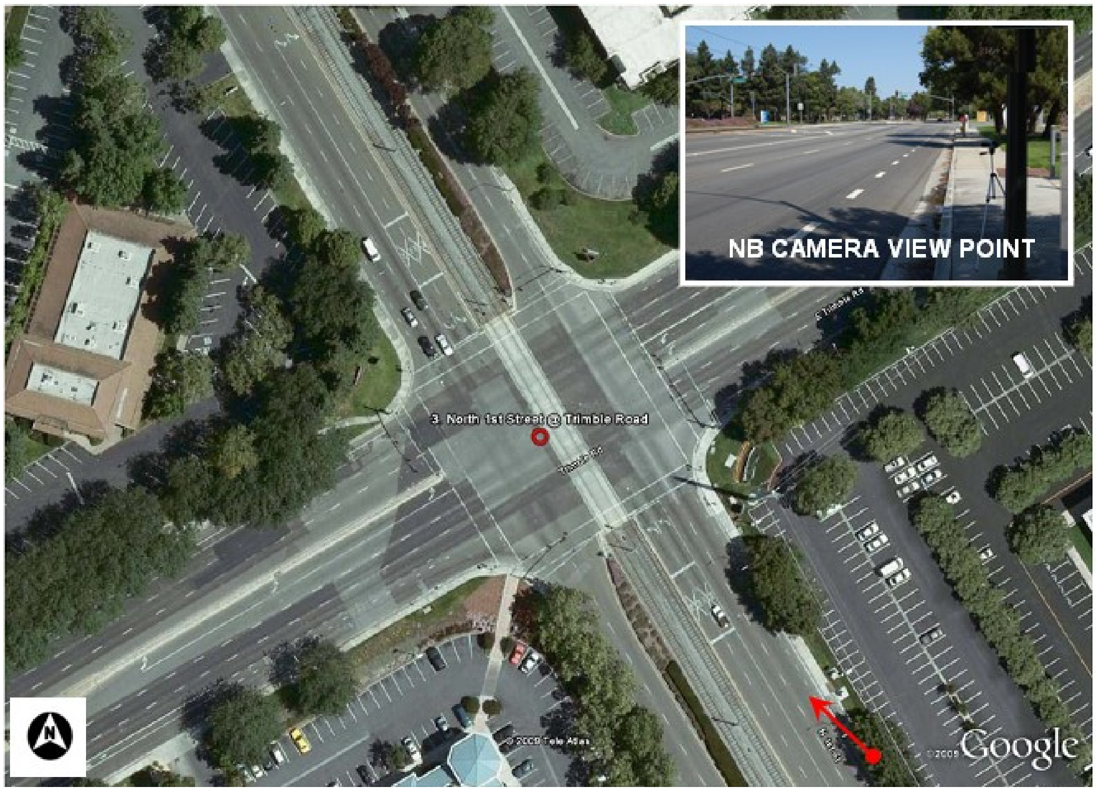

Figure 9. North First Street at Trimble Road

A group of five technicians was trained off-site and in the field as camera operators and observers before the actual field data collection commenced. Training included operating the video equipment; positioning the cameras and video settings to maximize the coverage areas, conflict events, and risky behavior maneuvers that should be identified; making notes of the implications of any of these conflicts or risky behaviors, if any; and manual recording of any special events such as crashes and conflicts that could not be seen within the camera view or that could bias the risky behavior observations. Following these training sessions, an engineer supervisor visited each intersection to set up the cameras and mark the position of the tripod legs on the sidewalk so that identical set-ups could be repeated on each of the five data collection days. The angle of the camera view and optimal zoom ratio to capture the intersection area also were noted at each location. Camera operators were also instructed to be inconspicuous but able to observe and time-stamp written notes of special events such as crashes, trapped pedestrians, near misses, or track intrusions. This information would later assist the data reduction team to observe and confirm those events.

Observations were recorded on five consecutive weekdays starting on Monday, June 22, 2009 between the hours of 7:00 a.m. and 9:00 a.m., 11:00 a.m. and 2:00 p.m., and 4:00 p.m. and 7:00 p.m., for a total of 8 hours each day. In total, 160 hours were recorded. A typical headway between LRVs in the same direction was 7.5 to 8 minutes, which resulted in 64 light rail crossings in each direction (128 crossings in both directions at each intersection on each observed day). LRV presence and headways were recorded by the observers throughout the 8-hour data collection period. Based on this headway information, there were 1,920 crossings where an LRV was present in either direction during the entire 160-hr data collection period at the three study intersections.

Collected data were reduced and summarized in the office by two trained technicians. The technicians tallied the observations for a pre-determined set of risky behaviors. Both technicians were supervised by the same engineering supervisor that trained and supervised the field technicians.

Risky behavior data that were collected from the video observations included the following categories:

- Motorists entering the intersection on change/clearance intervals (mainline or cross-street);
- Motorists entering the intersection on red interval (mainline or cross-street);
- Hesitation of left-turners and/or stopping beyond the stop line on North First St.;
- Unsafe lane change and/or backing for motorists on North First St.;
- Motorists stopping on tracks or queuing on tracks (due to congestion, etc.) for North First St. mainline left-turn or cross-street traffic movements;
- Pedestrians standing on or between tracks;
- Pedestrians/bicyclists crossing intersection on Don’t Walk display;
- Bicyclists stopping on tracks; and
- Light rail operator entering and clearing intersection during horizontal bar.

Field Video Data Results

Baseline field video data of drivers’ and pedestrians’ risky behaviors were collected during the week of June 22, 2009. Data were reduced by tallying the observations regarding a pre-determined set of risky behaviors. In order to clarify risky driver behavior patterns, the following were developed to categorize relevant risky behavior characteristics:

- Group 1: Left-Turn and Cross-Street Movements;
- Group 2: Right-of-Way (ROW) and Positioning Related;
- Group 3: Stopping on Tracks;
- Group 4: Pedestrian or Bicycle Related;
- Group 5: Light Rail Vehicle Related; and
- Group 6: Risky Behavior Observed without Direct LRT Impact.

Table 13 shows the categories and descriptions of risky behavior data collected in the field, and Table 14 summarizes the results of the risky behavior observations recorded for a total of 160 hours at three intersections locations.

Table 13. Risky Behavior Categories and Descriptions

RISKY BEHAVIOR OBSERVATION	DESCRIPTION OF BEHAVIOR
GROUP 1: LEFT-TURN AND CROSS-STREET MOVEMENTS	
Mainline left-turn change and clearance interval violation	Left turn motorist from North First St. enters intersection at the end of the yellow change interval or during the all-red clearance interval with and without train presence
Mainline left-turn red-light violation	Left turn motorist from North First St. Motorists enters intersection during the red interval with and without train presence
Mainline U-turn change and clearance interval violation	U-turn motorist from North First St. enters intersection at the end of the yellow change interval or during the all-red clearance interval with and without train presence
Mainline U-turn red-light violation	U-turn motorist from North First St. enters intersection during the red interval with and without train presence
Cross-street red-light violation	Motorist on cross-street enters intersection during the red interval with and without train presence
GROUP 2: RIGHT-OF-WAY AND POSITIONING RELATED	
Mainline through lane stop bar intrusion	Through motorist on North First St. stops on or passed the stop bar during the red interval
Mainline left-turn stop bar intrusion	Left- or U-turn motorist on North First St. stops on or passed the stop bar during the red interval
Lane change violation	Motorist in either the through or right-turn lane makes an illegal lane change to turn left from North First St.
Track intrusion violation	Motorist wrongly enters track right-of-way
GROUP 3: STOPPING ON TRACKS	
Vehicle stopped on tracks	Motorist stops on tracks for reasons other than queuing, blocking, or yielding to violating motorists or pedestrians

RISKY BEHAVIOR OBSERVATION	DESCRIPTION OF BEHAVIOR
Mainline left-turn vehicles queued on tracks.......	Left turn motorist from North First St. stops on tracks due to a queue spillback on cross-street
Cross-street left-turn vehicles queued on tracks	Left turn motorist from cross-street stops on tracks due to a queue spillback on North First St.
Cross-street through vehicles queued on tracks	Through motorist from cross-street stops on tracks due to a queue spillback in the downstream receiving lanes
GROUP 4: PEDESTRIAN OR BICYCLE RELATED	
Pedestrian standing on tracks	Pedestrian did not complete crossing during Walk or Flashing Don't Walk signal display and is standing between the tracks or in the track right-of-way envelope
Pedestrian intersection violation	Pedestrian crosses North First St. during the Don't Walk signal display
Pedestrian jay-walking violation..........................	Pedestrian crosses North First St. outside of a designated crosswalk
Bicyclist mainline left-turn red-light violation	Left turn bicyclist on North First St. enters intersection during the red interval
Bicyclist cross-street red-light violation...............	Bicyclist on cross-street enters intersection during the red interval
GROUP 5: LIGHT RAIL VEHICLE RELATED	
Light rail vehicle violation	Light rail vehicle enters or clears intersection during the horizontal white bar LRV signal indication
Light rail emergency braking..............................	Light rail operator applies emergency/maximum brakes
GROUP 6: RISKY BEHAVIOR OBSERVED WITHOUT DIRECT LRT IMPACT	
Other..	Any event that is not described above and considered 'risky', but does not have a direct impact on the LRT operations and/or ROW (e.g., vehicles backing up to change lanes after stopping at the intersection, right turn maneuvers from the left turn lane), any signs of aggressive driver behavior (i.e., cutting off, abrupt stops and lane change maneuvers, etc.), and right turns on red that conflicts with opposing traffic.
Vehicles backing up to change lanes	
Right turn or through maneuvers from the left lane	
Left turn from through or right turn lane	
Aggressive driver behavior (cutting off, abrupt stops)	
Right turn on red that opposes through traffic	
Mainline through red-light violation	Through motorist from North First St. Motorists enters intersection during the red interval without train presence

Table 14. Summary of Risky Behavior Observations

RISKY BEHAVIOR OBSERVATION	Number of Risky Behavior Observations	North First St. at							
		Brokaw Rd.		Charcot Ave.		Charcot Ave.		Trimble Rd.	
		Northbound		Northbound		Southbound		Northbound	
GROUP 1: LEFT-TURN AND CROSS STREET MOVEMENTS									
Mainline left-turn change and clearance interval violation	19	5		4		4		6	
Mainline left-turn red-light violation	2	0		0		1		1	
Mainline U-turn change and clearance interval violation	9	4		3		2		0	
Mainline U-turn red-light violation	3	0		1		2		0	
Cross-street red-light violation	9	EB	WB	EB		WB		EB	WB
		2	0	1		5		1	0
GROUP 2: RIGHT-OF-WAY AND POSITIONING RELATED									
Mainline through lane stop bar intrusion	13	9		2		0		2	
Mainline left-turn stop bar intrusion	12	0		2		2		8	
Lane change violation	1	0		0		1		0	
Track intrusion violation	2	0		0		2		0	
GROUP 3: STOPPING ON TRACKS									
Vehicle stopped on tracks	2	2		0		0		0	
Mainline left-turn vehicles queued on tracks	2	2		0		0		0	
Cross street left-turn vehicles queued on tracks	28	EB	WB	EB	WB	EB	WB	EB	WB
		0	28	0	0	0	0	0	0
Cross street through vehicles queued on tracks	6	EB	WB	EB	WB	EB	WB	EB	WB
		5	1	0	0	0	0	0	0
GROUP 4: PEDESTRIAN OR BICYCLE RELATED									
Pedestrian standing on tracks	4	0		1		1		2	
Pedestrian intersection violation	22	7		7		2		6	
Pedestrian jay-walking violation	2	1		1		0		0	
Bicyclist mainline left-turn red-light violation	0	0		0		0		0	
Bicyclist cross-street red-light violation	0	0		0		0		0	
GROUP 5: LIGHT RAIL VEHICLE RELATED									
Light rail vehicle violation	0	0		0		0		0	
Light rail emergency braking	0	0		0		0		0	
GROUP 6: RISKY BEHAVIOR OBSERVED WITHOUT DIRECT LRT IMPACT									
Other	14	65*		6		6		2	
Vehicles backing up to change lanes	17			9		4		4	
Right turn or through maneuvers from the left lane	64			21		14		29	
Left turn from through or right turn lane	40			9		4		27	
Aggressive driver behavior (cutting off, abrupt stops)	1			0		0		1	
Right turn on red that opposes through traffic	1	0		1		0		0	
Mainline through red-light violation	35	NB	SB	NB		SB		NB	SB
		8	2	6		13		5	1
TOTAL (GROUPS 1-6)	373	141		74		63		95	

* During the data reduction for North First St. and Brokaw Rd. intersection, risky behavior observations under the "RISKY BEHAVIOR OBSERVED W/O DIRECT LRT IMPACT" were not separated into subcategories; however, these observations are included in the total number of observations.

A brief summary of the baseline condition data is as follows:

- The most observed risky behavior associated with a light rail maneuver was a left-turn during the yellow change and all-red clearance intervals, and in several cases completing the turn while the red interval was expiring. This behavior occurred consistently at all three intersections.
- The type of risky behavior with the highest potential for severe results was entering the intersection on red several seconds after the yellow interval had expired.
- Pedestrian risky behavior did not demonstrate a high potential of severe implications. Several pedestrians crossed the intersection either during the Don't Walk interval, or continued to cross after the Flashing Don't Walk had expired. Risky behaviors were rare events and tended to be proportional to the frequency of the maneuvers. All three intersections had minimal pedestrian activities.
- Risky behavior associated with cross-street motorists entering the intersection on red was minimal; a mere nine violations were observed during the 160 hours of data collection. The westbound movement at Charcot Ave. had the highest frequency of red light violations; five of the total nine observations at all three intersections.
- There were no observations of vehicles getting stuck in the track right-of-way.
- The intersection of North First St. and Brokaw Rd. had the highest frequency of risky behaviors. Vehicles making westbound left turns onto southbound North First St. often could not clear the intersection due to downstream queuing, which resulted in vehicles stopped on the tracks.
- Overall, none of the three intersections demonstrated unusual risky behaviors.

ASSESSMENT OF THE OPERATIONAL AND SAFETY ASPECTS OF ALTERNATIVE AND POSSIBLE SUPPLEMENTAL TRAFFIC CONTROL DEVICES

The primary means for assessing the operational and safety aspects of alternative and possible supplemental traffic control devices was through the use of focus groups with local drivers.

Focus Group Design and Process

Focus groups were conducted in June 2009 in San Jose, CA. The focus groups were conducted to explore the opinions of drivers regarding existing traffic control devices as well as a variety of alternative and supplemental traffic signal displays, signs, and pavement markings at intersections where traffic interfaces with light rail transit. Focus groups were conducted in San Jose to obtain input from local drivers with experience driving in proximity to the VTA light rail system.

Thirty people (recruited by a local company in the San Jose area) participated in three focus group sessions. Participants were:

- Fairly evenly divided by sex – 57 percent were female;
- Representative of a range of ages – 60 percent were under 40 years old, 30 percent were between the ages of 40 and 60, and the remaining 10 percent were 60 years old or above;
- Long time residents of the San Jose area – almost one-third reported having lived in San Jose their entire lives, and 40 percent lived there over 20 years; and
- Well acquainted with the light rail system – nearly 75 percent drove "often" or "frequently" on streets that included light rail and many had used the light rail system (though most do not currently use the system except to attend "crowded" events).

The focus groups were designed around three different scenarios in which motor vehicles interfaced with LRT at signalized intersections. The three scenarios included:

- No Left Turn Allowed Scenario (parallel to the LRT line);
- Left Turn Allowed Scenario (parallel to the LRT line); and
- Cross-Street Scenario (perpendicular to the LRT line).

Participants were shown 27 different simulated scenes from the driver's perspective in an automobile. The No Left Turn Allowed Scenario is illustrated in Figure 10. In this scenario, participants were told that the driver was traveling parallel to a light rail line and needed to turn left at the first intersection where a left turn was allowed. Under this scenario, participants were shown eight different scenes. In each scene, the left-turn movement was restricted at the intersection, and a passive sign was provided to indicate this restriction to drivers. However, the scenes varied in terms of whether the through movement had circular green or green arrow displays and the type of sign present (three different signs were used, as shown in Figure 10).

10a. (R3-2) 10b. 10c.

Figure 10. No Left-Turn Allowed Scenario with Various Combinations of Traffic Signal Displays and Three Different Signs

The Left Turn Allowed Scenario is illustrated in Figure 11. In this scenario, participants were also told that the driver was traveling parallel to a light rail line and needed to turn left at the first intersection where a left turn was allowed. Under this scenario, participants were shown ten different scenes. In each scene, a left turn was allowed at the intersection, and an active blank-out warning sign was provided to indicate to the driver if a train was approaching. However, the scenes varied in terms of whether the left-turn movement had the green or red arrow signal display, whether the through movement had circular green displays or green arrow displays, whether a train was approaching, and the type of active blank-out sign present (five different activated blank-out signs were used, as shown in Figure 11).

11a. (W10-7) 11b. 11c. 11d. 11e. (R3-2a)

Figure 11. Left-Turn Allowed Scenario with Various Combinations of Traffic Signal Displays and Five Different Blank-out Signs

The Cross-Street Scenario is illustrated in Figure 12 and Figure 13. In this scenario, participants were told that the driver was traveling on a street running parallel to a light rail line and needed to go through the intersection, crossing over the tracks. Both through movements and left-turn movements were allowed at the intersection shown in this scenario; however, the car was positioned in a through lane. Under this scenario, participants were shown nine different scenes. In each scene, some form of warning sign was present, whether it be passive, active, or both. The scenes varied in terms of whether the left-turn movement had a green or red arrow signal display, whether the through movement had green or red signal displays, whether a train was approaching, and the type of passive and active traffic control devices that were present (two different passive signs were used—a trolley crossing warning sign and the R15-7 regulatory sign, as shown in Figure 12—and two different active devices were used—the W10-7 sign (shown in the top picture of Figure 13) and in-pavement lights (shown in the bottom picture of Figure 13).

Figure 12. Cross-Street Scenarios with Various Combinations of Traffic Signal Displays and Two Different Passive Signs (Trolley Crossing Warning and R15-7)

Figure 13. Cross-Street Scenarios with Various Traffic Signal Displays and Two Different Types of Active Traffic Control Devices (W10-7 Sign and In-pavement Lights)

Each focus group was divided into the following three activities, shown in the order that they occurred:

- Comprehension activity;
- Comparison activity; and
- Discussion.

During the comprehension activity, the participants were shown all 27 scenes. They were told to pay attention to the lane that the car was in and were asked to determine if the driver should stop, turn left, or go straight. A response sheet was provided for the participants on which to record their answers for each of the 27 scenes. They were also asked to record, based on the information in each scene, the probability that a train was approaching the intersection. They were asked to record any value between 0 and 100 percent – 100 percent if they were absolutely certain a train *was approaching* the intersection and 0 percent if they were absolutely certain a train *was not approaching* the intersection.

During the comparison activity, the participants were shown pictures in pairs. Each pair of pictures showed a particular situation with a slight variation in traffic signal displays, signs, or pavement markings. During this activity, participants were asked to decide which of the two scenes was better at conveying to drivers what they should do at the intersection. In each pair of pictures there was a picture labeled “A” and a picture labeled “B.” The participants were provided another response sheet to record their choice. There were a total of 20 comparisons.

During the discussion activity, participants were asked specific questions about the traffic control devices they saw during the previous activities. Questions included:

- Which of the three traffic signs is the best for indicating to drivers that a left turn is NOT permitted at the intersection?
- Which of the five electronic signs is best for indicating to drivers that a train is coming and that a left turn MUST NOT be made at this time?
- Which of the two traffic signs is better to indicate to drivers that they are at an intersection that crosses light rail tracks?
- Is an electronic train-coming sign helpful in the cross-street situation? Are both the passive traffic sign and the electronic sign needed?

Asking these questions during the focus group provided a more in-depth understanding about why participants may not have understood the meaning of particular device and why participants chose one device over another in the comparison activity.

Focus Group Results

For the No Left Turn Allowed scenario, the results of the comprehension activity are shown in Table 15. Regardless of the type of sign or traffic signal displayed, participants overwhelmingly were aware of the appropriate action, with between 83 and 93 percent responding correctly to “go straight.” Scene 17, which had the R3-2 No Left Turn symbol sign (Figure 10a) and green thru arrow signal displays yielded the highest percentage of correct responses of the eight scenes. Interestingly, when through arrows on the pavement in both lanes were added to this scene, which was done in Scene 23, this yielded one of the lowest percentages of correct responses. Scene 25, the only other scene with through arrow pavement markings, also yielded a mere 83 percent correct responses.

With regards to the probability that a train was approaching, it was never known whether or not a train was approaching; therefore, the correct response in all eight scenes was “maybe.” While the majority of respondents gave the correct response in all scenes except Scene 11, fewer participants correctly interpreted that a train might be coming as compared with their understanding of what they should do at the intersection. In examining the findings, there does not seem to be a reasonable explanation as to why the respondents answered the way they did. The traffic signal was always green, which, it was anticipated, would have indicated more to participants that a train would be coming than “definitely not” coming, which was the second most common response. One explanation could be that the participants were not familiar with this particular scenario and were confused about the relation between these scenes and the arrival of the trains. It almost appears as though the responses improved as the scenes were shown, indicating that participants may have "learned" to interpret and understand the scenes under this scenario.

Table 15. Comprehension: No Left Turn Allowed Scenario

Scene Numbers	What SHOULD the driver do?	Participant's Response			Is there a train coming?	Participant's Response to probability of train approaching		
		Go		Stop		Definitely Not	Maybe	Definitely Yes
		Left	Straight					
11	Go Straight	0%	93%	7%	Not Known	63%	37%	0%
13	Go Straight	10%	83%	7%	Not Known	33%	57%	10%
15	Go Straight	3%	93%	3%	Not Known	33%	57%	10%
17	Go Straight	0%	97%	3%	Not Known	37%	53%	10%
19	Go Straight	10%	87%	3%	Not Known	27%	70%	3%
21	Go Straight	7%	87%	7%	Not Known	24%	69%	7%
23	Go Straight	3%	83%	14%	Not Known	30%	67%	3%
25	Go Straight	3%	83%	14%	Not Known	30%	67%	3%

The results of the comparison activity are shown in Table 16. The R3-2 No Left Turn symbol sign (Figure 10a) was compared with the version that also depicted railroad tracks (Figure 10b), as well as with the text version of the sign (Figure 10c). The majority of the participants preferred the R3-2 sign in both comparisons. In the discussions, most participants did not like the symbol sign with the tracks because it was not clear what the tracks were; some thought it looked like a ladder. The text version of the sign was the least popular among participants. Some participants commented that not all drivers can read English, and the sign might take longer to process. The R3-2 sign was thought to be simple, with no need for further interpretation or modification.

When comparing the traffic signal displays (comparison 4), in general, the green arrow displays were preferred over the circular green displays, and the through arrows on the pavement were generally popular with participants (comparison 5). When the green arrow signal displays were compared with the circular green signal displays and through arrows on the pavement (comparison 6), the majority of participants preferred the circular green signal displays and the arrow pavement markings. When the two different signal displays were paired with through arrows on the pavement (comparison 7), participants were split almost evenly on the arrow versus circular signal displays. In this case, a few participants noted that having arrows on both the signal displays and on the pavement might be unnecessary or "too much."

Table 16. Comparisons: No Left Turn Allowed Scenario

#	Traffic Signal Displays	Comparison	Traffic Control Devices for Scenario A	Traffic Control Devices for Scenario B	Which scenario is BETTER at conveying what the driver SHOULD do?	
					A	B
1	Green thru signals	Passive Signs	R3-2 sign	No Left Turn Across Tracks (symbol)	53%	47%
2	Green thru signals	Passive Signs	R3-2 sign	No Left Turn Across Tracks (text)	73%	27%
3	Green thru signals	Passive Signs	No Left Turn Across Tracks (text)	No Left Turn Across Tracks (symbol)	70%	30%
4	Green thru signals	Thru signals	Circular greens	Green arrows	37%	63%
5	Green thru signals	Pavement markings	No pavement markings	Through arrows on pavement	3%	97%
6	Green thru signals	Thru signals / pavement markings	Green arrows/ no pavement markings	Circular greens / through arrows on pavement	30%	70%
7	Green thru signals	Thru signals	Green arrows / through arrows on pavement	Circular greens / through arrows on pavement	53%	47%

For the Left Turn Allowed scenario, the results of the comprehension activity are shown in Table 17. Overall, an overwhelming number of participants knew what they should do in each of the 27 scenes. However, the blank-out signs shown in scenes 20, 22, and 24 (Figure 11c, d, and e, respectively) were not well understood by participants as compared to the W10-7 sign (shown in scenes 10, 16, 18, 26, and 27). While a majority of participants knew they should stop (there was a red left-turn arrow in each of these three scenes), less than a third of the participants knew for certain that a train was approaching when these signs were displayed. For the most part, it would appear that most participants did not realize these signs were meant to replace the W10-7 signs. This result may be because these three signs are unfamiliar to drivers in the San Jose area, who are accustomed to the W10-7 train-coming sign.

Table 17. Comprehension: Left Turn Allowed Scenario

Scene Numbers	What SHOULD the driver do?	Participant's Response			Is there a train coming?	Participant's Response to probability of train approaching		
		Go		Stop		Definitely Not	Maybe	Definitely Yes
		Left	Straight					
10	Stop	0%	0%	100%	Yes	0%	6%	93%
12	Turn Left	100%	0%	0%	No	87%	13%	0%
14	Turn Left	100%	0%	0%	No	77%	23%	0%
16	Stop	0%	3%	97%	Yes	0%	3%	97%
18	Stop	0%	0%	100%	Yes	3%	0%	97%
20	Stop	0%	3%	97%	Yes	13%	63%	23%
22	Stop	0%	10%	89%	Yes	13%	53%	33%
24	Stop	7%	13%	80%	Yes	7%	63%	30%
26	Stop	0%	3%	97%	Yes	0%	3%	97%
27	Stop	0%	3%	97%	Yes	0%	0%	100%

The other discrepancies in the responses for probability of a train approaching are not as clear. It is possible that a few people were aware that a train could technically be approaching even if the left turn movement had the green (in San Jose, the intersections are not pre-empted by the train; therefore, sometime the train must stop at the intersection). As such, while the left turn green arrow shown in scenes 12 and 14 was meant to indicate to drivers that a train was not approaching, it is not actually incorrect to respond that a train might be approaching, as did some participants. A few participants reported that they do not trust the lights. One participant said that even though there is a green light, he always assumes there is a train coming, "just to be cautious."

The results of the comparison activity for the Left Turn Allowed scenario are shown in Table 18. With regard to the W10-7 sign, the addition of the word "Train" seemed to be an improvement over the icon alone (80 percent of participants preferred the sign with the word "Train" in comparison number 10). There was a comment in the discussion about how the sign with the word "Train" makes it larger and more impressive, so there is a possibility that the size, not the message, may have swayed some of the participants. When comparing the W10-7 with the word "Train" to the VTA's new active train-coming sign, which alternates between the train icon and the No Left Turn symbol (comparison number 14), 63 percent of participants preferred the alternating sign. This is an interesting result when considering that the No Left Turn symbol activated blank-out sign, on its own, was not very popular when compared to the W10-7 (comparison number 11). One participant pointed out that if the alternating sign included the word "Train" it would be even better. Another participant noted that, because of the No Left Turn symbol, this sign could be confusing about whether you could ever make a left turn at this intersection. Overall, however, it appears from the results that the majority of participants favored the VTA's new alternating train-coming sign over all other options.

Table 18. Comparisons: Left Turn Allowed Scenario

#	Traffic Signal Displays	Comparison	Traffic Control Devices for Scenario A	Traffic Control Devices for Scenario B	Which scene is BETTER at conveying what the driver SHOULD do? A	B
8	Green thru and left signals	Thru signals	Circular greens	Green arrows	60%	40%
9	Green thru signals with Red turn signal	Thru signals	Circular greens	Green arrows	60%	40%
10	Green thru signals with Red turn signal	Active blank-out signs	W10-7	W10-7 with word “Train”	20%	80%
11	Green thru signals with Red turn signal	Active blank-out signs	W10-7	No Left Turn (symbol) activated blank-out sign	77%	23%
12	Green thru signals with Red turn signal	Active blank-out signs	No Left Turn Across Tracks (symbol) activated blank-out sign	No Left Turn (symbol) activated blank-out sign	50%	50%
13	Green thru signals with Red turn signal	Active blank-out signs	No Left Turn Across Tracks (symbol) activated blank-out sign	R3-2a activated blank-out sign	70%	30%
14	Green thru signals with Red turn signal	Active blank-out signs	W10-7 with word “Train”	W10-7 alternating with No Left Turn (symbol) activated blank-out sign	37%	63%
20	Green thru signals with Red turn signal	Existing versus improved conditions (per VTA project)	W10-7 with “Train”	W10-7 alternating with No Left Turn (symbol) activated blank-out, “Keep Clear” and bull nose pavement markings, and bollards	23%	77%

The improvements currently in progress by the VTA at several intersections across their system were illustrated in scene number 27, and participants were asked to compare the existing conditions to these improved conditions (comparison number 20). The participants comprehended the situation almost perfectly (as discussed above), and the majority (77 percent) thought the improvements would better convey to drivers what to do. In the discussion section, everyone seemed to prefer the improvements over the existing conditions. According to the comments, the yellow bull nose pavement markings and the “Keep Clear” pavement marking were big improvements over the existing conditions. The general consensus was this improved situation would make most people stop farther back from the intersection at the stop bar.

Another interesting comparison under this scenario was that the results of the circular green signal displays versus the green arrow signal displays (comparisons 8 and 9). The responses were split 60/40, with a slight majority preferring the circular green displays in both comparisons. Some reasons given for this result were that the circular green displays stand out more than the green arrow displays (they cover more surface area) and that too many arrows made the situation too overwhelming and confusing. The participants that liked the arrows reported that they provide drivers with more information and reinforced to drivers what they were supposed to do.

For the Cross-Street Scenario, the results of the comprehension activity are shown in Table 19. In all of the eight scenes, the through signals were red and the correct driver action was to stop; however, different left-turn displays and various active warning devices were used to indicate to participants whether or not a train was approaching the intersection. In only two scenes (scenes 2 and 4) was the approach of a train unknown based on the traffic control devices.

As with the other scenarios, a large majority of participants understood what they should do at the intersection. There did seem to be some confusion for a small percentage of the participants about whether the correct action was to stop or go (straight or left); however, this was likely a function of the design of the focus group activity not the traffic control devices. With the Cross-Street scenario, participants did appear to be less aware or confident of the meaning of the traffic control devices in relation to whether or not a train was approaching than in the scenarios on the parallel street. This finding could be a function of the predictive priority system used in San Jose (sometimes the train does have to stop at the intersections), as discussed previously. It does appear that some type of active device on the cross-street could help clear up some of the uncertainty drivers appeared to have on the cross-street as to the arrival of a train.

The results of the comparison activity are shown in Table 20. The trolley crossing warning sign used in San Jose was compared to the MUTCD R15-7 divided highway regulatory sign (comparisons 15 and 18). The majority of participants preferred the trolley crossing over the R15-7 sign. The participants preferred the warning sign because it was yellow and would attract the driver's attention. They also thought the R15-7 sign was confusing and did not necessarily give the message that there were in tracks and not just a wide median. However, many participants felt the trolley crossing warning sign could be improved by saying instead "Train Crossing." This change would make the sign seem more serious and less "friendly looking."

Table 19. Comprehension: Cross-Street Scenario

Scene Numbers	What SHOULD the driver do?	Participant's Response			Is there a train coming?	Participant's Response to probability of train approaching		
		Go		Stop		Definitely Not	Maybe	Definitely Yes
		Left	Straight					
1	Stop	7%	10%	83%	No	63%	36%	0%
2	Stop	3%	3%	93%	Not Known	20%	64%	17%
3	Stop	10%	7%	83%	No	57%	42%	0%
4	Stop	3%	3%	93%	Not Known	23%	67%	10%
5	Stop	13%	3%	83%	No	53%	40%	7%
6	Stop	0%	3%	97%	Yes	7%	10%	83%
7	Stop	10%	7%	80%	No	67%	29%	3%
8	Stop	0%	0%	100%	Yes	7%	3%	90%
9	Stop	0%	3%	97%	Yes	7%	64%	30%

Table 20. Comparisons of Different Intersection Treatments: Cross-Streets

#	Situation	Comparison	Traffic Control Devices for Scenario A	Traffic Control Devices for Scenario B	Which scene is BETTER at conveying what the driver SHOULD do?	
					A	B
15	Red thru signals with Green turn signal	Passive signs	Trolley crossing warning sign	R15-7 divided highway sign	63%	37%
16	Red thru signals with Green turn signal	With or without W10-7 sign (with trolley crossing sign)	Without W10-7 sign	With W10-7 sign	10%	90%
17	Red thru and left signals	R15-7 divided highway sign with or without W10-7 sign	Without W10-7 sign	With W10-7 sign	7%	93%
18	Red thru and left signals	Passive signs (with active warning device)	Trolley crossing warning sign	R15-7 divided highway sign	70%	30%
19	Red thru and left signals	Different active warnings (with trolley crossing sign)	W10-7 sign	In-pavement lights	83%	17%

When comparing the existing conditions without an active warning device on the cross-street to a scene with a W10-7 sign mounted on the mast arm (comparisons 16 and 17), the overwhelming majority of participants preferred the scene with the W10-7 sign. All the participants generally agreed that the active blank-out signs were helpful on the cross-street. Most people agreed that the extra information was useful and would better catch the driver's attention, although some felt that it was not necessary because the light was already red. A couple of participants noted that the active signs could also be helpful for pedestrians as it would stop them from crossing the main street when a train is coming.

In comparison 19, the W10-7 sign was compared with in-pavement lights (similar to those used in Houston). A few of the participants (17 percent) indicated they preferred the in-pavement lights over the W10-7 sign. Most did not understand the in-pavement lights (several did not even notice them), and they felt that there would need to be a supporting sign explaining the meaning of the lights. This result could have been partially a function of the way the lights looked in the simulated scene.

SUMMARY AND CONCLUSIONS REGARDING OPERATIONAL AND SAFETY ASPECTS OF EXISTING, ALTERNATIVE, AND POSSIBLE SUPPLEMENTAL TRAFFIC CONTROL DEVICES

The operational and safety aspects of existing, alternative, and possible supplemental traffic control devices associated with controlling traffic at signalized intersections that interface with light rail transit were assessed as part of this research project. Existing traffic control devices at the three study intersections consist of conventional traffic signals, W10-7 train-coming activated blank-out signs for the left turn movements on North First St. (mounted adjacent to the left-turn signals), "RR Xing" pavement markings in the left-turn pockets on North First St., and "Trolley Xing" warning signs on the cross-street approaches.

To assess the operational and safety aspects of these existing traffic control devices, the research team gathered and analyzed data that would indicate how well the intersections currently operate and the existing level of safety at the intersections. These data consisted of historical crash and near-miss incident data and observations of operations specifically, driver behaviors at the intersections.

The team also assessed the operational and safety aspects of alternative and possible supplemental traffic control devices that might be used at the intersections to improve driver situational awareness and safety in general and under increased LRV speed conditions. Alternative and possible supplemental traffic control devices assessed included: a variety of alternative (and possible supplemental) train-coming activated blank-out signs, a variety of passive warning and regulatory signs, and alternative pavement markings. To assess these traffic control devices, the team conducted a series of focus groups with local San Jose drivers to obtain their feedback on the devices.

With regard to the existing traffic control devices, both the historical data and the observations of driver behaviors made at the three intersections show that the intersections currently operate well, with minor safety concerns. Drivers appear to understand the operation of the intersection with the LRT and generally respect and comply with the traffic control devices at the intersections. The primary crash type tends to be read-end crashes, followed by right-angle crashes. Rear-end crashes generally have little to do with traffic control device compliance (they are usually a result of speeding and drivers not paying attention) and they have almost no impact on LRT operations or safety. Right-angle crashes, on the other hand, can be indicative of problems with device compliance (e.g., drivers running red lights) and can have direct impact on the occurrence of LRT-motor vehicle crashes (when the red-light running is occurring on the cross-streets). However, right-angle crashes make up a small portion of the overall crashes at the study intersections. Of the 109 crashes that occurred at the intersections in the past 3 years, there were 19 right-angle crashes (17 percent). In addition, the data show that most of the red-light running is occurring on North First St., not the cross-streets. In fact, there were three crashes in the past 3 years (one at each intersection) where a cross-street driver was cited for running a red light). This is also supported in the near-miss incident and observational data. In a week’s worth of observational data (160 hours), there were nine observed red-light violations on the cross-streets (approximately three per intersection) as compared with 35 observed on the main street (North First St.) through red-light violations.

The primary operational and safety concern with regard to the traffic control devices appears to be the left-turn movements from North First St. onto the cross-streets; however the concerns are relatively minor. According to the crash data provided by the VTA, there were 11 LRV-motor vehicle crashes at the 3 intersections over the past 3 years (approximately 2 crashes per year at the intersection of Brokaw Rd., 1 crash per year at the intersection of Trimble Rd. and less than 1 crash per year at the intersection of Charcot Ave). Ten of the 11 crashes were a result of a left-turn violation. The driver observational data show that there were only five left-turn drivers observed running a red-light in the 160 hours’ worth of data. It is not clear whether the North First St. left-turn violations are a question of driver misunderstanding or confusion, or one of blatant noncompliance. The low number of violations and crashes suggests that it is not the former. If drivers were confused about what to do, the violation and crash rates would likely be much higher.

This interpretation is supported by the results and feedback received in the focus groups. While some participants did admit that North First St. can be confusing (especially for drivers not familiar with the situation), none of the participants was confused about what to do in the three left-turn allowed scenes with the existing traffic control devices (i.e., 100 percent comprehension about what to do). In addition, the feedback provided was that the existing traffic control devices are clear at conveying to drivers what they are supposed to do.

With regard to the alternative and possible supplemental traffic control devices, a number of findings stand out. First are the findings from the comparisons of the existing W10-7 sign to alternative train coming activated blank-out signs. Participants did seem to prefer the version of this sign with the word “Train” to the existing W10-7 sign (the sign with “Train” was preferred by four times as many participants, although there was no consensus on this). The fact that drivers familiar with LRT operations preferred the sign with the word “Train” could indicate that it could result in an operational and/or safety improvement over the existing sign.

Probably the most significant finding of the focus groups was the result and feedback received regarding the overall VTA improvements being made at all three study intersections. When the W10-7 sign with the word “Train” was compared to VTA’s new alternating blank-out sign, twice as many participants preferred VTA’s new sign, suggesting that it could be even a bigger improvement over the current sign. When comparing the overall VTA improvements (including pavement markings, recessed stop bar, and bollards) to the existing conditions (including the word “Train” on the W10-7), participants preferred the VTA improvements by nearly three to one. It appears that, based on the results of the focus groups, the VTA improvements are expected to result in improved operational and safety conditions.

With regard to the W10-7 sign on the cross-street, most participants thought it was helpful, but not necessary. Participants mentioned that at busy intersections it *could* be an improvement because you cannot always see the passive sign (it might be blocked by other cars or be mounted on one side of the road making it hard for drivers to see in the far lanes). Also, in cases when the signal phase is longer than normal, drivers may wonder why and start to get impatient. The W10-7 sign on the cross-street might inform them it is taking longer than normal because a train is coming.

Recommended Traffic Control Devices

Based on analyses of the historical safety data, observations of driver behaviors, and focus group findings, the supplemental and alternative traffic control devices being implemented by the VTA appear to address the issues of most concern at the study intersections (i.e., left-turn violations on North First St.). The VTA’s enhancements focus on changing driver behaviors during left-turn movements from both North First St. and the cross-streets that can lead to left-turn collisions and track intrusions, respectively. While the occurrence of these incidents was relatively low, the enhancements being made to the intersections should help further mitigate against these types of incidents in the future.

The VTA’s improvements do not include traffic control devices aimed at cross-street traffic. That is because the data (both historical safety data and observational driver behavior data) do not necessarily warrant such treatments. As stated previously, right-angle crashes represented a mere 17 percent of the crashes at these intersections over the past 3 years, and most of the red-light running appears to be occurring on North First St. as opposed to the cross-streets. Likewise, in the observational data, there were nine observed cross-street red-light violations as compared with 35 observed North First St. through red-light violations. In addition, focus group participants did not feel that the installation of the W10-7 signs on the cross-street was a necessary safety measure in San Jose.

However, while the crash and observational data may not necessarily warrant treatment on the cross-streets in San Jose, the research team would recommend that in some locations, the installation of W10-7 signs on the cross-street approaches would be a prudent countermeasure if train speeds were to be increased to 40 mph. The primary reason for this recommendation is to provide an active warning to drivers on the cross-street regarding the arrival of an LRV. Currently, when trains are operating in excess of 35 mph, the MUTCD requires the use of flashing lights on the cross-street and recommends the use of crossing gates. Therefore, the W10-7 signs could be used in lieu of flashing lights to provide the active warning to the cross-street drivers. Secondly, focus group participants were supportive of providing the W10-7 signs on the cross-street, especially at wide, busy intersections. In both comparisons of a cross-street scene without a W10-7 sign to one with a W10-7 sign, 90 percent or more of participants chose the scene with the W10-7 sign as the better option for conveying to drivers what they should do at the intersection. As the use of W10-7 signs for left-turning vehicles has been effective at mitigating left-turn collisions, some agencies (e.g., TriMet) have also found them to be effective at mitigating right-angle collisions due to red-light running on the cross-street approaches.

Another concern associated with the increase in LRV speeds above 35 mph is pedestrians. As VTA's improvements aim to mitigate against left-turn crashes and track intrusions, they are not focused on pedestrians. Similar to the cross-streets in San Jose, data that were reviewed in relation to pedestrian operations and safety in San Jose do not necessary warrant special treatments for pedestrians. Pedestrian volumes at the three study intersections are extremely low, and there has not been an LRV-pedestrian crash at any of the three study intersections in the past 3 years. However, in consideration of other areas that may experience higher pedestrian volumes or higher LRV-pedestrian crash rates, the research team would recommend the consideration of pedestrian countdown signals at crossings where LRV speeds are increased above 35 mph. This recommendation is of particular importance at wide intersections to give pedestrians information on how much time they have to cross. This information can help pedestrians make better decisions about whether or not to start crossing and could help reduce the number of pedestrians trapped in the middle of the road.

As an added note, several focus group participants indicated that installing W10-7 signs on the cross-street (within view of the pedestrians) may also help alert pedestrians when a train is coming.

Preliminary Cost Estimates of Traffic Control Devices

Cost estimates were obtained from the VTA for the Light Rail Left-Hand Turn and Track Intrusion Project – Phase I, which includes improvements to nine intersections, with a very similar type of work at each intersection. The cost for all improvements was approximately $360,000, an average of about $40,000 per intersection. Therefore, for the three intersections in this study, the total cost was approximately $120,000.

The current edition of the MUTCD requires the use of flashing lights and recommends the use of flashing lights at LRT crossings where LRVs operate at speeds higher than 35 mph. As part of Task 3, the TCRP A-32 research team was to compare the costs of traffic control devices or safety countermeasures that could be used in lieu of flashing lights and crossing gates to allow LRVs to operate at speeds above 35 mph.

A typical gated LRT crossing includes four gates at the intersection and flashing lights on each approach, one gate on each of the side streets, and one gate for each left-turn movement on the major street. All gates require signal communications and gate assembly equipment. Typical gate assemblies are manufactured to accommodate gates up to 40 feet long.

Cost information obtained from the Maryland Department of Transportation and the Maryland Transit Administration for gate assembly, flashing lights, controller and cabinet, communications, and track circuit detection revealed that the cost for one intersection would be in the range of $550,000.

With regard to the additional recommendation (in some locations) for W10-7 signs on the cross-street approaches, the cost to install two W10-7 signs at an intersection would be approximately $7,000, assuming that they can be installed on the existing mast arms. With regard to the recommendation (in some locations) for the installation of pedestrian countdown signals to replace the existing conventional pedestrian signal heads, the cost to retrofit each intersection is approximately $10,000 for eight signal heads. Table 21 shows a summary of these costs.

Table 21. Cost Estimate Summary for Three Intersections

Item	Cost Per Intersection
Left-turn and track intrusion enhancements (per VTA)	$40,000
Flashing light / signal assembly	$125,000
Gate assembly	$425,000
W10-7 signs on cross-street approaches, 2 signs	$7,000
Retrofitting pedestrian head with countdown signals, 8 signal heads	$10,000

Based on the estimated costs presented above, the cost ratio of the flashing lights and gates scenario to the VTA improvements is nearly 14 to 1. Even with the VTA improvements, the W10-7 signs on the cross-street, and pedestrian countdown signals on all four approaches, the cost ratio of the flashing lights and gates scenario to these improvements is still nearly 10 to 1.

Finally, it is important to note that sign modifications in California, are subject to additional requirements established by local regulatory agencies (California Public Utilities Commission) that would also have to agree to modify their traffic control device standards in order for the higher speeds to be implemented.

CHAPTER 4: MODELING/SIMULATION OF LIGHT RAIL OPERATING CONDITIONS: NORTH FIRST STREET FROM EAST BROKAW ROAD TO TRIMBLE ROAD

INTRODUCTION

Objectives: The objective of this study was to develop a micro-simulation model for the Light Rail corridor on North Frist St. from East Brokaw Road to Trimble Road in San Jose, California in order to analyze the simulated intersection safety under existing and suggested conditions (increasing LRV operating speed from 35 mph to 45 mph). Using the FHWA's newly developed SSAM model (Surrogate Safety Assessment Model), it would be feasible to compare the frequency of various types of conflicts (rear-end, angle and lane change) among the base condition and the various alternatives. The micro-simulation approach was determined by the panel to be a feasible alternative to conducting a field evaluation, necessitated by the City of San Jose's decision to not participate in a field test.

Study Area: The study area roadway network is located in San Jose, California, and includes an approximate 1.3 mile section of North First St. and five signalized intersections along the corridor. The Light Rail track runs in the median between the northbound and southbound travel lanes. There are no gates at the at-grade light rail crossings on North First St.. There are two light rail stops in the northbound direction and three stops in the southbound direction within the study limits. The light rail service, operated by the Santa Clara Valley Transportation Authority (VTA) has two lines that utilize the stops within the study limits of the model: The Alum Rock-Santa Teresa and the Mountain View-Winchester lines.

MODELING METHODOLOGY AND ANALYSIS TOOLS

The modeling effort comprised of three analysis tools: Synchro™, VISSIM™ and SSAM. Each model/analysis tool is discussed briefly below.

SYNCHRO™

Synchro™ (developed by Trafficware, Inc.) is a macroscopic analysis tool capable of modeling signalized and unsignalized intersections. Synchro™ is commonly used for intersection capacity and level-of-service analysis and signal timing optimization. Synchro™ has the ability to compute optimum timings for intersection offsets, cycle lengths, phase splits, and phase sequence. Synchro™ can display time-space diagrams that illustrate vehicle progression through a network. Since Synchro™ performs its analysis at a platoon level instead of an individual vehicle level, it is categorized as a macroscopic simulation model. Synchro™ version 7 was used to code the existing and alternative scenario models, in order to optimize the signal timing for all tested scenarios.

VISSIM™

VISSIM™ is a time-step and behavior-based microscopic traffic simulation software. It is characterized as microscopic simulation software because of its ability to model and analyze each entity of the network at an individual vehicle level. VISSIM™ is capable of simulating multiple modes of traffic including cars, heavy vehicles, high-occupancy vehicles, bus transit, light rail, heavy rail, rapid transit, cyclists, and pedestrians, for urban as well as rural conditions.

The VISSIM™ model consists internally of two distinct components: the traffic simulator and the signal state generator. These components are constantly communicating detector calls and signal status to each other through an interface. The traffic simulator is a microscopic traffic flow simulation model including car following, lane changing, and gap acceptance logic. The signal state generator is signal-control software that polls detector information from the traffic simulator on a discrete time-step basis (1/10 s). It then determines the signal status for the following time-step and returns this information to the traffic simulator. This interaction is the driving force behind modeling a signalized intersection. VISSIM™ version 5.30 release was utilized in this project to code the alternative scenarios and collect the vehicle trajectory data.

SSAM

SSAM, a model developed by the Federal Highway Administration, combines micro-simulation and automated conflict analysis to analyze the frequency and character of narrowly averted vehicle-to-vehicle collisions (conflicts) to compute surrogate measures of the safety of traffic facilities. SSAM determines and quantifies three types of conflicts: crossing (angle), lane changing, and rear end. For the purpose of this study, SSAM is used to determine the change in the frequency of conflicts among the various tested scenarios and the existing condition.

MODEL DEVELOPMENT

Model Geometry

The VISSIM model of existing conditions was coded using scaled aerial images of the study network. The lane geometry was confirmed with provided lane configuration diagrams at key locations. The light rail tracks were modeled as one continuous track in each direction with two stops in the northbound direction and three stops in the southbound direction. Figure 14 illustrates the VISSIM network model created for the study.

Speed Data

For purposes of the model, speed distributions were developed using best engineering judgment based on field observations and the posted speed limit along North First St. and the adjacent roads. The posted speed limit along North First St. is 45mph throughout the study network. A speed distribution curve for cars was developed with a desired speed ranging from 35 mph to 50 mph with an 85th percentile speed of 45 mph. Trucks and buses were assigned a speed distribution ranging from 36 to 42 mph. Other desired speed distributions were created for intersecting roadways and multiple types of turning movements. The speed distribution for light rail vehicles was based on the 35 mph speed limit currently imposed on Light Rail Vehicles

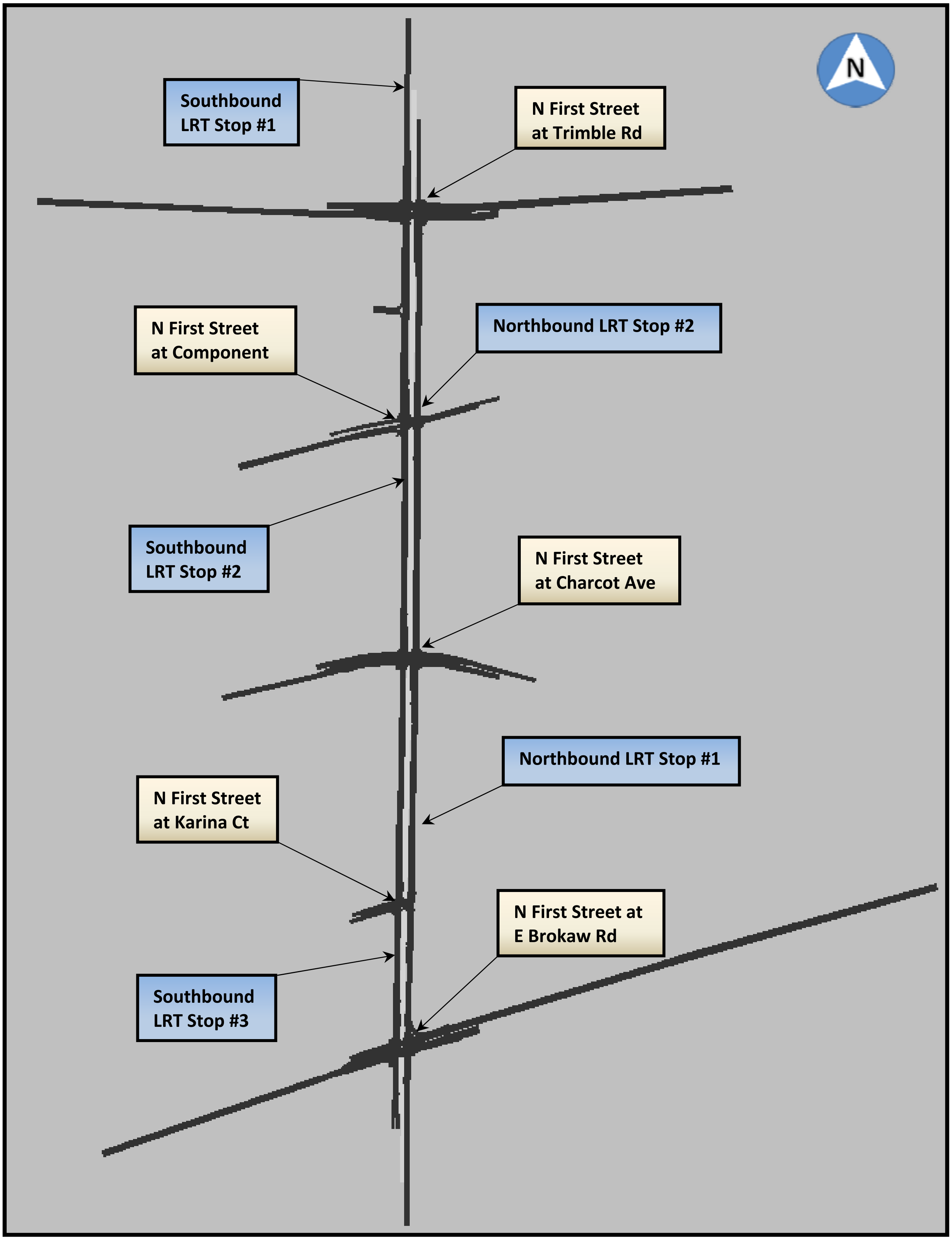

Figure 14. VISSIM Network Model

crossing ungated intersections. A linear distribution was assigned, which ranged from 34.5 to 35.5 mph. The deceleration and acceleration rates for the light rail vehicles were estimated in the field by timing and measuring the distance at which a train began to decelerate or accelerate to the point at which it stopped or reached its desired speed, respectively. Acceleration rates were calculated and modeled at 2.75 mph/s (4.03 ft/s^2) while the deceleration rates were 3.0 mph/s (4.40 ft/s^2).

In order to analyze and report safety performance measures, pedestrian and bicycle speeds were modeled based on field video observations, while taking into consideration the guidelines outlined in the 2009 MUTCD. A speed distribution of 3.5 ft/s to 4.25 ft/s was assigned to pedestrians, while bicycles were assigned a desired speed between 9 mph and 15 mph.

Transit Signal Priority

The Light Rail operation within the study network runs parallel to the northbound and southbound automotive traffic. Detectors are placed along the track at various points in advance of and following an intersection. The signal controllers communicate with the detectors and attempt to provide priority for the Light Rail Vehicle approaching by applying the following methods:

- Shortening phases not on the mainline so that the through phases which run in conjunction with the Light Rail signals can be called at an earlier time than would be in standard operation
- Extending the through phases which run in conjunction with the Light Rail so that the Light Rail signal stays green until the Light Rail Vehicle clears the intersection
- Adjusting the sequence in which the phases are called so that left turns which cross the Light Rail track lag behind the through phases rather than lead before them, as is the case in standard operation.

Balanced Volume Network and Vehicle Routing

A balanced volume network was developed for both the AM and PM peak periods, based on traffic counts taken in 2009 at the intersections of North First St. and East Brokaw Road, Charcot Avenue, and Trimble Road. These counts separated automobiles, bicycles, and pedestrians. Supplemental count data was provided by the City of San Jose at the intersection of North First St. and Karina Court and Component Drive.

For the purposes of the model, the access points along the network into and out of parking lots and businesses were deemed inconsequential in the relationship between light rail operation and overall safety in the network. However, there were midblock access points to corporate office buildings (eBay, Yahoo and several other large IT companies) with as many as 1,000 parking spaces in the parking lot which account for imbalances between intersections. As such, the volume network was balanced so that there was no more than a 10% difference (rather than 0%) between the traffic count volumes and the network volumes. Based on the count data, the peak hours modeled were 8:00AM – 9:00AM and 5:00PM – 6:00PM. Figure 15 shows the volume balanced network.

Routing decision points were placed at the origin links and destination links to define the vehicle routing. These routes are static in this model, meaning vehicles are routed from a starting point to a defined destination point using a static percentage for each destination. In order to allow for adequate lane changing distance, the routing decisions were placed according to the observed driver behavior in the model, and adjusted so that vehicles had adequate time to make the decision to change lanes to reach their desired destination. Because origin-destination data was not obtained, as it is not crucial to the purpose of this study, routing decisions were placed following each intersection, so that all of the source links feed the destination links proportionately.

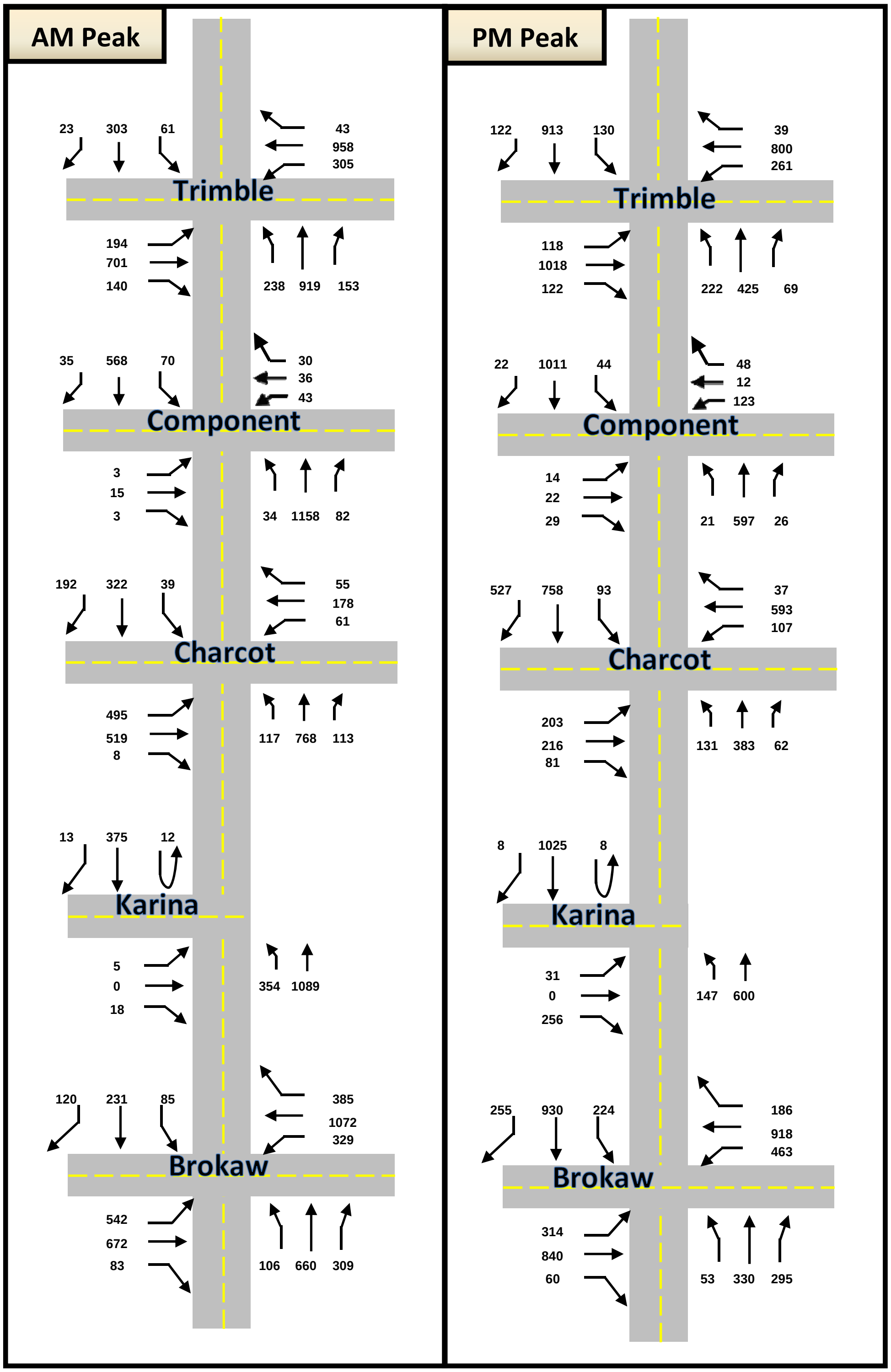

Figure 15. Volume Balanced Networks

Vehicle Types and Compositions

Based on the available data and observations recorded and made in the field, a system wide composition was assigned to all input links which included 96% Cars, 3% Trucks, and 1% Buses. Independent bicycle volumes were assigned, as were pedestrian volumes at each intersection. The input composition for the Light Rail tracks reflects the peak demand on the system. As such, all of the light rail vehicles entering the network are composed of three cars attached at a total length of approximately 265 feet. Each car is modeled to reflect the critical dimensions of the Kinki Sharyo LRV in use by the Santa Clara VTA which includes length, center pivot distance, and wheelbase.

Dwell Time and Arrival Times at Light Rail Stations

In order to calculate and assign dwell times to the transit stations in the corridor, stop time data was obtained from a 2009 study as part of the Regional Signal Timing Program (RSTP), which measured the dwell times at each stop along the Alum Rock-Santa Teresa Line. Due to the variability in dwell times between individual runs and from station to station, an overall empirical distribution was developed to be assigned to all stations in the study network. In this process, outliers were eliminated so that the model would not reflect a long stop time that may be attributed to an operator waiting at a station for the light rail signal to change to green. Outliers on the lower end were also eliminated, as this may reflect a stop with no passengers boarding or alighting. The empirical distribution developed ranges from 5 seconds to 55 seconds, with an 85th percentile stop time of 29 seconds.

The arrival times coded in the VISSIM model are based on the observed headways in the field. From the field data, it was observed that the light rail vehicles operated with headways between seven and seven and a half minutes. To reflect this variability in arrival times, the entry times of the vehicles into the network were developed using a random number generator. The headway between each train was assigned to be a random time between seven minutes and seven minutes and thirty seconds.

Model Calibration and Validation

Calibration of a model can be explained as the adjustment of the model parameters so that the model produces a simulation with behavior and output performance measures consistent with existing field operation. Calibration requires development of a base conditions model, comparison with field traffic conditions, and adjustment of model parameters so that the base computer model accurately resembles field conditions. The goal of model calibration is to improve the model’s ability to simulate existing conditions, and thus increase the analyst’s confidence in the results of the alternative condition models.

In calibrating the model in this study, the main parameter involved was throughput. The network was calibrated so that the intersections at the beginning and end of the network had throughput within five percent of the target volumes developed in the volume balanced network. In order to validate the model, visual observations were made on intersection operation, transit priority behavior, and intersection queues, and compared to video observations taken during peak hours at multiple intersections.

BASE CONDITION ANALYSIS

Following the development of the base condition model in VISSIM, trajectory files were output for processing in SSAM. Five 5-hour simulations were run per peak period, with peak hour volumes input for each of the five hours. The headway for train is approximately 7 to 7.5 minutes in each direction, which amounts to simulating a total of 200 trains in each direction at each intersection. Following the processing of the output trajectory files using SSAM, the conflicts were identified and sorted by type and intersection. A conflict, as defined in the Surrogate Safety Assessment Model and Validation Final Report as an observable situation in which two or more road users approach each other in time and space to such an extent that there is risk of collision if their movements remain unchanged. It is important to note that a conflict does not mean a collision. For example, rear-end conflicts are common in situations where a following driver reacts to a leading driver applying their brakes. If the following driver were to continue their course and speed, a collision would occur. The default/recommended parameters in SSAM were used for the analysis, among which includes a maximum 1.5 second TTC (Time to Collision) value. The TTC value of 1.5 seconds can be explained as follows: If two interacting vehicles were on a path such that if neither changed their desired speed or course in 1.5 seconds or less, they would collide; this is logged as a conflict. This study specifically focused on the crossing conflicts (angle and left-turn conflicts) that involved light rail vehicles.

The results of the SSAM analysis for the base conditions are shown in Figure 16 and Figure 17. The intersection at North First St. and East Brokaw Road shows the greatest number of total conflicts (an average of 481 and 588 conflicts during each 5-hour simulation period) for both AM and PM peak periods, respectively. The majority of these conflicts are rear-end or lane change types. The intersections of North First St., East Brokaw Road and Trimble Road showed/simulated the greatest number of non-LRV crossing conflicts during the AM peak and PM peaks periods, respectively; an average of 2 to 3 crossing conflicts for each 5-hour simulation period. However, none of those conflicts involved a light rail vehicle. The findings of the simulation were not unusual considering that between May 2006 and May 2009 an average of one or two light rail vehicle accidents was reported each year at the most critical intersection of the study, North First St. at Brokaw Road. The findings related to the non-LRV conflicts during the peak periods are also confirmed by the field data, which showed the intersection of North First St. and East Brokaw Road to be the intersection with the greatest number of observed conflicts.

The challenge in this modeling task is that the number of conflicts that could be observed under the various alternatives may or may not show any significant increase or change in the LRV-related conflicts. This is in part because no LRV conflicts were reported in the simulation for any of the existing conflicts scenarios.

AM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2407	11	2287	109
N First St at Karina Ct	523	0	486	37
N First St at Charcot Ave	1337	3	1295	39
N First St at Component Dr	1020	8	986	26
N First St at Trimble Rd	1824	4	1742	78

Note:
No light rail conflicts were observed or recorded.

AM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	432	5	409	18
	2	499	1	482	16
	3	486	4	458	24
	4	490	1	470	19
	5	500	0	468	32
	Total	**2407**	**11**	**2287**	**109**
	Average	**481**	**2**	**457**	**22**
	St. Dev	**28.2**	**2.2**	**28.4**	**6.4**
	Coefficient of Variation	**0.06**	**0.99**	**0.06**	**0.29**
N First St at Karina Ct	1	79	0	75	4
	2	100	0	94	6
	3	106	0	95	11
	4	123	0	117	6
	5	115	0	105	10
	Total	**523**	**0**	**486**	**37**
	Average	**105**	**0**	**97**	**7**
	St. Dev	**16.8**	**0.0**	**15.5**	**3.0**
	Coefficient of Variation	**0.16**	**0.00**	**0.16**	**0.40**
N First St at Charcot Ave	1	247	1	238	8
	2	286	1	278	7
	3	259	1	250	8
	4	274	0	264	10
	5	271	0	265	6
	Total	**1337**	**3**	**1295**	**39**
	Average	**267**	**1**	**259**	**8**
	St. Dev	**14.9**	**0.5**	**15.4**	**1.5**
	Coefficient of Variation	**0.06**	**0.91**	**0.06**	**0.19**
N First St at Component Dr	1	190	1	187	2
	2	219	2	211	6
	3	202	1	197	4
	4	204	2	199	3
	5	205	2	192	11
	Total	**1020**	**8**	**986**	**26**
	Average	**204**	**2**	**197**	**5**
	St. Dev	**10.3**	**0.5**	**9.0**	**3.6**
	Coefficient of Variation	**0.05**	**0.34**	**0.05**	**0.69**
N First St at Trimble Rd	1	359	0	337	22
	2	362	2	346	14
	3	372	0	362	10
	4	372	2	354	16
	5	359	0	343	16
	Total	**1824**	**4**	**1742**	**78**
	Average	**365**	**1**	**348**	**16**
	St. Dev	**6.7**	**1.1**	**9.8**	**4.3**
	Coefficient of Variation	**0.02**	**1.37**	**0.03**	**0.28**

Figure 16. Summary of AM Peak Hour Conflicts

PM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2942	6	2831	105
N First St at Karina Ct	1235	4	1147	84
N First St at Charcot Ave	1465	4	1365	96
N First St at Component Dr	465	4	446	15
N First St at Trimble Rd	1781	8	1714	59

Note:
No light rail conflicts were observed or recorded.

PM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	579	0	559	20
	2	577	1	556	20
	3	605	1	583	21
	4	595	2	574	19
	5	586	2	559	25
	Total	**2942**	**6**	**2831**	**105**
	Average	**588**	**1**	**566**	**21**
	St. Dev	**11.7**	**0.8**	**11.7**	**2.3**
	Coefficient of Variation	**0.02**	**0.70**	**0.02**	**0.11**
N First St at Karina Ct	1	267	1	246	20
	2	259	1	240	18
	3	219	0	205	14
	4	244	1	225	18
	5	246	1	231	14
	Total	**1235**	**4**	**1147**	**84**
	Average	**247**	**1**	**229**	**17**
	St. Dev	**18.3**	**0.4**	**15.9**	**2.7**
	Coefficient of Variation	**0.07**	**0.56**	**0.07**	**0.16**
N First St at Charcot Ave	1	313	2	295	16
	2	276	0	263	13
	3	282	1	262	19
	4	301	0	272	29
	5	293	1	273	19
	Total	**1465**	**4**	**1365**	**96**
	Average	**293**	**1**	**273**	**19**
	St. Dev	**14.8**	**0.8**	**13.3**	**6.0**
	Coefficient of Variation	**0.05**	**1.05**	**0.05**	**0.31**
N First St at Component Dr	1	92	1	89	2
	2	86	1	81	4
	3	97	1	93	3
	4	96	1	91	4
	5	94	0	92	2
	Total	**465**	**4**	**446**	**15**
	Average	**93**	**1**	**89**	**3**
	St. Dev	**4.4**	**0.4**	**4.8**	**1.0**
	Coefficient of Variation	**0.05**	**0.56**	**0.05**	**0.33**
N First St at Trimble Rd	1	362	2	344	16
	2	356	4	341	11
	3	371	0	362	9
	4	337	1	325	11
	5	355	1	342	12
	Total	**1781**	**8**	**1714**	**59**
	Average	**356**	**2**	**343**	**12**
	St. Dev	**12.5**	**1.5**	**13.1**	**2.6**
	Coefficient of Variation	**0.04**	**0.95**	**0.04**	**0.22**

Figure 17. Summary of PM Peak Hour Conflicts

ALTERNATIVE ANALYSIS

The tasks below were the focus of the alternatives that were developed and analyzed:

Task 7. Code an alternative speed increase for 40 mph and optimize signal timing (left-turn phase sequence and offsets) and detector locations accordingly. Refine the 40 mph scenario with adjustments to the change and clearance intervals (Yellow + All Red). Simulate an increase in traffic demand on the cross streets by 10%, 15%, and 20%. Simulate an increase in traffic demand for left turns by 10%, 15%, and 20%.

Task 8. Code an alternative speed increase for 45 mph and optimize signal timing (left-turn phase sequence and offsets) and detector locations accordingly. Refine the 45 mph scenario with adjustments to the change and clearance intervals (Yellow + All Red).

The following scenarios were modeled and analyzed for safety using the same guidelines for analysis as the existing conditions, so that a direct comparison could be conducted:

- 40 mph LRV; No Change to any volume inputs or routing decisions
- 45 mph LRV; No Change to any volume inputs or routing decisions
- 40 mph LRV; 10%, 15%, and 20% increase in cross street volume inputs and demand for left turns (cross street and main-line).
- 45 mph LRV; 10%, 15%, and 20% increase in cross street volume inputs and demand for left turns (cross street and main-line).

With both AM and PM peak periods being analyzed under the conditions described above, a total of eighteen different files were created. In order to accurately model these conditions and the likely changes to be made in actual field operation, the following adjustments were made:

- Adjust "travel time" parameter in signal controllers for detectors, including remote detectors along the light rail track. This will account for the increased speed of the train and decreased projected arrival times from the location of each detector to the intersection.
- Increase red clearance intervals of phases that may run before the transit phase
- Adjust offsets to optimize progression on North First St.
- Increase minimum green time for certain phases when the signal controller is in priority/recovery mode in order to avoid excessive queuing and cycle failures due to the increased demand for left turns.

Detector Locations

To effectively optimize the detector locations along the light rail track, the projected travel time values were changed rather than changing the physical location of the detectors. For the purpose of transit priority, the effect of decreasing the projected travel time for a detector in a given location is the equivalent of moving the detector further from the intersection (using existing travel time values), assuming the light rail vehicle is traveling at a higher speed than in existing conditions. The methodology for adjusting the projected travel times for the detectors was based on using the same assumptions that could be made when assigning a travel time to the detectors under existing conditions. These assumptions were that the travel times account for the projected time to accelerate, decelerate, dwell at a transit stop, etc. A spreadsheet was developed to separate the travel time that could be attributed to the train arriving as if it were traveling at a constant speed, and the time that was factored into the travel time value that could be attributed to the train accelerating, decelerating, or dwelling at a stop. When calculating the proposed travel times, the additional time spent accelerating and decelerating from higher speeds was taken into consideration. Figure 18 shows the values assigned in adjusting the detector parameters.

Clearance Intervals

The clearance intervals for the phases that may run before the transit phase were increased in order to decrease the probability of a light rail vehicle colliding with an automobile, pedestrian, or bicycle. These phases corresponded to the through movements on the side streets and the left-turn movements on North First St. when they were operating as “leading turns.” An additional 0.5 seconds was added to these phases for both the 40 mph and 45 mph scenarios, in order to account for the LRV traveling at a faster speed, and therefore crossing the intersection in less time. The yellow clearance intervals were kept at the existing value of six seconds, as this is adequate time for the higher speed LRVs to clear the intersection.

Optimizing Offsets

The goal of adjusting offsets was to optimize the coordination and progression along North First St.. To accomplish this, the existing models were used absent of any light rail vehicles that would affect the normal operation of the signal controllers. Using the simulated volumes, a Synchro model was developed with the existing timings, for the purpose of optimizing the offsets using the optimize feature as well as manual adjustments based on the time-space diagram which the program outputs. These offsets were plugged into the signal controllers within the VISSIM model. Since VISSIM does not have an automated optimize feature for offsets, the offsets were adjusted further based on observations of multiple simulation runs.

Following the optimization of the offsets on North First St., the light rail vehicles were entered back into the models. The apparent coordination of the signals may be impacted by the operation of the transit priority despite the offsets being optimized. This is due to the decrease or increase of green time during other phases in both priority and recovery modes which can influence progression.

Method of Comparison

To compare the model output of existing conditions to the alternative scenarios, the conflict data was processed in SSAM using a t-test for each peak period. The t-test is a commonly applied method of determining whether the means of two different data sets representing a larger population in an experiment are different at a statistically significant level. In order to compare the safety of the modeled scenarios to existing conditions, each type of conflict was tested for statistical significance (95-percent level of confidence) including a comparison of total conflicts, light rail related conflicts, crossing conflicts, rear end conflicts, and lane change conflicts.

Arrival Time Values for Light Rail Vehicle Detectors (seconds)										
Intersection with N First St	Detector Number (Assigned In VISSIM model)	Track Direction	Existing Distance to Intersection	Existing Travel Time	Proposed Travel Time (40 mph)	Proposed Travel Time (45 mph)	Time to Arrival at Constant 35 mph	Travel Time Not Attributed to Constant Speed	Time to Arrival at Constant 40 mph	Time to Arrival at Constant 45 mph
E Brokaw St	310	↓ S	3808'	**125**	**117**	**111**	74.2	51.8	64.9	58.7
	311	↓ S	2327'	**82**	**77**	**74**	45.3	37.7	39.7	36.3
	312	↓ S	495'	**14**	**14**	**14**	9.6	5.4	8.4	8.5
	316	N ↑	736'	**15**	**14**	**14**	14.3	1.7	12.5	12.2
Karina Ct	310	↓ S	4307'	**127**	**118**	**110**	83.9	44.1	73.4	66.3
	311	↓ S	2693'	**60**	**54**	**50**	52.5	8.5	45.9	41.8
	312	↓ S	1402'	**30**	**28**	**26**	27.3	3.7	23.9	22.2
	315	N ↑	1692'	**43**	**40**	**38**	33.0	11.0	28.8	26.6
	316	N ↑	714'	**25**	**24**	**24**	13.9	12.1	12.2	11.8
Charcot Ave	310	↓ S	3328'	**110**	**103**	**98**	64.8	46.2	56.7	51.4
	311	↓ S	2718'	**90**	**84**	**80**	52.9	38.1	46.3	42.2
	312	↓ S	1104'	**33**	**31**	**30**	21.5	12.5	18.8	17.7
	315	N ↑	2304'	**85**	**80**	**77**	44.9	41.1	39.3	35.9
	316	N ↑	1154'	**33**	**31**	**30**	22.5	11.5	19.7	18.5
	334	N ↑	3282'	**105**	**98**	**93**	63.9	42.1	55.9	50.7
Component Dr	311	↓ S	1781'	**45**	**42**	**39**	34.7	11.3	30.4	28.0
	312	↓ S	1172'	**24**	**22**	**21**	22.8	2.2	20.0	18.8
	314	N ↑	3845'	**121**	**113**	**106**	74.9	47.1	65.5	59.3
	315	N ↑	2696'	**61**	**55**	**51**	52.5	9.5	46.0	41.8
	316	N ↑	1338'	**26**	**24**	**22**	26.1	0.9	22.8	21.3
Trimble Rd	312	↓ S	410'	**15**	**15**	**15**	8.0	8.0	7.0	7.2
	310	N ↑	4047'	**109**	**100**	**93**	78.8	31.2	69.0	62.3
	314	N ↑	2890'	**88**	**82**	**77**	56.3	32.7	49.3	44.8
	315	N ↑	1347'	**61**	**59**	**57**	26.2	35.8	23.0	21.4
	316	N ↑	912'	**23**	**22**	**21**	17.8	6.2	15.5	14.8

Figure 18. Summary of Changes to LRV Detectors

A. Alternative Comparison

The primary reason for modeling an increase in Light Rail Vehicle speed was to analyze and determine if this would be done at the detriment to automobile, pedestrian, and cyclist safety, specifically left-turn and angle related conflicts. In the 16 models involving increased light rail vehicle speed (four volume alternatives, two speed alternatives, and two peak periods), there were no recorded conflicts involving Light Rail Vehicles. However, since intersection safety was the main concern, the conflicts involving other modes were analyzed and compared. The results of the t-tests for each peak period are displayed in numerical form in Figure 19 and Figure 20 for the AM and PM peak period, respectively. Figures 21 through 27 show a direct comparison between each alternative and the existing conditions, while Appendix C includes this data in tabular form.

	AM Peak Hour Total t values (All Conflicts)							
	AM 40 mph 0 Percent	AM 40 mph 10 Percent	AM 40 mph 15 Percent	AM 40 mph 20 Percent	AM 45 mph 0 Percent	AM 45 mph 10 Percent	AM 45 mph 15 Percent	AM 45 mph 20 Percent
Existing AM (35 mph)	-1.107	-5.289	-8.248	-10.636	-1.268	-4.981	-6.091	-11.39
AM 40 mph 0 Percent		-4.228	-7.408	-9.986	-0.089	-3.886	-5.223	-10.819
AM 40 mph 10 Percent			-5.115	-8.596	4.67	0.662	-2.361	-11.229
AM 40 mph 15 Percent				-5.38	8.36	6.11	0.61	-6.699
AM 40 mph 20 Percent					10.868	9.286	4.26	1.516
AM 45 mph 0 Percent						-4.299	-5.542	-12.354
AM 45 mph 10 Percent							-2.811	-12.673
AM 45 mph 15 Percent								-3.926
	Significant							
Existing AM (35 mph)	NO	YES	YES	YES	NO	YES	YES	YES
AM 40 mph 0 Percent		YES	YES	YES	NO	YES	YES	YES
AM 40 mph 10 Percent			YES	YES	YES	NO	YES	YES
AM 40 mph 15 Percent				YES	YES	YES	NO	YES
AM 40 mph 20 Percent					YES	YES	YES	NO
AM 45 mph 0 Percent						YES	YES	YES
AM 45 mph 10 Percent							YES	YES
AM 45 mph 15 Percent								YES

	AM Peak Hour Crossing t values							
	AM 40 mph 0 Percent	AM 40 mph 10 Percent	AM 40 mph 15 Percent	AM 40 mph 20 Percent	AM 45 mph 0 Percent	AM 45 mph 10 Percent	AM 45 mph 15 Percent	AM 45 mph 20 Percent
Existing AM (35 mph)	-0.693	-1.686	-2.213	-1.36	-1.692	-0.792	0	-1.461
AM 40 mph 0 Percent		-0.368	-0.822	-0.667	-0.775	-0.169	0.632	-0.584
AM 40 mph 10 Percent			-0.784	-0.506	-0.645	0.103	1.365	-0.391
AM 40 mph 15 Percent				-0.098	-0.123	0.501	1.848	0.124
AM 40 mph 20 Percent						0.459	1.273	0.171
AM 45 mph 0 Percent						0.519	1.532	0.201
AM 45 mph 10 Percent							0.74	-0.347
AM 45 mph 15 Percent								-1.321
	Significant							
Existing AM (35 mph)	NO	NO	YES	NO	NO	NO	NO	NO
AM 40 mph 0 Percent		NO	NO	NO	NO	NO	NO	NO
AM 40 mph 10 Percent			NO	NO	NO	NO	NO	NO
AM 40 mph 15 Percent				NO	NO	NO	NO	NO
AM 40 mph 20 Percent					NO	NO	NO	NO
AM 45 mph 0 Percent						NO	NO	NO
AM 45 mph 10 Percent							NO	NO
AM 45 mph 15 Percent								NO

Legend

- No Significant Change
- Significant Decrease
- Significant Increase

Figure 19. AM Peak Hour Conflicts t-test

	AM Peak Hour Rear-end t values							
	AM 40 mph 0 Percent	AM 40 mph 10 Percent	AM 40 mph 15 Percent	AM 40 mph 20 Percent	AM 45 mph 0 Percent	AM 45 mph 10 Percent	AM 45 mph 15 Percent	AM 45 mph 20 Percent
Existing AM (35 mph)	-1.01	-5.208	-7.406	-9.887	-1.031	-4.988	-5.852	-10.308
AM 40 mph 0 Percent		-4.435	-6.891	-9.562	0.053	-4.179	-5.202	-10.155
AM 40 mph 10 Percent			-3.917	-7.755	5.134	0.769	-2.22	-9.414
AM 40 mph 15 Percent				-5.105	7.972	5.244	0.075	-5.527
AM 40 mph 20 Percent					10.568	8.74	3.697	1.549
AM 45 mph 0 Percent						-4.91	-5.659	-11.783
AM 45 mph 10 Percent							-2.742	-11.693
AM 45 mph 15 Percent								-3.117
	Significant							
Existing AM (35 mph)	NO	YES	YES	YES	NO	YES	YES	YES
AM 40 mph 0 Percent		YES	YES	YES	NO	YES	YES	YES
AM 40 mph 10 Percent			YES	YES	YES	NO	YES	YES
AM 40 mph 15 Percent				YES	YES	YES	NO	YES
AM 40 mph 20 Percent					YES	YES	YES	NO
AM 45 mph 0 Percent						YES	YES	YES
AM 45 mph 10 Percent							YES	YES
AM 45 mph 15 Percent								YES

	AM Peak Hour Lane changing t values							
	AM 40 mph 0 Percent	AM 40 mph 10 Percent	AM 40 mph 15 Percent	AM 40 mph 20 Percent	AM 45 mph 0 Percent	AM 45 mph 10 Percent	AM 45 mph 15 Percent	AM 45 mph 20 Percent
Existing AM (35 mph)	-0.686	-0.799	-4.654	-4.037	-1.705	-0.617	-2.248	-5.312
AM 40 mph 0 Percent		0.05	-4.246	-3.62	-0.913	-0.032	-1.56	-4.961
AM 40 mph 10 Percent			-6.19	-4.343	-1.935	-0.076	-2.754	-6.666
AM 40 mph 15 Percent				-0.484	5.83	3.355	4.243	-1.257
AM 40 mph 20 Percent					3.817	3.122	3.1	-0.455
AM 45 mph 0 Percent						0.637	-1.633	-6.289
AM 45 mph 10 Percent							-1.151	-4.046
AM 45 mph 15 Percent								-5.016
	Significant							
Existing AM (35 mph)	NO	NO	YES	YES	NO	NO	YES	YES
AM 40 mph 0 Percent		NO	YES	YES	NO	NO	NO	YES
AM 40 mph 10 Percent			YES	YES	YES	NO	YES	YES
AM 40 mph 15 Percent				NO	YES	YES	YES	NO
AM 40 mph 20 Percent					YES	YES	YES	NO
AM 45 mph 0 Percent						NO	NO	YES
AM 45 mph 10 Percent							NO	YES
AM 45 mph 15 Percent								YES

Legend

- No Significant Change
- Significant Decrease
- Significant Increase

Figure 19. (Continued) AM Peak Hour Conflicts t-test

	PM Peak Hour Total t values (All Conflicts)							
	PM 40 mph 0 Percent	PM 40 mph 10 Percent	PM 40 mph 15 Percent	PM 40 mph 20 Percent	PM 45 mph 0 Percent	PM 45 mph 10 Percent	PM 45 mph 15 Percent	PM 45 mph 20 Percent
Existing PM (35 mph)	1.144	1.198	-2.337	-5.219	0.759	1.079	-2.504	-9.26
PM 40 mph 0 Percent		-0.187	-2.613	-4.826	-0.502	-0.077	-2.615	-6.998
PM 40 mph 10 Percent			-2.838	-5.323	-0.376	0.103	-2.956	-8.248
PM 40 mph 15 Percent				-2.508	2.54	2.587	0.355	-4.487
PM 40 mph 20 Percent					5.077	4.84	3.152	-1.365
PM 45 mph 0 Percent						0.425	-2.614	-8.018
PM 45 mph 10 Percent							-2.593	-7.09
PM 45 mph 15 Percent								-5.798
	Significant							
Existing PM (35 mph)	NO	NO	YES	YES	NO	NO	YES	YES
PM 40 mph 0 Percent		NO	YES	YES	NO	NO	YES	YES
PM 40 mph 10 Percent			YES	YES	NO	NO	YES	YES
PM 40 mph 15 Percent				YES	YES	YES	NO	YES
PM 40 mph 20 Percent					YES	YES	YES	NO
PM 45 mph 0 Percent						NO	YES	YES
PM 45 mph 10 Percent							YES	YES
PM 45 mph 15 Percent								YES

	PM Peak Hour Crossing t values							
	PM 40 mph 0 Percent	PM 40 mph 10 Percent	PM 40 mph 15 Percent	PM 40 mph 20 Percent	PM 45 mph 0 Percent	PM 45 mph 10 Percent	PM 45 mph 15 Percent	PM 45 mph 20 Percent
Existing PM (35 mph)	0.453	-0.771	-0.523	-1.945	-0.478	-1.171	-0.351	-0.822
PM 40 mph 0 Percent		-1.006	-0.802	-2.252	-1.033	-1.383	-0.73	-1.192
PM 40 mph 10 Percent			0.275	-0.73	0.566	-0.389	0.518	0.203
PM 40 mph 15 Percent				-1.123	0.272	-0.673	0.241	-0.117
PM 40 mph 20 Percent					1.753	0.251	1.554	1.159
PM 45 mph 0 Percent						-0.998		-0.526
PM 45 mph 10 Percent							0.93	0.639
PM 45 mph 15 Percent								-0.435
	Significant							
Existing PM (35 mph)	NO	NO	NO	YES	NO	NO	NO	NO
PM 40 mph 0 Percent		NO	NO	YES	NO	NO	NO	NO
PM 40 mph 10 Percent			NO	NO	NO	NO	NO	NO
PM 40 mph 15 Percent				NO	NO	NO	NO	NO
PM 40 mph 20 Percent					NO	NO	NO	NO
PM 45 mph 0 Percent						NO	NO	NO
PM 45 mph 10 Percent							NO	NO
PM 45 mph 15 Percent								NO

Legend

- No Significant Change
- Significant Decrease
- Significant Increase

Figure 20. PM Peak Hour Conflicts t-test

	PM Peak Hour Rear-end t values							
	PM 40 mph 0 Percent	PM 40 mph 10 Percent	PM 40 mph 15 Percent	PM 40 mph 20 Percent	PM 45 mph 0 Percent	PM 45 mph 10 Percent	PM 45 mph 15 Percent	PM 45 mph 20 Percent
Existing PM (35 mph)	1.257	1.476	-2.042	-5.149	0.935	1.436	-2.063	-7.556
PM 40 mph 0 Percent		-0.05	-2.483	-4.77	-0.417	0.086	-2.445	-6.266
PM 40 mph 10 Percent			-2.783	-5.338	-0.421	0.149	-2.818	-7.16
PM 40 mph 15 Percent				-2.631	2.361	2.661	0.298	-4.173
PM 40 mph 20 Percent					4.928	5.008	3.182	-1.264
PM 45 mph 0 Percent						0.528	-2.343	-6.706
PM 45 mph 10 Percent							-2.648	-6.585
PM 45 mph 15 Percent								-4.997
	Significant							
Existing PM (35 mph)	NO	NO	YES	YES	NO	NO	YES	YES
PM 40 mph 0 Percent		NO	YES	YES	NO	NO	YES	YES
PM 40 mph 10 Percent			YES	YES	NO	NO	YES	YES
PM 40 mph 15 Percent				YES	YES	YES	NO	YES
PM 40 mph 20 Percent					YES	YES	YES	NO
PM 45 mph 0 Percent						NO	YES	YES
PM 45 mph 10 Percent							YES	YES
PM 45 mph 15 Percent								YES

	PM Peak Hour Lane changing t values							
	PM 40 mph 0 Percent	PM 40 mph 10 Percent	PM 40 mph 15 Percent	PM 40 mph 20 Percent	PM 45 mph 0 Percent	PM 45 mph 10 Percent	PM 45 mph 15 Percent	PM 45 mph 20 Percent
Existing PM (35 mph)	-0.459	-1.335	-2.604	-1.874	-1.145	-1.039	-1.528	-4.51
PM 40 mph 0 Percent		-0.435	-1.375	-1.262	-0.304	-0.403	-0.861	-2.869
PM 40 mph 10 Percent			-1.937	-1.222	0.275	-0.055	-0.723	-4.579
PM 40 mph 15 Percent				-0.351	2.168	1.127	0.332	-2.758
PM 40 mph 20 Percent					1.336	1.022	0.517	-1.062
PM 45 mph 0 Percent						-0.218	-0.864	-4.755
PM 45 mph 10 Percent							-0.55	-2.958
PM 45 mph 15 Percent								-2.006
	Significant							
Existing PM (35 mph)	NO	NO	YES	YES	NO	NO	NO	YES
PM 40 mph 0 Percent		NO	NO	NO	NO	NO	NO	YES
PM 40 mph 10 Percent			YES	NO	NO	NO	NO	YES
PM 40 mph 15 Percent				NO	YES	NO	NO	YES
PM 40 mph 20 Percent					NO	NO	NO	NO
PM 45 mph 0 Percent						NO	NO	YES
PM 45 mph 10 Percent							NO	YES
PM 45 mph 15 Percent								YES

Legend

- No Significant Change
- Significant Decrease
- Significant Increase

Figure 20. (Continued) PM Peak Hour Conflicts t-test

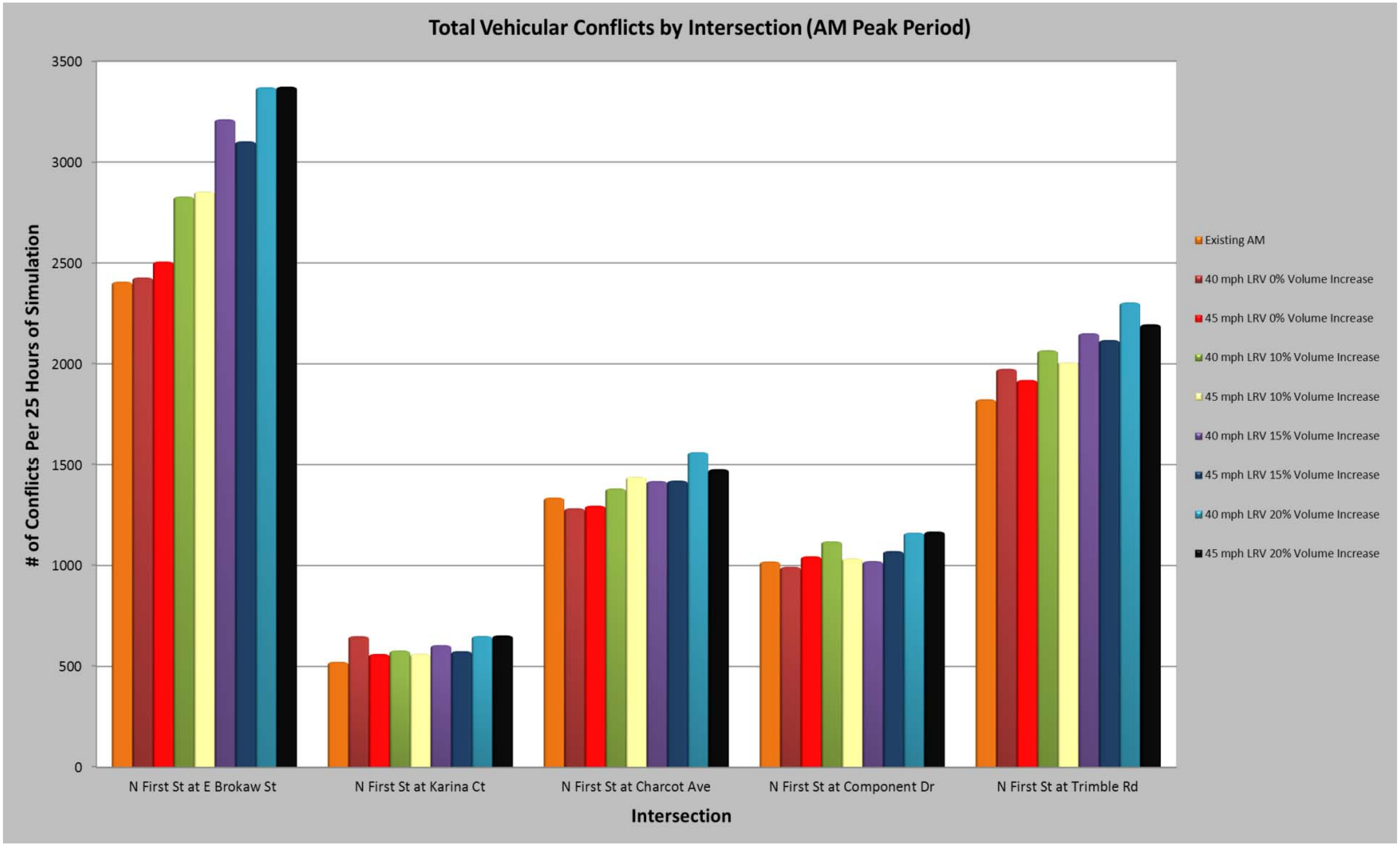

Figure 21. AM Peak Hour Total Conflicts

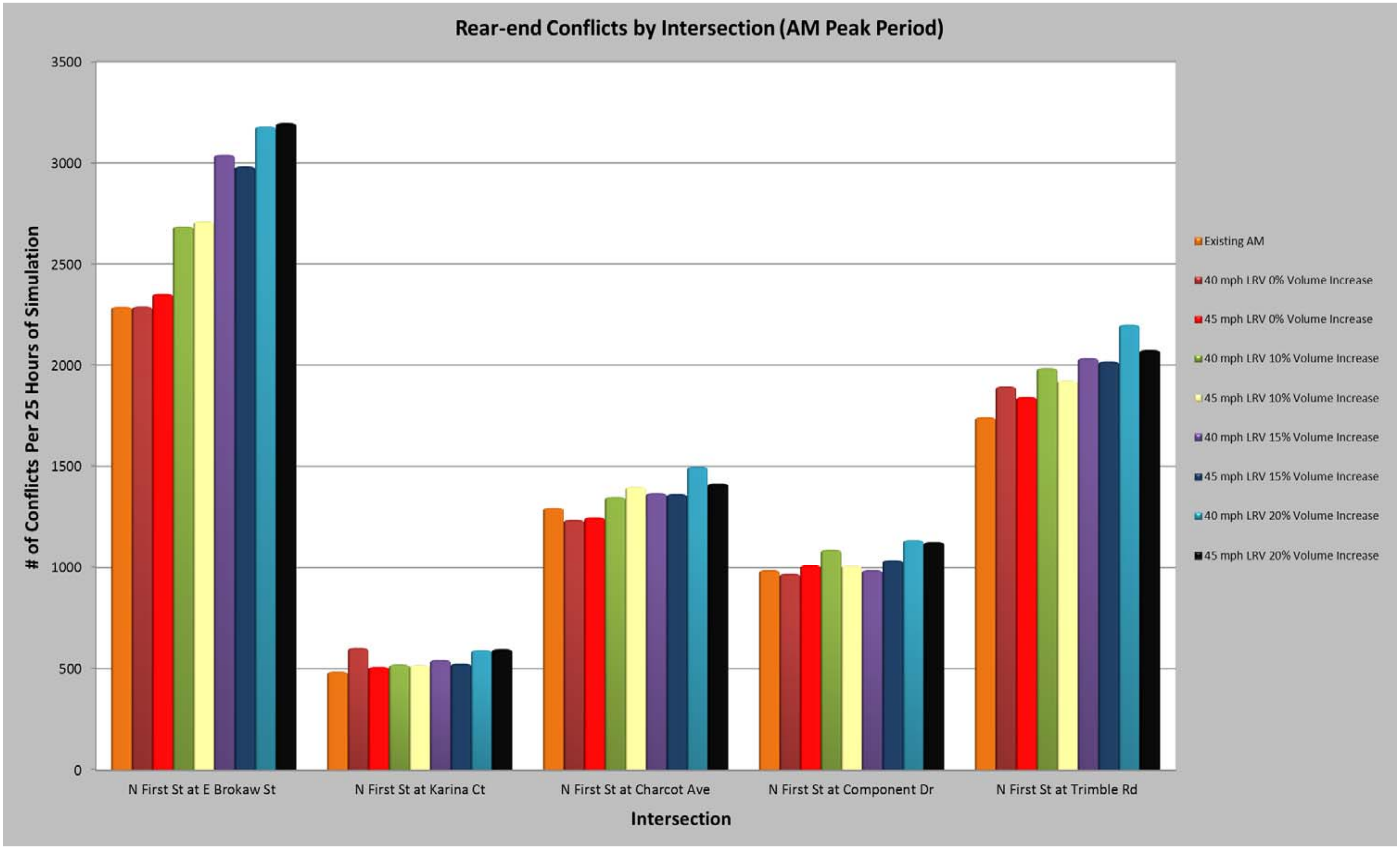

Figure 22. AM Peak Hour Rear-end Conflicts

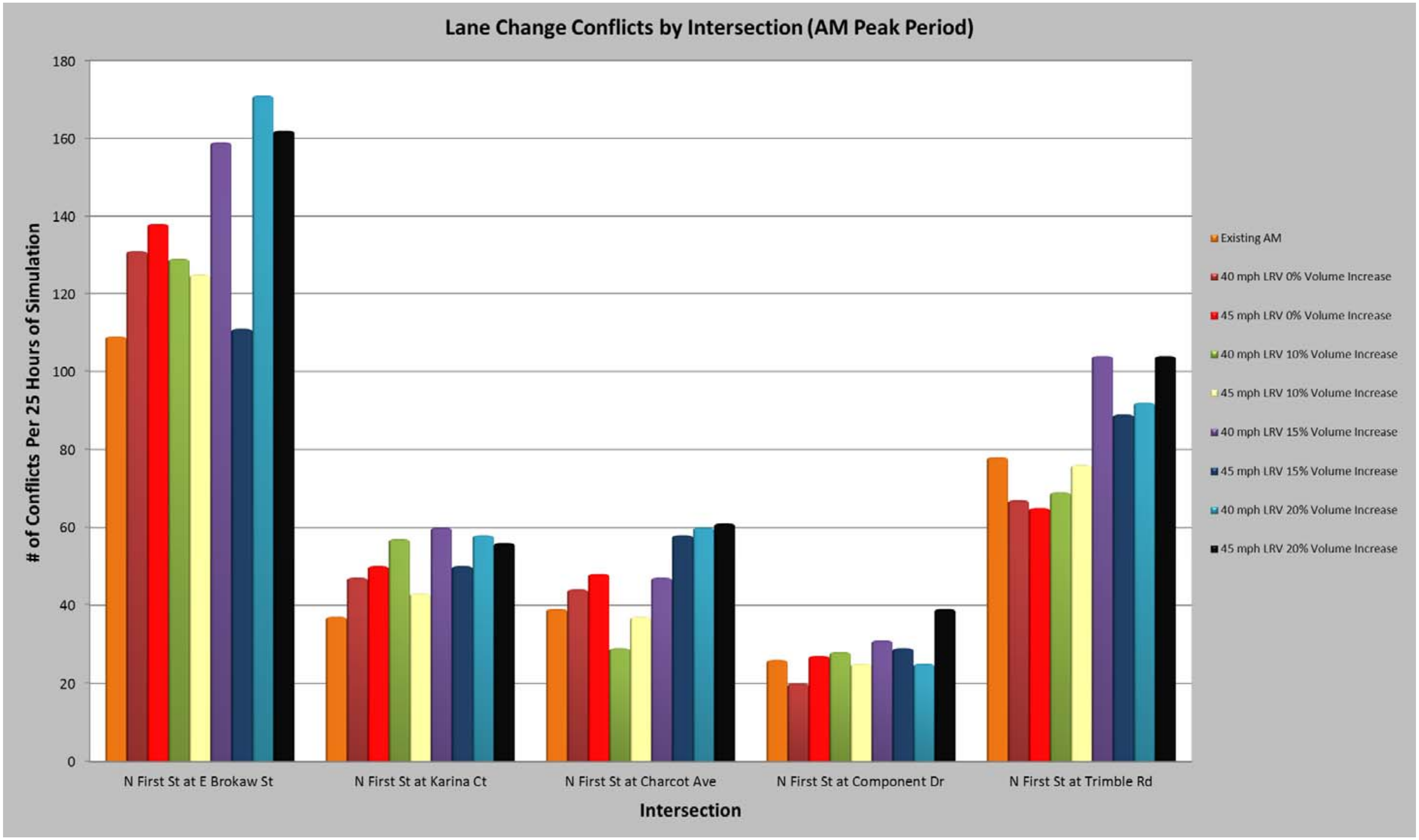

Figure 23. AM Peak Hour Lane Change Conflicts

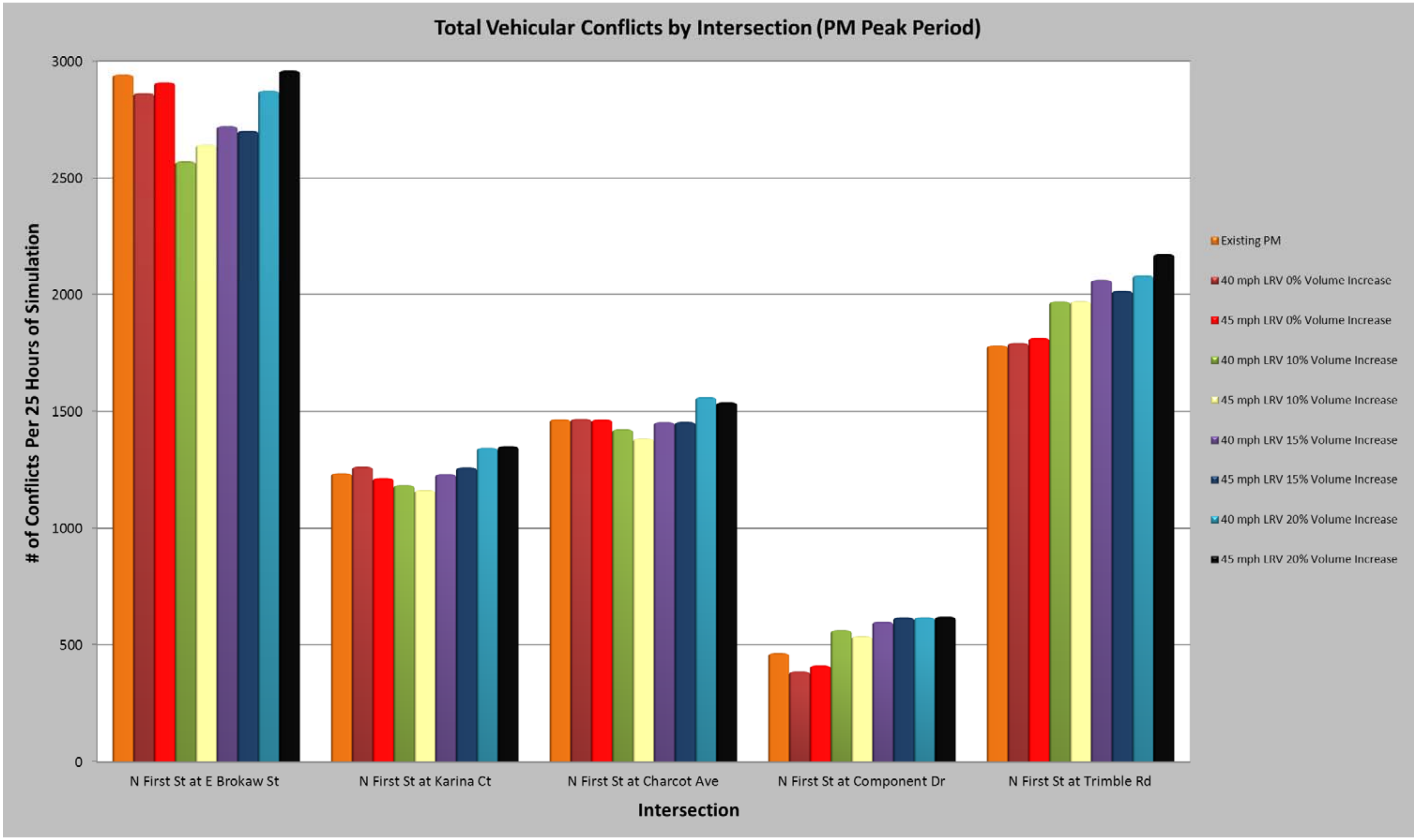

Figure 24. PM Peak Hour Total Conflicts

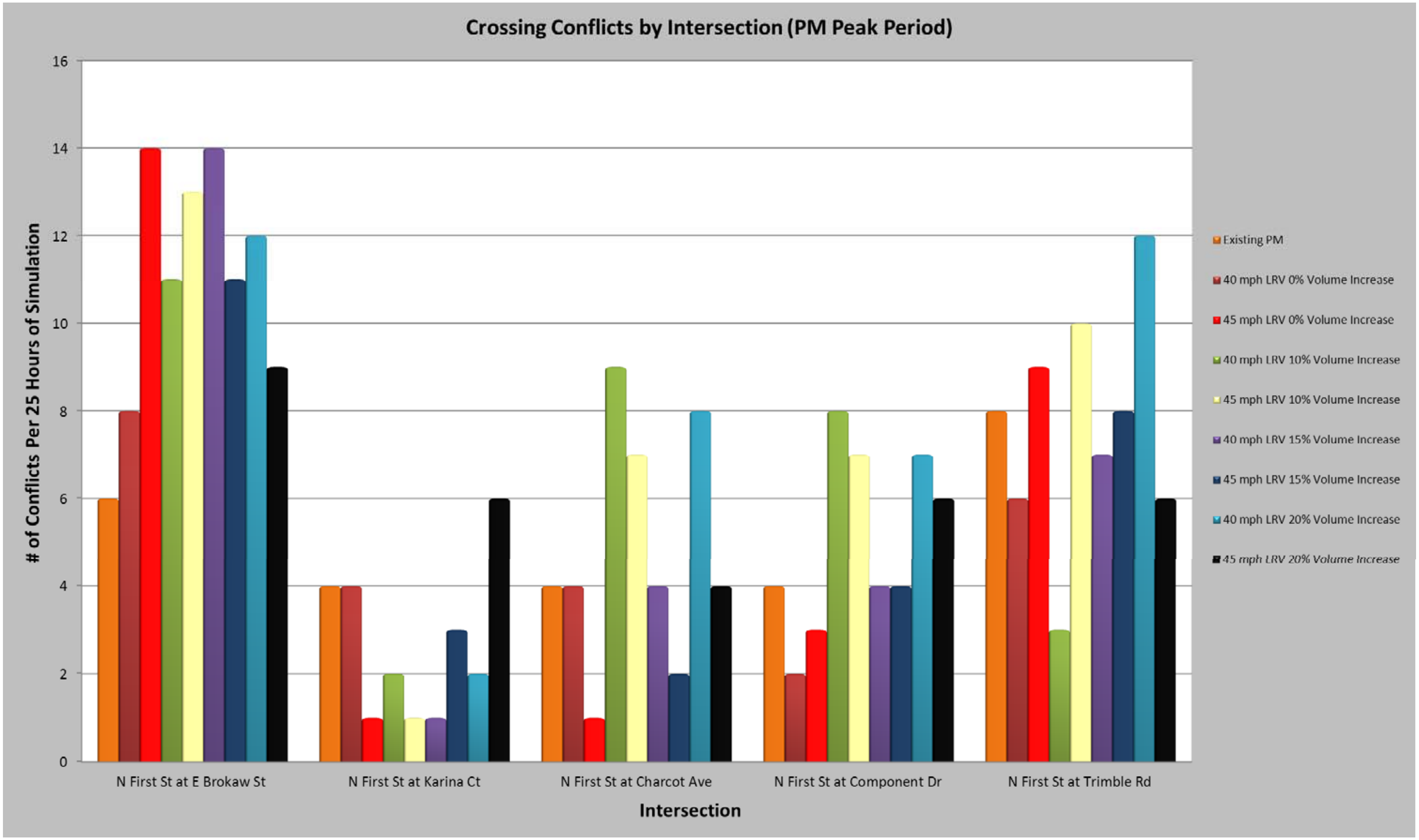

Figure 25. PM Peak Hour Crossing Conflicts

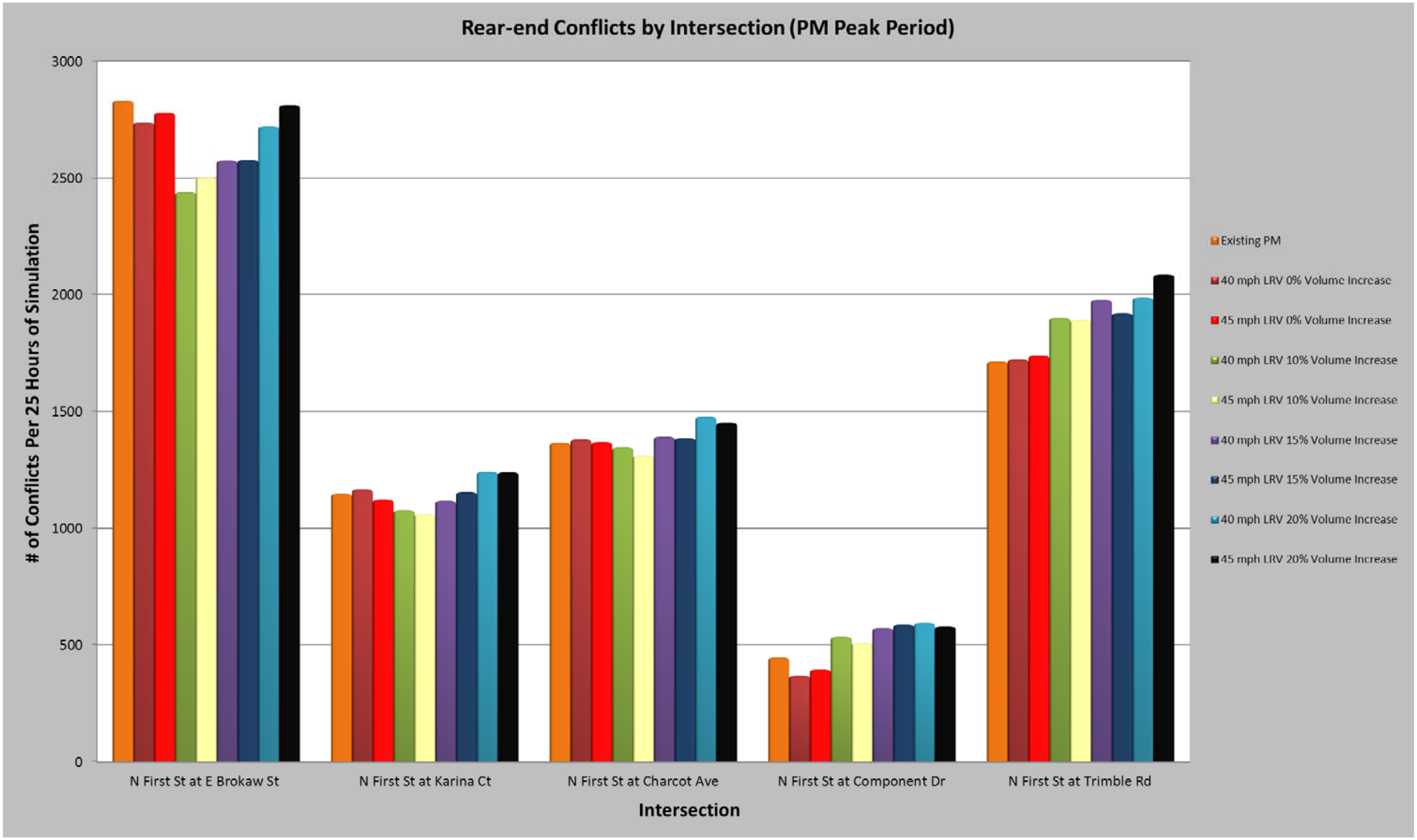

Figure 26. PM Peak Hour Rear-end Conflicts

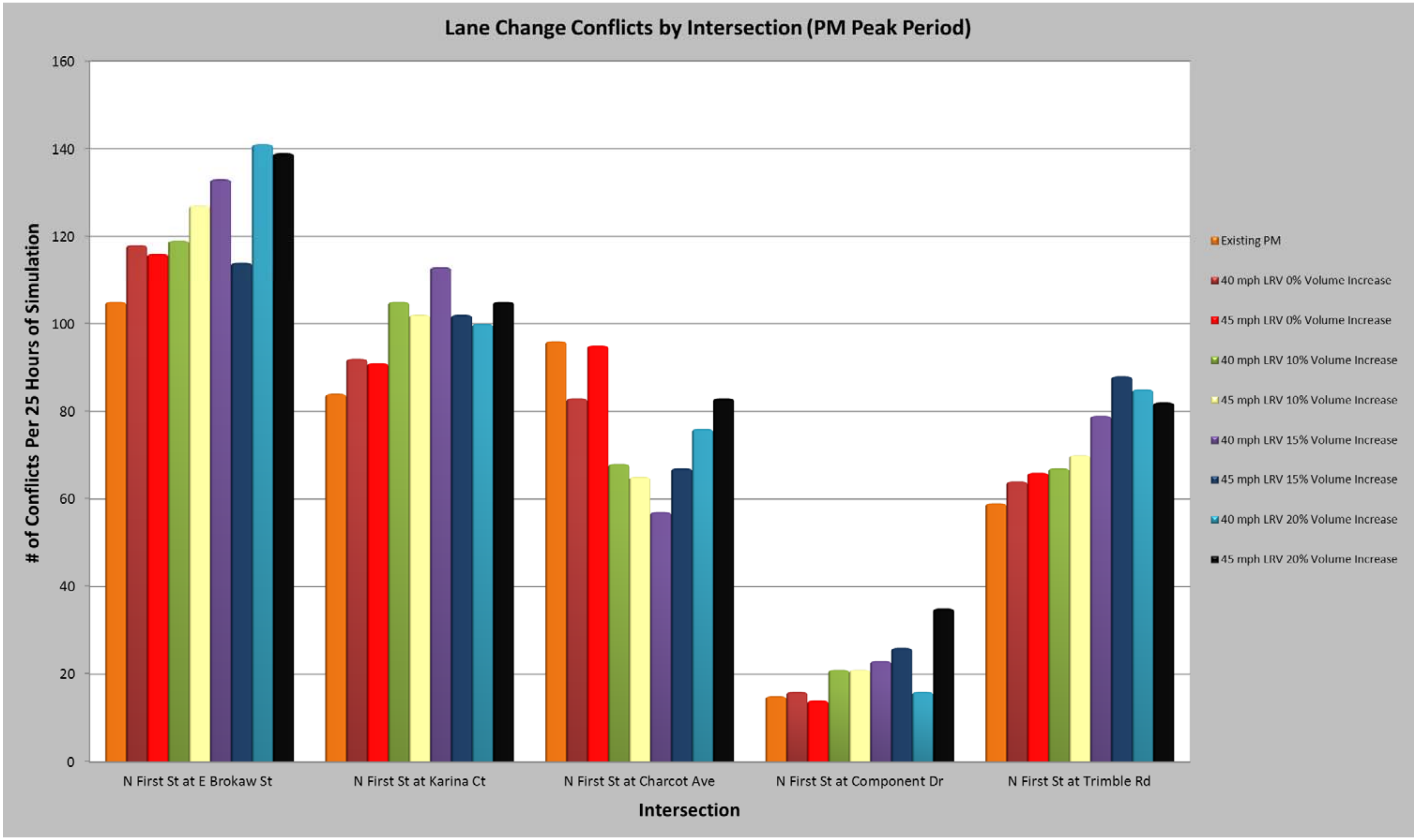

Figure 27. PM Peak Hour Lane Change Conflicts

Critical Observations and Changes

In the processing of conflicts involving automobiles, pedestrians, and bicycles (there were no LRV conflicts recorded), it is important to note the changes made to alternative conditions that may influence conflicts, as well as observations made in all of the models which may explain increases and decreases in conflicts between alternatives.

One key observation made in both existing and alternative condition models occurred at the intersection of North First St. and East Brokaw Road. This observation identified risky behavior from eastbound left-turning vehicles. In both existing and alternative models, the corresponding phase for this movement often reached its maximum green time due to high demand, and automobiles would proceed through the intersection on yellow, sometimes not clearing the intersection before the opposing westbound through movement had a green light. If a pedestrian began to cross on the north side while the vehicle was still in the intersection, the driver would yield to the pedestrian, blocking one westbound through lane. In reality, the driver in the outside turn lane would most likely make a lane-change to the inner lane to avoid the pedestrian, or the pedestrian would yield to the vehicle. However, in the simulation, conflict areas are setup so that vehicles must yield to pedestrians who cross exclusively on “walk” and flashing “don’t walk” signals, since this is common for permitted right-turning and left-turning vehicles. This occurrence, which appears to occur randomly, could explain a variation in the crossing conflicts between models at the intersection of East Brokaw Road and North First St.

In the existing conditions model, and currently in the field, the phases corresponding to the eastbound and westbound through movements on Trimble Road at North First St. are set to max recall in the signal controller. Because these phases were recalling to their maximum splits, transit priority was not operating as efficiently as it would if these phases were actuated, because a call from a light rail vehicle could not decrease the green time on Trimble Road in order to serve North First St. sooner. In the future conditions models, the phases corresponding to the through movements on Trimble Road were set to min recall, and were actuated. This allowed the transit priority to operate more efficiently and decreased delay on North First St., while slightly increasing the queues on Trimble Road. This change may have an effect on the number of conflicts at this intersection.

a. 40 mph LRV: No change to volume inputs or routing decisions

The first alternative modeled involves the scenario that is essentially the base conditions (35 mph), but with changes made to the light rail operating speed, offsets, clearance intervals, and detector parameters described earlier in Section VI of the report. No changes were made to volumes, heavy vehicle percentages, or other parameters directly relating to the composition or characteristics of automobiles.

The results of the t-test directly comparing conflicts by type show no significant increase or decrease in crossing, lane change, and rear-end collisions. This is concurrent with the test showing no significant change in the total number of collisions. On an individual intersection basis, the number of crossing conflicts did increase at Trimble Road and Charcot Avenue during the AM peak period. During the PM peak period, the number of conflicts recorded for this alternative increased at the intersection of East Brokaw Road. Again, it is critical to note that there were no recorded conflicts with light rail vehicles, and that the increase and decrease of conflicts by conflict type, location, and peak period fluctuated compared to the conflicts recorded under existing conditions. The conflict results of the 40 mph scenario are concurrent with the existing conditions results, in that East Brokaw St. and Trimble Road have the greatest number of conflicts and risky behavior.

b. 45 mph LRV: No change to volume inputs or routing decisions

This alternative retains the same parameters as the first alternative (40 mph LRV: No change to volume inputs or routing decisions), except for modified detector travel time parameters on the light rail track, and a light rail vehicle speed of 45 mph. There were no recorded conflicts involving light rail vehicles. There were a greater number of crossing conflicts recorded at the intersections at East Brokaw St. and Trimble Road, compared to the existing conditions. However, the t-test comparing the alternative to existing conditions showed that simulating an increased light rail vehicle speed from 35 mph to 45 mph did not significantly increase or decrease any of the types of conflicts when the network was analyzed as a whole. The conflict results of the 45 mph scenario are concurrent with the existing conditions results, in that East Brokaw St. and Trimble Road have the greatest number of conflicts and risky behavior.

c. 40 mph LRV: 10% increase in cross-street volumes and left-turn demand on North First Street

This alternative involving increasing the light rail vehicle speed to 40 mph and increasing the cross-street volumes and main-line left-turn demand by 10% yielded no LRV related conflicts, while there was an increase in the total number of conflicts that was significant when compared to the existing conditions. However, there was no significant increase in crossing conflicts and lane-change conflicts. It is not unusual that the number of rear-end conflicts increased due to the increase in cross-street volume and more vehicles approaching a queue on these approaches. Crossing conflicts at particular intersections appeared to increase at the intersection of East Brokaw St., while fluctuating at others.

d. 45 mph LRV: 10% increase in cross-street volumes and left-turn demand on North First Street

This alternative involving increasing the light rail vehicle speed to 45 mph and increasing the cross-street volumes and main-line left-turn demand by 10% yielded no LRV related conflicts, while there was an increase in the total number of conflicts that was significant when compared to the existing conditions, just as in the 40 mph scenario with the same increase in volumes. Crossing conflicts at particular intersections appeared to increase at the intersection of East Brokaw St., while fluctuating at others when compared to existing conditions. A t-test was also performed comparing alternatives of the same volume growth and increase in left-turn demand, but with different light rail vehicle speeds. This alternative, with a 45 mph light rail vehicle speed did not significantly yield more or less conflicts, compared to the alternative with the same volumes and a 40 mph light rail vehicle speed.

e. 40 mph LRV: 15% increase in cross-street volumes and left-turn demand on North First Street

This alternative involving increasing the light rail vehicle speed to 40 mph and increasing the cross-street volumes and main-line left-turn demand by 15% yielded no LRV related conflicts. There was an increase in the total number of conflicts, crossing conflicts (AM only), lane-change conflicts, and rear-end conflicts that was significant when compared to the existing conditions. Compared to existing conditions, crossing conflicts at particular intersections increased at the intersection of East Brokaw St. and Trimble Road, while fluctuating at others. Compared to the models with a 10% increase in cross-street volumes and left-turn demand, there was a significant increase in total conflicts, rear-end conflicts, and lane-change conflicts.

f. 45 mph LRV: 15% increase in cross-street volumes and left-turn demand on North First Street

This alternative involving increasing the light rail vehicle speed to 45 mph and increasing the cross-street volumes and main-line left-turn demand by 15% yielded no LRV related conflicts. There was an increase in the total number of conflicts, lane-change conflicts, and rear-end conflicts that was significant when compared to the existing conditions. Compared to existing conditions, crossing conflicts at particular intersections increased at the intersection of East Brokaw St., and Trimble Rd., while fluctuating at others. Compared to the models with a mere 10% increase in cross-street volumes and left-turn demand, there was a significant increase in total conflicts, rear-end conflicts, and lane-change conflicts.

g. 40 mph LRV: 20% increase in cross-street volumes and left-turn demand on North First Street

This alternative involving increasing the light rail vehicle speed to 40 mph and increasing the cross-street volumes and main-line left-turn demand by 20% yielded no LRV related conflicts. There was a significant increase in the total number of conflicts, crossing conflicts (PM only), lane-change conflicts, and rear-end conflicts when compared to the existing conditions. Compared to existing conditions, crossing conflicts at particular intersections increased at the intersection of East Brokaw St., and Trimble Road, while fluctuating at others. Based on the increase in volumes, and demand for main-line left-turns, extensive queuing was observed which appears to have a correlation with rear-end conflicts. The increase in volumes also appears to be positively correlated with lane-change conflicts. There appears to be a slight correlation between an increase in volumes and crossing conflicts. However, as the volumes near or exceed capacity, the throughput does not increase linearly, so crossing conflicts were not observed to increase as great as they did in the other incremental volume increase (i.e. 0% to 10% and 10% to 15%).

h. 45 mph LRV: 20% increase in cross-street volumes and left-turn demand on North First Street

This alternative involving increasing the light rail vehicle speed to 45 mph and increasing the cross-street volumes and main-line left-turn demand by 20% yielded no LRV related conflicts. There was a significant increase in the total number of conflicts, lane-change conflicts, and rear-end conflicts when compared to the existing conditions. Compared to existing conditions, crossing conflicts at particular intersections increased at the intersection of East Brokaw St., and Trimble Road, while fluctuating at others, similar to the other alternatives modeled. The results were for this alternative were similar to the alternative with the same volume increase with a 40 mph LRV, as they are not significantly different in any of the conflicts tested.

DELAY COMPARISON

Following the testing of alternatives and comparison of conflicts, queues and delays at the study intersections were compiled for existing conditions and scenarios with 20% increase in cross-street and left-turn traffic volumes As expected, delays and queues associated with the cross-streets and turning movements increased as overall traffic volumes increased. Long queuing and spillback was observed at key intersections in the increased volume scenarios. However, due to all roadways having physical separation from the light rail right-of-way, when spillback occurred, it was either on a cross-street, or upstream from the intersection at which the spillback occurred. There were no instances observed of excessive queues backing onto the light rail crossings. Figure 28 shows the VISSIM output of average delays and maximum queues by movement between the Existing AM Peak model and the scenario with a 20% increase cross-street and mainline left-turn traffic volumes. Figure 29 shows the delays and queues for the scenario described above, but with the light rail vehicle speed at 45 mph. Figure 30 and Figure 31 reflect the PM peak hour output for the scenarios described above.

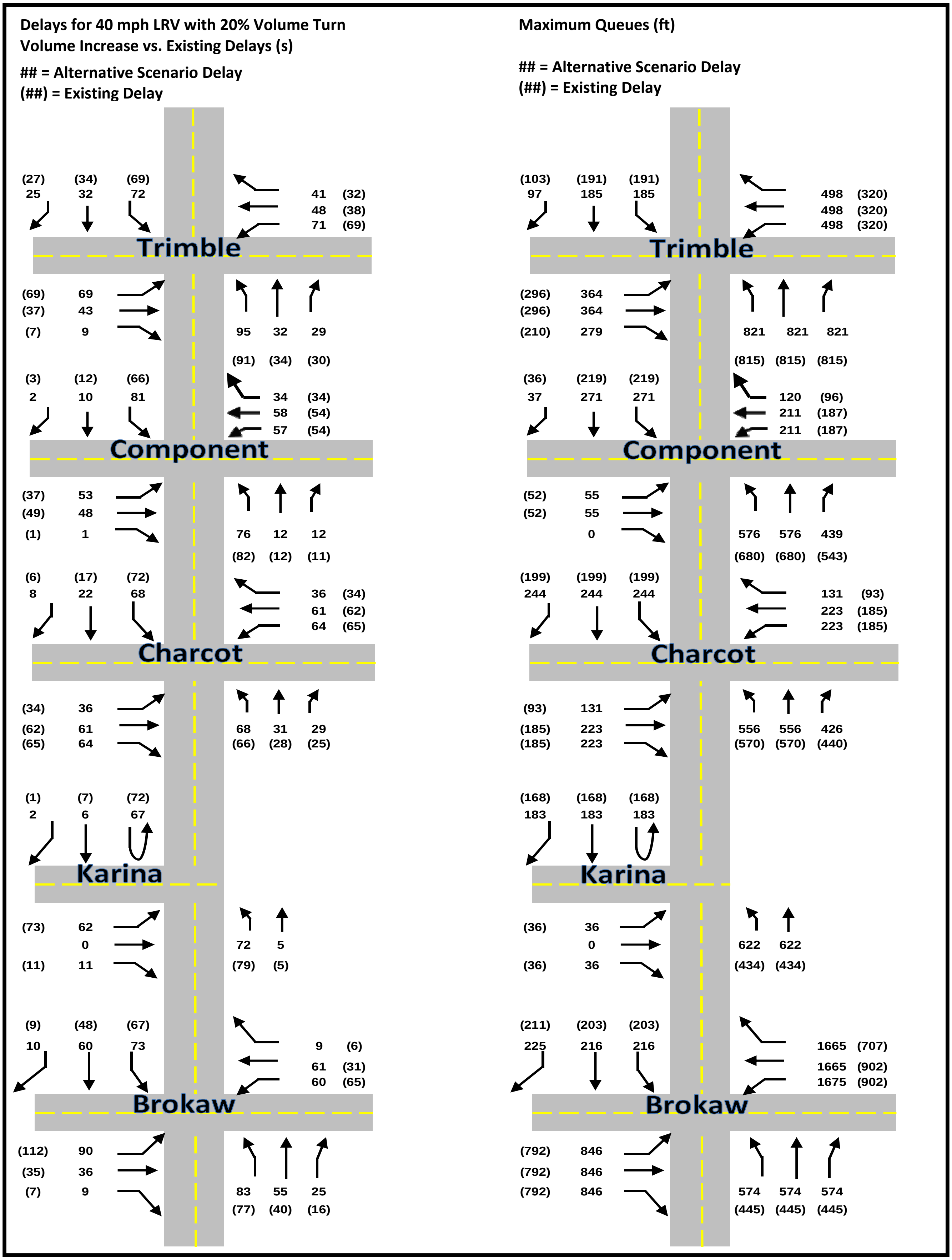

Figure 28. AM Peak Delays and Queues for Scenario with 40 mph LRV and 20% Turning Volume Increase vs. Existing Conditions

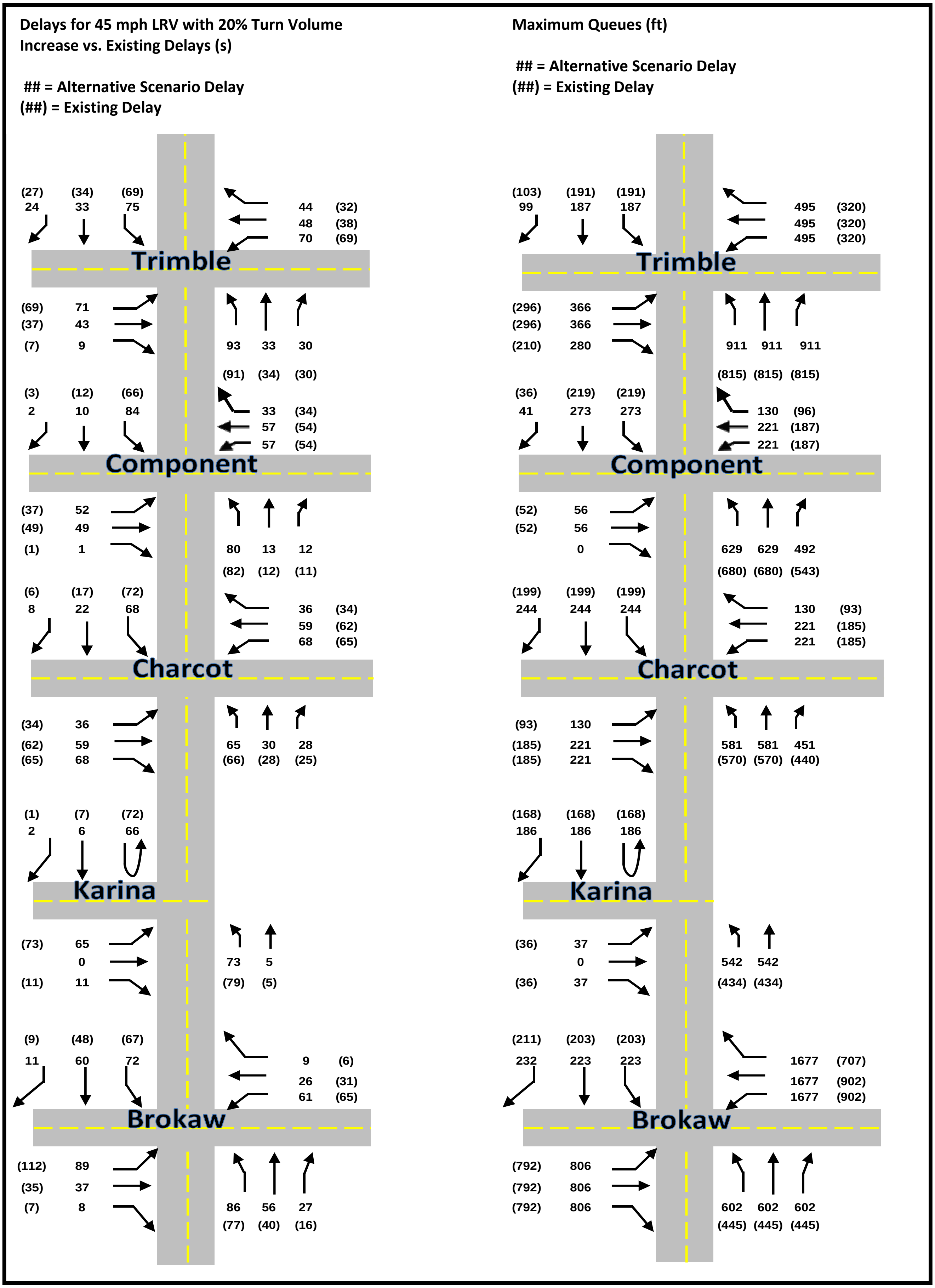

Figure 29. AM Peak Delays and Queues for Scenario with 45 mph LRV and 20% Turning Volume Increase vs. Existing Conditions

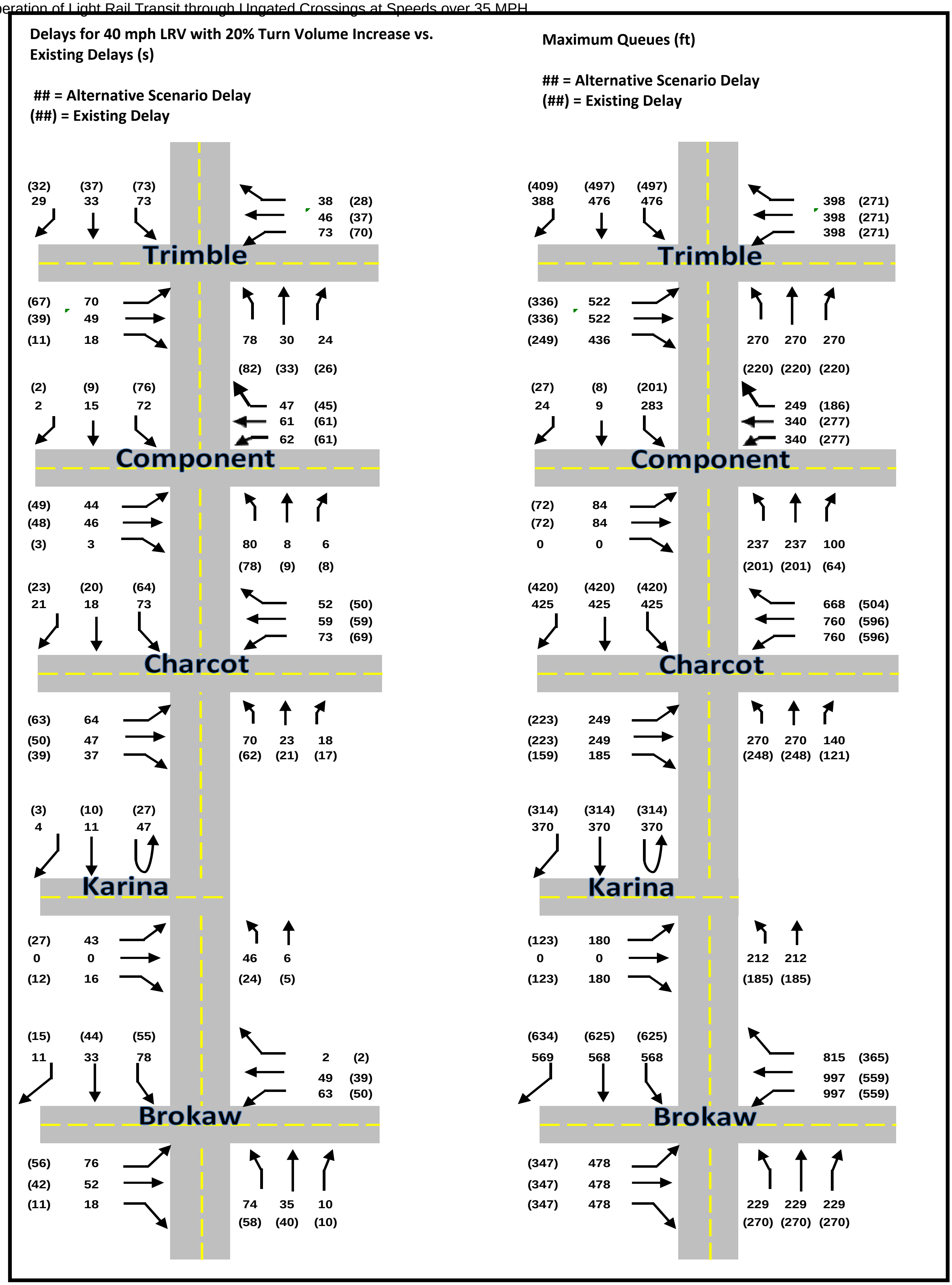

Figure 30. PM Peak Delays and Queues for Scenario with 45 mph LRV and 20% Turning Volume Increase vs. Existing Conditions

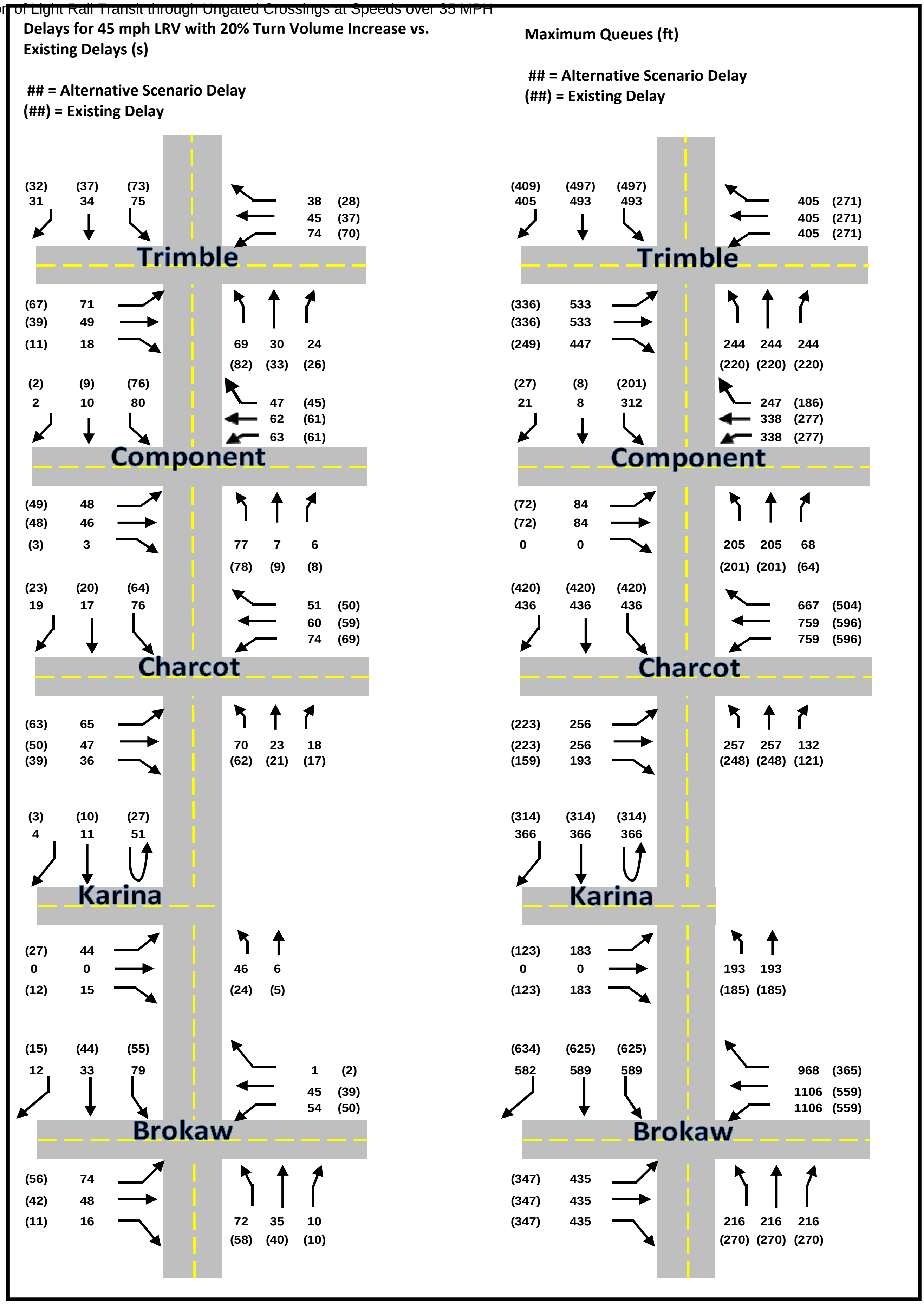

Figure 31. PM Peak Delays and Queues for Scenario with 45 mph LRV and 20% Turning Volume Increase vs. Existing Conditions

PRELIMINARY CONCLUSIONS

The results of the simulation did not demonstrate any change or significant evidence of an increase in LRV-related conflicts that are associated with increasing the operating speed of light rail vehicles. Likewise, the increase in the number of crossing type conflicts did not demonstrate a statistical significance among the various scenarios associated with increases in LRV speeds and traffic volumes.

CHAPTER 5: RISK ANALYSIS

This chapter describes the risk analysis conducted for the test of higher speed LRV operations. The risk analysis identifies and measures potential safety impacts of the test, including:

- What is the probability that a crash (or crashes) will occur?
- What types of crashes are likely to occur?
- How severe will the crashes be?

In order to answer these questions, it is useful to consider the rates reflected in the past (i.e., observed crashes, near-miss incidents, and risky behaviors). These historical data, described in detail in Chapter 3, are a strong predictor of future events. Additionally, it is imperative to consider all the variables of change that could impact future outcomes. In the case of this test, change can result from the following:

- The installation of alternative traffic control devices;
- The addition up new traffic control devices or safety measures; and
- An increase in LRV speed.

Other factors that could change over time during the testing period that could impact future outcomes might include factors such as traffic volumes, traffic patterns, pedestrian volumes, and signal timing plans.

Early on, it was envisioned that a probabilistic approach using regression analysis would be used for the risk analysis to predict the impacts and level of severity of crashes associated with an increase in LRV speed. However, the frequency of LRV-related crashes at the three study intersections over the past 3 years was very low, and there were no fatalities or serious injuries associated with any of the LRV-related crashes at the intersections. Therefore, it is not possible to correlate the crash data, traffic volumes, and observed risky behaviors at the three intersections. As a result, a frequency-based analysis was determined to be a more appropriate approach to the risk analysis considering the 3-year history.

CRASH DATA

The city data indicated that there were 6 LRV-related crashes in the past 3 years at the 3 study intersections. Four (67 percent) of the six crashes occurred at Brokaw Rd. One LRV-related crash was reported at each of the other two intersections. Of the LRV-related crashes, none involved pedestrians or bicyclists. One-half of the crashes (three of the six) involved vehicles making left turns from North First St. onto the cross-streets.

The crash data provided by VTA indicate that there were 11 LRV-related crashes over the same 3-year period. Six (55 percent) of the 11 crashes occurred at Brokaw Rd. There were two LRV-related crashes reported at Charcot Ave. and three LRV-related crashes reported at Trimble Rd. in the past 3 years. As with the city data, none of the LRV-related crashes involved pedestrians or bicyclists. Nearly all of the crashes (10 of the 11 crashes, or 91 percent) involved vehicles making left turns from North First St. onto the cross-streets.

These data are summarized in Table 22.

Table 22. Summary of Historical LRV-Related Crash Data

Intersection of N. First St.	Total Crashes*		Ped or Bike		Left Turn Red-Light Running		LRV Signal Violation		Other	
	City	VTA	City	VTA	City	VTA	City	VTA	City	VTA
Brokaw Rd.	4	6	0	0	2	5	0	0	2	1
Charcot Ave.	1	2	0	0	1	1	0	0	0	1
Trimble Rd.	1	3	0	0	0	1	0	1	1	1
Total (n)	6	11	0	0	3	7	0	1	3	3
Percent of total			0%	0%	50%	64%	0%	9%	50%	27%
Average	8.5		0 (0%)		5 (57%)		0.5 (4.5%)		3 (38.5%)	
* No fatal crashes reported. Three crashes involved minor injuries.										

These data show that the crash rate hovered between 2.0 and 3.7 crashes per year across the three intersections, depending on the data source used. If all factors were to remain constant, it would be possible to expect similar crash rates for the 1-year test period being proposed. Conservatively, using the VTA data, it would be expected that there could be approximately four crashes during the test year; two of these would be expected to occur at Brokaw Rd., and one would be expected to occur at the other two intersections. Based on the historical data, it is also likely that there would be no pedestrian or bicycle crashes observed in the 1-year test period. Most (if not all) of the observed crashes during the test year would be the result of a left-turn red-light violation from North First St..

It is important to note that history is merely predictive. A variety of factors could influence actual crash rates, which could presumably result in abnormally low or high crash rates during the 1-year test period. These factors include anomalies due to weather, construction, fuel costs, and others that could affect road conditions in such a way as to make a crash more likely or more severe or that could affect the amount of driving people do (and thus their exposure to crash opportunities).

RISKY BEHAVIOR

The historical crash data described above are predictive of future crash rates. However, risky behaviors provide a more detailed understanding of the potential for events that may not have been captured in a snapshot of crashes. For instance, in the 3 years of crash data reviewed, there were no LRV-pedestrian crashes. Relying solely on crash data to predict outcomes during the test year would predict zero LRV-pedestrian crashes. However, such a perspective would be naive. Examining risky behavior provides a more meaningful and realistic understanding of potential safety problems.

The repeated occurrence of a particular driver and/or pedestrian behavior could explain why a specific type of an incident or a crash would occur. As Chapter 3 reported in detail, there were 29 near-miss incidents reported by train operators at the 3 study intersections during the past 3 years. Seventeen (57 percent) of these near-miss incidents were reported at Brokaw Rd., while 6 (21 percent) were reported at each of the other two intersections. A majority of the near-miss incidents (21, or 72 percent) involved left- or U-turning vehicles, many of which were classified as a "left-turn violation." There were two near-miss incidents, both at Brokaw Rd. that involved a pedestrian crossing in front of a train.

In addition to the historical safety data, the team conducted field observational studies as a means of assessing the operational and safety aspects of the existing traffic control devices. These data, also detailed in Chapter 3, showed that the most frequently-observed risky behavior was a left-turn during the yellow change or all-red clearance interval, and in several cases completing the turn at the end of the all-red clearance interval. This behavior occurred consistently at all three intersections. Observed pedestrian risky behavior did not demonstrate a high potential of severe implications. Pedestrian activity was low at all three intersections. Several pedestrians crossed the intersection either during the Don't Walk interval, or continued to cross after the Flashing Don't Walk had expired. Risky behaviors associated with cross-street motorists entering the intersection on red were also minimal; a mere 9 violations were observed during the 160 hours of data collection. The highest frequency of violations, overall, was observed at the intersection of North First St. at Brokaw Rd. The highest frequency of red-light violations (five of the nine) was observed for the westbound movement at Charcot Ave. Overall, however, none of the three intersections demonstrated unusual risky behaviors.

This observational study data represents approximately 2 percent of operations in a year (1 out of 52 weeks). Extrapolating to a full year, the overall number of risky behaviors would likely increase. For example, there were 19 mainline left-turn change and clearance interval violations observed during the 1-week field data collection. Assuming a linear relationship and multiplying by a factor of 52, as many as 988 violations may be observed in a year. Similarly, there were 4 instances of pedestrians standing on the tracks. Thus, in one year, there might be approximately 208 events of pedestrians standing on the tracks. Fortunately, as seen in the low rates of crashes noted in the historical data, not every risky behavior leads to a crash. Also, the observed risky behaviors do not indicate the particular likelihood of a crash occurring that had not been reported in the crash data. Examination of the risky behavior data indicates that left-turn violations are the behaviors most likely to lead to crashes. Other crashes, such as those involving pedestrians remain unlikely (although not impossible, as pedestrians are occasionally present).

IMPACT OF CHANGES

The major changes that will occur during the test, and that were not reflected in the historical safety-related data or the observational behavior data, are:

- Installation of alternative traffic control device (e.g., replacing the W10-7 sign to an alternating version of the sign, as previously described);
- Installation of supplemental traffic control devices and safety countermeasures to change driver behavior (specifically, to increase awareness of LRV presence, discourage turning violations, and provide positive guidance to mitigate against track intrusions); and
- Increase LRV speed from 35 to 40 mph.

- Closely monitor the increase in traffic volumes over the duration of the test period to track any significant fluctuation. Address any major volume changes through signal timing adjustments in order to avoid excessive queuing and subsequent blockage of the track which may increase the likelihood of a light rail vehicle/automobile conflict or crash.

These changes during the test period will likely impact the rate and severity of crashes that do occur; however, they are likely to have effects that may counteract one another. For instance, increasing LRV speed may increase the severity of an injury should a crash occur. But fewer crashes may occur due to the new traffic control devices and safety measures. This may produce a net result of fewer but potentially more severe crashes.

Impact of Safety Countermeasures

The alternative traffic control devices and supplemental safety measures being installed during this test period have been well described in this report. These traffic control devices and safety measures focus on mitigating left-turn crashes from North First St., as well as mitigating track intrusions. Thus, it is expected that the crash rate for these types of crashes will be the most impacted as a result of the countermeasures.

Conversely, it is also possible that some element of the installed countermeasures will have a detrimental effect on risky behaviors, near-miss incidents, or even crash rates. For instance, signs and markings, especially unfamiliar ones, can be misunderstood by drivers or may seem confusing, leading to an increase in unsafe actions and possibly even crashes. While the research team feels this outcome is unlikely, it is for this reason that the test and evaluation has been structured to include multiple stages. By first measuring the risky behaviors, near-miss incidents, and crash rates in the Baseline Conditions, there is a basis for comparison for the After Safety Improvement Conditions, which do not include an increase in LRV speed. Only after it has been established that there have been no unanticipated outcomes as a result of the safety improvements will the LRV speeds be raised to 40 mph. This is one of the primary ways of mitigating the risk associated with the test.

Impact of Increased LRV Speed

Theoretically, an increase in LRV speed from 35 to 40 mph should not increase the probability of crash occurrence per se. This small increase in speed should be transparent to drivers and therefore should not impact driver decision-making or behaviors. Assuming the intersection operations (track circuitry and traffic signal timing) have been modified to accommodate the speed increase, there is little reason to anticipate an increased likelihood of crashes at the intersections. The one exception may be that during a driver violation (such as running a red light during a left turn) the slightly faster LRV speed will result in decreased time for the vehicle to clear the intersection before impact, as well as increased braking distance for the LRV to come to a stop. These factors could, in some cases, result in crashes occurring that would have resulted in near-miss incidents at 35 mph. In examining the near-miss incidents over the past 3 years, there were 12 incidents where the driver applied the maximum brake (approximately four incidents per year). It is in these four cases that the speed increase may play a factor in whether or not a crash might occur.

What can also be anticipated is a probable increase in crash severity should a crash occur during the test. The question then becomes, what impact does the 5 mph increase in speed have on crash severity? Considering the 11 LRV-motor vehicle crashes reported in the past 3 years, none of the crashes resulted in a fatality, and three of the 11 crashes (27 percent) resulted in minor injuries. According to the European Road Safety Observatory, when collision speed increases, the amount of energy that is released increases as well, and part of this energy will be absorbed by the human body. When the amount of external forces exceeds the physical threshold a human body can tolerate, serious or fatal injury will occur. This is particularly true for occupants of light vehicles, when colliding with more heavy vehicles and for unprotected road users, such as pedestrians and cyclists when colliding with motorized vehicles.[1] Based on this, Nilsson developed the following equation, which describes the effects of a speed increase on the rate of minor injury crashes:[2]

$$A_2 = A_1 (v_2 / v_1)^2$$

where:

A_2 = the number of injury crashes after the speed change;

A_1 = the number of injury crashes before the speed change;

v_1 = the original velocity; and

v_2 = the increased velocity.

Applying this equation to the situation at hand,

$$A_2 = 3\,(40\text{ mph} / 35\text{ mph})^{2} = 4\text{ injury crashes}$$

Therefore, according to this equation, one could expect approximately 5 injury crashes, as opposed to 3 injury crashes, in a 3-year period after the increase in speed, or approximately 1.23injury crashes in the 1-year test period (as opposed to 1 injury crash per year before the speed increase). As this equation does relate to motor vehicle crashes, not LRV-motor vehicle crashes, the increase in the rate of injury crashes would be expected to be greater. In addition, absolute speed is not the sole factor that would affect crash severity. Other factors such as relative speed, angle of impact, vehicle crashworthiness, occupant restraint usage, and occupant characteristics will also impact the severity of the crash; however, in the absence of an equation specific to LRV crashes, the result gives some idea of the magnitude of increase in injury crash rates.

Other Potential Impacts

As noted above, other factors ranging from weather to fuel costs can impact collision rates. One notable impact to crash rates is the impact of changes in traffic volumes. In addition to the traffic volumes obtained from the City of San Jose, the research team observed traffic volumes for the left and through movements on North First St. from the field video data for each of the data collection periods. These data are relevant when comparing the frequency of “before and

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[1] European Road Safety Observatory, Speed and Injury Severity, http://www.erso.eu/knowledge/content/20_speed/speed_and_injury_severity.htm, as of September 15, 2009.

[2] Nilsson, G. The effects of speed limits on traffic crashes in Sweden. In: Proceedings of the international symposium on the effects of speed limits on traffic crashes and fuel consumption, Dublin. Organization for Economy, Co-operation, and Development (OECD), Paris, 1982.

after" risky behaviors. It is possible that if traffic volumes are higher, the frequency of a particular type of conflict may also be higher.

North First St. is characterized as a technology corridor, and traffic volumes could fluctuate substantially as the number of workers (i.e., commuters) in technology sector vacillates. It was noted that during the data collection period in June 2009, several of the adjacent office buildings were vacant, several of which had more than 1,000 parking spaces unoccupied. In fact, comparing the traffic volumes that were obtained from the City of San Jose in 2008 and 2009 to those that were retrieved from the June 2009 video observations, it appears that the traffic volumes have decreased at the Brokaw Rd. intersection; traffic volumes have generally increased at the Charcot Ave. intersection during the afternoon peak hour and decreased slightly during the morning peak hour; and traffic volumes have stayed within about 10-12 percent at the Trimble Rd. intersection. Traffic data from the City of San Jose and from the observation counts are summarized in Table 23.

Table 23. Summary of Traffic Volume Data

Movement: North First St. at:	Counts from City of San Jose AM (PM) Peak Hour*	Observation Counts AM (PM) Peak Hour*	Ratio: Video Observation Traffic Count to City Traffic Count AM (PM) Peak Hour*
Date	9/23/08	6/24/09	
NB Left at Brokaw Rd.	106 (53)	95 (47)	87% (89%)
NB Through at Brokaw Rd.	660 (330)	524 (243)	79% (74%)
Date	3/24/09	6/24/09	
NB Left at Charcot Ave.	71 (58)	68 (71)	96% (122%)
NB Through at Charcot Ave.	447 (354)	523 (373)	117% (105%)
SB Left at Charcot Ave.	37 (93)	30 (98)	81% (105%)
SB Through at Charcot Ave.	305 (601)	294 (639)	96% (106%)
Date	9/23/08	6/24/09	
NB Left at Trimble Rd.	201 (193)	176 (187)	88% (97%)
NB Through at Trimble Rd.	619 (388)	651 (403)	105% (104%)

* AM Peak Hour: 8:00 AM – 9:00 AM, PM Peak Hour: 5:00 PM – 6:00 PM.

CONCLUSIONS

In conclusion, as would be expected, there is a potential for increased risks associated with the 1-year test of increased LRV speeds, although these increased risks are considered to be relatively minor given the historical safety-related data and the field observational data. These risks include:

- <u>Potential for increase in number of crashes</u>—The historical near-miss incident data show that there were approximately four near-miss incidents per year where the LRV operator applied the maximum brake. It is possible that if the LRV had been operating at 40 mph (as opposed to 35 mph), one or more of these near-miss incidents could have resulted in a crash. Thus, there may be a potential for an increase of up to four crashes in the 1-year test period.

- Potential for increase in rate of minor injury crashes—Historical data show that 3 of the 11 LRV-related crashes resulted in minor injuries at the 3 study intersections in the past 3 years. With trains operating at 40 mph, the proportion of minor injury crashes is anticipated to increase by at least 67 percent to at least 1.23 during the 1-year test period.
- Potential for increase in crash severity—While no specific functions or models were identified to express crash severity as a function of LRV speed, the laws of physics suggest that even a slight increase in LRV speed could have severe outcomes in the event of a crash. However, speed alone cannot be the sole predictor of the severity of a crash. Other factors such as relative speed, angle of impact, and driver characteristics (such as age) will also affect crash severity.

In addition, the improvements being made to the intersections by the VTA prior to the increase in train speeds are expected to counteract some of these potential increased risks in a number of ways. The improvements are expected to:

- Make left-turning drivers more aware of the arrival of a train;
- Give left-turning drivers more opportunity to see a train approaching the intersection;
- Provide more positive guidance to left-turning drivers;
- Provide visual separation between the left-turn pocket and the trackway;
- Decrease driver risky behaviors;
- Improve driver compliance with traffic control devices; and overall,
- Reduce the number of LRV-motor vehicle crashes.

APPENDIX A: SUMMARY OF CRASH DATA AT THE INTERSECTIONS OF NORTH FIRST STREET AND BROKAW ROAD, CHARCOT AVENUE, AND TRIMBLE ROAD

Details of the crash data at the intersection of North First St. and Brokaw Rd. are shown in Table A-1.

Table A-1. Details of Crashes at North First St. and Brokaw Rd.

Accident Type	# of Accidents	Probable Cause	# of Accidents
Other	13	Unlicensed Driver	1
Head on	3	Ran red light	9
Light Rail Vehicle	**4**	Unsafe turn	2
Rear	25	Unsafe backing	3
Sideswipe	4	Speeding	19
Fixed Object	1	Unsafe Lane Change	8
Right-angle	10	Failure to obey pedestrian signal	1
Pedestrian	2	Following too closely	2
Parked Vehicle	0	Wrong Way on Bicycle	1
Motorcycle	0	Failure to yield	1
Bicycle	2	Driving in bike lane	1
		Pedestrian failure to yield	1
		Other Impaired Driving	0
		Spilling Load	1
		Sudden Stop	0
		Other	14
Total	**64**	**Total**	**64**
Reported Year	**# of Accidents**	**Direction of Movement**	**# of Vehicles involved**
2006	9	SB (L, T, R)	36
2007	23	NB (L, T, R)	27
2008	24	EB (L, T, R)	17
2009	8	WB (L, T, R)	51
Total	**64**	**Total**	**131**
Severity	**# of Accidents**	**Weather**	**# of Accidents**
Fatal	0	Clear	53
Injury	15	Cloudy	8
Property Damage Only	49	Rain	3
Total	**64**	**Total**	**64**
Illumination	**# of Accidents**	**Surface Conditions**	**# of Accidents**
Daylight	52	Wet	5
Dark-Lights On	9	Dry	59
Dark-No Lights	0	Ice/Snow	0
Dawn/Dusk	3		
Total	**64**	**Total**	**64**

Data were provided by the City of San Jose Department of Streets and Traffic.

Analysis of the crash data at Brokaw Rd. identified the following key findings:

- Fifty-six (88%) crashes occurred during weekdays, and eight (12%) occurred on weekends;
- Thirteen (20%) crashes occurred during the morning and afternoon peak periods (i.e., 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m.), of which eight occurred during the morning peak and five occurred during the evening peak;
- Fifty-two (81%) crashes occurred during daylight, and 12 (19%) occurred during dusk/dark;
- Fifty-three (83%) crashes occurred under clear weather conditions, and 11 (17%) occurred under cloudy/rainy weather conditions;
- Fifty-nine (92%) crashes occurred on dry pavement, and five (8%) occurred on wet pavement;
- The distribution of the severity of the crashes was 0 (0%) fatality, 15 (23%) injury (all injuries combined), and 49 (77%) property damage only. Seventeen people were reported as injured in 15 of the crashes;
- “Speeding” was the predominant probable cause (30%) of all crashes, followed by “running red light” (41%), and “unsafe lane change” (13%);
- Rear-end crashes were the predominant type of crash (39%) at the intersection; 44% of the rear-end crashes occurred in the westbound direction, 24% occurred both in the northbound and southbound directions, and 8% occurred in the eastbound direction. For all the rear-end crashes, “speeding” was recorded as the probable cause;
- Right-angle crashes made up 19% of the crashes, of which five (50%) involved vehicles traveling in the southbound and westbound directions and five (50%) involved vehicles traveling in the southbound and eastbound directions. Four (40%) of the right-angle crashes occurred as a result of red-light running, three (75%) of which were a result of the vehicle running the red light in the southbound direction;
- Four crashes at the intersection involved a collision with an LRV;
- All four LVR-motor vehicle crashes occurred on a weekday in the off-peak period;
- Of the four LRV-motor vehicle crashes, two involved vehicles traveling in the northbound direction running a red light while making a left-hand turn; and
- One of the LRV-motor vehicle crashes involved “unsafe backing” of a vehicle traveling in the northbound direction on wet pavement during the extended morning peak period (i.e., within 15 minutes before and/or after); the other LRV-motor vehicle crash involved an unsafe lane change in the southbound direction.

Details of the crashes at Charcot Ave. are shown in Table A-2.

Table A-2. Details of Crashes at North First St. and Charcot Ave.

Accident Type	# of Accidents	Probable Cause	# of Accidents
Other	0	Unlicensed Driver	0
Head on	1	Ran red light	4
Light Rail Vehicle	**1**	Unsafe turn	0
Rear	3	Unsafe backing	0
Sideswipe	0	Speeding	3
Fixed Object	1	Unsafe Lane Change	1
Right-angle	5	Failure to obey pedestrian signal	0
Pedestrian	1	Following too closely	0
Parked Vehicle	0	Wrong Way on Bicycle	0
Motorcycle	1	Failure to yield	0
Bicycle	1	Driving in bike lane	1
		Pedestrian failure to yield	0
		Other Impaired Driving	1
		Spilling Load	0
		Sudden Stop	0
		Other	4
Total	**14**	**Total**	**14**
Reported Year	**# of Accidents**	**Direction of Movement**	**# of Vehicles involved**
2006	3	SB (L, T, R)	4
2007	4	NB (L, T, R)	11
2008	4	EB (L, T, R)	10
2009	3	WB (L, T, R)	3
Total	**14**	**Total**	**28**
Severity	**# of Accidents**	**Weather**	**# of Accidents**
Fatal	0	Clear	14
Injury	7	Cloudy	0
Property Damage Only	7	Rain	0
Total	**14**	**Total**	**14**
Illumination	**# of Accidents**	**Surface Conditions**	**# of Accidents**
Daylight	11	Wet	0
Dark-Lights On	3	Dry	14
Dark-No Lights	0	Ice/Snow	0
Dawn/Dusk	0		
Total	**14**	**Total**	**14**

Data were provided by the City of San Jose Department of Streets and Traffic.

Analysis of the crashes at Charcot Ave. identified the following key findings:

- All of the reported crashes occurred during weekdays;
- Two crashes occurred during the morning and afternoon peak periods, of which one occurred during the extended afternoon peak period (i.e., within 15 minutes of afternoon peak);
- Eleven (79%) crashes occurred during daylight, and three (21%) occurred during dusk/dark;
- All of the reported crashes occurred under clear weather conditions;
- All of the reported crashes occurred on dry pavement;
- The distribution of the severity of the crashes was zero (0%) fatality, seven (50%) injury (all injuries combined), and seven (50%) property damage only. Eight people were reported as being injured in seven of the crashes;
- “Red-light running” was the predominant probable cause (29%) of all crashes, followed by “speeding” with three (21%) incidents, and “unsafe lane change” with one (7%) incident;
- Right-angle crashes were the predominant type of crash, with five (36%) incidents; two of the right-angle crashes occurred with vehicles traveling in the southbound and eastbound directions, one occurred with vehicles traveling in the northbound and eastbound directions, one occurred with vehicles traveling in the southbound and westbound directions, and one occurred with vehicles traveling in the northbound and westbound directions. The noted probably cause of two of the right-angle crashes was “running red light” (in one incident the southbound vehicle ran the red light, and in the other the eastbound vehicle ran the red light);
- Rear-end crashes made up 21% of the crashes, of which two involved vehicles traveling in the northbound direction, and one involved vehicles traveling in the eastbound direction; and
- One crash at the intersection involved a collision with an LRV. This crash involved a vehicle traveling in the northbound direction running a red light while making a left-hand turn. The crash occurred at 9:00 p.m. on a weekday, on dry pavement, in dark conditions, and with clear weather.

Details of the crash data at the intersection of North First St. and Trimble Rd. are shown in Table A-3.

Table A-3. Details of Crashes at North First St. and Trimble Rd.

Accident Type	# of Accidents	Probable Cause	# of Accidents
Other	5	Unlicensed Driver	0
Head on	5	Ran red light	4
Light Rail Vehicle	1	Unsafe turn	1
Rear	7	Unsafe backing	0
Sideswipe	2	Speeding	11
Fixed Object	3	Unsafe Lane Change	3
Right-angle	5	Failure to obey pedestrian signal	0
Pedestrian	1	Following too closely	0
Parked Vehicle	1	Wrong Way on Bicycle	0
Motorcycle	0	Failure to yield	2
Bicycle	1	Driving in bike lane	0
		Pedestrian failure to yield	0
		Other Impaired Driving	0
		Spilling Load	1
		Sudden Stop	1
		Other	8
Total	31	Total	31
Reported Year	# of Accidents	Direction of Movement	# of Vehicles involved
2006	7	SB (L, T, R)	20
2007	11	NB (L, T, R)	12
2008	10	EB (L, T, R)	14
2009	3	WB (L, T, R)	18
Total	31	Total	64
Severity	# of Accidents	Weather	# of Accidents
Fatal	0	Clear	28
Injury	21	Cloudy	2
Property Damage Only	10	Rain	1
Total	31	Total	31
Illumination	# of Accidents	Surface Conditions	# of Accidents
Daylight	27	Wet	2
Dark-Lights On	4	Dry	29
Dark-No Lights	0	Ice/Snow	0
Dawn/Dusk	0		
Total	31	Total	31

Source: City of San Jose Department of Streets and Traffic.

Analysis of the crashes at Trimble Rd. identified the following key findings:

- Twenty-six (84%) crashes occurred during weekdays, and five (16%) occurred on weekends;
- Ten (20%) crashes occurred during the morning and afternoon peak periods, of which four occurred in the morning peak, and 6 occurred in the afternoon peak;
- Twenty-seven (87%) crashes occurred during daylight, and four (13%) occurred during dusk/dark;
- Twenty-eight (90%) crashes occurred under clear weather conditions, and three (10%) occurred under cloudy/rainy weather conditions;
- Twenty-nine (94%) crashes occurred on dry pavement, and two (6%) occurred on wet pavement;
- The distribution of the severity of the crashes was 0 (0%) fatality, 10 (32%) injury (all injuries combined), and 21 (68%) property damage only. Fifteen people were reported as injured in 10 of the crashes;
- “Speeding” was the predominant probable cause (36%) of all of the crashes, followed by “running red light” (13%), and “unsafe lane change” (10%);
- Rear-end crashes were the predominant type of crash at the intersection (23%), with a total of seven rear-end crashes, where three (43%) occurred in the southbound direction, two (29%) occurred in the westbound direction, one (14%) occurred in the northbound direction, and one (14%) occurred in the eastbound direction. For all of the rear-end crashes, “speeding” was noted as the probable cause;
- Right-angle crashes made up 16% of the crashes at the intersection. Of the five right-angle crashes, two involved vehicles traveling in the northbound and westbound directions, one involved vehicles traveling in the southbound and eastbound directions, one involved vehicles traveling in the southbound and westbound directions, and one involved vehicles traveling in the northbound and eastbound directions;
- Three of the five right-angle crashes were a result of “red-light running,” (one incident occurred in each of the westbound, southbound, and northbound direction);
- Head-on crashes also made up 16% of the crashes at the intersection; and
- One crash at the intersection involved a collision with an LRV (with a vehicle making a southbound U-turn). The crash occurred at 12:35 p.m. on a Thursday, on dry pavement, in daylight conditions, and in clear weather. The probable cause for this crash was recorded as “unknown.”

APPENDIX B: VTA *DRAFT* LETTER TO FHWA REQUESTING PERMISSION TO EXPERIMENT WITH AN INCREASE IN LRV SPEEDS TO 40 MPH THROUGH THREE UNGATED CROSSINGS

Mr. Hari Kalla
MUTCD Team Leader
Federal Highway Administration
Office of Transportation Operations, HOTO-1
1200 New Jersey Avenue, S.E., Mailstop E846-302
Washington, DC 20590

Subject: **Request to Experiment with Enhanced Traffic Control Devices In Lieu of Flashing-Light Signals at a Highway-Light Rail Transit Grade Crossing In Order to Increase Transit Speeds at Three Intersections**

Dear Mr. Kalla:

The Santa Clara Valley Transportation Authority (VTA) requests permission to use MUTCD approved enhancements using lane markings and signs in lieu of flashing-light signals on the North First St. corridor in San Jose, California at three signalized intersections. Per Section 10D.02 of the 2003 Manual on Uniform Traffic Control Devices (MUTCD), “Highway-light rail grade crossings in semi-exclusive alignments shall be equipped with flashing-light signals where light rail transit speeds exceed 60 km/h (35 mph). Flashing-light signals shall be clearly visible to motorists, pedestrians, and bicyclists.” In cooperation with a research study performed through the Transit Cooperative Research Program (TCRP), VTA would like to:

1. Increase the speed of light rail transit in the corridor through three test signalized intersections/crossings to 40 mph while using traffic control devices that are an improvement over the required traffic control devices in the MUTCD and still provide an active warning to motorists.
2. Use a blank-out sign similar to the W10-7 but including an alternating No-Left Turn indication along with the standard Train Approaching symbol to provide an active warning to motorists.

TCRP Project A-32 entitled “Operation of Light Rail Transit through Ungated Crossings at Speeds over 35 MPH” is being conducted by Science Applications International Corporation (SAIC). The research effort involves a risk analysis and a safety evaluation before and after the addition of the enhanced lane markings and signs as well as before and after the speed increase from 35 MPH to 40 MPH.

Problem Statement

Where light rail transit (LRT) operates in semi-exclusive rights-of-way, such as in the roadway median, light rail vehicles (LRVs) interface with motor vehicles at highway intersections. Where LRVs operate through these highway intersections at speeds over 35 mph, Part 10 of the (MUTCD) recommends the use of automatic gates and requires flashing lights to warn motorists of the presence of a train. Most transit agencies that operate LRT in median-running environments have found it challenging and costly to install flashing lights and automatic gates at every intersection. As a result, they operate LRVs at speeds not greater than 35 mph, even where the parallel motor vehicle traffic operates at speeds higher than 35 mph.

In 2007, the TCRP sponsored a research project to document the relationship between existing traffic control requirements, LRV operating speeds through LRT-highway crossings, and safety. The results of this research suggested the need for further research that would establish a defined risk assessment and evaluation process that might lead to conditional higher LRV running speeds at limited locations.

The Subject Test Locations

The subject test locations including the following light rail crossings:

- North First St. & Brokaw Rd. (CPUC # 82B-1.44)
- North First St. & Charcot Ave. (CPUC # 82B-1.91)
- North First St. & Trimble Rd. (CPUC # 82B-2.46)

Please note that the two intermediate crossings, North First St. & Karina Court (CPUC # 82B-1.61) and North First St. and Component Drive (CPUC# 82B-2.20), at which speeds will remain the same due to the proximity of the to the Karina and Component LRT stations, respectively.

Description of Proposed Change, Deviation from MUTCD, and Improvement Over the MUTCD Standard

VTA is planning to add enhanced signs and markings, as illustrated in Appendix A, as part of a safety improvement effort. These enhancements include:

- Installation of an alternating Train Approaching (W10-7) / No Left Hand Turn blank-out sign for parallel left-turning vehicles to signify when LRT vehicles are approaching the crossing
- Relocation of existing stop bars in left-turn lanes adjacent to LRT tracks 20' back from the crosswalk (or existing location) to enhance the visibility of an approaching LRT vehicle by left-turning traffic
- Use of "KEEP CLEAR" pavement markings on left-turn lanes (between the relocated stop bar and the crosswalk / intersection) adjacent to the LRT tracks to reinforce stopping at the stop bar
- Installation of yellow painted channelization pavement markings and yellow pavement markers around the tracks on the near and far sides of the intersection to guide cars to the proper lanes and avoid entering the VTA right-of-way to avoid left-turn crashes
- Installation of California Type Q Markers along the tracks in the vicinity of the crossings to guide vehicles away from the tracks during left turns from both the parallel and cross-streets

Research Plan

Details of the research plan can be found in Appendix B, an excerpt of the TCRP A-32 amplified work plan. The research team has already collected baseline behavioral and crash data. Once the proposed enhancements (as shown above) are installed, the team will then collect another round of behavioral and crash data. Once the analysis is complete, VTA proposes to increase the speed of the LRT vehicles to 40 mph through the three test crossings for a three month period in which crash and near-miss data will be monitored to assure there are no adverse impacts of the increase in speeds.

Length of Experimentation

The proposed experiment is scheduled to least nine months (estimated from September to December 2010). VTA and the research team will continuously monitor crash data and other safety data during the implementation period of the increase in speed. After the experiment, the speeds will be lowered to the original 35 mph speed.

VTA is aware of the CPUC regulatory process (i.e., waiver of speed restrictions in GO 143-B). It is the goal to obtain the necessary concurrence from the CPUC and the City of San Jose.

Thank you for considering this request. Please do not hesitate to call VTA should you require any further information in order to process this request.

Sincerely,

NAME
TITLE
Santa Clara Valley Transportation Authority

Cc: Felix Ko, CPUC
Rupta Shitole, CPUC
Arun Mehta, CPUC
Lily Lim-Tsao, City of San Jose
Joel Roque, City of San Jose
Michael Hursh, VTA
Art Douwes, VTA
Jane Yu, VTA

Proposed Safety Enhancements Locations

Appendix A-1 (North First St. & Brokaw)
1. VTA Letter - G.O. 88B Request (dated xxx)
2. CPUC G.O. 88B Approval Letter (dated xxx)

Appendix A-2 (North First St. & Charcot)
1. VTA Letter - G.O. 88B Request (dated xxx)
2. CPUC G.O. 88B Approval Letter (dated xxx)

Appendix A-2 (North First St. & Trimble)
1. VTA Letter - G.O. 88B Request (dated xxx)

CPUC G.O. 88B Approval Letter (dated xxx)

APPENDIX C: CONFLICT DATA

40 MPH LRV, 0 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2428	9	2288	131
N First St at Karina Ct	650	0	603	47
N First St at Charcot Ave	1284	4	1236	44
N First St at Component Dr	994	5	969	20
N First St at Trimble Rd	1975	14	1894	67

PM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2863	8	2737	118
N First St at Karina Ct	1263	4	1167	92
N First St at Charcot Ave	1467	4	1380	83
N First St at Component Dr	387	2	369	16
N First St at Trimble Rd	1793	6	1723	64

AM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	494	1	467	26
	2	481	1	451	29
	3	457	3	434	20
	4	470	3	438	29
	5	526	1	498	27
	Total	**2428**	**9**	**2288**	**131**
	Average	**486**	**2**	**458**	**26**
	St. Dev	**26.4**	**1.1**	**26.0**	**3.7**
	Coefficient of Variation	**0.05**	**0.61**	**0.06**	**0.14**
N First St at Karina Ct	1	112	0	103	9
	2	107	0	99	8
	3	139	0	131	8
	4	132	0	117	15
	5	160	0	153	7
	Total	**650**	**0**	**603**	**47**
	Average	**130**	**0**	**121**	**9**
	St. Dev	**21.4**	**0.0**	**22.1**	**3.2**
	Coefficient of Variation	**0.16**	**0.00**	**0.18**	**0.34**
N First St at Charcot Ave	1	264	0	254	10
	2	248	1	240	7
	3	237	1	229	7
	4	279	1	266	12
	5	256	1	247	8
	Total	**1284**	**4**	**1236**	**44**
	Average	**257**	**1**	**247**	**9**
	St. Dev	**15.9**	**0.4**	**14.0**	**2.2**
	Coefficient of Variation	**0.06**	**0.56**	**0.06**	**0.25**
N First St at Component Dr	1	211	0	209	2
	2	222	3	213	6
	3	167	0	164	3
	4	181	0	178	3
	5	213	2	205	6
	Total	**994**	**5**	**969**	**20**
	Average	**199**	**1**	**194**	**4**
	St. Dev	**23.5**	**1.4**	**21.6**	**1.9**
	Coefficient of Variation	**0.12**	**1.41**	**0.11**	**0.47**
N First St at Trimble Rd	1	369	1	355	13
	2	402	4	385	13
	3	391	0	376	15
	4	392	3	374	15
	5	421	6	404	11
	Total	**1975**	**14**	**1894**	**67**
	Average	**395**	**3**	**379**	**13**
	St. Dev	**18.9**	**2.4**	**17.8**	**1.7**
	Coefficient of Variation	**0.05**	**0.85**	**0.05**	**0.12**

PM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	546	1	518	27
	2	551	2	529	20
	3	598	2	579	17
	4	581	1	554	26
	5	587	2	557	28
	Total	**2863**	**8**	**2737**	**118**
	Average	**573**	**2**	**547**	**24**
	St. Dev	**22.9**	**0.5**	**24.2**	**4.8**
	Coefficient of Variation	**0.04**	**0.34**	**0.04**	**0.20**
N First St at Karina Ct	1	253	2	238	13
	2	237	1	217	19
	3	265	0	247	18
	4	260	0	243	17
	5	248	1	222	25
	Total	**1263**	**4**	**1167**	**92**
	Average	**253**	**1**	**233**	**18**
	St. Dev	**10.9**	**0.8**	**13.2**	**4.3**
	Coefficient of Variation	**0.04**	**1.05**	**0.06**	**0.24**
N First St at Charcot Ave	1	273	1	255	17
	2	300	1	281	18
	3	279	0	267	12
	4	299	0	282	17
	5	316	2	295	19
	Total	**1467**	**4**	**1380**	**83**
	Average	**293**	**1**	**276**	**17**
	St. Dev	**17.4**	**0.8**	**15.4**	**2.7**
	Coefficient of Variation	**0.06**	**1.05**	**0.06**	**0.16**
N First St at Component Dr	1	71	0	71	0
	2	74	1	70	3
	3	69	1	63	5
	4	92	0	86	6
	5	81	0	79	2
	Total	**387**	**2**	**369**	**16**
	Average	**77**	**0**	**74**	**3**
	St. Dev	**9.3**	**0.5**	**8.9**	**2.4**
	Coefficient of Variation	**0.12**	**1.37**	**0.12**	**0.75**
N First St at Trimble Rd	1	343	0	331	12
	2	351	1	331	19
	3	363	2	352	9
	4	365	2	353	10
	5	371	1	356	14
	Total	**1793**	**6**	**1723**	**64**
	Average	**359**	**1**	**345**	**13**
	St. Dev	**11.3**	**0.8**	**12.5**	**4.0**
	Coefficient of Variation	**0.03**	**0.70**	**0.04**	**0.31**

40 MPH LRV, 10 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)

Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2829	14	2686	129
N First St at Karina Ct	579	1	521	57
N First St at Charcot Ave	1382	4	1349	29
N First St at Component Dr	1120	3	1089	28
N First St at Trimble Rd	2067	13	1985	69

PM Peak Period Conflicts (5 simulations of 5 hours each)

Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2570	11	2440	119
N First St at Karina Ct	1184	2	1077	105
N First St at Charcot Ave	1423	9	1346	68
N First St at Component Dr	563	8	534	21
N First St at Trimble Rd	1970	3	1900	67

AM Peak Period Conflicts (5 hour simulation period)

Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	568	2	543	23
	2	570	2	539	29
	3	566	2	541	23
	4	586	4	554	28
	5	539	4	509	26
	Total	**2829**	**14**	**2686**	**129**
	Average	**566**	**3**	**537**	**26**
	St. Dev	**16.9**	**1.1**	**16.8**	**2.8**
	Coefficient of Variation	**0.03**	**0.39**	**0.03**	**0.11**
N First St at Karina Ct	1	105	0	97	8
	2	124	0	112	12
	3	98	1	87	10
	4	130	0	115	15
	5	122	0	110	12
	Total	**579**	**1**	**521**	**57**
	Average	**116**	**0**	**104**	**11**
	St. Dev	**13.6**	**0.4**	**11.8**	**2.6**
	Coefficient of Variation	**0.12**	**2.24**	**0.11**	**0.23**
N First St at Charcot Ave	1	267	0	261	6
	2	291	1	282	8
	3	285	1	278	6
	4	274	1	271	2
	5	265	1	257	7
	Total	**1382**	**4**	**1349**	**29**
	Average	**276**	**1**	**270**	**6**
	St. Dev	**11.3**	**0.4**	**10.7**	**2.3**
	Coefficient of Variation	**0.04**	**0.56**	**0.04**	**0.39**
N First St at Component Dr	1	218	0	215	3
	2	223	2	217	4
	3	221	0	212	9
	4	213	1	206	6
	5	245	0	239	6
	Total	**1120**	**3**	**1089**	**28**
	Average	**224**	**1**	**218**	**6**
	St. Dev	**12.3**	**0.9**	**12.6**	**2.3**
	Coefficient of Variation	**0.06**	**1.49**	**0.06**	**0.41**
N First St at Trimble Rd	1	430	6	408	16
	2	423	1	409	13
	3	378	4	360	14
	4	414	2	397	15
	5	422	0	411	11
	Total	**2067**	**13**	**1985**	**69**
	Average	**413**	**3**	**397**	**14**
	St. Dev	**20.6**	**2.4**	**21.4**	**1.9**
	Coefficient of Variation	**0.05**	**0.93**	**0.05**	**0.14**

PM Peak Period Conflicts (5 hour simulation period)

Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	523	4	494	25
	2	515	1	489	25
	3	491	2	472	17
	4	516	4	480	32
	5	525	0	505	20
	Total	**2570**	**11**	**2440**	**119**
	Average	**514**	**2**	**488**	**24**
	St. Dev	**13.6**	**1.8**	**12.7**	**5.7**
	Coefficient of Variation	**0.03**	**0.81**	**0.03**	**0.24**
N First St at Karina Ct	1	224	0	204	20
	2	232	1	211	20
	3	236	1	211	24
	4	228	0	207	21
	5	264	0	244	20
	Total	**1184**	**2**	**1077**	**105**
	Average	**237**	**0**	**215**	**21**
	St. Dev	**15.8**	**0.5**	**16.3**	**1.7**
	Coefficient of Variation	**0.07**	**1.37**	**0.08**	**0.08**
N First St at Charcot Ave	1	283	0	270	13
	2	306	1	288	17
	3	277	5	257	15
	4	277	1	265	11
	5	280	2	266	12
	Total	**1423**	**9**	**1346**	**68**
	Average	**285**	**2**	**269**	**14**
	St. Dev	**12.2**	**1.9**	**11.5**	**2.4**
	Coefficient of Variation	**0.04**	**1.07**	**0.04**	**0.18**
N First St at Component Dr	1	114	0	109	5
	2	106	0	102	4
	3	117	3	111	3
	4	107	3	102	2
	5	119	2	110	7
	Total	**563**	**8**	**534**	**21**
	Average	**113**	**2**	**107**	**4**
	St. Dev	**5.9**	**1.5**	**4.4**	**1.9**
	Coefficient of Variation	**0.05**	**0.95**	**0.04**	**0.46**
N First St at Trimble Rd	1	402	0	387	15
	2	411	0	397	14
	3	376	1	362	13
	4	383	1	373	9
	5	398	1	381	16
	Total	**1970**	**3**	**1900**	**67**
	Average	**394**	**1**	**380**	**13**
	St. Dev	**14.3**	**0.5**	**13.3**	**2.7**
	Coefficient of Variation	**0.04**	**0.91**	**0.04**	**0.20**

40 MPH LRV, 15 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)

Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	3212	13	3040	159
N First St at Karina Ct	606	3	543	60
N First St at Charcot Ave	1419	4	1368	47
N First St at Component Dr	1022	5	986	31
N First St at Trimble Rd	2152	14	2034	104

PM Peak Period Conflicts (5 simulations of 5 hours each)

Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2721	14	2574	133
N First St at Karina Ct	1231	1	1117	113
N First St at Charcot Ave	1453	4	1392	57
N First St at Component Dr	599	4	572	23
N First St at Trimble Rd	2063	7	1977	79

AM Peak Period Conflicts (5 hour simulation period)

Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	668	2	626	40
	2	643	5	605	33
	3	638	3	600	35
	4	647	3	623	21
	5	616	0	586	30
	Total	**3212**	**13**	**3040**	**159**
	Average	**642**	**3**	**608**	**32**
	St. Dev	**18.7**	**1.8**	**16.6**	**7.0**
	Coefficient of Variation	**0.03**	**0.70**	**0.03**	**0.22**
N First St at Karina Ct	1	97	2	83	12
	2	135	0	122	13
	3	147	0	136	11
	4	122	0	111	11
	5	105	1	91	13
	Total	**606**	**3**	**543**	**60**
	Average	**121**	**1**	**109**	**12**
	St. Dev	**20.6**	**0.9**	**21.8**	**1.0**
	Coefficient of Variation	**0.17**	**1.49**	**0.20**	**0.08**
N First St at Charcot Ave	1	316	1	309	6
	2	280	0	270	10
	3	265	1	253	11
	4	277	1	263	13
	5	281	1	273	7
	Total	**1419**	**4**	**1368**	**47**
	Average	**284**	**1**	**274**	**9**
	St. Dev	**19.1**	**0.4**	**21.2**	**2.9**
	Coefficient of Variation	**0.07**	**0.56**	**0.08**	**0.31**
N First St at Component Dr	1	218	2	213	3
	2	203	1	198	4
	3	199	1	191	7
	4	179	1	166	12
	5	223	0	218	5
	Total	**1022**	**5**	**986**	**31**
	Average	**204**	**1**	**197**	**6**
	St. Dev	**17.4**	**0.7**	**20.6**	**3.6**
	Coefficient of Variation	**0.08**	**0.71**	**0.10**	**0.57**
N First St at Trimble Rd	1	429	3	406	20
	2	417	3	393	21
	3	410	3	385	22
	4	449	1	427	21
	5	447	4	423	20
	Total	**2152**	**14**	**2034**	**104**
	Average	**430**	**3**	**407**	**21**
	St. Dev	**17.5**	**1.1**	**18.3**	**0.8**
	Coefficient of Variation	**0.04**	**0.39**	**0.04**	**0.04**

PM Peak Period Conflicts (5 hour simulation period)

Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	537	1	511	25
	2	557	3	527	27
	3	498	1	471	26
	4	542	6	511	25
	5	587	3	554	30
	Total	**2721**	**14**	**2574**	**133**
	Average	**544**	**3**	**515**	**27**
	St. Dev	**32.4**	**2.0**	**30.1**	**2.1**
	Coefficient of Variation	**0.06**	**0.73**	**0.06**	**0.08**
N First St at Karina Ct	1	242	0	220	22
	2	242	0	219	23
	3	259	1	234	24
	4	240	0	219	21
	5	248	0	225	23
	Total	**1231**	**1**	**1117**	**113**
	Average	**246**	**0**	**223**	**23**
	St. Dev	**7.8**	**0.4**	**6.4**	**1.1**
	Coefficient of Variation	**0.03**	**2.24**	**0.03**	**0.05**
N First St at Charcot Ave	1	293	0	283	10
	2	299	1	289	9
	3	282	1	273	8
	4	301	2	281	18
	5	278	0	266	12
	Total	**1453**	**4**	**1392**	**57**
	Average	**291**	**1**	**278**	**11**
	St. Dev	**10.2**	**0.8**	**9.0**	**4.0**
	Coefficient of Variation	**0.04**	**1.05**	**0.03**	**0.35**
N First St at Component Dr	1	108	1	103	4
	2	111	0	108	3
	3	133	1	126	6
	4	112	2	105	5
	5	135	0	130	5
	Total	**599**	**4**	**572**	**23**
	Average	**120**	**1**	**114**	**5**
	St. Dev	**13.1**	**0.8**	**12.6**	**1.1**
	Coefficient of Variation	**0.11**	**1.05**	**0.11**	**0.25**
N First St at Trimble Rd	1	410	0	392	18
	2	419	3	400	16
	3	384	0	369	15
	4	421	0	408	13
	5	429	4	408	17
	Total	**2063**	**7**	**1977**	**79**
	Average	**413**	**1**	**395**	**16**
	St. Dev	**17.4**	**1.9**	**16.2**	**1.9**
	Coefficient of Variation	**0.04**	**1.39**	**0.04**	**0.12**

40 MPH LRV, 20 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	3371	20	3180	171
N First St at Karina Ct	651	1	592	58
N First St at Charcot Ave	1562	4	1498	60
N First St at Component Dr	1163	2	1136	25
N First St at Trimble Rd	2304	13	2199	92

PM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2873	12	2720	141
N First St at Karina Ct	1344	2	1242	100
N First St at Charcot Ave	1561	8	1477	76
N First St at Component Dr	617	7	594	16
N First St at Trimble Rd	2083	12	1986	85

AM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	624	1	588	35
	2	685	2	658	25
	3	718	4	670	44
	4	637	5	604	28
	5	707	8	660	39
	Total	**3371**	**20**	**3180**	**171**
	Average	**674**	**4**	**636**	**34**
	St. Dev	**41.9**	**2.7**	**37.2**	**7.8**
	Coefficient of Variation	**0.06**	**0.68**	**0.06**	**0.23**
N First St at Karina Ct	1	127	0	116	11
	2	123	1	113	9
	3	131	0	119	12
	4	123	0	111	12
	5	147	0	133	14
	Total	**651**	**1**	**592**	**58**
	Average	**130**	**0**	**118**	**12**
	St. Dev	**10.0**	**0.4**	**8.7**	**1.8**
	Coefficient of Variation	**0.08**	**2.24**	**0.07**	**0.16**
N First St at Charcot Ave	1	319	0	300	19
	2	316	1	304	11
	3	316	1	306	9
	4	309	2	298	9
	5	302	0	290	12
	Total	**1562**	**4**	**1498**	**60**
	Average	**312**	**1**	**300**	**12**
	St. Dev	**6.9**	**0.8**	**6.2**	**4.1**
	Coefficient of Variation	**0.02**	**1.05**	**0.02**	**0.34**
N First St at Component Dr	1	233	0	228	5
	2	253	1	247	5
	3	208	0	204	4
	4	224	1	219	4
	5	245	0	238	7
	Total	**1163**	**2**	**1136**	**25**
	Average	**233**	**0**	**227**	**5**
	St. Dev	**17.7**	**0.5**	**16.7**	**1.2**
	Coefficient of Variation	**0.08**	**1.37**	**0.07**	**0.24**
N First St at Trimble Rd	1	479	0	459	20
	2	479	4	458	17
	3	472	3	450	19
	4	439	2	421	16
	5	435	4	411	20
	Total	**2304**	**13**	**2199**	**92**
	Average	**461**	**3**	**440**	**18**
	St. Dev	**22.0**	**1.7**	**22.3**	**1.8**
	Coefficient of Variation	**0.05**	**0.64**	**0.05**	**0.10**

PM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	596	1	558	37
	2	563	1	539	23
	3	538	3	513	22
	4	555	4	520	31
	5	621	3	590	28
	Total	**2873**	**12**	**2720**	**141**
	Average	**575**	**2**	**544**	**28**
	St. Dev	**33.4**	**1.3**	**31.1**	**6.1**
	Coefficient of Variation	**0.06**	**0.56**	**0.06**	**0.22**
N First St at Karina Ct	1	269	1	249	19
	2	246	1	231	14
	3	269	0	246	23
	4	281	0	258	23
	5	279	0	258	21
	Total	**1344**	**2**	**1242**	**100**
	Average	**269**	**0**	**248**	**20**
	St. Dev	**13.9**	**0.5**	**11.1**	**3.7**
	Coefficient of Variation	**0.05**	**1.37**	**0.04**	**0.19**
N First St at Charcot Ave	1	307	1	292	14
	2	328	3	301	24
	3	301	3	288	10
	4	325	0	310	15
	5	300	1	286	13
	Total	**1561**	**8**	**1477**	**76**
	Average	**312**	**2**	**295**	**15**
	St. Dev	**13.4**	**1.3**	**10.0**	**5.3**
	Coefficient of Variation	**0.04**	**0.84**	**0.03**	**0.35**
N First St at Component Dr	1	123	0	120	3
	2	112	2	107	3
	3	125	4	120	1
	4	113	1	107	5
	5	144	0	140	4
	Total	**617**	**7**	**594**	**16**
	Average	**123**	**1**	**119**	**3**
	St. Dev	**12.9**	**1.7**	**13.5**	**1.5**
	Coefficient of Variation	**0.10**	**1.20**	**0.11**	**0.46**
N First St at Trimble Rd	1	397	6	379	12
	2	464	3	432	29
	3	406	2	394	10
	4	389	0	376	13
	5	427	1	405	21
	Total	**2083**	**12**	**1986**	**85**
	Average	**417**	**2**	**397**	**17**
	St. Dev	**30.1**	**2.3**	**22.7**	**7.9**
	Coefficient of Variation	**0.07**	**0.96**	**0.06**	**0.47**

45 MPH LRV, 0 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)

Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2507	17	2352	138
N First St at Karina Ct	562	2	510	50
N First St at Charcot Ave	1297	1	1248	48
N First St at Component Dr	1046	8	1011	27
N First St at Trimble Rd	1920	12	1843	65

PM Peak Period Conflicts (5 simulations of 5 hours each)

Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2909	14	2779	116
N First St at Karina Ct	1214	1	1122	91
N First St at Charcot Ave	1464	1	1368	95
N First St at Component Dr	412	3	395	14
N First St at Trimble Rd	1814	9	1739	66

AM Peak Period Conflicts (5 hour simulation period)

Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	491	2	456	33
	2	477	4	450	23
	3	492	3	462	27
	4	512	3	479	30
	5	535	5	505	25
	Total	**2507**	**17**	**2352**	**138**
	Average	**501**	**3**	**470**	**28**
	St. Dev	**22.5**	**1.1**	**22.2**	**4.0**
	Coefficient of Variation	**0.04**	**0.34**	**0.05**	**0.14**
N First St at Karina Ct	1	99	1	93	5
	2	125	1	113	11
	3	101	0	88	13
	4	119	0	110	9
	5	118	0	106	12
	Total	**562**	**2**	**510**	**50**
	Average	**112**	**0**	**102**	**10**
	St. Dev	**11.7**	**0.5**	**10.9**	**3.2**
	Coefficient of Variation	**0.10**	**1.37**	**0.11**	**0.32**
N First St at Charcot Ave	1	254	0	243	11
	2	266	1	256	9
	3	247	0	236	11
	4	251	0	242	9
	5	279	0	271	8
	Total	**1297**	**1**	**1248**	**48**
	Average	**259**	**0**	**250**	**10**
	St. Dev	**13.0**	**0.4**	**14.0**	**1.3**
	Coefficient of Variation	**0.05**	**2.24**	**0.06**	**0.14**
N First St at Component Dr	1	213	1	207	5
	2	191	2	183	6
	3	209	2	203	4
	4	186	0	184	2
	5	247	3	234	10
	Total	**1046**	**8**	**1011**	**27**
	Average	**209**	**2**	**202**	**5**
	St. Dev	**24.0**	**1.1**	**20.8**	**3.0**
	Coefficient of Variation	**0.11**	**0.71**	**0.10**	**0.55**
N First St at Trimble Rd	1	356	1	341	14
	2	412	1	398	13
	3	392	2	379	11
	4	389	3	371	15
	5	371	5	354	12
	Total	**1920**	**12**	**1843**	**65**
	Average	**384**	**2**	**369**	**13**
	St. Dev	**21.4**	**1.7**	**22.1**	**1.6**
	Coefficient of Variation	**0.06**	**0.70**	**0.06**	**0.12**

PM Peak Period Conflicts (5 hour simulation period)

Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	592	3	560	29
	2	533	2	514	17
	3	609	3	586	20
	4	584	3	556	25
	5	591	3	563	25
	Total	**2909**	**14**	**2779**	**116**
	Average	**582**	**3**	**556**	**23**
	St. Dev	**28.8**	**0.4**	**26.1**	**4.7**
	Coefficient of Variation	**0.05**	**0.16**	**0.05**	**0.20**
N First St at Karina Ct	1	249	0	232	17
	2	254	1	229	24
	3	244	0	233	11
	4	249	0	231	18
	5	218	0	197	21
	Total	**1214**	**1**	**1122**	**91**
	Average	**243**	**0**	**224**	**18**
	St. Dev	**14.3**	**0.4**	**15.4**	**4.9**
	Coefficient of Variation	**0.06**	**2.24**	**0.07**	**0.27**
N First St at Charcot Ave	1	275	1	257	17
	2	309	0	290	19
	3	311	0	295	16
	4	274	0	251	23
	5	295	0	275	20
	Total	**1464**	**1**	**1368**	**95**
	Average	**293**	**0**	**274**	**19**
	St. Dev	**17.8**	**0.4**	**19.5**	**2.7**
	Coefficient of Variation	**0.06**	**2.24**	**0.07**	**0.14**
N First St at Component Dr	1	86	0	84	2
	2	78	1	73	4
	3	81	1	77	3
	4	85	0	81	4
	5	82	1	80	1
	Total	**412**	**3**	**395**	**14**
	Average	**82**	**1**	**79**	**3**
	St. Dev	**3.2**	**0.5**	**4.2**	**1.3**
	Coefficient of Variation	**0.04**	**0.91**	**0.05**	**0.47**
N First St at Trimble Rd	1	368	3	353	12
	2	350	1	334	15
	3	380	2	356	22
	4	361	1	355	5
	5	355	2	341	12
	Total	**1814**	**9**	**1739**	**66**
	Average	**363**	**2**	**348**	**13**
	St. Dev	**11.7**	**0.8**	**9.8**	**6.1**
	Coefficient of Variation	**0.03**	**0.46**	**0.03**	**0.47**

45 MPH LRV, 10 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2854	18	2711	125
N First St at Karina Ct	563	2	518	43
N First St at Charcot Ave	1440	4	1399	37
N First St at Component Dr	1036	3	1008	25
N First St at Trimble Rd	2007	7	1924	76

PM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2642	13	2502	127
N First St at Karina Ct	1163	1	1060	102
N First St at Charcot Ave	1383	7	1311	65
N First St at Component Dr	536	7	508	21
N First St at Trimble Rd	1971	10	1891	70

AM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	533	3	504	26
	2	564	1	534	29
	3	574	3	554	17
	4	555	3	527	25
	5	628	8	592	28
	Total	**2854**	**18**	**2711**	**125**
	Average	**571**	**4**	**542**	**25**
	St. Dev	**35.4**	**2.6**	**33.1**	**4.7**
	Coefficient of Variation	**0.06**	**0.72**	**0.06**	**0.19**
N First St at Karina Ct	1	96	0	89	7
	2	111	0	100	11
	3	117	1	110	6
	4	111	0	100	11
	5	128	1	119	8
	Total	**563**	**2**	**518**	**43**
	Average	**113**	**0**	**104**	**9**
	St. Dev	**11.6**	**0.5**	**11.4**	**2.3**
	Coefficient of Variation	**0.10**	**1.37**	**0.11**	**0.27**
N First St at Charcot Ave	1	281	0	272	9
	2	294	1	282	11
	3	267	0	261	6
	4	303	1	295	7
	5	295	2	289	4
	Total	**1440**	**4**	**1399**	**37**
	Average	**288**	**1**	**280**	**7**
	St. Dev	**14.1**	**0.8**	**13.6**	**2.7**
	Coefficient of Variation	**0.05**	**1.05**	**0.05**	**0.37**
N First St at Component Dr	1	208	0	206	2
	2	226	1	221	4
	3	201	1	190	10
	4	208	1	201	6
	5	193	0	190	3
	Total	**1036**	**3**	**1008**	**25**
	Average	**207**	**1**	**202**	**5**
	St. Dev	**12.2**	**0.5**	**12.9**	**3.2**
	Coefficient of Variation	**0.06**	**0.91**	**0.06**	**0.63**
N First St at Trimble Rd	1	418	2	405	11
	2	388	1	373	14
	3	406	1	390	15
	4	431	0	406	25
	5	364	3	350	11
	Total	**2007**	**7**	**1924**	**76**
	Average	**401**	**1**	**385**	**15**
	St. Dev	**26.2**	**1.1**	**23.6**	**5.8**
	Coefficient of Variation	**0.07**	**0.81**	**0.06**	**0.38**

PM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	512	1	480	31
	2	559	5	529	25
	3	529	5	503	21
	4	501	1	472	28
	5	541	1	518	22
	Total	**2642**	**13**	**2502**	**127**
	Average	**528**	**3**	**500**	**25**
	St. Dev	**23.0**	**2.2**	**24.3**	**4.2**
	Coefficient of Variation	**0.04**	**0.84**	**0.05**	**0.16**
N First St at Karina Ct	1	242	0	214	28
	2	213	1	194	18
	3	247	0	223	24
	4	235	0	220	15
	5	226	0	209	17
	Total	**1163**	**1**	**1060**	**102**
	Average	**233**	**0**	**212**	**20**
	St. Dev	**13.5**	**0.4**	**11.4**	**5.4**
	Coefficient of Variation	**0.06**	**2.24**	**0.05**	**0.27**
N First St at Charcot Ave	1	268	0	255	13
	2	302	2	285	15
	3	292	5	274	13
	4	267	0	253	14
	5	254	0	244	10
	Total	**1383**	**7**	**1311**	**65**
	Average	**277**	**1**	**262**	**13**
	St. Dev	**19.7**	**2.2**	**16.8**	**1.9**
	Coefficient of Variation	**0.07**	**1.56**	**0.06**	**0.14**
N First St at Component Dr	1	104	0	100	4
	2	103	0	98	5
	3	110	1	104	5
	4	105	4	97	4
	5	114	2	109	3
	Total	**536**	**7**	**508**	**21**
	Average	**107**	**1**	**102**	**4**
	St. Dev	**4.7**	**1.7**	**4.9**	**0.8**
	Coefficient of Variation	**0.04**	**1.20**	**0.05**	**0.20**
N First St at Trimble Rd	1	373	3	362	8
	2	423	3	405	15
	3	406	2	387	17
	4	388	2	368	18
	5	381	0	369	12
	Total	**1971**	**10**	**1891**	**70**
	Average	**394**	**2**	**378**	**14**
	St. Dev	**20.2**	**1.2**	**17.7**	**4.1**
	Coefficient of Variation	**0.05**	**0.61**	**0.05**	**0.29**

45 MPH LRV, 15 PERCENT INCREASE IN TURNS/CROSS STREET VOLUMES

AM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	3103	9	2983	111
N First St at Karina Ct	576	0	526	50
N First St at Charcot Ave	1421	0	1363	58
N First St at Component Dr	1072	6	1037	29
N First St at Trimble Rd	2118	11	2018	89

PM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2702	11	2577	114
N First St at Karina Ct	1260	3	1155	102
N First St at Charcot Ave	1454	2	1385	67
N First St at Component Dr	617	4	587	26
N First St at Trimble Rd	2015	8	1919	88

AM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	636	2	612	22
	2	591	1	564	26
	3	625	2	603	20
	4	621	3	596	22
	5	630	1	608	21
	Total	**3103**	**9**	**2983**	**111**
	Average	**621**	**2**	**597**	**22**
	St. Dev	**17.5**	**0.8**	**19.2**	**2.3**
	Coefficient of Variation	**0.03**	**0.46**	**0.03**	**0.10**
N First St at Karina Ct	1	128	0	119	9
	2	133	0	121	12
	3	106	0	96	10
	4	106	0	97	9
	5	103	0	93	10
	Total	**576**	**0**	**526**	**50**
	Average	**115**	**0**	**105**	**10**
	St. Dev	**14.1**	**0.0**	**13.6**	**1.2**
	Coefficient of Variation	**0.12**	**0.00**	**0.13**	**0.12**
N First St at Charcot Ave	1	293	0	276	17
	2	285	0	275	10
	3	270	0	257	13
	4	294	0	286	8
	5	279	0	269	10
	Total	**1421**	**0**	**1363**	**58**
	Average	**284**	**0**	**273**	**12**
	St. Dev	**10.0**	**0.0**	**10.6**	**3.5**
	Coefficient of Variation	**0.04**	**0.00**	**0.04**	**0.30**
N First St at Component Dr	1	243	3	236	4
	2	200	1	194	5
	3	195	0	187	8
	4	200	2	192	6
	5	234	0	228	6
	Total	**1072**	**6**	**1037**	**29**
	Average	**214**	**1**	**207**	**6**
	St. Dev	**22.3**	**1.3**	**22.8**	**1.5**
	Coefficient of Variation	**0.10**	**1.09**	**0.11**	**0.26**
N First St at Trimble Rd	1	435	3	422	10
	2	439	5	416	18
	3	388	1	369	18
	4	427	1	405	21
	5	429	1	406	22
	Total	**2118**	**11**	**2018**	**89**
	Average	**424**	**2**	**404**	**18**
	St. Dev	**20.5**	**1.8**	**20.6**	**4.7**
	Coefficient of Variation	**0.05**	**0.81**	**0.05**	**0.26**

PM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	529	2	504	23
	2	509	3	492	14
	3	551	1	520	30
	4	552	3	523	26
	5	561	2	538	21
	Total	**2702**	**11**	**2577**	**114**
	Average	**540**	**2**	**515**	**23**
	St. Dev	**21.1**	**0.8**	**17.8**	**6.0**
	Coefficient of Variation	**0.04**	**0.38**	**0.03**	**0.26**
N First St at Karina Ct	1	253	0	235	18
	2	254	1	234	19
	3	256	1	229	26
	4	232	1	209	22
	5	265	0	248	17
	Total	**1260**	**3**	**1155**	**102**
	Average	**252**	**1**	**231**	**20**
	St. Dev	**12.1**	**0.5**	**14.2**	**3.6**
	Coefficient of Variation	**0.05**	**0.91**	**0.06**	**0.18**
N First St at Charcot Ave	1	313	0	301	12
	2	293	0	276	17
	3	303	0	286	17
	4	266	1	252	13
	5	279	1	270	8
	Total	**1454**	**2**	**1385**	**67**
	Average	**291**	**0**	**277**	**13**
	St. Dev	**18.7**	**0.5**	**18.2**	**3.8**
	Coefficient of Variation	**0.06**	**1.37**	**0.07**	**0.28**
N First St at Component Dr	1	116	1	112	3
	2	115	0	111	4
	3	136	1	130	5
	4	118	2	109	7
	5	132	0	125	7
	Total	**617**	**4**	**587**	**26**
	Average	**123**	**1**	**117**	**5**
	St. Dev	**9.8**	**0.8**	**9.4**	**1.8**
	Coefficient of Variation	**0.08**	**1.05**	**0.08**	**0.34**
N First St at Trimble Rd	1	392	1	378	13
	2	411	2	377	32
	3	420	1	406	13
	4	407	2	394	11
	5	385	2	364	19
	Total	**2015**	**8**	**1919**	**88**
	Average	**403**	**2**	**384**	**18**
	St. Dev	**14.3**	**0.5**	**16.3**	**8.6**
	Coefficient of Variation	**0.04**	**0.34**	**0.04**	**0.49**

AM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	3374	15	3197	162
N First St at Karina Ct	654	1	597	56
N First St at Charcot Ave	1478	1	1416	61
N First St at Component Dr	1169	3	1127	39
N First St at Trimble Rd	2196	18	2074	104

PM Peak Period Conflicts (5 simulations of 5 hours each)				
Intersection	Total Conflicts	Type of Conflict		
		Crossing	Rear End	Lane Change
N First St at E Brokaw	2959	9	2811	139
N First St at Karina Ct	1351	6	1240	105
N First St at Charcot Ave	1538	4	1451	83
N First St at Component Dr	620	6	579	35
N First St at Trimble Rd	2174	6	2086	82

AM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	666	2	634	30
	2	651	3	616	32
	3	677	3	645	29
	4	692	2	658	32
	5	688	5	644	39
	Total	**3374**	**15**	**3197**	**162**
	Average	**675**	**3**	**639**	**32**
	St. Dev	**16.7**	**1.2**	**15.6**	**3.9**
	Coefficient of Variation	**0.02**	**0.41**	**0.02**	**0.12**
N First St at Karina Ct	1	118	0	110	8
	2	141	0	126	15
	3	118	0	109	9
	4	128	1	115	12
	5	149	0	137	12
	Total	**654**	**1**	**597**	**56**
	Average	**131**	**0**	**119**	**11**
	St. Dev	**13.9**	**0.4**	**11.9**	**2.8**
	Coefficient of Variation	**0.11**	**2.24**	**0.10**	**0.25**
N First St at Charcot Ave	1	310	1	299	10
	2	306	0	296	10
	3	274	0	259	15
	4	294	0	278	16
	5	294	0	284	10
	Total	**1478**	**1**	**1416**	**61**
	Average	**296**	**0**	**283**	**12**
	St. Dev	**14.0**	**0.4**	**16.0**	**3.0**
	Coefficient of Variation	**0.05**	**2.24**	**0.06**	**0.25**
N First St at Component Dr	1	251	0	245	6
	2	236	1	227	8
	3	201	0	193	8
	4	250	1	240	9
	5	231	1	222	8
	Total	**1169**	**3**	**1127**	**39**
	Average	**234**	**1**	**225**	**8**
	St. Dev	**20.3**	**0.5**	**20.4**	**1.1**
	Coefficient of Variation	**0.09**	**0.91**	**0.09**	**0.14**
N First St at Trimble Rd	1	453	3	434	16
	2	430	3	402	25
	3	463	4	438	21
	4	423	1	405	17
	5	427	7	395	25
	Total	**2196**	**18**	**2074**	**104**
	Average	**439**	**4**	**415**	**21**
	St. Dev	**17.7**	**2.2**	**19.7**	**4.3**
	Coefficient of Variation	**0.04**	**0.61**	**0.05**	**0.21**

PM Peak Period Conflicts (5 hour simulation period)					
Intersection	Simulation #	Total Conflicts	Type of Conflict		
			Crossing	Rear End	Lane Change
N First St at E Brokaw	1	609	1	574	34
	2	565	3	541	21
	3	590	0	566	24
	4	555	2	526	27
	5	640	3	604	33
	Total	**2959**	**9**	**2811**	**139**
	Average	**592**	**2**	**562**	**28**
	St. Dev	**34.3**	**1.3**	**30.3**	**5.6**
	Coefficient of Variation	**0.06**	**0.72**	**0.05**	**0.20**
N First St at Karina Ct	1	279	2	257	20
	2	278	0	255	23
	3	289	0	269	20
	4	249	3	224	22
	5	256	1	235	20
	Total	**1351**	**6**	**1240**	**105**
	Average	**270**	**1**	**248**	**21**
	St. Dev	**16.9**	**1.3**	**18.1**	**1.4**
	Coefficient of Variation	**0.06**	**1.09**	**0.07**	**0.07**
N First St at Charcot Ave	1	306	0	290	16
	2	304	2	279	23
	3	313	2	293	18
	4	306	0	295	11
	5	309	0	294	15
	Total	**1538**	**4**	**1451**	**83**
	Average	**308**	**1**	**290**	**17**
	St. Dev	**3.5**	**1.1**	**6.5**	**4.4**
	Coefficient of Variation	**0.01**	**1.37**	**0.02**	**0.26**
N First St at Component Dr	1	107	0	103	4
	2	128	3	116	9
	3	128	2	121	5
	4	141	1	130	10
	5	116	0	109	7
	Total	**620**	**6**	**579**	**35**
	Average	**124**	**1**	**116**	**7**
	St. Dev	**13.0**	**1.3**	**10.5**	**2.5**
	Coefficient of Variation	**0.10**	**1.09**	**0.09**	**0.36**
N First St at Trimble Rd	1	458	1	443	14
	2	412	2	392	18
	3	448	1	426	21
	4	443	0	422	21
	5	413	2	403	8
	Total	**2174**	**6**	**2086**	**82**
	Average	**435**	**1**	**417**	**16**
	St. Dev	**21.1**	**0.8**	**20.0**	**5.5**
	Coefficient of Variation	**0.05**	**0.70**	**0.05**	**0.34**

APPENDIX D: TESTING PLAN

As stated in the amplified work plan for this research project, two of the objectives of the research are to:

- "Identify potential supplemental safety measures for use with traffic signals in lieu of highway-light rail grade crossing flashing lights and gates where LRVs could operate at speeds in excess of 35 mph in a semi-exclusive public right-of-way"; and
- "Test higher-speed LRV operation (above 35 mph) at selected locations using identified supplemental safety measures."

This chapter outlines the testing plan that could be implemented if the agency had agreed to participate. The testing plan provides an overview of the test, defines the roles and responsibilities of the participating agencies and the research team, and describes the details of the various components of the test. While the details of the test plan focus on testing in San Jose, it can be modified for application in other agencies.

Overview of Test

The goal of the test is to assess the impacts of higher LRV speeds through selected crossings, equipped with supplemental safety measures, along a 1-mile segment of the North First St. corridor in San Jose, CA. Maximum LRV speeds in this segment of the corridor are currently 35 mph. The test will include implementation of a number of supplemental safety measures at three "test" crossings and an increase in the maximum LRV speed to 40 mph in the corridor, but specifically through the test crossings. Test crossings include:

- North First St. and Brokaw Rd.;
- North First St. and Charcot Ave.; and
- North First St. and Trimble Rd.

All three intersections are being implemented with supplemental / alternative traffic control devices. Higher speeds will be tested at all three locations in the northbound and southbound directions.

The testing period will extend from approximately September 2009 through May 2011. The supplemental safety devices will be tested with a 35 mph LRV speed limit for a 9-month period from approximately September 2009 through May 2010. Increased LRV speeds of 40 mph will be tested for a 12-month period from approximately June 2010 through May 2011.

The test will be implemented by the VTA and the City of San Jose. A simultaneous evaluation of the test will be conducted by the SAIC team (the evaluation plan is described in the following chapter).

Roles and Responsibilities

The lead agency implementing the test will be the VTA. The VTA will be supported by the City of San Jose and the SAIC team throughout the test. This section lists the roles and responsibilities of each organization. Details of each aspect of the testing program are described in the following section.

SAIC Team Roles and Responsibilities

The SAIC team will assist the VTA and the City of San Jose in the following activities:

- Prepare letter to FHWA requesting permission to experiment with alternative traffic control devices as well as an increase in LRV speeds to 40 mph. A copy of the letter can be found in Appendix B.
- Prepare application package to the California Public Utilities Commission (CPUC) requesting permission to deviate from the 35 mph maximum LRV speed.
- Specify traffic signal timing requirements to allow for an increase in LRV speeds from 35 to 40 mph.

VTA Roles and Responsibilities

The roles and responsibilities of the VTA include the following activities:

- Install supplemental and alternative safety measures / traffic control devices at the test intersections within the specified timeframe;
- Prepare and train operators for the increase in speed during the 1-year testing period;
- Notify the public, as deemed necessary, of the demonstration test;
- Make necessary infrastructure modifications to allow for the speed increase, for example:
  - Sign the tracks for 40 mph speed;
  - Relocate detectors as necessary; and
  - Assure sufficient stopping sight distance.

City of San Jose Roles and Responsibilities

The City of San Jose’s primary roles and responsibilities will be to:

- Modify the signal timing as necessary to allow for higher speed LRT operations; and
- Provide crash data to the SAIC team every 3 months throughout the testing and evaluation period.

Details of Testing Program

This section describes the details of the various aspects of the testing program.

Supplemental Safety Measures and Alternative Traffic Control Devices

The VTA is in the process of enhancing the safety of a number of crossings with a variety of supplemental safety measures and alternative traffic control devices. Specifically, these enhancements include:

- Relocation of existing stop bars in left-turn lanes adjacent to LRT tracks 20’ back from the crosswalk (or existing location) to enhance the visibility of an approaching LRT vehicle by left-turning traffic;
- Use of “KEEP CLEAR” pavement markings on left-turn lanes (between the relocated stop bar and the crosswalk / intersection) adjacent to the LRT tracks to reinforce stopping at the stop bar;
- Installation of yellow painted channelization pavement markings and yellow pavement markers around the tracks on the near and far sides of the intersection to promote appropriate lane tracking through the intersection to limit inappropriate track intrusions;

- Installation of California Type Q Markers along the tracks in the vicinity of the crossings to guide vehicles away from the tracks during left turns from both the parallel and cross-streets; and
- Installation of an alternating Train Approaching (W10-7) / No Left Hand Turn blank-out sign for parallel left-turning vehicles to signify when LRT vehicles are approaching the crossing.

Phase I of the VTA's improvements includes nine intersections, three of which are located within the 1-mile test segment of the North First St. corridor:

- North First St. and Brokaw Rd.;
- North First St. and Charcot Ave.; and
- North First St. and Karina Ct.

The construction at all nine intersections is expected to be complete by September 2009. Phase II of the VTA's improvements include installation of the safety improvements at a number of additional intersections, including one within the 1-mile test segment along North First St.:

- North First St. and Trimble Rd.

Phase II construction is expected to begin in the spring of 2010 and be complete by summer. The VTA has indicated that they can request that the intersection of North First St. and Trimble Rd. be moved to the beginning of the construction schedule to allow for the testing of the higher speeds to be implemented by summer 2010.

Infrastructure Modifications

The VTA will make the necessary infrastructure modifications to support an increase in train speeds from 35 to 40 mph. Examples of infrastructure modifications that may be necessary include:

- <u>Sign the tracks for 40 mph speed</u>—currently the tracks are signed for a maximum speed of 35 mph. To indicate to the LRV operators when 40 mph speeds are permitted, the VTA may need to install new signs along the trackways. This will include replacing all speed signs currently used with the 35 mph zone with new signs associated with the 40 mph zone.
- <u>Relocate detectors as necessary</u>—Current detection of light rail vehicles at all study intersections is based on a maximum speed of 35 mph, and uses track circuits in advance of each intersection. Therefore, changing the approach speed to 40 mph may require relocation of the track circuits in order to provide earlier detection.
- <u>Assure sufficient stopping sight distance</u>—At a minimum, the current stopping sight distance for light rail vehicles is based on a 35 mph running speed. Changing the approach speed to 40 mph will require a longer stopping sight distance to stop safely in the event the light rail signal display on the approach and at the intersection are malfunctioning or the signal timing at the intersection is not working properly. Therefore, the VTA will need to check all track visual aids and stopping sight distances at each approach of the three intersections to ensure adequate stopping sight distance from a speed of 40 mph.

Signal Timing Modifications

The SAIC team will work with the City of San Jose to determine signal timing requirements to support an increase in train speeds from 35 to 40 mph. Increasing the speed of trains to 40 mph at the study intersections will require a longer window of opportunity for trains to cross, thus requiring longer green time on North First St. Train operators should see a vertical bar signal several seconds before they enter the intersection, thus allowing the train to continue moving at 40 mph without any hesitation. This window of opportunity may require the vertical bar signal to be displayed at least 10 to12 seconds prior to the train arrival. Train movements can overlap with the through movements on North First St., but the left-turn movements must terminate before the train receives the vertical bar signal. The City of San Jose is currently developing new signal timing plans for North First St., and the SAIC team will coordinate the development of the signal timing plans with the City to accommodate a provision for the higher train speed. Currently, no change in cycle length or in the left-turn phase sequence at any of the three intersections is anticipated.

Operator Training

One of the biggest issues in early discussions with the VTA and the City of San Jose was train operator behavior and the variability in travel times between stations. The City of San Jose bases the signal timing in part on the average LRV travel times between stations. The City noted that there was a large variability between operators. The VTA noted that this variability is likely due to the signal priority given to the LRT (i.e., predictive priority) and that the operators are not guaranteed to receive a go bar when approaching a crossing.

In response to this issue, as well as the general issue of raising the maximum speed above what has been customary, it will be necessary to provide some form of training to the operators. The VTA will provide this training to operators prior to the implementation of the test.

Community Outreach

Prior to the implementation of the test, it may be necessary to conduct public outreach to let local drivers know that the trains will be operating at slightly higher speeds. It will be up to the VTA to determine if community outreach is necessary, and if so, in what format. The VTA will be responsible for conducting the public outreach.

Increase LRV Speeds to 40 MPH

Figure 32 illustrates the North First St. corridor where the increase in LRV speeds will take place. The figure shows six test segments, three in the northbound direction and three in the southbound direction.

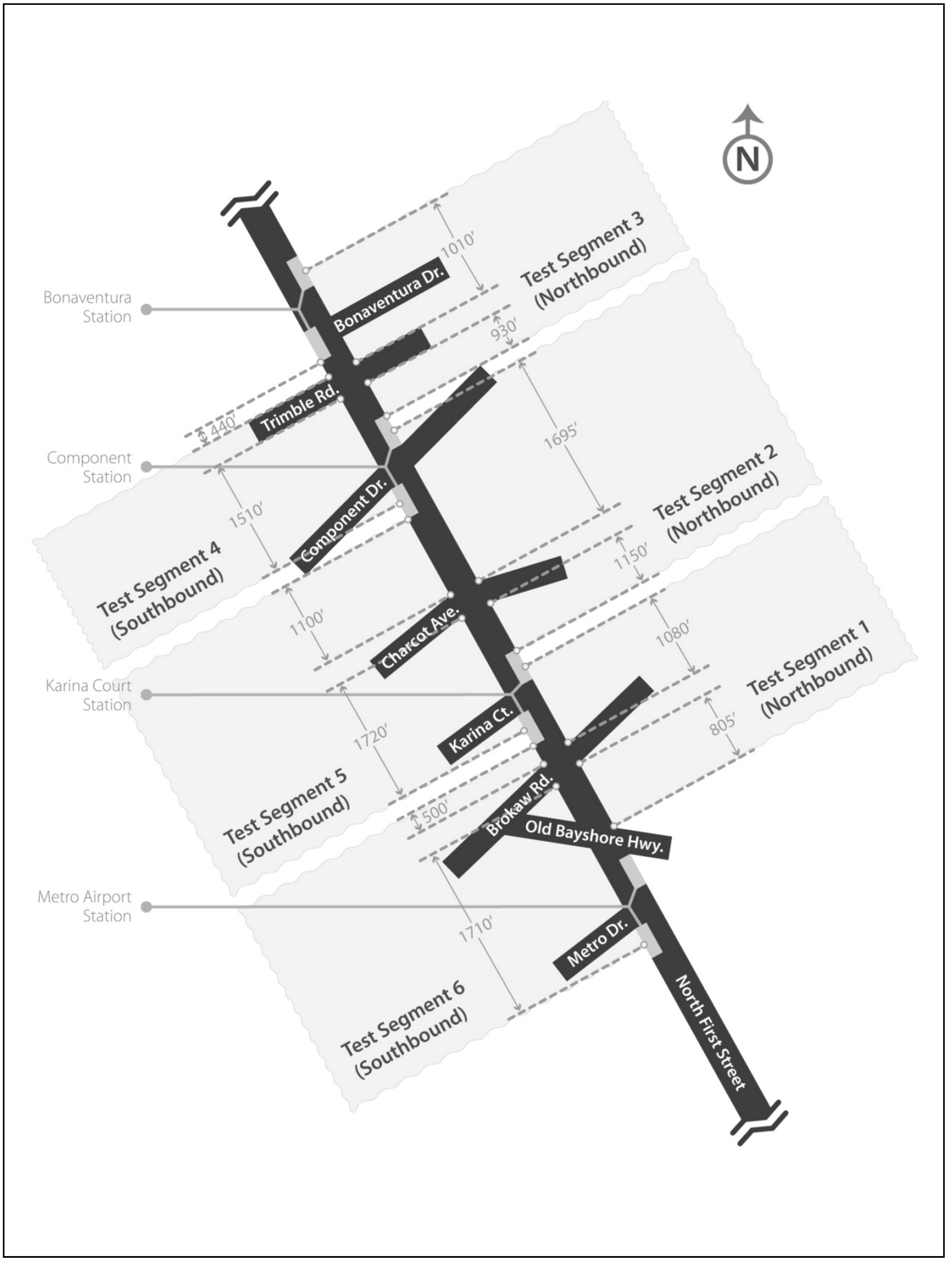

Figure 32. Graphical Representation of the Four Test Segments along the North First St. Corridor

Test Segment 1 begins at the intersection of North First St. and Old Bayshore Hwy. and stretches north to the Karina station, a distance of about 2,000 feet. Northbound LRVs will leave the

Metro / Airport station, accelerating to 35 mph through the crossing at Old Bayshore Hwy. Once the train has passed through the crossing at Old Bayshore Hwy., the train operator can accelerate to 40 mph prior to and through the crossing at Brokaw Rd. Once through the crossing at Brokaw Rd., the train operator will begin decelerating in preparation to stop at the Karina station. As the required stopping distance from 40 mph is estimated to be approximately 400 feet[3], the train operator will be able to maintain a speed of 40 mph for approximately 1600 feet. The 5 mph difference in speed over this distance equates to approximately 4 seconds of travel time savings between the two stations.

Test Segment 2 begins at the northbound Karina station and stretches north to the Component station, a distance of about 2,950 feet. Northbound LRVs will leave the Karina station, accelerating to 40 mph prior to and through the crossing at Charcot Ave. At some distance downstream of the crossing at Charcot Ave., the train operator will begin decelerating in preparation to stop at the Component station. As the required distance to accelerate to 40 mph is estimated to be approximately 425 feet,[4] and the stopping distance from 40 mph is estimated to be approximately 400 feet, the train operator will be able to maintain a speed of 40 mph for approximately 2,125 feet in this segment. The 5 mph difference in speed over this distance equates to approximately 5 seconds of travel time savings between the two stations.

Test Segment 3 begins at the northbound Component station and stretches north to the Bonaventura station, a distance of about 2,100 feet. Northbound LRVs will leave the Component station, accelerating to 40 mph prior to and through the crossing at Trimble Rd. Once through the crossing at Trimble Rd, the train operator will begin decelerating in preparation to stop at the Bonaventura station. As the required distance to accelerate to 40 mph is estimated to be approximately 425 feet, and the required stopping distance from 40 mph is estimated to be approximately 400 feet, the train operator will be able to maintain a speed of 40 mph for approximately 1,275 feet. The 5 mph difference in speed over this distance equates to approximately 3 seconds of travel time savings between the two stations.

Test Segment 4 begins at the southbound Bonaventura station and stretches south to the Component station, also a distance of about 2,100 feet. Southbound LRVs will leave the Bonaventura station, accelerating to 40 mph just as they pass through the crossing at Trimble Rd. At some point downstream of the crossing at Trimble Rd., the train operator will begin to decelerate in preparation to stop at the Component station. As the required distance to accelerate to 40 mph is estimated to be approximately 425 feet, and the required stopping distance from 40 mph is estimated to be approximately 400 feet, the train operator will be able to maintain a speed of 40 mph for approximately1,275 feet. The 5 mph difference in speed over this distance equates to approximately 3 seconds of travel time savings between the two stations.

Test Segment 5 begins at the southbound Component station and stretches south to the Karina station, a distance of about 2,975 feet. Southbound LRVs will leave the Component station, accelerating to 40 mph prior to and through the crossing at Charcot Ave. At some point downstream of the crossing at Charcot Ave, the train operator will begin to decelerate in preparation to stop at the Karina station. As the required distance to accelerate to 40 mph is estimated to be approximately 425 feet, and the required stopping distance from 40 mph is

[3] The estimated distance of 400 feet to decelerate from 40 mph is based on a deceleration rate of 3 mph per second (mphps).

[4] The estimated distance of 425 feet to accelerate to 40 mph is based on an acceleration rate of 2.75 mphps.

estimated to be approximately 400 feet, the train operator will be able to maintain a speed of 40 mph for approximately 2,150 feet. The 5 mph difference in speed over this distance equates to approximately 5 seconds of travel time savings between the two stations.

Test Segment 6 begins at begins at the southbound Karina station and stretches south to the Metro / Airport station, a distance of about 2,325 feet. Southbound LRVs will leave the Karina station, accelerating to 40 mph just as they pass through the crossing at Brokaw Rd. Approximately 700 feet downstream of the crossing at Brokaw Rd., the train operator will need to decelerate to 35 mph before entering the crossing at Old Bayshore Hwy. Therefore, the train operator will be able to maintain a speed of 40 mph for approximately 900 feet. The 5 mph difference in speed over this distance equates to approximately 2 seconds of travel time savings between the two stations.

APPENDIX E: EVALUATION PLAN

This chapter describes how the SAIC team will evaluate the installed safety improvements and the test of higher speed LRT operations.

CONDITIONS UNDER EVALUATION

The evaluation will take place over three phases or "conditions":

- Existing or Baseline Conditions.—The existing or baseline conditions represent the current crash, near-miss, and risky behaviors along the North First St. corridor at the three test intersections prior to any safety improvements or changes in speed. The purpose of collecting data for the existing conditions is to establish a baseline for the existing operations to compare against the improved and test conditions.
- After Safety Improvement Conditions. —This phase begins following implementation of all safety improvements (namely blank-out signs, passive signs, pavement markings, flexible post delineators and raised pavement markers) by the VTA at the test intersections. It is expected that the installation of the improvements at Brokaw Rd. and Charcot Ave. will be completed by the end of September 2009. Improvements at the Trimble Rd. crossing are expected to be completed during the summer of 2010. During these conditions, light rail operation is not expected to change; i.e., no change in headway or operating speeds.
- After Conditions with LRV Speed Increase.—This condition begins when all agencies have reached a mutual agreement to increase the operating speed for light rail (based on successful implementation of the supplemental safety measures) at the three study intersections, and therefore assumes that the results attained from the "After Safety Improvements Conditions" are satisfactory to the City and the VTA. During this test period, light rail speed will be increased to 40 mph. The after conditions with LRV speed increase will last for 12 months.

MEASURES OF EFFECTIVENESS

The research team will use a number of measures of effectiveness (MOEs) to evaluate the impacts of the intersection improvements and the higher speed LRT operations on safety as well as to determine the success of the test. Primary MOEs that will be used include:

- Driver, pedestrian, and bicyclist behaviors (risky behaviors and compliance with traffic control devices);
- Train operator behaviors;
- Crashes (auto-auto and auto-train);
- Near misses (auto-train); and
- LRV speeds.

Each of these MOEs is described in more detail below.

Driver, Pedestrian, Bicyclist, and Train Operator Behaviors

Specific driver, pedestrian, bicyclist, and train operator behaviors that will be collected at the test intersections as part of the evaluation include the following:

- Mainline left-turn change and clearance interval violation—Left-turn motorist from North First St. enters intersection at the end of the yellow change interval or during the all-red clearance interval with and without train presence;
- Mainline U-turn change and clearance interval violation—U-turn motorist from North First St. enters intersection at the end of the yellow change interval or during the all-red clearance interval with and without train presence;
- Mainline left-turn red-light violation—Left-turn motorist from North First St. enters intersection during the red interval with and without train presence;
- Mainline through red-light violation—Through motorist from North First St. enters intersection during the red interval without train presence;
- Lane change violation—Motorist in either the through or right-turn lane makes an illegal lane change to turn left from North First St.;
- Mainline U-turn red-light violation—U-turn motorist from North First St. enters intersection during the red interval with and without train presence;
- Cross-street red-light violation—Motorist on cross-street enters intersection during the red interval with and without train presence;
- Mainline left-turn stop bar intrusion—Left- or U-turn motorist on North First St. stops on or beyond the stop bar during the red interval;
- Mainline through lane stop bar intrusion—Through motorist on North First St. stops on or beyond the stop bar during the red interval;
- Track intrusion violation—Motorist wrongly enters track right-of-way;
- Mainline left-turn vehicles queued on tracks— Left-turn motorist from North First St. stops on tracks due to a queue spillback on cross-street;
- Cross-street left-turn vehicles queued on tracks— Left-turn motorist from cross-street stops on tracks due to a queue spill back on North First St.;
- Cross-street through vehicles queued on tracks— Through motorist from cross-street stops on tracks due to a queue spill back in the downstream receiving lanes.
- Vehicle stopped on tracks—Motorist stops on tracks for reasons other than queuing, blocking, or yielding to violating motorists or pedestrians;
- Pedestrian standing on tracks—Pedestrian did not complete crossing during Walk or Flashing Don't Walk signal display and is standing between the tracks or in the track right-of-way;
- Pedestrian intersection violation—Pedestrian crosses North First St. during the Don't Walk signal display;
- Pedestrian jay-walking violation—Pedestrian crosses North First St. outside of a designated crosswalk;
- Bicyclist mainline left-turn red-light violation—Left turn bicyclist on North First St. enters intersection during the red interval;
- Bicyclist cross-street red-light violation—Bicyclist on cross-street enters intersection during the red interval;
- Light rail vehicle violation—Light rail operator enters or clears intersection during the horizontal white bar LRV signal indication; and

- Light rail emergency braking—Light rail operator applies emergency/maximum brakes.

Risky behavior analysis will be performed for each intersection to evaluate the magnitude of each risky behavior action and its relationship to actual crashes. For example, a high frequency of red-light running is more critical to safety than the same frequency of left-turn vehicles making a turn on yellow. The analysis will focus on establishing a baseline risky behavior condition based on the prevailing traffic volumes, history of crashes, near misses, and track intrusion data as provided by the VTA and the City of San Jose. It is expected that following the implementation of the on-going improvements by the VTA, the frequency of risky behavior for left-turn conflicts should be reduced when compared to the frequency and type of conflicts under the base condition. Similar results are anticipated for track intrusion and near-miss incidents.

Crashes and Near-Misses

In addition to the surrogate safety measures listed above, the research team will gather and analyze crash and near miss data from the City of San Jose and the VTA. Measures of effectiveness include:

- Number / rate (by type) of vehicle-vehicle crashes;
- Number / rate (by type) of vehicle-train collisions; and
- Number / rate (by type) of vehicle-train near-misses.

As crashes are rare events, due to the timeframe of the evaluation, there likely will not be enough time to determine if there was a statistically significant change in actual crash rates. Therefore, auto-train near-miss data (maintained by the VTA) will also be examined. While a near-miss does not result in an actual collision, near-misses are excellent surrogate measures of safety. And as near-misses occur more frequently than actual collisions, the evaluation time frame should be sufficient to determine if there is a statistically significant change in the rate of near-misses.

LRV Speeds

As a final MOE to the evaluation, LRV speeds will be measured and examined to determine the actual train speeds at different points along the test corridor, particularly through the three test crossings. In order for the test to be successful, train operators must achieve speeds of 40 mph through the test crossings.

DATA COLLECTION PLAN

An overview of the data to be collected, the data collection dates, and the data sources is shown in Table 24.

The research team has already collected a variety of baseline data, as indicated in Table 24, which has been analyzed to establish the existing or baseline conditions (these data are presented following discussion of the data collection plan).

Table 24. Overview of Data to be Collected for Evaluation

Evaluation Condition	Data to be Collected	Estimated Date to Collect Data	Data Source
Existing or Baseline Conditions	Traffic, pedestrian, and bicycle counts	Complete	City of San Jose
	Signal plans, signal phase sequence and signal timing	Complete	City of San Jose
	Intersection crash data (2005-2008)	Complete	City of San Jose
	Collision and near miss data (2005-2008)	Complete	VTA
	Light rail ridership data for year 2008	Complete	VTA
	Observations of driver, pedestrian, and bicyclist behaviors	Complete	Field video data collected by SAIC team
After Safety Improvement Conditions	Crash data for intersections of: --North First St. & Brokaw Rd. --North First St. & Charcot Ave.	Every 3 months following implementation of safety improvements: Nov 2009, Feb 2010, May 2010	City of San Jose
	Collision and near miss data for intersections of: --North First St. & Brokaw Rd. --North First St. & Charcot Ave.	Every 3 months following implementation of safety improvements: Nov 2009, Feb 2010, May 2010	VTA
	Observations of driver, pedestrian, bicyclist, and train operator behaviors	Nov 2009	Field video data collected by SAIC team
	Traffic, pedestrian, and bicycle counts	Nov 2009	City of San Jose or samples from video data
After Conditions with LRV Speed Increase	Crash data for intersections of: --North First St. & Brokaw Rd. --North First St. & Charcot Ave. --North First St. & Trimble Rd.	Every 3 months following increase in train speeds: Sept 2010, Dec 2010, Mar 2011, Jun 2011	City of San Jose
	Collision and near miss data for intersections of: --North First St. & Brokaw Rd. --North First St. & Charcot Ave. --North First St. & Trimble Rd.	Every 3 months following increase in train speeds: Sept 2010, Dec 2010, Mar 2011, Jun 2011	VTA
	On-board measurement of LRV speeds and observations of driver, pedestrian, and bicyclist behaviors through crossings	Sept 2010	On-board data collected by SAIC team
	Traffic, pedestrian, and bicycle counts	Sept 2010, June 2011	City of San Jose or samples from video data

To understand the impact of the safety improvements on driver, pedestrian, bicyclist, and train operator behaviors (risky behaviors and compliance with traffic control devices) at the intersections, the research team will collect a second round of data, which will represent the "After Safety Improvement Conditions." Currently, the research team plans to begin the data collection for these conditions in November 2009. As improvements at the intersections of North First St. and Brokaw and North First St. are expected to be complete by the end of

September, this will allow time for drivers, pedestrians, and bicyclists to become accustomed to the changes at the intersections before data collection commences. This second phase of data collection is planned for mid-November 2009 at the Brokaw Rd. and Charcot Ave. crossings. The team will follow the same data collection methodology for the video observations performed for the existing conditions. In addition, the team will request updated traffic, pedestrian, and bicyclist counts from the City of San Jose, if such data have been collected. If not, the team will obtain samples from the video data. Traffic, pedestrian, and bicyclist counts will be compared with the baseline conditions to determine if there has been a change in counts between the two conditions. The team will also request crash data from the city, as well as collision and near-miss data from the VTA every 3 months following implementation of the improvements to determine if the improvements had any impact on safety.

Finally, to understand the impact of the increase in train speeds to 40 mph, the research team will collect a third round of data, which will represent the “After Conditions with LRV Speed Increase.” This third round of data collection will begin approximately 3 months following the speed increase, which is anticipated for June 2010. The primary MOEs for the test conditions will be the crash data (collected every 3 months beginning in September 2010) from the City of San Jose and the collision and near-miss data (collected every 3 months beginning in September 2010) from the VTA. Due to the resources needed to conduct, reduce, and analyze an additional round of field video data collection, the research team is proposing instead to have two data collectors ride LRVs between the Metro / Airport Station northbound to the Bonaventura Station and between the Bonaventura Station southbound to the Metro / Airport Station. Both the research team and the VTA feel that there is little reason to expect any changes in driver behavior during this phase of the evaluation (any behavioral changes that would result from the safety improvements would be captured during the “After Safety Improvement Conditions”). During the rides, data collectors will carry portable GPS devices, which will record LRV speeds northbound and southbound between the two stations. Data collectors will be stationed in the train operator cab as a “silent” observer and will record driver, pedestrian, and bicyclist behaviors at the intersections, as well as near misses.

In addition, traffic, pedestrian, and bicyclist counts will be compared with those of the two previous conditions to determine if exposure levels have changed.

DATA COLLECTION METHODOLOGY

Field Video Data Collection Methodology

For the first two evaluation conditions, video data will be collected to identify driver, pedestrian, bicyclist, and train operator behaviors (e.g., risky behaviors and compliance with traffic control devices). Baseline field video data were collected in June 2009, as was described in Chapter 3. Field video data will also be collected in the After Safety Improvement Conditions in the exact same manner that they were collected in the Baseline Conditions (see Chapter 3 for a complete description of the field video data collection methodology).

Methodology for On-Board Observations

Two data collectors will ride the trains between the Metro / Airport station and the Bonaventura station for 5 consecutive days during one week. The data collectors will ride the trains between the two stations during the designated data collection hours, which will be identical to those used in the video data collection methodology (i.e., 7:00 a.m. to 9:00 a.m., 11:00 a.m. to 2:00 p.m., and 4:00 p.m. to 7:00 p.m.). The first data collector will begin at the Metro / Airport Station at 7:00 a.m. and will board the first northbound train. The data collector will ride the train to the Bonaventura station. At the Bonaventura station, the data collector will exit the northbound train and will board the next southbound train. Once back at the Metro / Airport station, the data collector will repeat the processes of riding the trains between the two stations. The second data collector will go through the same process but on the next train following the first data collector.

During the rides, data collectors will carry portable GPS devices, which will record LRV speeds northbound and southbound between the two stations. The GPS data will allow an analysis of the speed profiles northbound and southbound between the two stations. The speed profiles will indicate if operators were able to achieve 40 mph and if so at what point and over what distance. As the speed data will be collected passively by the portable GPS devices, the data collectors will be free to observe what is happening both outside the LRV and inside the operator's cab. Specifically, data collectors will be trained to watch for unusual / unsafe driver, pedestrian, and bicyclist behaviors when the LRV is approaching the crossings, as well as when the LRV is in the crossing. Data collectors will record any observed behaviors or near miss incidents on a data collection sheet.

Assuming a train headway of 7.5 seconds in each direction, there would be approximately 64 northbound and 64 southbound trains during one day (8 hours) of data collection. Two data collectors should be able to ride about one-half of the trains, meaning 32 trains per day northbound and 32 trains per day southbound. As the test of higher speeds will be through three intersections in the northbound direction, this would allow for 96 observations. With a single test intersection in the southbound direction, this would allow for 32 crossing observations per day. Over a 5-day data collection period, there would be a total of approximately 480 crossing observations in the northbound direction and 160 crossing observations in the southbound direction for a total of 640 crossing observations.