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16. ABSTRACT

This report examines the existing conditions around the Richmond San-Rafael Bridge, both quantitatively through data collection and qualitatively through stakeholder interviews. This is the first part of a study effort aiming to evaluate the impacts of the proposed pilot modifications on bridge operations. Planned future work will continue to monitor bridge operations during the implementation of the proposed changes. A comprehensive evaluation similar to the one outlined in the report will be conducted a few months after completion of the changes once traffic conditions have stabilized. These future evaluations will be used by Caltrans to assess whether to make the modifications permanent.

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INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Richmond-San Rafael Bridge Access Improvements Project Before Study Evaluation and Report

April 20, 2018

(photo credit: Flickr / User: Don McCullough)

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EXECUTIVE SUMMARY

At four miles in length, the Richmond-San Rafael Bridge is one of the major over-water crossings in the San Francisco Bay Area. This crossing carries I-580 and connects the Alameda and Contra Costa Counties of the East Bay Region with Marin County on the coast. In its current configuration, each direction of travel only accommodates two traffic lanes, plus an additional shoulder lane for breakdowns and emergency access. As a result of significant growth in traffic volumes, this configuration often lead to significant delays and queues at the bridge approaches during commute hours. In particular, the eastbound PM commute traffic from Marin County often experiences substantial delays, with queues spilling over onto local streets and arterials.

To alleviate the eastbound congestion, Caltrans has decided to pilot the use of the eastbound shoulder lane for general travel during weekday PM peak periods, expanding capacity of the bridge from two to three lanes. While this capacity increase is expected to reduce eastbound travel times, there are potential pitfalls as the shoulder lane will no longer be available to accommodate broken down vehicles, causing them to sit in a general traffic lane. Along with these changes, Caltrans is also proposing to install a removable barrier in the westbound direction (upper deck) to separate the general-purpose lanes from the shoulder and to enable the creation of a multi-use path that will accommodate bicycles and pedestrians. Concerns surrounding the elimination of the westbound shoulder lane are similar to those associated with the eastbound lane in that broken down vehicles will no longer have a location to pull out of the traffic stream.

This report examines the existing conditions within the study area. This is the first part of a study effort aiming to evaluate the impacts of the proposed pilot modifications on bridge operations. Planned future work will continue to monitor bridge operations during the implementation of the proposed changes, with a comprehensive evaluation similar to the one outlined in this report to be conducted a few months after completion of the changes once traffic conditions will have stabilized. These future evaluations will be used by Caltrans to assess whether to make the modifications permanent.

Utilizing data collected between July 2015 and June 2016, researchers were able to examine traffic volumes, driver delays, and incidents. Looking closely at the primary commute directions, delays were observed in the westbound direction on the Richmond side of the bridge from 6:30 to 9:00 AM as a result of the toll plaza operations and the need for vehicles to quickly merge onto two lanes downstream of the facility. On the Marin approach, eastbound delays were present from 3:00 PM to almost 7:30 PM, with traffic on I-580 sometimes queuing up all the way to US-101 in San Rafael and queues of freeway-bound traffic observed on local arterials near the Marin approach. When comparing to free-flow conditions, congestion delays typically double travel times during the AM commute and triple them during the PM commute.

In regard to incidents, information provided by Caltrans revealed that severe incidents, i.e., ones that take 60 minutes or more to clear, were extremely rare and that typically incident management procedures were routinely followed. A majority of the incidents involved car breakdowns, running out of gas, or flat tires, with average clearance times under 20 minutes.

The largest clearance times occurred with maintenance activities or an severe injury crash but examinations of the distribution of clearance times still indicated that these incidents were cleared fairly reliably. In terms of quantity, there were more incidents westbound than eastbound, with much of the difference between the two directions occurring right at the merge after the toll plaza. Local police observed minor crashes on the Marin County side during the PM commute, as queues of vehicles backed up onto local streets.

Although the genesis of this project was to provide relief to the eastbound PM commute, the new multi-use path is also expected to create a new normal in the westbound lanes. Currently, there are no direct off-street connections for bicycles or pedestrians to the bridge itself. However, existing bus service carries between 400 and 850 bicycles per month, indicating a potential demand for a non-vehicle crossing, particularly in the summer. Future studies will need to examine bicycle counts on the new path and see how they compare with existing counts on the bus service.

The final component of the project was to assess how the existing congestion on the eastbound approach to the bridge affects quality of life in Marin County. This was done by interviewing staff from various local businesses on streets that were commonly used as alternate routes to I-580 and on which traffic congestion often developed. Employees at these businesses expressed concern over the spillover of traffic onto local streets and how that affected revenue at their place of business. Managers noted that the local street congestion both affected the commutes of their employees, who had to plan for a longer commute time to get to and from home reliably, and the ability of customers to reach their stores.

In summary, this report has reviewed the existing conditions around the Richmond San-Rafael Bridge both quantitatively through data collection and qualitatively through stakeholder interviews. After the physical modifications are completed, the research team expects positive changes to occur in traffic congestion during the PM eastbound commute as a result of the additional traffic lane, and unknown changes in both directions in regards to incident response due to the lack of shoulder space to move affected vehicles out of the way. To ensure that appropriate comparisons will be able to be made between before and after situations, special care will thus need to be taken during future studies to ensure that adequate and accurate data can be collected.

1. INTRODUCTION

This existing conditions review is an examination of the current state of the system in and around the four mile long John McCarthy Richmond-San Rafael Bridge, including the bridge toll plaza as well as portions of the communities of Richmond and San Rafael in close proximity to the bridge. This review examined bridge travel speeds, associated congestion, crashes, response times by emergency responders and maintenance crews, public transit use, and quality of life through interviews with local businesses. The objective is to provide a baseline of verifiable data to compare with stabilized conditions once modifications to the bridge operations have been completed. These include converting the existing westbound shoulder lane on the upper deck into a bike path and the existing eastbound shoulder lane on the lower deck into a traffic lane during peak travel conditions. The focus of the evaluations is on three measures: the effect of the shoulder lane use on the bridge as compared to the length and severity of the congested queue on the Marin approach, the effect of the removal of the emergency shoulder lane on crash/incident duration, and quantifying the use of the multi-use path by bicycles and pedestrians.

The report contains the following elements:

- Project background
- Study area
- Project team members
- Overview of data collected and analyzed
- Evaluation of congestion around the Richmond-San Rafael Bridge
- Evaluation of incident clearance times
- Evaluation of the rate and severity of major incidents
- Assessment of bicycle and pedestrian crossing demand
- Evaluation of existing quality of life on Marin County roadways affected by bridge congestion
- Preparation for the future evaluations
- Summary and recommendations

2. PROJECT BACKGROUND

The Richmond-San Rafael Bridge opened to traffic in September of 1956 as the second-to-last major bridge in the Bay Area to be constructed. Spanning a slightly narrower section between the San Francisco and San Pablo Bays, the crossing was, and still is, the second longest bridge in California with a length of four miles, behind only the San Mateo-Hayward crossing further south. It connects Richmond in Contra Costa County with San Rafael in Marin County providing access to Marin County from other points east and south. The total price tag for the bridge was $62 million dollars (about $550 million in 2017 dollars). It features two identical cantilever spans of 1,070 feet, with the highest clearance over water being 185 feet, and a lower section in between. For much of its length, the structure has upper and lower decks rather than having the decks side-by-side. As a result of this feature, it has been compared aesthetically to a roller coaster, a sea serpent, or a bent coat hanger.

The bridge currently carries an average daily traffic flow (ADT) of approximately 82,000 vehicles. As indicated in Table 2-1, this is noticeably lower than other bridges in the Bay Area, in great part due to the lower number of lanes on the bridge and its location relative to the main traffic destinations in the Bay Area.

Table 2-1: ADT of Sample Bridges in the San Francisco Bay Area (North to South)

Bridge Name	Connections	ADT
Carquinez Strait	Vallejo – Contra Costa County	123,000
Richmond-San Rafael	Richmond – San Rafael	82,000
San Francisco Bay	Oakland – San Francisco	268,000
Golden Gate	Marin County – San Francisco	119,000
San Mateo	Hayward – San Mateo	110,000
Dumbarton	Fremont – Palo Alto	71,000

(Source: 2015 Caltrans Traffic Census)

Although the bridge was originally part of State Road 17, it is currently signed as Interstate 580. The primary commute movement is westbound during the AM peak and eastbound during the PM peak. Similar to other Bay Area bridges, a $5 toll is currently assessed in the westbound direction at a toll plaza on the eastern shore in Richmond and no toll charged in the reverse direction. Figure 2-1 shows the toll plaza and the east approach of the bridge on the Richmond side of the crossing.

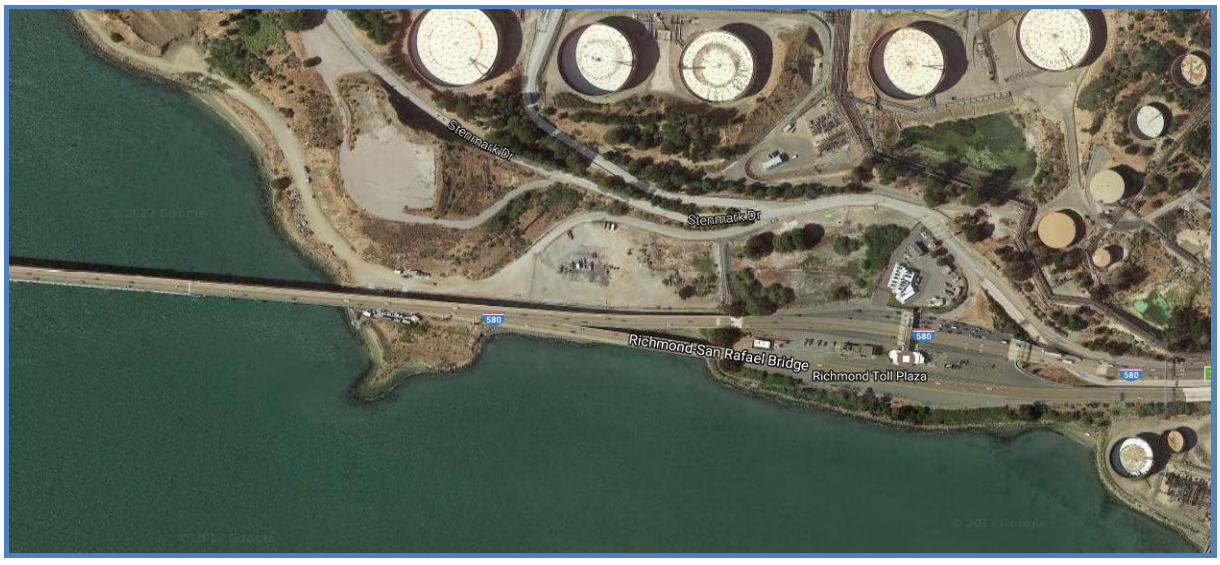


Figure 2-1: Richmond-San Rafael Toll Plaza and East Approach

The width of the bridge can accommodate three lanes of traffic in each direction with no emergency shoulder. However, Caltrans has striped each direction for only two lanes, leaving the third lane for emergencies or maintenance vehicles. The extra shoulder lane proved particularly helpful during the 1976-1977 drought when the East Bay Water District was able to lay a temporary water pipe to Marin County (which had run out of water) without disrupting traffic. However, increased volumes have led to congestion and reduced speeds, which will be discussed at length in this report. Queues in the westbound direction have increased during the

AM peak period as more users switch from cash to a toll tag (FasTrak). More toll tag users allow higher volumes to enter the lane drop merge at the bridge proper. Consequently, the merge has become more congested. The eastbound approach in Marin County also has significant congestion during the PM peak period. This congestion is primarily caused by a reduction from three lanes to two lanes 2,000 feet from the foot of the bridge and from traffic merging onto the freeway from an on-ramp with a non-standard acceleration lane at the foot of the bridge itself. This is shown in Figure 2-2.

Figure 2-2: Merge at West End of Richmond-San Rafael Bridge

For travelers without a car, Golden Gate Transit currently offers bus service across the bridge. To accommodate bicyclists who wish to cross the bridge, the agency has equipped its buses with a bike rack in the front. Over the past two years, this service has been used by between 500 and 800 individuals per month, depending on the season, with the largest demand occurring during the summer months. Other than the buses, there are no physical accommodations on the bridge itself for allowing bicycles or pedestrians to cross it. To remediate this situation, bicycle advocates have thus long advocated the use of one of the shoulder lanes for bicycle use, as it would provide a vital link in the sprawling Bay Trail multi-use path network.

To address the above issues, a consortium of Caltrans, BATA/MTC, and local jurisdictions started formulating in 2014 a pilot project that would allow for vehicular traffic to use the shoulder in the eastbound direction during the PM peak period while at the same time constructing a multi-use path for bicycles and pedestrians in the westbound shoulder. The objective of the pilot would be "to reduce congestion on eastbound I-580 . . . and to provide a bike/pedestrian link between the two counties" (MTC 2017). The multi-use path would be

protected from general traffic by a moveable zipper barrier, used widely across the country, to allow access for maintenance vehicles.

The proposed pilot was formally approved in the summer of 2015 and was named the "Richmond-San Rafael Access Improvements" pilot project. The project includes improvements to the approaches for bicycle lane access (upper deck) and access to the eastbound shoulder lane (lower deck). Construction is expected to be finished by 2018 and followed by four years of observation. Data gathered during the observations period will further be used to assess whether to keep or modify the improvements. The following picture, courtesy of MTC, shows a conceptual mock-up of what the shoulder lane use will look like in both directions once completed.

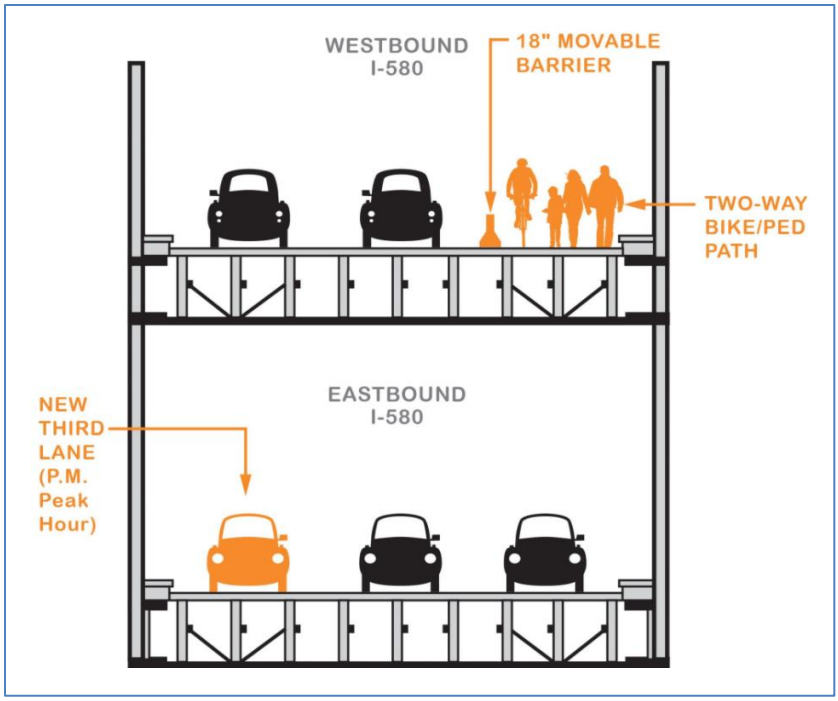


Figure 2-3: Mockup of Proposed Modifications

The implementation of shoulder lane use for alternative purposes will change the nature of how the bridge functions. Most notably, the shoulder will no longer be available in both directions for incident response, which could lead to longer queues from incidents and more delays to drivers. Theoretically, there could also be a new set of emergency responses for the multi-use path, either for a bicycle crash or suicide attempt. To assess the extent of these potential impacts, Caltrans has commissioned the University of California, Berkeley to monitor the changes in bridge operations resulting from the, starting with a study of existing conditions ("before") and data gathering and to be followed by an evaluation of operational conditions after implementation of the changes.

3. STUDY AREA

The study area for this project includes sections of I-580 in Richmond and San Rafael in addition to the bridge itself and the toll plaza, shown in Figures 3-1, 3-2, and 3-3. Important local roads that were examined include the following:

- **Richmond side:** Stenmark Drive, Marine Street, Castro Street, Richmond Parkway, Cutting Boulevard, Harbour Way
- **San Rafael side:** Andersen Drive, Bellam Boulevard, East Francisco Boulevard, Sir Francis Drake Boulevard

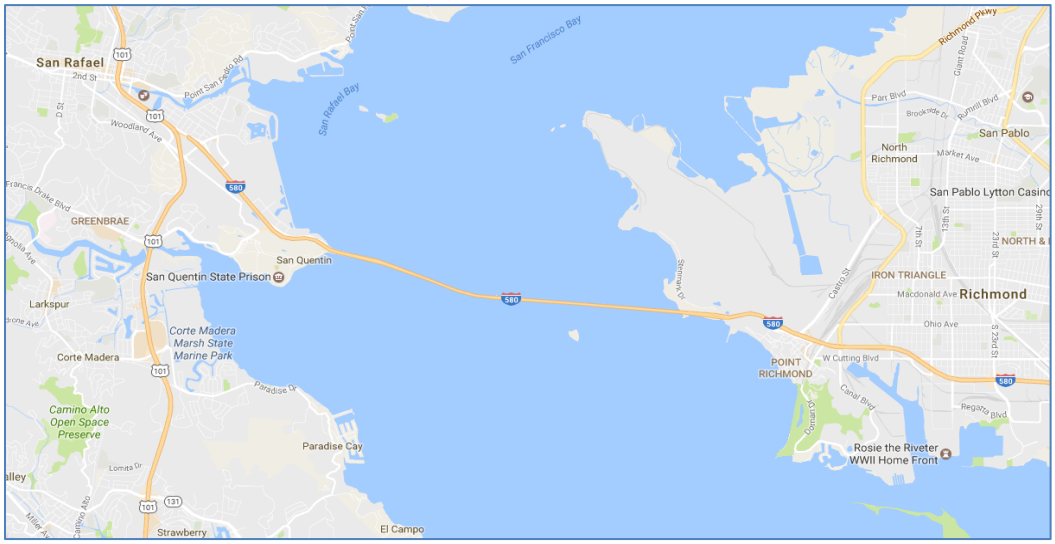


Figure 3-1: Overview of Richmond-San Rafael Bridge

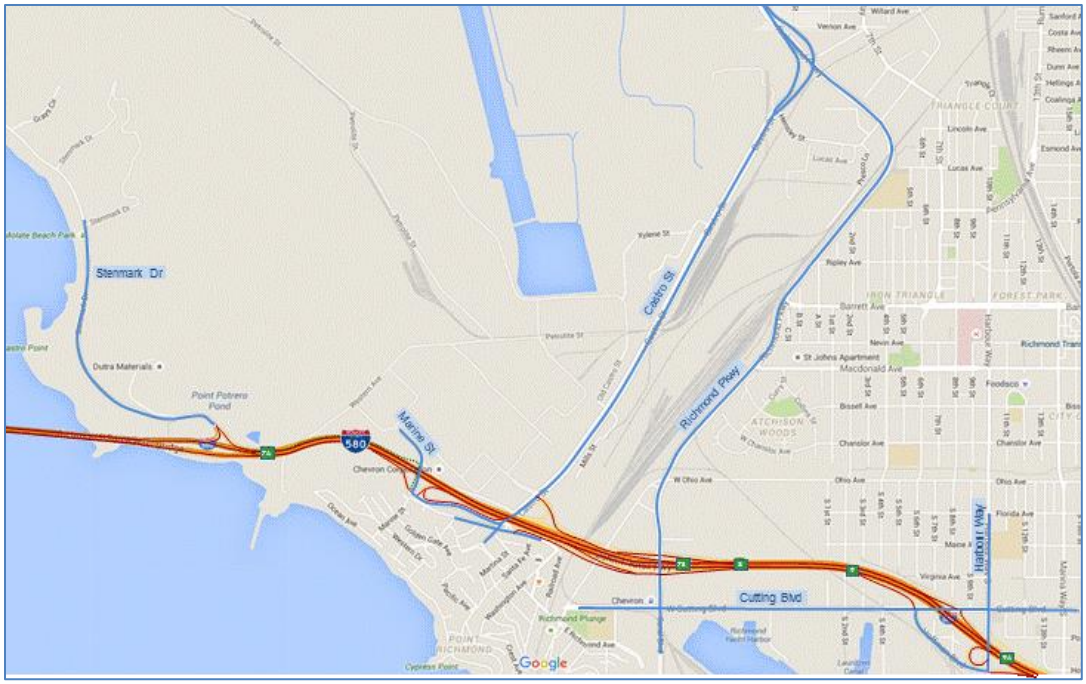


Figure 3-2: Richmond (Eastern) Approach

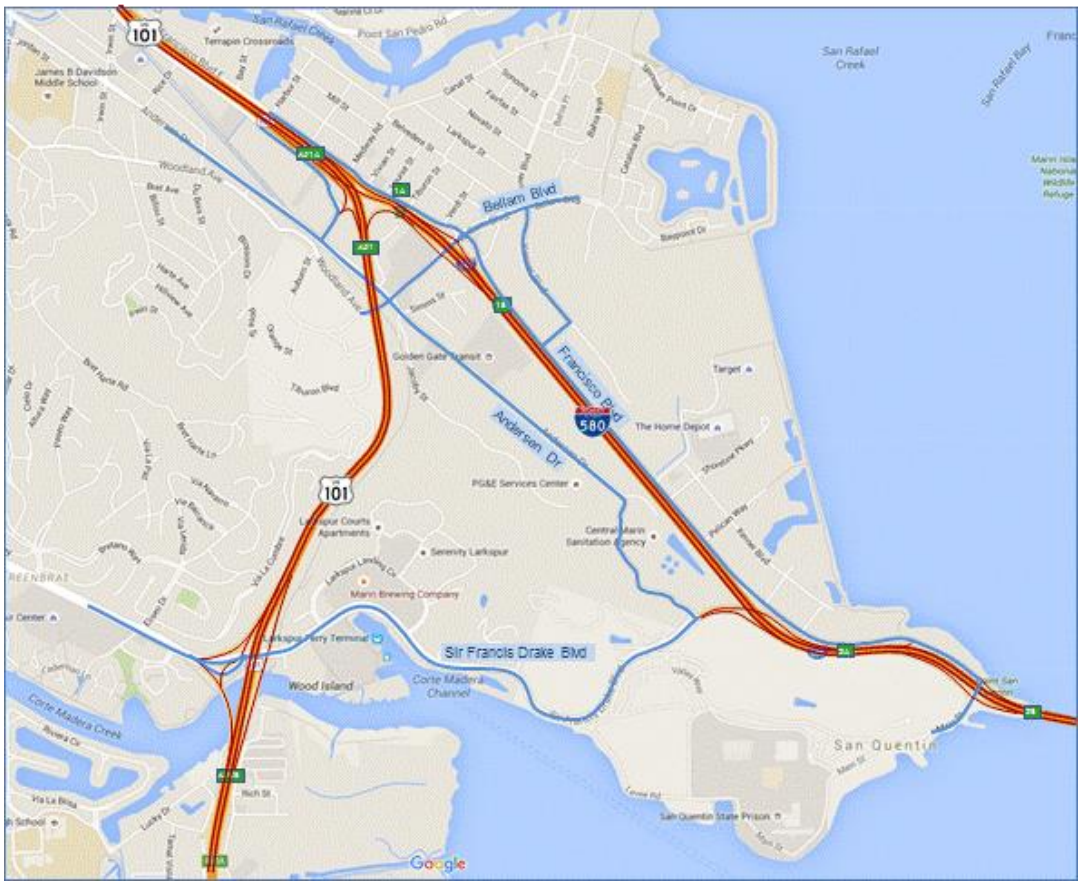


Figure 3-3: San Rafael (Western) Approach

4. PROJECT TEAM MEMBERS

In addition to this study being performed by the University of California, Berkeley, the project team members include the following entities:

- **Project Proponents:** Bay Area Toll Authority (BATA), Contra Costa Transportation Authority (CCTA) and the Transportation Authority of Marin (TAM). These organizations have provided the funding and have expedited the permitting process.
- **Project Overseer:** Caltrans District 4, responsible for approving the design and providing quality assurance during construction.
- **Project Designer:** HNTB Corporation, response for the design and implementation of the improvements.

5. OVERVIEW OF DATA COLLECTED AND ANALYZED

For all data collection, the preferred study period for assessing bridge operations before the implementation of the proposed changes was July 1, 2015 to June 30, 2016. This was the closest one-year period during which bridge operations would not have been disturbed by construction activities.

Specific data that were gathered by the project team include the following:

- **I-580 Freeway Characteristics:** The project team collected data on speeds and flows along I-580 within the study area. This allowed the project team to assess delays, travel times, congestion duration, discharge flows, and travel time reliability. Data was obtained from the Caltrans Performance Measurement System (PeMS) and private Inrix information. Additional ramp and mainline counts to supplement existing data and cover areas with problematic PeMS data or without information were performed in May 2016 by NDS, a data collection a consultant hired by PATH as part of the project. PeMS information is fairly sparse on this section of I-580, with no detection on a seven-mile segment that includes the bridge itself and adjacent approaches.
- **Incident Data:** Caltrans District 4 has shared information from the BAIRS reporting program, the Major Incident Database (MIDB), the California Highway Patrol Computer-Aided Dispatch (CHP CAD) system, and the Statewide Integrated Traffic Report System (SWITRS). This enabled the team to examine crash and incident rates within the study area. Additionally, information from the Freeway Service Patrol (FSP), towing companies, and bridge call boxes has given the project team the ability to analyze additional non-crash responses. San Rafael has further provided crash data on local streets, enabling the team to track the safety impacts of traffic using local roads, particularly during the PM peak period.
- **Bicycle Counts:** Golden Gate Transit, provided the project team with bicycle counts on their buses. Automated counting stations are further being installed as part of the pilot project. These counting stations will allow the team to obtain more direct observations of

bicycle use of the newly installed bike path on the bridge once these stations become operational.

Due to various reasons, the project team was not able to find all the data items for the identified assessment period. In many cases, the specific data being sought were simply unavailable. In other cases, the discovered data were not relevant to the project. The following is a list of the data issues that were uncovered:

- **Bluetooth data for speeds and travel times:** While the team initially hoped that Bluetooth data would be available to supplement PeMS and Inrix data, no Bluetooth data were found to be available for the study area.
- **Local street characteristics:** Neither Richmond nor the multiple jurisdictions in Marin County had detailed information on local streets. As detailed later, all that could be assembled was limited data for the major arterials through Inrix and a limited traffic counts conducted in May 2016.
- **IMMS Information:** The team reviewed IMMS and concluded the information was duplicated by other resources.
- **Existing bike/pedestrian counts:** There were no existing bike/ped events to monitor, as the bike/ped path is not open yet. Consequently, aside from the data provided by Golden Gate Transit on bicycles carried across the bridge, there was no other existing data characterizing bike or pedestrian demand for travel across the bridge.
- **Call box data:** Incident management data did show if the call came from a bridge call box. However, the specific location on the bridge from where a call originated was not included, thus significantly limiting the usability of the data provided.

6. CONGESTION EVALUATION

With PeMS data supplemented by Inrix, the PATH research team evaluated the existing congestion in the Richmond-San Rafael Bridge corridor. Congestion on I-580 within the study area is typically *unidirectional* as it follows the commute direction; it is westbound from Richmond to San Rafael during the AM peak and the opposite during the PM peak. In both cases, the capacity of the bridge cannot accommodate the peak period volume of the primary commute direction. The secondary or reverse commute direction does not generally create volume-related congestion; speeds only drop for crashes or other non-recurring incidents.

The following subsections provide the following elements:

- Definition of congestion statistics used
- Evaluation of the morning commute delays
- Evaluation of the afternoon commute delays

6.1. DEFINITIONS

This evaluation uses some selected traffic engineering terms that should be defined in detail. Average travel speeds and travel time should be self-explanatory, however definitions are provided for travel time index, the buffer time index and the planning time index. These are measures promoted by the Federal Highway Administration to assess travel time reliability, and definitions are presented below:

- The **travel time index** is the ratio of the average (50^{th} percentile) **travel time** divided by the expected free-flow travel time. During the off-peak hours, this index typically has a value of 1.00 as the numerator and denominator are roughly equal. A value of 2.00 would equal a travel time that is double the free-flow time, indicating an average speed that is only 50% of the free flow speed.
- The **planning time index** is the ratio of the 95^{th} percentile travel time, known as **planning time**, divided by the expected free-flow time. Planning time indicates how long a commuter would need to budget to ensure they arrive on time 95% of the time. Focusing on the typical worst case, the planning time index is a good measure of reliability for the study segment. If the planning time index is not significantly different than the travel time index, drivers can have a good expectation of what the travel time will be. However, if the planning time index is far greater than the regular travel time index, travel times on the study segment are likely to be unreliable.
- The **buffer time** indicates the time between the 50^{th} percentile (average time) and the 95^{th} percentile (planning time). Buffer time is the amount commuters must add to the average travel time to ensure an on-time arrival 95% of the time. The **buffer time index** is the raw difference between the two indices.

Figure 6-1 shows a chart of the city-wide travel time index and planning time index for the city of Los Angeles in 2003, taken from the FHWA document "Travel Time Reliability," FHWA-HOP-06-070. Buffer time would equal the difference in the two indices multiplied by the average travel time. Note that from 9:30 PM to 5:00 AM, the planning time index and the travel time index are the same and have a value of 1.00, indicating that in 2003, citywide traffic moved very reliably at or near free-flow speeds after 9:30 PM.

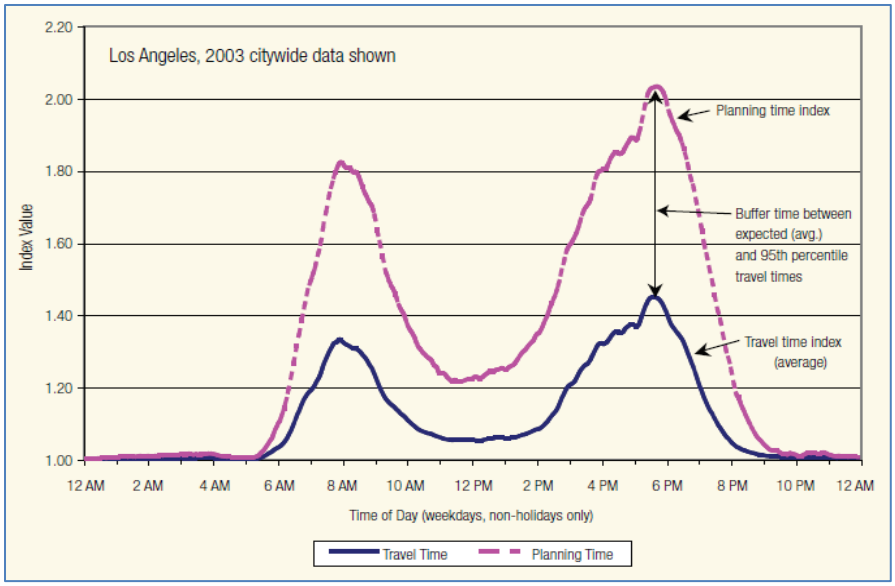


Figure 6-1: Definition of Travel Time Reliability Indices

6.2. MORNING COMMUTE PERIODS (I-580 RICHMOND DELAYS)

During the AM peak, congestion on I-580 is in the westbound direction at the bridge toll plaza. Seven lanes within the physical toll plaza serve three lanes of I-580 WB. An additional on-ramp from Stenmark Drive with low volumes merges into the mainline right before the plaza. The three lanes on the left are for vehicles with FasTrak toll tags only, while the four lanes on the right are manned booths for both cash transactions and FasTrak. During the peak hours, the far left lane is reserved for carpools and buses only. Of note, the research team examined the entire length of I-580 from the bridge to I-80 in Albany, and daily recurring congestion can extend from the vicinity of the toll plaza back to the Marina Bay Parkway interchange.

Due to the proximity of the toll barrier to the bridge itself, the merge to two lanes is approximately 1000 feet from the barrier. Although the guidance from the lane striping is not necessarily observed during the peak, within the merge area the four cash lanes are merged into one lane and the three FasTrak lanes are merged into two. The single lane discharging the cash transactions must merge with the right FasTrak lane; this lane will become the shoulder (third) lane merging to just two lanes on the bridge. Figure 6-2 shows a satellite overview, 6-3 shows the typical AM congestion and 6-4 shows a schematic of the approach.

Figure 6-2: Satellite Overview of Richmond Toll Plaza and Merge Bottleneck

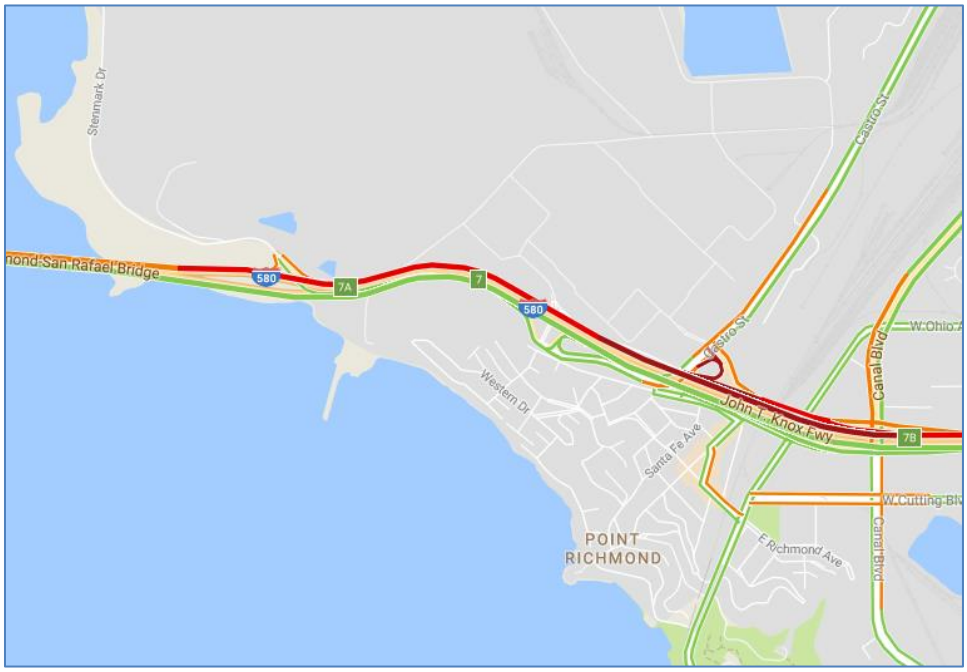


Figure 6-3: Congestion on the Richmond Approach, Typical Wednesday 8:00 AM

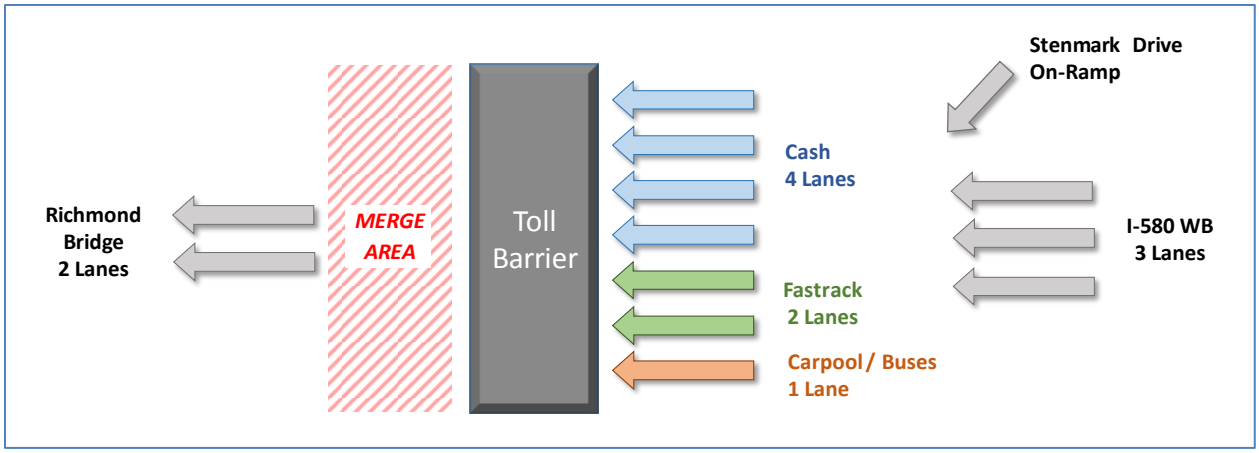


Figure 6-4: Schematic Diagram of Richmond-San Rafael Bridge Westbound Approach

Figures 6-5 and 6-6 shows the hourly and 15 minute volumes, respectively, that were measured by the payments at the toll plaza for May 10, 11 and 12 in 2016. These volumes were collected in five minute intervals and provided to the research team by Caltrans and BATA. As can be observed, the volumes are relatively constant across the three observation days with May 12 slightly higher after 7:00 AM and with the highest volumes from approximately 6:00 to 9:00 AM. During this time period the throughput from the toll plaza ranged from approximately 2,700 to 4,100 vehicles per hour onto the bridge. The maximum value of 4,100 vehicles per hour reflects one 15 min period (7:30-7:45) where the average volume was 1,025 vehicles per 15 minutes. Examining Figure 6-5, the highest observed hourly volume was 3,857 vehicles from 7:00 to 8:00 AM.

As expected, the period with peak volumes corresponds to the period when the lowest speeds are observed due to congestion at the toll plaza. Figure 6-7 shows the average speeds on the final 3 miles approaching the bridge that were measured for roughly the same observation period in mid-May 2016 as the data of Figure 6-5, while Figure 6-8 shows the corresponding travel times on the segment. The speeds and travel times correlate strongly and indicate a congested period extending from approximately 6:40 to 9:15 AM. At the height of the congestion, between 7:30 and 8:00 AM, the average travel time over the observation period approaches 12 minutes, which is over 350% more than the free flow time of roughly 3.2 minutes.

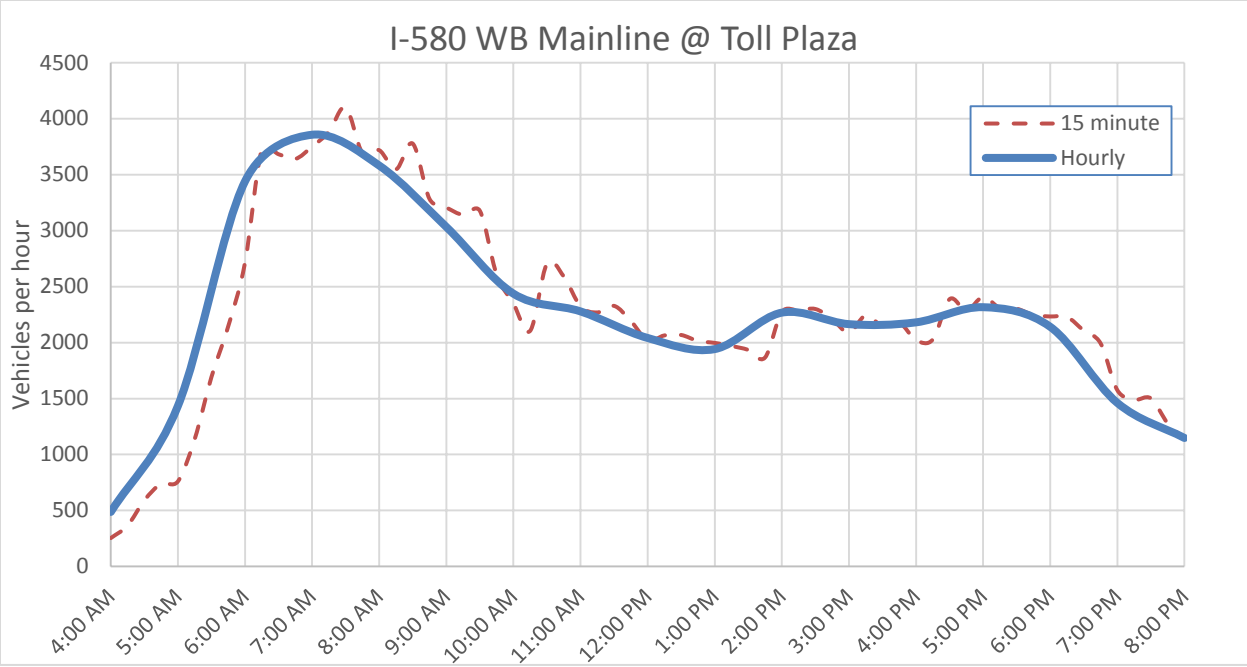


Figure 6-5: WB I-580 Average Volumes at the Toll Plaza

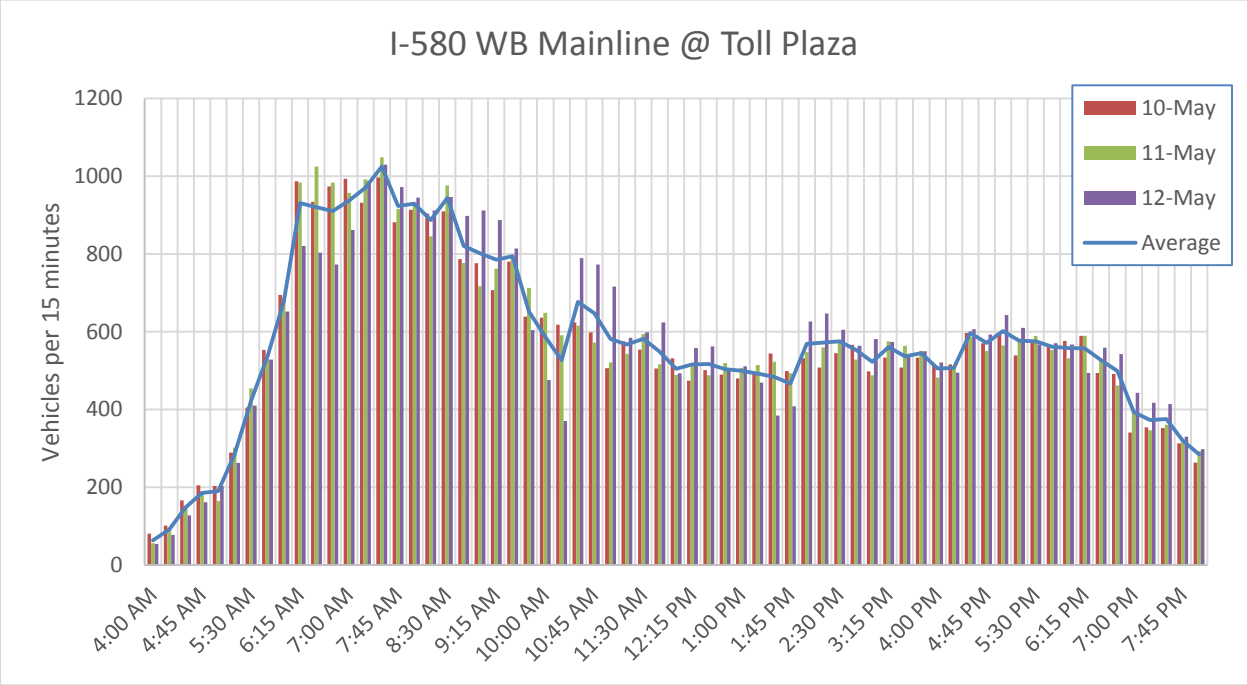


Figure 6-6: WB I-580 Volumes at the Toll Plaza (15 min)

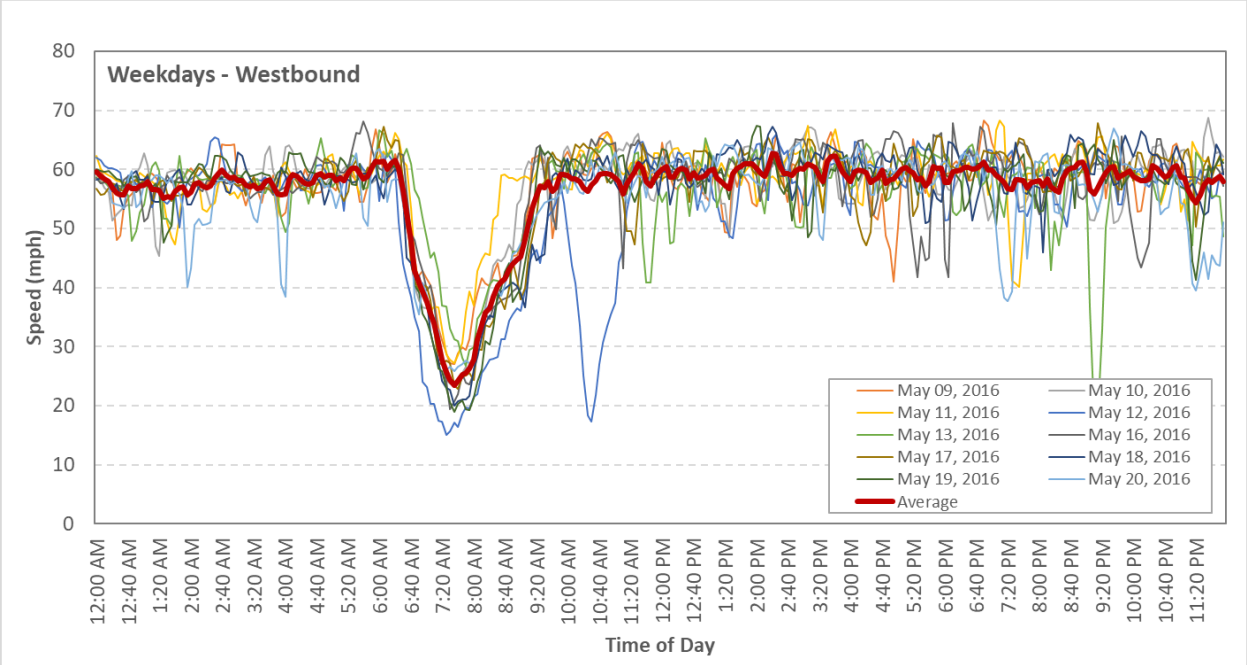


Figure 6-7: Average speed on I-580 Westbound, Richmond (Cutting to Toll Plaza)

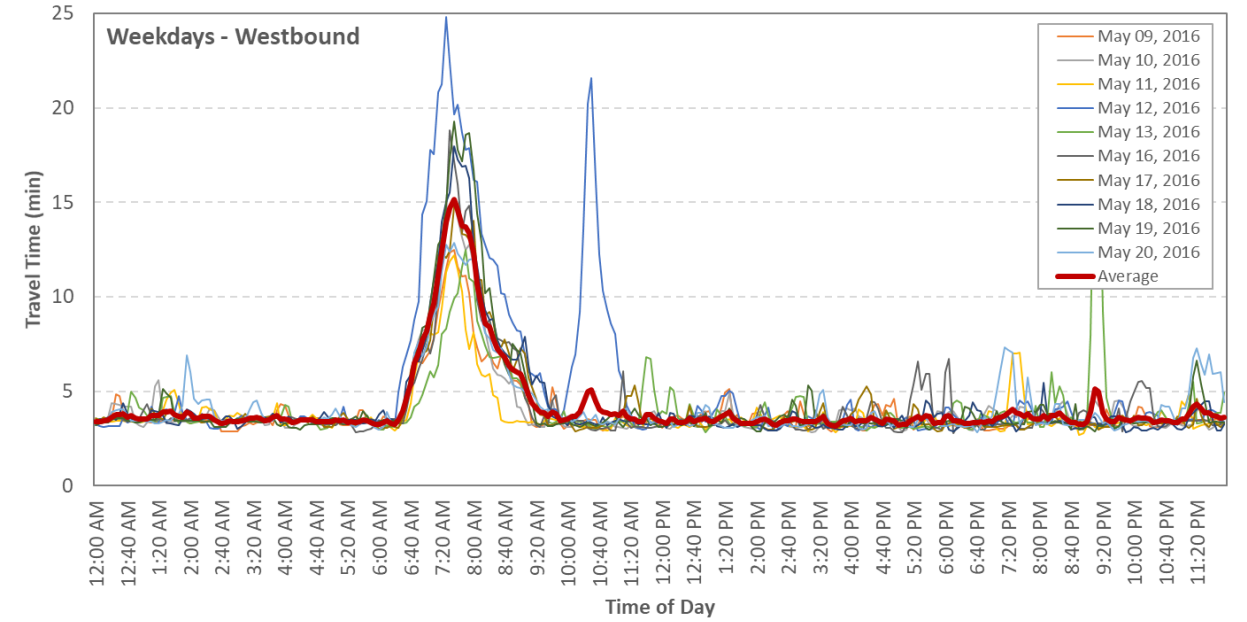


Figure 6-8 Average travel time on I-580 Westbound, Richmond (Cutting Boulevard to Toll Plaza)

Table 6-1 further illustrates the travel time reliability metrics that were measured over a two-month period covering the months of February and March 2016. For this table and all subsequent tables that describe indices, the AM period refers to 6-10 AM, midday refers to 10 AM to 2 PM and the PM period is 2 PM to 7 PM. A longer study period than used for the analysis of Figures 6-5 and 6-6 was utilized to obtain a better measurement of the variability of

traffic conditions during weekdays. This explains the lower peak average travel times (between 7 and 8 minutes) listed in the table than those shown in Figure 6-8 (around 12 minutes). Over the two-month observation period, the average westbound peak travel time in the morning was measured to be around 7.5 minutes on all weekdays, except Fridays when the travel times only peaks at 5 minutes. A travel time of 7.5 minutes is roughly 250% above the free-flow travel time of 3.2 minutes, thus producing a travel time index of oscillating around 2.5 on Mondays, Tuesdays, Wednesdays and Thursdays. The high day-to-day variability in observed travel times further result in travel times exceeding 16 minutes on all weekdays except Friday, and thus in planning time indices exceeding 5.0, meaning that travelers must typically budget more than 5 times the free-flow rate to ensure an on-time arrival 95% of the time on these days.

Table 6-1: Indices and Travel Times for the Westbound I-580 in Richmond

	Travel Time (min)			Travel Time Index			Buffer Time (min)			Buffer Time Index			Planning Time (min)			Planning Time Index		
	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM
Monday	7.30	3.60	3.34	2.40	1.19	1.10	13.60	1.70	1.26	4.13	0.52	0.40	16.89	4.97	4.46	5.56	1.64	1.47
Tuesday	7.85	3.38	3.25	2.58	1.11	1.07	12.71	1.08	0.91	3.83	0.33	0.29	16.03	4.33	4.07	5.28	1.43	1.34
Wednesday	7.24	3.32	3.26	2.38	1.09	1.07	12.77	0.87	0.91	3.82	0.27	0.29	16.11	4.13	4.05	5.30	1.36	1.33
Thursday	7.98	3.55	3.30	2.63	1.17	1.09	15.57	1.93	0.86	4.70	0.60	0.27	18.88	5.18	4.02	6.22	1.70	1.32
Friday	5.04	3.31	3.25	1.66	1.09	1.07	7.18	0.86	0.81	2.22	0.26	0.26	10.42	4.11	3.99	3.43	1.35	1.31
Saturday	3.49	6.03	3.82	1.15	1.99	1.26	1.71	13.52	3.52	0.56	4.21	1.10	4.79	16.73	6.72	1.58	5.51	2.21
Sunday	3.36	5.91	4.33	1.10	1.95	1.43	1.50	15.07	5.47	0.49	4.89	1.77	4.54	18.15	8.56	1.49	5.98	2.82

Finally, one should note that the reverse commute does not suffer from systemic delay or congestion. Table 6-2 shows the three indices for the non-traditional direction. As can be observed, the travel time indices remain around 1.0, which indicates that travel times remain close to the free-flow travel times of 2.9 minutes. Variability in traffic conditions further result in 95% peak travel times of about 3.2 minutes, and a planning time index that does not exceed 1.14.

Table 6-2: Indices and Travel Times for the Eastbound I-580 in Richmond

	Travel Time (min)			Travel Time Index			Buffer Time (min)			Buffer Time Index			Planning Time (min)			Planning Time Index		
	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM
Monday	2.92	2.91	2.92	1.01	1.00	1.01	0.32	0.18	0.28	0.11	0.06	0.09	3.29	3.23	3.27	1.14	1.12	1.13
Tuesday	2.88	2.92	2.94	0.99	1.01	1.02	0.32	0.19	0.26	0.11	0.06	0.09	3.27	3.24	3.27	1.13	1.12	1.13
Wednesday	2.88	2.95	2.96	0.99	1.02	1.02	0.29	0.22	0.31	0.10	0.07	0.10	3.26	3.26	3.32	1.13	1.13	1.14
Thursday	2.89	2.94	2.93	1.00	1.01	1.01	0.33	0.26	0.32	0.11	0.09	0.11	3.28	3.27	3.31	1.13	1.13	1.14
Friday	2.93	2.95	2.95	1.01	1.02	1.02	0.34	0.24	0.27	0.12	0.08	0.09	3.30	3.29	3.31	1.14	1.14	1.14
Saturday	2.86	2.88	2.94	0.99	0.99	1.02	0.37	0.33	0.43	0.13	0.11	0.15	3.29	3.24	3.38	1.13	1.12	1.17
Sunday	2.93	2.88	2.93	1.01	0.99	1.01	0.39	0.38	0.42	0.13	0.13	0.14	3.29	3.30	3.36	1.14	1.14	1.16

6.3. AFTERNOON COMMUTE PERIODS (I-580 MARIN DELAYS)

In the afternoon, the constraint of only two travel lanes on the bridge proper creates significant congestion and increased travel time in the eastbound direction on the approaches to the bridge in Marin County, with queues spilling onto local streets. In this manner, the afternoon congestion on the Marin side differs from the morning congestion that is largely confined to the toll plaza. As will be discussed further in the quality of life section, queues on local streets from bridge congestion are very common in the afternoon and have a negative effect on businesses in

these areas. Streets that are typically affected are Sir Francis Drake Boulevard, Kerner Boulevard, Andersen Drive, and East Francisco Boulevard. Figures 6-9 through 6-11 show the map view of the Marin approach, followed by the Google Maps typical Wednesday afternoon and a schematic. E. Francisco is the road directly to the north of the freeway.

Figure 6-9: Satellite Overview of the Marin Approach

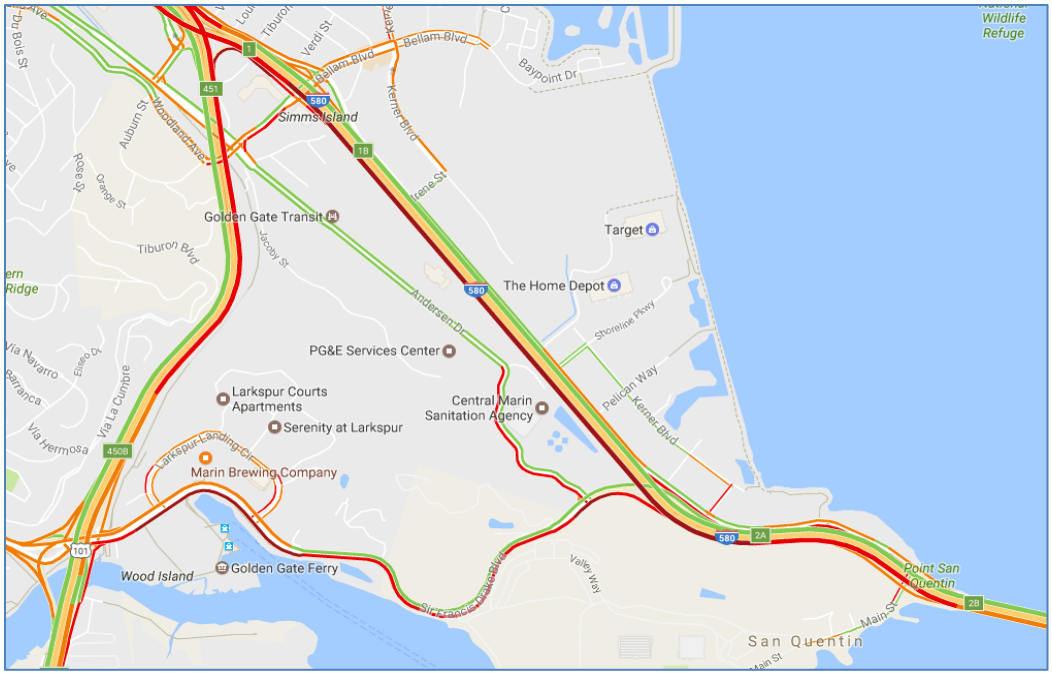


Figure 6-10: Congestion on the Marin Approach, Typical Wednesday 5:00 PM

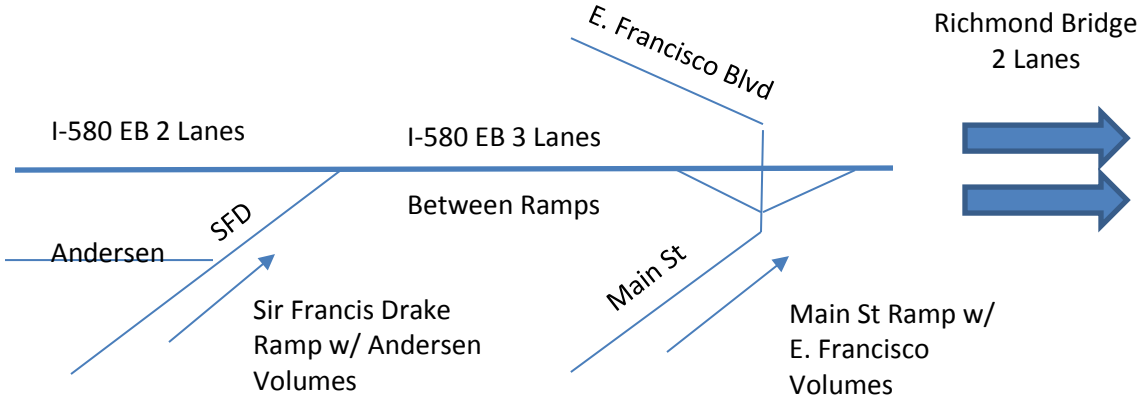


Figure 6-11: Schematic of the Marin Approach

Figures 6-12 and 6-13 shows the volumes in the eastbound direction as they pass the toll plaza unimpeded, measured May 10, 11 and 12 in 2016. Notice that the increased volume starts as early as 2:30 PM and continues through 7:30 PM.

In the eastbound direction, volumes peak at 900 vehicles per 15 minutes or 3,600 vehicles per hour. This corresponds to 1,800 vehicles per lane.

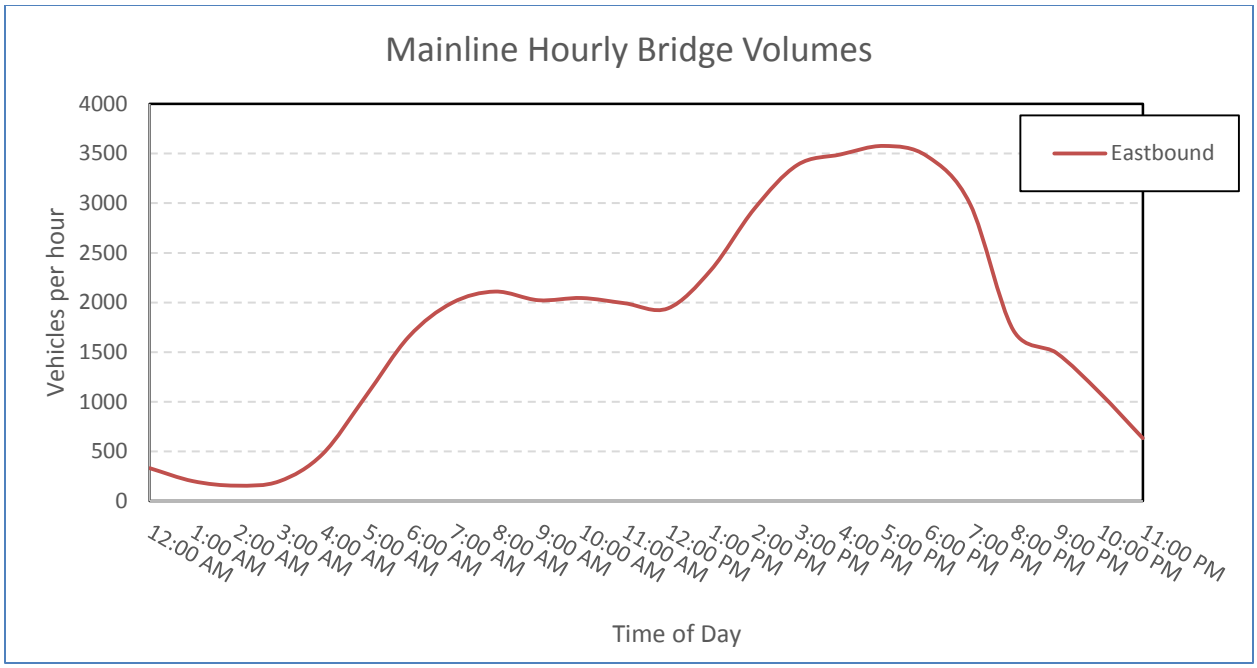


Figure 6-12: Eastbound I-580 Volumes at the Toll Plaza (Hourly)

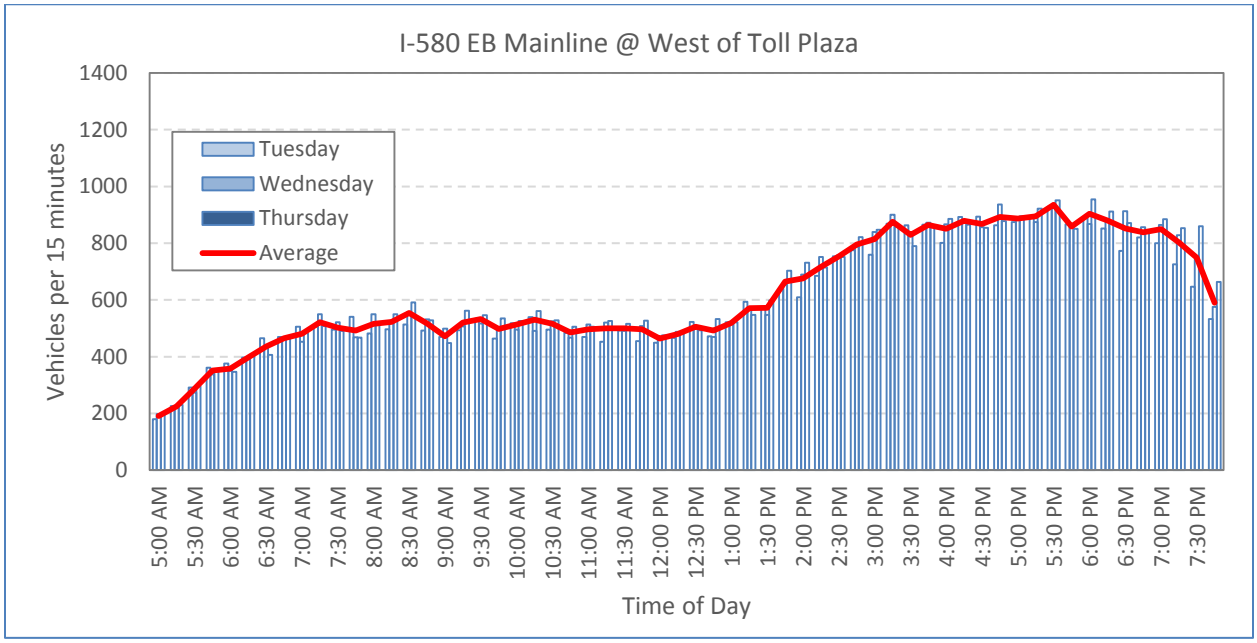


Figure 6-13: Eastbound I-580 Volumes at the Toll Plaza (15 min)

The congestion and delay primarily occur in Marin County, before the bridge proper. Figures 6-14 and 6-15 show the eastbound speeds and travel times for the Marin approach, from Bellam Boulevard to the bridge proper, measured over the same observation period as the data of Figure 6-10.

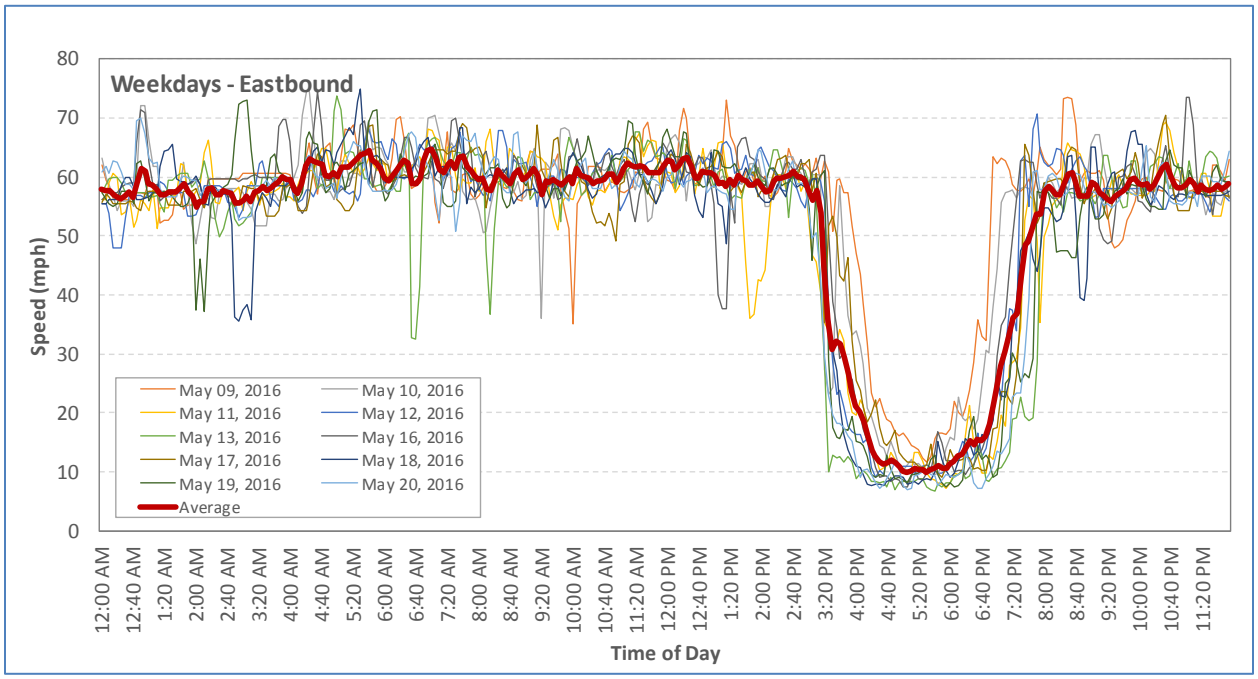


Figure 6-14: Speeds on I-580 Eastbound, Marin Approach

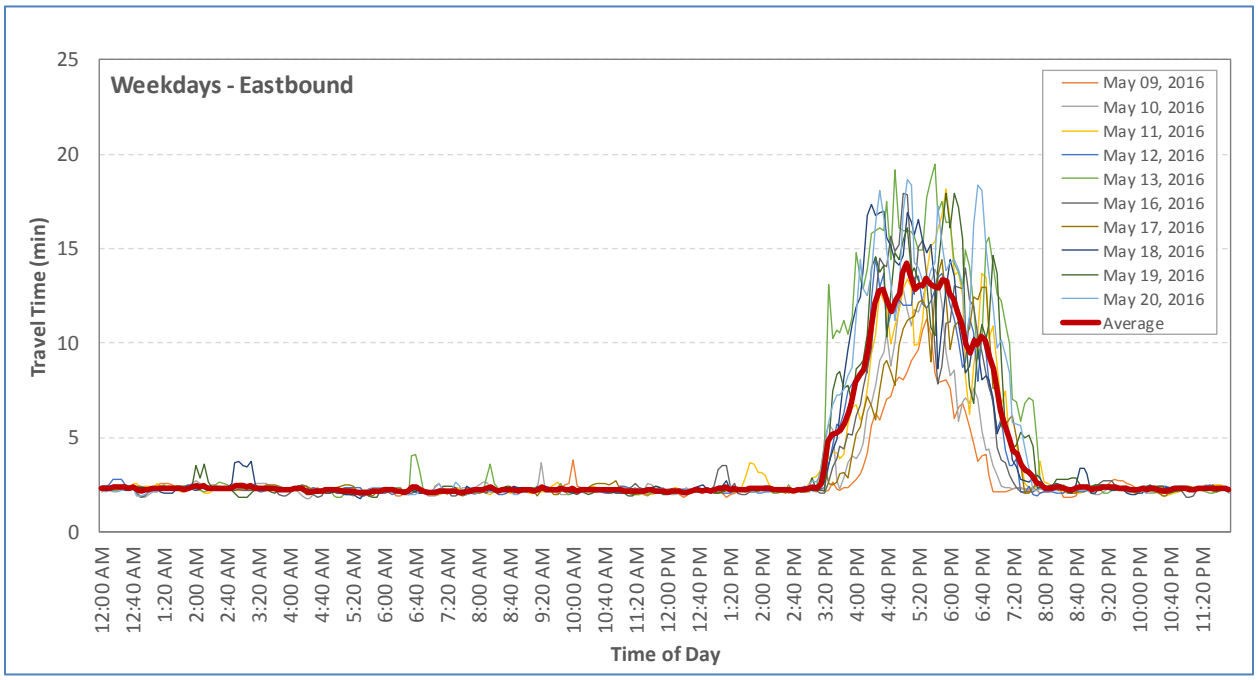


Figure 6-15: Travel Times on I-580 Eastbound, Marin Approach

As shown by examining the figures, there is significant congestion on I-580 eastbound on the Marin approach starting as early as 3:15 pm and continuing until past 7:00 pm. In contrast to the morning congestion, where average speeds never went below 25 mph on the segment approaching the toll plaza, average speeds on the Marin approach drop as low as 15 mph for

more than 90 minutes (4:00 pm to 5:30 pm). This would indicate severe daily congestion on the segment from Bellam Boulevard to the bridge itself.

The observed delays produce high travel time and planning time indices in the eastbound direction for travel during the afternoon peak. Similar to Table 6-1 and 6-2, Table 6-3 lists the reliability metrics that were estimated using Inrix data covering the months of February and March 2016. In this case, average peak travel times were measured to vary between 6.2 minutes on Monday and 9.4 minutes on Friday. This corresponds to travel time indices varying between 2.93 and 4.39. The variability of traffic conditions further result in 95% travel times varying between 14 and 20 minutes, producing travel time indices ranging from 6.6 to 9.4. It can further be noted that congestion is minimal throughout the day in the westbound direction.

Table 6-3: Indices and Travel Times for the Westbound I-580 in Marin County

	Travel Time (min)			Travel Time Index			Buffer Time (min)			Buffer Time Index			Planning Time (min)			Planning Time Index		
	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM
Monday	2.28	2.25	2.23	1.02	1.01	1.00	0.06	0.10	0.10	0.03	0.04	0.04	2.44	2.45	2.51	1.09	1.10	1.13
Tuesday	2.29	2.28	2.25	1.02	1.02	1.01	0.07	0.14	0.06	0.03	0.06	0.02	2.46	2.49	2.58	1.10	1.12	1.16
Wednesday	2.30	2.29	2.28	1.03	1.02	1.02	0.11	0.11	0.21	0.05	0.05	0.08	2.51	2.47	2.70	1.12	1.11	1.21
Thursday	2.30	2.27	2.35	1.03	1.02	1.05	0.08	0.11	0.48	0.03	0.05	0.18	2.50	2.49	3.09	1.12	1.11	1.38
Friday	2.28	2.27	2.30	1.02	1.02	1.03	0.05	0.03	0.21	0.02	0.01	0.07	2.45	2.51	2.99	1.10	1.13	1.34
Saturday	2.22	2.25	2.26	0.99	1.01	1.01	0.22	0.17	0.27	0.10	0.07	0.12	2.46	2.49	2.57	1.10	1.12	1.15
Sunday	2.19	2.24	2.25	0.98	1.00	1.01	0.16	0.20	0.27	0.07	0.09	0.12	2.40	2.46	2.52	1.07	1.10	1.13

Table 6-4: Indices and Travel Times for the Eastbound I-580 in Marin County

	Travel Time (min)			Travel Time Index			Buffer Time (min)			Buffer Time Index			Planning Time (min)			Planning Time Index		
	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM	AM	Mid	PM
Monday	2.17	2.17	6.25	1.02	1.02	2.93	0.15	0.10	14.69	0.07	0.04	6.57	2.39	2.35	16.93	1.12	1.10	7.94
Tuesday	2.15	2.17	6.61	1.01	1.02	3.1	0.12	0.10	11.93	0.05	0.04	5.31	2.38	2.35	14.17	1.11	1.10	6.64
Wednesday	2.16	2.19	8.19	1.01	1.03	3.84	0.13	0.12	14.81	0.06	0.06	6.52	2.39	2.37	17.08	1.12	1.11	8.01
Thursday	2.16	2.18	8.82	1.01	1.02	4.13	0.12	0.11	17.77	0.05	0.05	7.72	2.37	2.37	20.08	1.11	1.11	9.41
Friday	3.05	3.74	9.36	1.43	1.75	4.39	0.55	1.00	16.71	0.25	0.44	7.20	2.75	3.25	19.03	1.29	1.52	8.92
Saturday	2.16	2.19	3.92	1.01	1.03	1.84	0.38	0.35	7.79	0.18	0.16	3.54	2.53	2.55	9.99	1.19	1.19	4.68
Sunday	2.17	2.20	4.24	1.02	1.03	1.99	0.41	0.36	9.45	0.19	0.16	4.19	2.54	2.58	11.70	1.19	1.21	5.49

6.4. LOCAL STREETS

Utilizing additional Inrix data, the research team was able to examine congestion on local streets that could be affected by the freeway congestion caused by the capacity drop on the Richmond-San Rafael Bridge proper. Five streets were selected; Castro Street, Cutting Boulevard, and Richmond Parkway in Richmond; Bellam Boulevard and Sir Francis Drake Boulevard in Marin County. Figure 6-16 shows the location of the segments that were analyzed in relation to the I-580 freeway. In addition, data was provided by Inrix that examined US 101 in Marin County, as this freeway can be affected by queue spillover from the end of I-580 in San Rafael. To ensure correspondence with the previous analyses, the Inrix probe data was again taken from May 9 to May 13, 2016.

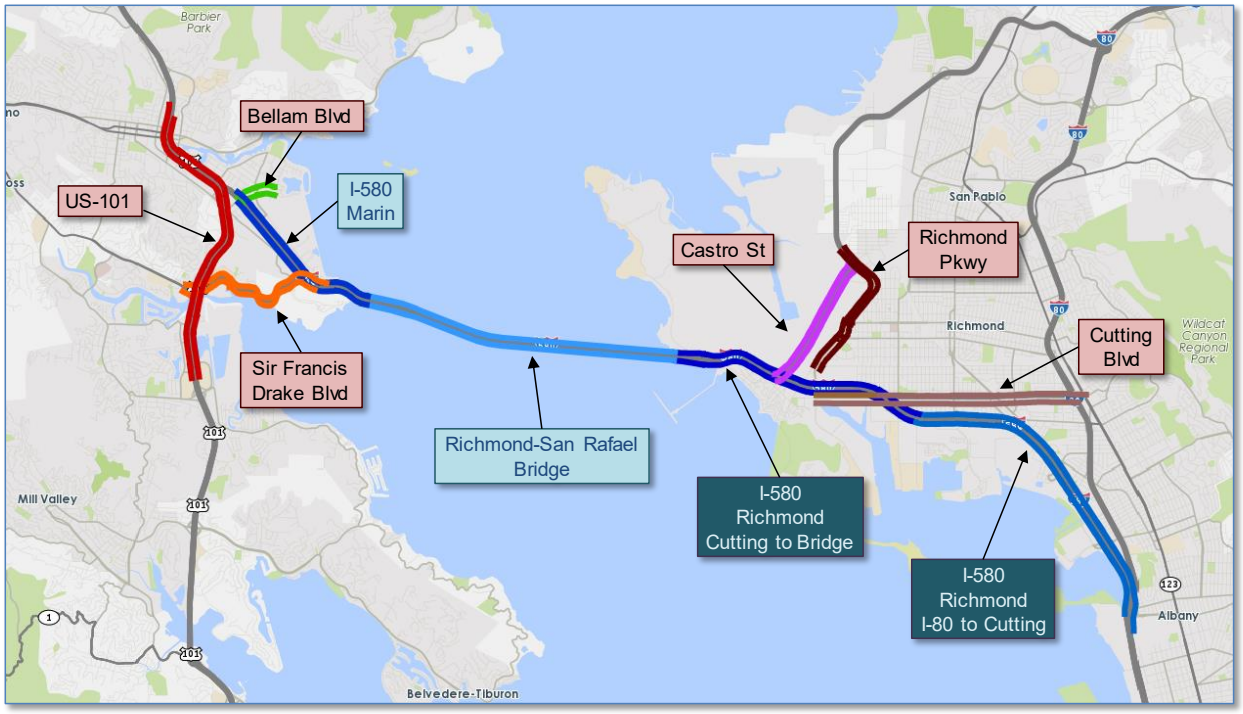


Figure 6-16: Additional Inrix Study Segments and relationship to Richmond-San Rafael Bridge

6.4.1. RICHMOND LOCAL STREETS

In Richmond, the three local streets analyzed with Inrix were Castro Street, Cutting Boulevard, and the Richmond Parkway. Figures 6-17 through 6-19 show the speed profiles for both directions of each street. The color legend is shown at the bottom of each diagram, with green used to represent speeds above 40 mph, yellow for speeds in the 30-mph range, orange for speeds in the 20-mph range, and red speeds below 20 mph. It should also be noted that the speed are average travel speeds across a defined segment, not point speeds as provided by traditional loop detectors. The estimated speeds thus also include delays caused by the operation of traffic signals.

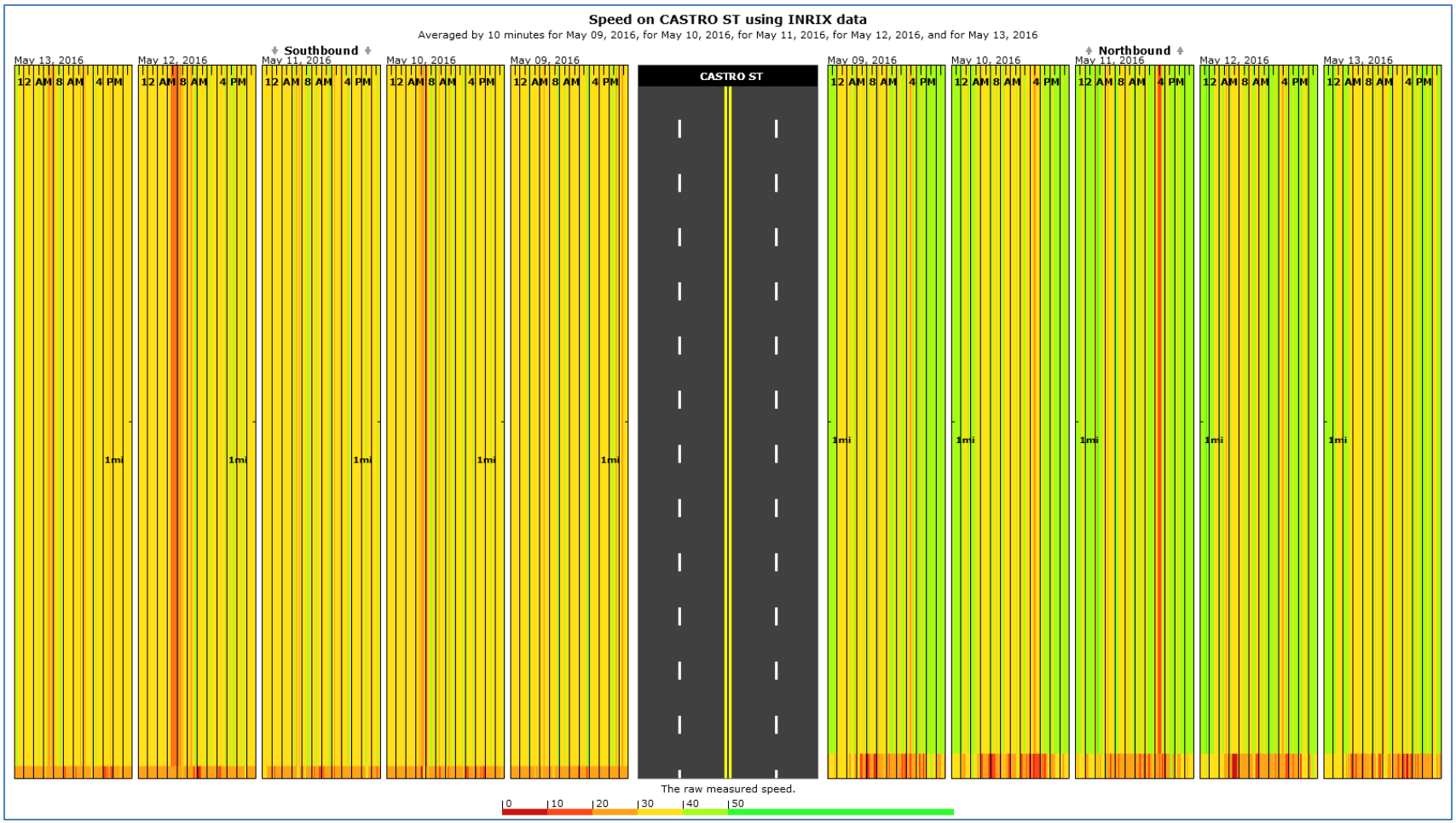


Figure 6-17: Speeds on Castro Street, Richmond

Note: Connection to I-580 & Approach to the Richmond-San Rafael Bridge is at the bottom of the figure.

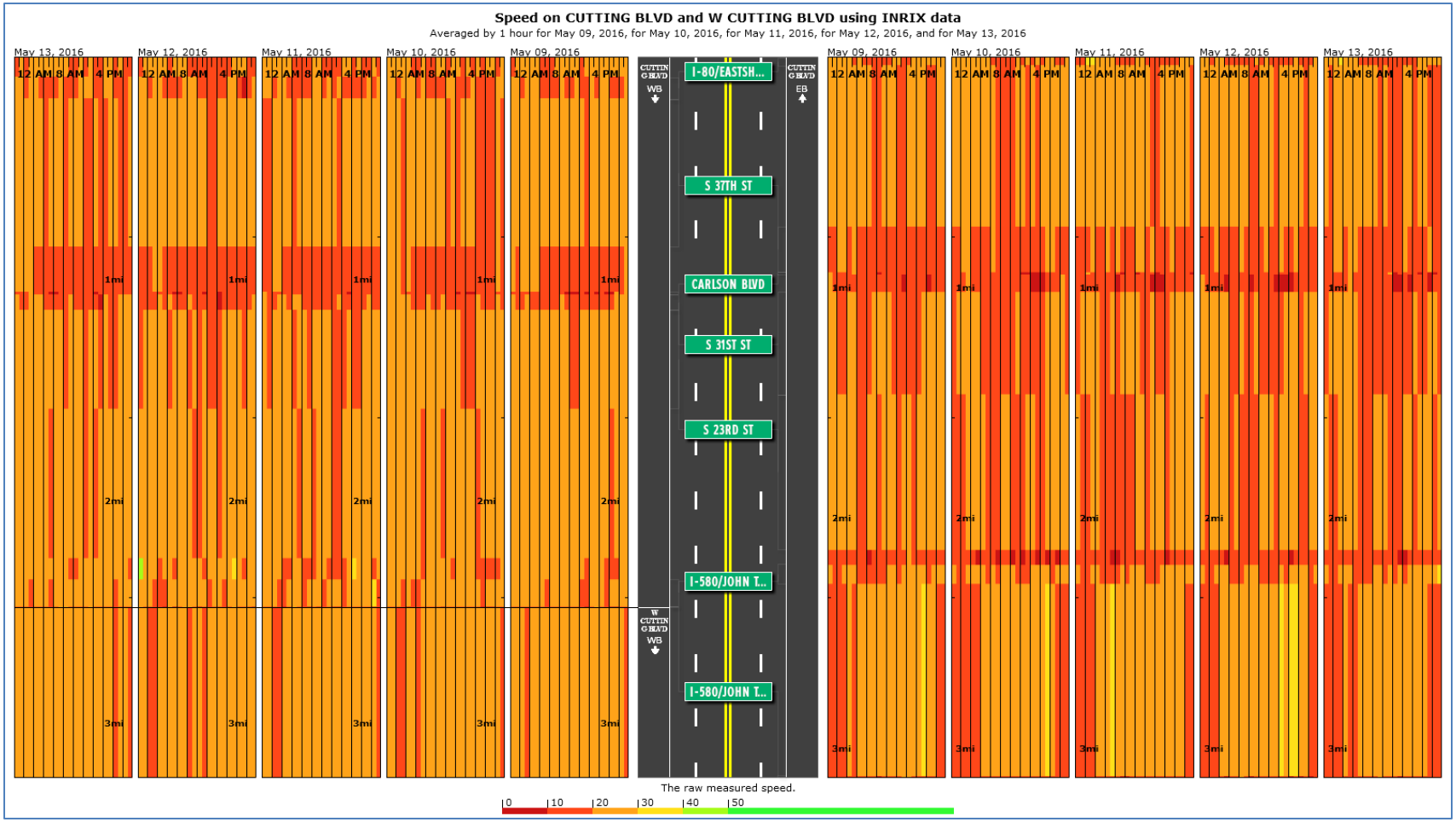


Figure 6-18: Speeds on Cutting Boulevard

Note: Connection to I-580 & Approach to the Richmond-San Rafael Bridge is in the middle of the figure

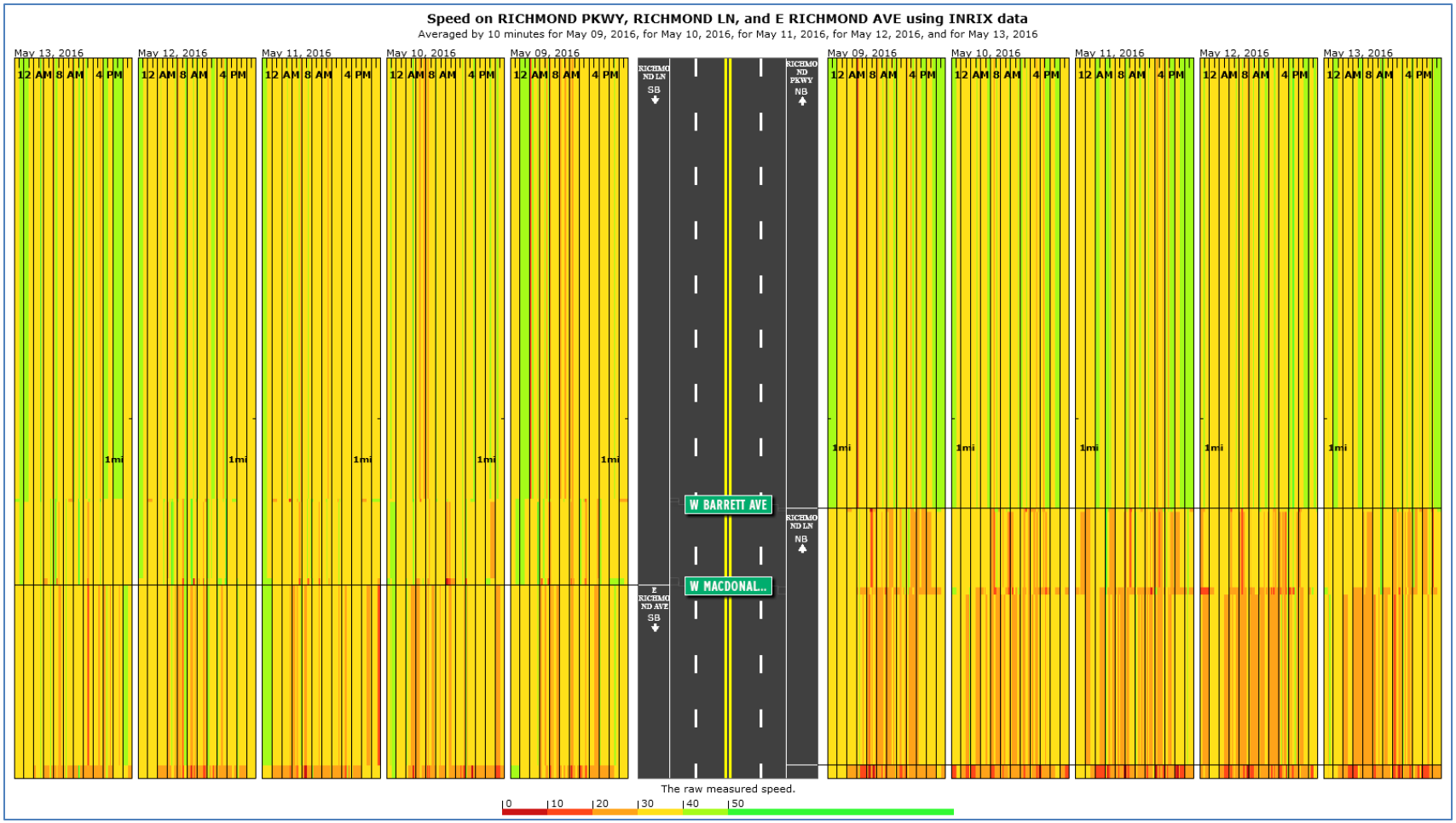


Figure 6-19: Speeds on Richmond Parkway, Richmond

Note: Connection to I-580 & Approach to the Richmond-San Rafael Bridge is at the bottom of the figure

As shown in the figures, speeds on Castro Street and Richmond Parkway are generally fairly close to free-flow speed except at approaches to I-580 and the bridge (the bottom of the figures). However, Cutting Boulevard, a major arterial of Richmond, is busy throughout the day, particularly near the intersection with Carlson Boulevard, corresponding to a multi-phase signal. Speeds on Cutting Boulevard near the I-580 interchange, approximately 2/3 of way down from the top, do not differ from the rest of the street.

6.4.2. MARIN LOCAL STREETS & US 101

In Marin County, the two local streets analyzed with Inrix were Bellam Boulevard and Sir Francis Drake Boulevard. In addition, an Inrix analysis of US 101 within San Rafael near the I-580 interchange was performed. Figures 6-20 through 6-22 show these speed profiles for both directions of each segment. Slower speeds are shown in dark red.

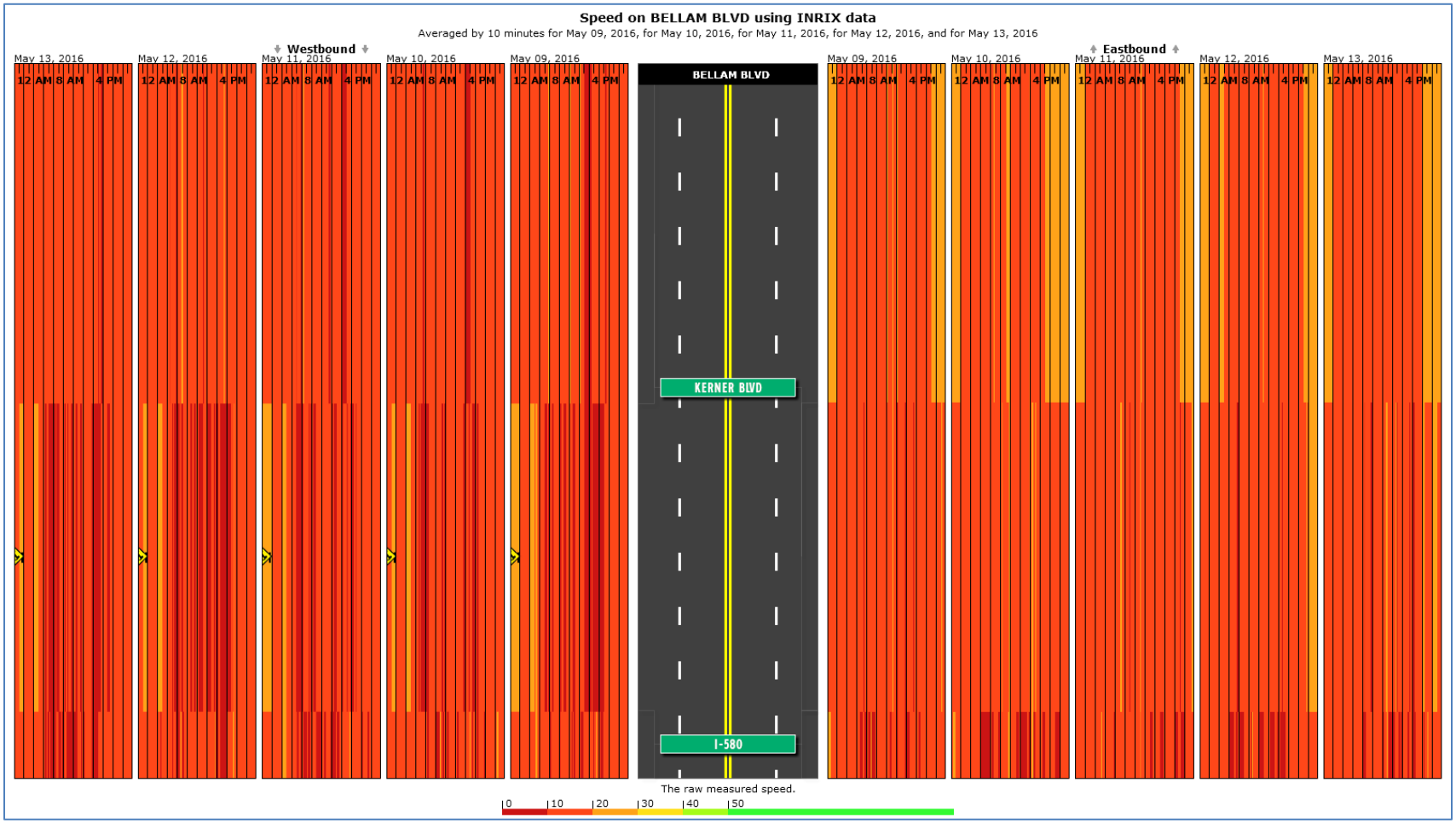


Figure 6-20: Speeds on Bellam Boulevard, San Rafael

Note: Connection to I-580 & Approach to the Richmond-San Rafael Bridge is at the bottom of the figure

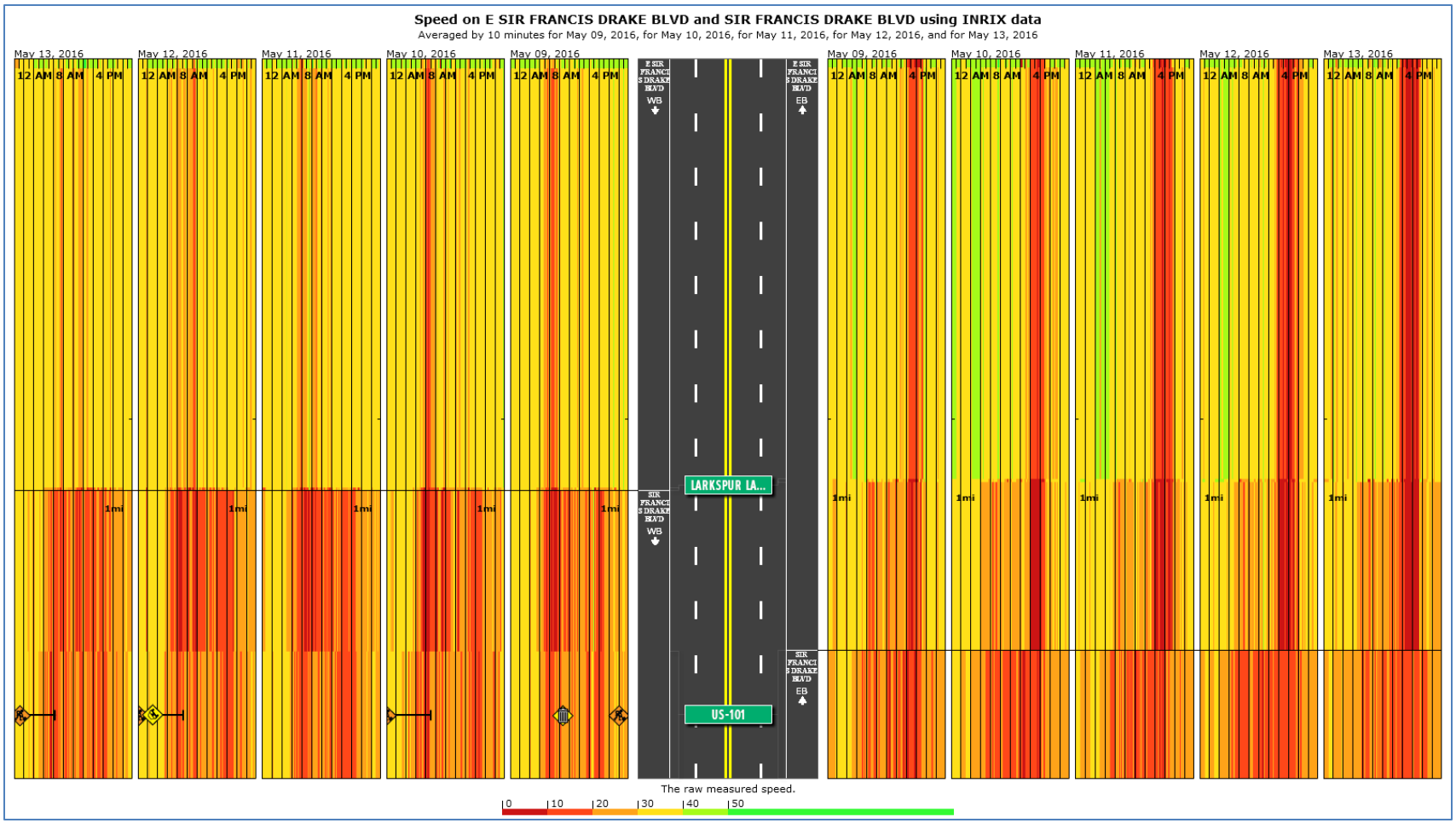


Figure 6-21: Speeds on Sir Francis Drake Boulevard, Larkspur

Note: Connection to I-580 & Approach to the Richmond-San Rafael Bridge is at the top of the figure

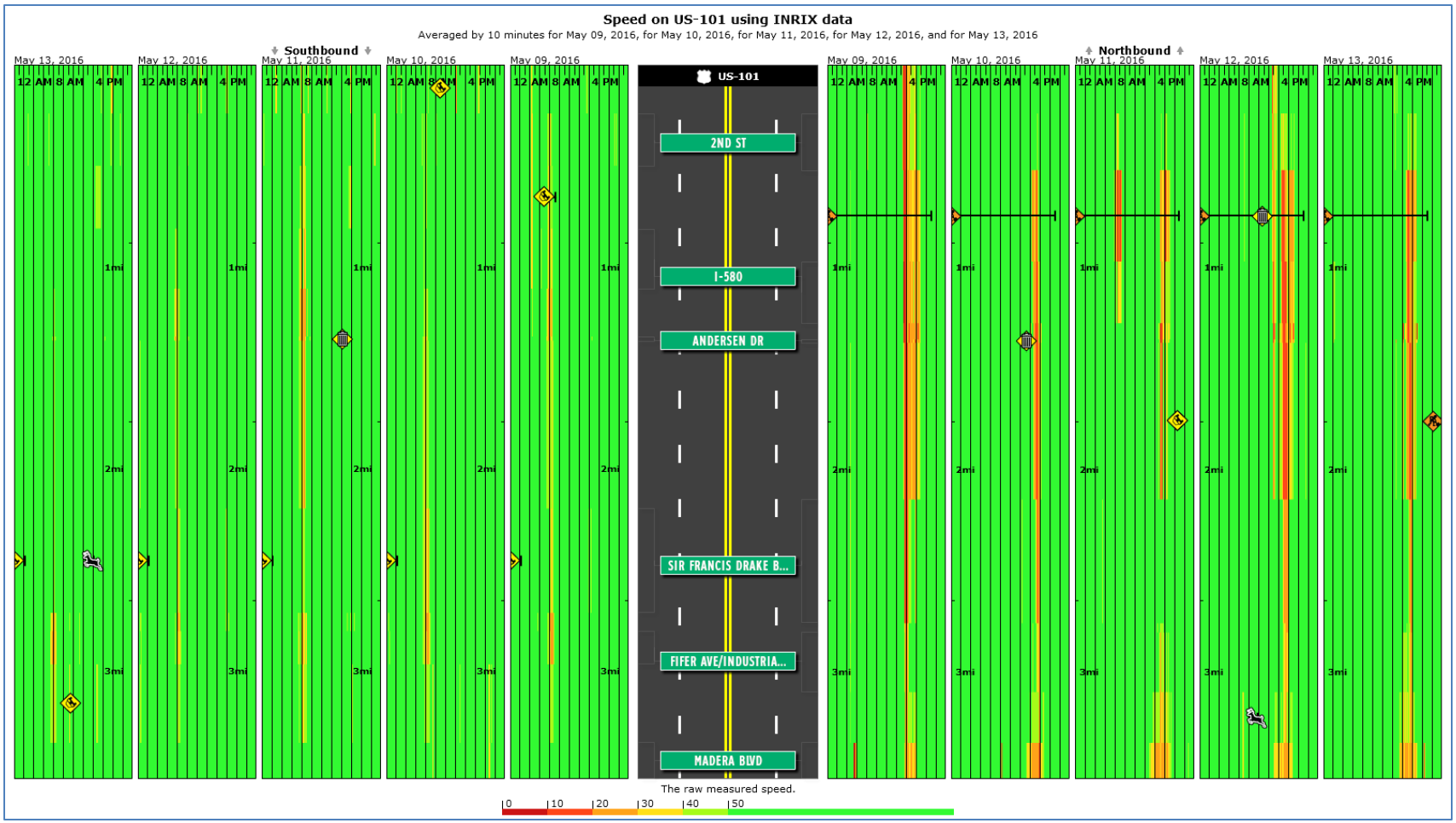


Figure 6-22: Speeds on US 101, San Rafael

Note: Connection to I-580 & Approach to the Richmond-San Rafael Bridge is in the middle of the figure

The Inrix profiles show different traffic states for all three study segments on the Marin County side. For Bellam Boulevard, similar to Cutting Boulevard in Richmond, speeds are fairly slow as there are multiple traffic signals on the segment, notably an intersection with Kerner Boulevard, and a large traffic generator, the Mi Pueblo supermarket. On Sir Francis Drake Boulevard, the queue spillover from I-580 can be seen on the right side of the figure. Every afternoon, the entire length of the segment has very low speeds. Lastly, although US 101 appears largely clear, the queue spillover from I-580 onto northbound 101 can again be seen the red stripes showing during the afternoon.

7. INCIDENT CLEARANCE TIMES

Caltrans District 4 has provided the research team with incident response data from two periods, January 2015 and January 2016 through June 2016. There were over 850 responses in total for both emergency and non-emergency incidents. As stated in the introduction, a comparison of times to clear before and after the physical modifications on the bridge is a crucial metric for determining the success of the project. Longer times to clear may create more delays and queues, undercutting potential benefits of the modifications themselves. These incidents occurred between the toll plaza to the east and the exit with Sir Francis Drake Boulevard in Marin County on the west side (see Figures 3-2 and 3-3).

7.1. EMERGENCY CLEARANCE TIMES

7.1.1. SUMMARY OF CLEARANCE TIMES

Table 7-1 summarizes the data with incident type, number of incidents and time to clear. This last descriptive item is the time between when the call is made and when the 1097 code “all clear” is sent out by the responder. Note, this does not necessarily mean all of the vehicles involved have left the scene but instead indicates the emergency responders are no longer needed.

Table 7-1 : Summary of Incident Response

Incident Type	Number of Incidents	Average Time to Clear (minutes)
Breakdown / Tow	168	18.8
Flat tire	120	14.9
Ran out of fuel	106	9.8
Crash	79	17.4
Auto check	75	8.6
Follow off	25	14.4
Push off	19	13.2
Minor repair	3	22.3
Overweight vehicle	2	20.0
Jump start	1	18.0
Check crash	1	15.0
Fire	1	9.0
Total	592	

7.1.2. FURTHER EXAMINATION OF THE TOP FOUR EMERGENCY INCIDENTS

Looking closer at the four most prevalent emergency incidents, namely breakdowns, flat tires, ran out of fuel, and crashes, researchers conducted a small statistical analysis and created modified cumulative distribution functions for each incident. Table 7-2 has more information about the average, standard deviation, and maximum for each of the four most prevalent incidents. The standard deviation implies that slightly less than 70% of all incidents will take the average plus or minus the standard deviation to clear. Generically, a standard deviation smaller than the average can indicate a fairly narrow set of data points.

Table 7-2: Additional Statistics for Four Incident Types

Incident Type	Number of Incidents	Average Time to Clear (minutes)	Standard Deviation (+/-)	Maximum Time to Clear (minutes)
Breakdown / Tow	168	18.8	13.2	73
Flat tire	120	14.9	11.8	82
Ran out of fuel	106	9.8	7.1	41
Crash	79	17.4	18.1	82

Figure 7-1 shows the modified cumulative distribution functions (CDF) for each of the four types in incidents listed in Table 7-2. The figure displays the cumulative percentage of incidents that require a certain time to clear as a proxy for the reliability of response. If the response is uniformly very fast, one would expect the percentage of incidents cleared in less than 10 or 15 minutes to be very high.

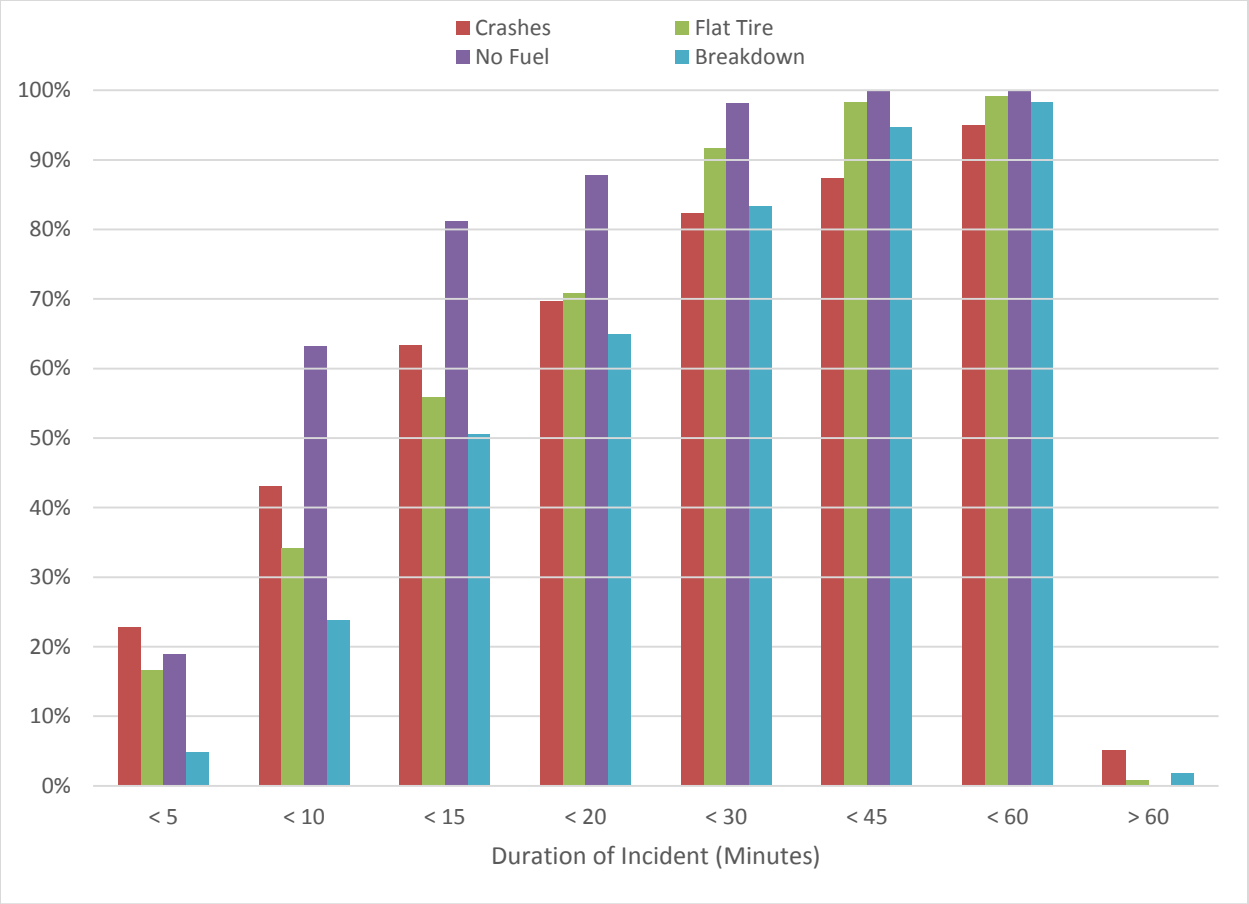


Figure 7-1: Cumulative Distribution of Emergency Responses

Examining the figure, the data agrees with a typical assumption regarding incident response, namely that refilling gas is the most simple response. Over 80% of responses for vehicles simply running out of fuel were completed within 15 minutes with none over one hour. Flat tires were also cleared fairly reliably with 90% under 30 minutes. The added complexities associated with crashes and incidents requiring a tow create a slightly lower standard of reliability. As can be observed in Figure 7-1, 30% of crashes and 35% of tow responses took over 20 minutes to clear. As expected, crashes had the largest share of responses over one hour with 5%.

Overall, responses on the bridge are fairly reliable as long responses were very unusual during the study period. Only responses to four crashes, three breakdowns/tows, and one flat tire exceeded one hour to clear. This represents a very small percentage of the overall number of responses (0.9%) for incidents occurring on the bridge and an indication that severe incidents are rare occurrences on the bridge itself.

7.2. NON-EMERGENCY INCIDENTS

Out of the 863 incident responses in total, 262 were non-emergency and were requests for Caltrans maintenance. These were sorted into two categories, general maintenance and removal of debris on the roadway. Table 7-3 shows summary statistics for these two categories followed by the CDF diagrams.

Table 7-3: Summary Statistics for Non-Emergency Responses

Incident Type	Number of Incidents	Average Time to Clear (minutes)	Standard Deviation (+/-)	Maximum Time to Clear (minutes)
Maintenance	138	13.2	17.1	114
Debris	124	8.3	13.0	100

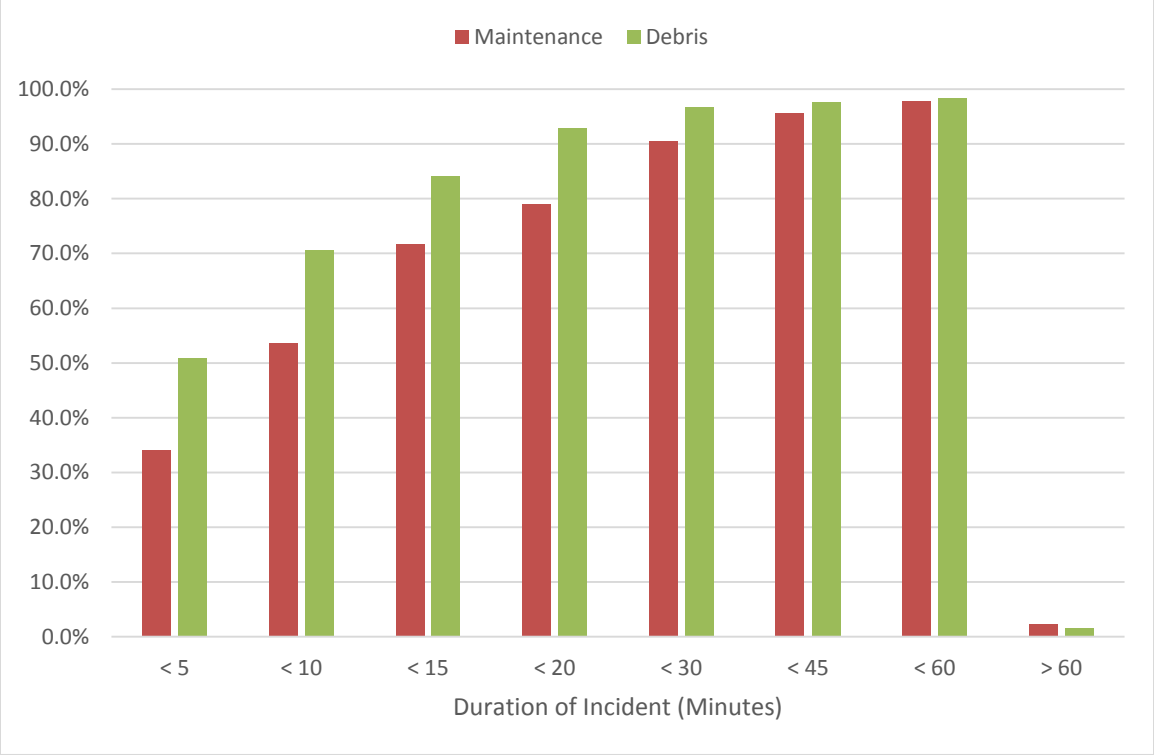


Figure 7-2: Cumulative Distribution of Non-Emergency Responses

As the table and figure shows while also comparing incidents responses from Figure 7-1, these two categories had the highest maximum clearance times of any category (114 and 100 minutes respectively), however the response was still fairly reliable. 75% of maintenance calls and 85% of debris in the roadway notifications were cleared within 15 minutes of the call.

7.2.1. INFORMATION NOT OBTAINED

Although the research team received bulk data regarding the overall response times for the bridge proper, the team did not receive response information for individual stakeholders such as ambulance, fire and tow.

8. RATE AND SEVERITY OF EMERGENCY INCIDENTS

To establish a baseline on the quantity and severity of incidents in and around the Richmond-San Rafael Bridge, the research team acquired CHP CAD data for I-580 within the study period (July 2015 to June 2016). Additional data from local jurisdictions were also obtained. As the team expects changes from the access improvements to affect incidents primarily on the bridge itself, in addition to summary information for the bridge and all approach segments, detailed information from the specific bridge segment will be presented within the body of the report. Detailed information about additional sections and segments will be shown in the appendix.

8.1. INCIDENTS ON I-580

8.1.1. CLASSIFICATIONS

For crashes that occurred on I-580, the team divided the freeway into the four following sections shown in Figure 8-1.

- **Marin County** – US 101 to the bridge
- **The bridge proper**
- **Richmond Section 1** - Toll Plaza to the Cutting Boulevard Interchange
- **Richmond Section 2** – Cutting Boulevard Interchange to I-80

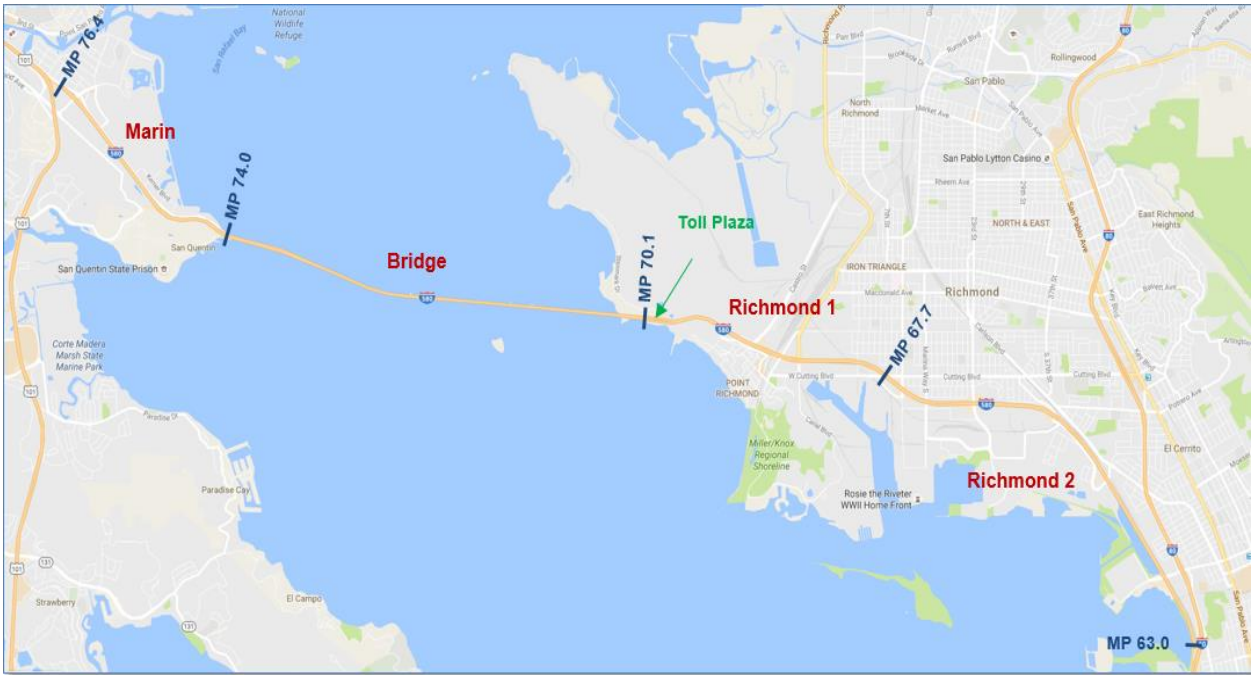


Figure 8-1: Summary of Study Segments

For each section, the team further categorized the data based on the location where the incident occurred, when it occurred and the type of incident.

For each segment, CHP CAD data was divided in the four following specific locations:

- Mainline
- On-Ramps
- Off-Ramps
- Toll Plaza (for the Richmond 1 Segment only)

Incidents at each locations were further divided into the following three time periods:

- AM Peak (6:00-10:00 AM)
- PM Peak (2:00-8:00 PM)
- All Day

The data was finally categorized based on 21 different types of incidents, ranging from animal on the roadway to severe crashes or a wrong-way driver. Ten of these types were CHP official codes, with the additional 11 being Caltrans denotations. These incident types are shown in Table 8-1. Note not all incident codes had specific incidents in our study area.

Table 8-1: Incident Codes, CHP and Caltrans

CHP Codes	Additional Caltrans Codes
1125 – Traffic Hazard	CFIRE – Car Fire
1125A – Animal Hazard	FIRE – Fire at incident site
1166 – Defective Traffic Signal	ANIMAL – Live or dead animal
1179 – Traffic Collision, Ambulance Required*	BREAK – Traffic Break Required
1181 – Traffic Collision, Minor Injury	CLOSURE – Road Closure
1182 – Traffic Collision, No Injury	CZP – Assist with Work Zone
1183 – Traffic Collision, Injury Unknown	DOT – Caltrans Request
1184 – Traffic Control Required	FLOOD – Roadway Flooding
20001 – Hit and Run, Injuries	TAVD – Traffic Advisory
20002 – Hit and Run, No Injuries	WIND – Wind Advisory
	WW – Wrong Way Driver

*Note: The data did not include information on code 1144, which is a confirmed fatality, for legal reasons. 1144's were included in 1179.

8.1.2. SUMMARY INFORMATION

Figures 8-1 through 8-3 show the total number of incidents during the study period and the total number of crashes only during both the AM and PM peak periods for I-580, eastbound and westbound. Table 8-2 further reports the total number of incidents by location.

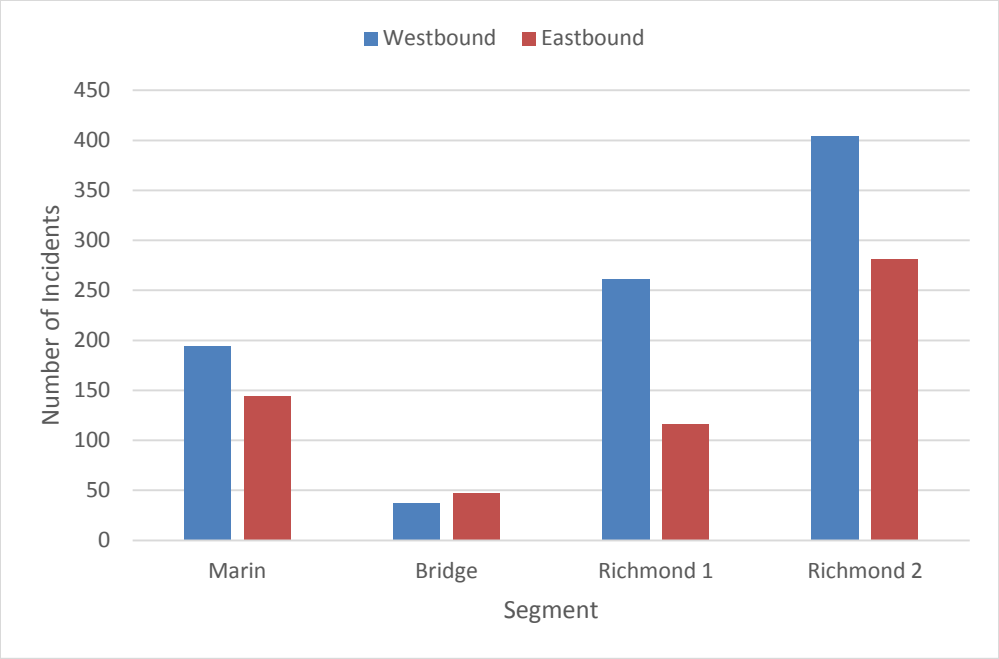


Figure 8-2: Total I-580 Incidents per Freeway Segment, All Day

Table 8-2: Total Incidents by Location

Segments		Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Eastbound	Marin	8	94	42	0	0	*144*
	Bridge	47	0	0	0	0	*47*
	Richmond 1	8	66	23	25	0	*116*
	Richmond 2	43	152	86	0	0	*281*
	Total	100	312	151	25	0	*588*
Westbound	Marin	6	112	30	0	46	*194*
	Bridge	37	0	0	0	0	*37*
	Richmond 1	4	69	35	153	0	*261*
	Richmond 2	153	195	56	0	0	*404*
	Total	200	376	121	153	46	*896*

As shown in Figure 8-1 and Table 8-2, there were approximately 300 more incidents in the westbound direction than eastbound during the study period, with 125 out of those 300 specifically occurring at the toll plaza and an additional 46 at the ramps onto US 101. The bridge itself had the fewest number of incidents; the Richmond 2 segment, located closest to I-80 at the eastern end of the study area, had the highest number of incidents at approximately 45% of the overall number. Many of these incidents occurred on on-ramps.

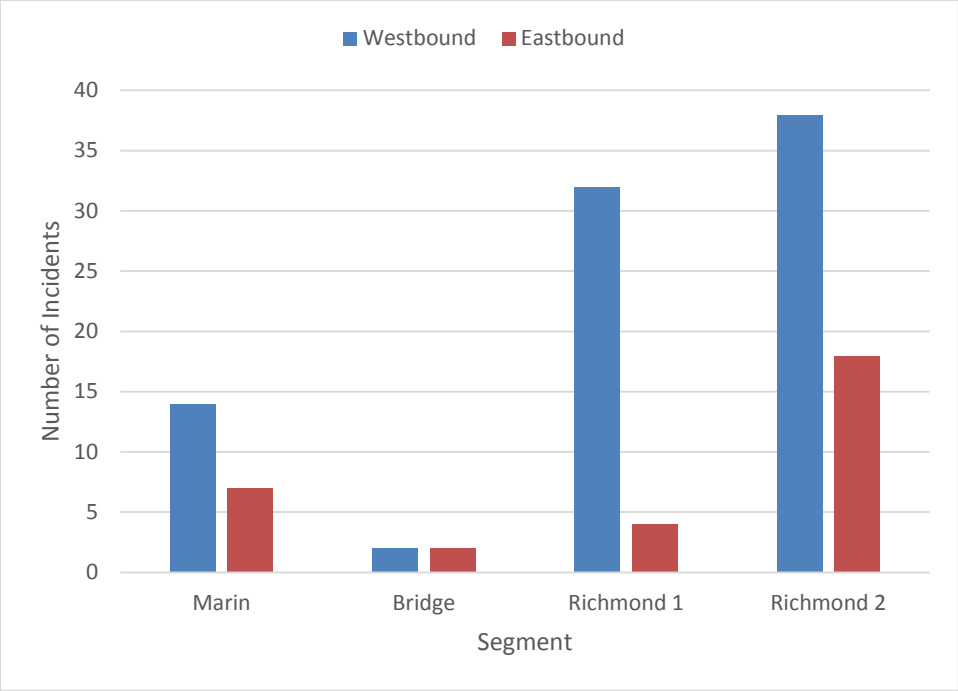


Figure 8-3: Crashes Only, AM Peak (6:00-10:00)

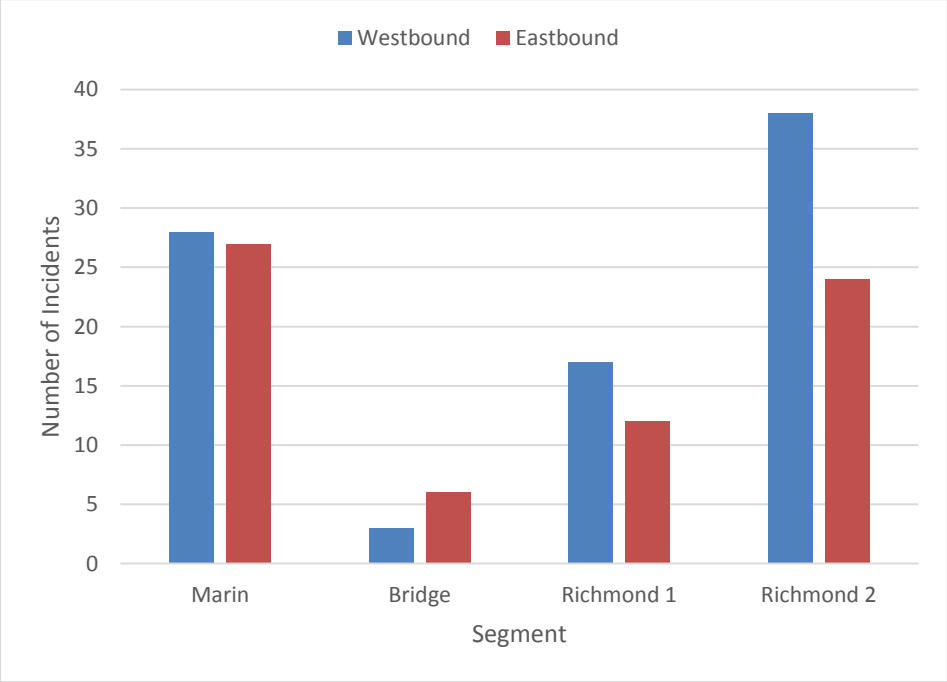


Figure 8-4: Crashes Only, PM Peak (2:00-8:00)

Figures 8-3 and 8-4 confirm that not only are the total incidents higher in the westbound direction but the number of crashes is higher as well. During the AM Peak there is a significant difference between the eastbound and westbound directions; this discrepancy is not as acute during the PM peak period. On the two segments in Richmond, the number of crashes is higher

in westbound direction during both peak periods, likely linked to the queues generated by the toll station.

8.1.3. INCIDENTS ON THE BRIDGE PROPER

The bridge itself had a relatively small number of crashes compared to other segment, in no small part due to the limited access on the bridge structure (i.e. no ramps). Table 8-2 shows the quantity, type, and average duration in minutes of incidents on the Richmond-San Rafael Bridge proper. As the bridge has no ramps, all the recorded incidents are categorized as "mainline" incidents. Incidents on other segments are located in Appendix B. Note that the totals do include off-peak incidents but do not include incident categories that had zero incidents.

Table 8-3: Classification of Incidents on the Richmond-San Rafael Bridge

Type	I-580 E						I-580 W					
	AM Peak		PM Peak		Total		AM Peak		PM Peak		Total	
	#	Min	#	Min	#	Min	#	Min	#	Min	#	Min
1125 Hazard	3	21.3	7	26.8	*23*	*29.3*	5	4.0	8	24.0	*24*	*12.4*
1125A Animal	1	9.0			*3*	*23.7*					-	-
1179 Crash					*1*	*120*					-	-
1181 Crash	1	15.0			*1*	*15*					-	-
1182 Crash			2	33.5	*5*	*36.8*	1	13.0	1	7.0	*5*	*12.6*
1183 Crash	1	22.0	3	30.0	*4*	*28*	1	46.0	2	36.0	*4*	*40.5*
20002 H&R			1	70.0	*2*	*64*					*1*	*7.0*
CFIRE Cars Only					-	-	1	74.0			*2*	*87.5*
CZP Work Zone	1	1.0	1	478.0	*6*	*343*						-
FIRE Other					-	-			1	77.0	*1*	*77.0*
TAVD Advisory			1	3.0	*1*	*3.0*					-	-
WW Wrong Way					*1*	*8.0*					-	-
Quantity Totals	7		15		*47*		8		12		*37*	

As shown in the table, the incidents that took the most time to clear were fires, injury crashes, and work zone closures. A majority of the incidents (55%) were listed as "traffic hazards" which is a general definition that includes debris on the roadway, a breakdown, flat tire, or a suicide attempt. Another conclusion from this chart is that serious crashes are fairly rare on the bridge itself. Within the study period there was only one "1179" crash, the most severe, plus 22 additional crashes including the minor ones, and three fires. Not surprisingly, eastbound had a higher number of incidents during the PM peak when eastbound in the primary direction.

8.2. CRASHES ON LOCAL STREETS (MARIN)

There are a number of local streets on the Marin side of the bridge that experience significant daily congestion as a result of the bottleneck merge at the bridge approach. Data on crashes was provided to the research team by the San Rafael Police Department and Larkspur Fire Department highlighting the local responses on study area streets. Again, the study period was from July 2015 to June 2016. Table 8-4 shows the crash responses for Andersen Drive, Bellam Boulevard, E. Francisco Boulevard, and Kerner Boulevard. Again, categories with zero incidents were not shown.

Table 8-4: Crashes on San Rafael Local Streets

	Andersen	Bellam	Francisco	Kerner	Totals
1179 – Injury w/ Ambulance	5	4	1	2	12 (5.3%)
1180 – Major Injury Accident	-	1	-	-	1 (0.4%)
1181 – Minor Injury Accident	4	4	2	5	15 (6.7%)
1182 – PDO Accident	23	47	13	45	128 (56.4%)
1183 – Accident Unknown Injury	4	9	10	-	23 (10.1%)
20001 – H&R Injury	2	-	-	1	3 (1.3%)
20002 – H&R No Injury	11	13	6	15	45 (19.8%)
AM Peak (6:00-10:00)	12	5	5	5	27 (11.9%)
PM Peak (2:00-8:00)	22	42	17	37	118 (52.0%)
Total	49	78	32	68	227

Table 8-4 reveals expected conclusions: 76% of the crashes were property damage only (codes 1182 + 20002), severe injuries are fairly rare due to low speeds, and more than half (52%) occurred during the PM Peak period.

9. BICYCLES AND PEDESTRIANS

As the current plan for the improvements to the Richmond-San Rafael Bridge includes a fully separated multi-use path for bicycles and pedestrians, it is important to survey the existing infrastructure for those two modes. Currently, non-motorized vehicles, including bicycles, are not allowed on the Richmond-San Rafael Bridge at any time of the day.

The following subsections review the following elements:

- The existing bicycle network
- Use of transit buses to carry bicycles across the bridge
- Pedestrians

9.1. EXISTING BICYCLE NETWORK

The following two figures show the current state of accommodations on both sides of the Richmond-San Rafael Bridge. There are three different classes of bicycle routes represented in each figure. Class I, shown in red in Figure 9-1 and magenta in 9-2 are off-street completely grade separated multi-use paths. Class II paths, solid green in Figure 9-1 and red in Figure 9-2 are primary streets with bicycle lanes or other markings such as sharrows. Finally, Class III, dashed green in Figure 9-1 and not shown in Figure 9-2, indicates a secondary route with rudimentary bicycle accommodation.

As shown in the two figures there are no existing bicycle paths that currently connect to the ends of the bridge at this time. On the Marin side, the closest off-street multi-use path, shown in solid red, is the path that allows bicycles and pedestrians to access the Larkspur ferry stop along Sir Francis Drake Boulevard. This path continues along the coastline to Remillard Park. Beyond

that point, Sir Francis Drake is marked as a "primary" route, indicating that there are painted markings in the road for bicycle use. Similar markings are located on Andersen Drive. In Richmond, there are no facilities near the bridge itself. The dashed green lines, including the ambitious one already marked on the bridge, indicates the position of the "Future Bay Trail." Existing multi-use paths and roadway markings, marked in purple and red, run along the Richmond Parkway. However, between that facility and the bridge is a significant gap of almost one mile.

Currently, the Transportation Agency of Marin (TAM) is actively working on a project that will change some of the infrastructure on Sir Francis Drake Boulevard, but there are no immediate plans to create an off-street multi-use path all the way from the ferry terminal in Larkspur to the bridge itself. This project is known as the "East Sir Francis Drake Traffic Improvements Project" and includes additional lane capacity for vehicles getting on to US 101, extending the third lane beyond the ferry terminal, signal timing optimization, and widening the shoulder to accommodate bicycles where the lane is extended. The off street bicycle path would still end at Remillard Park far short of the Richmond-San Rafael Bridge.

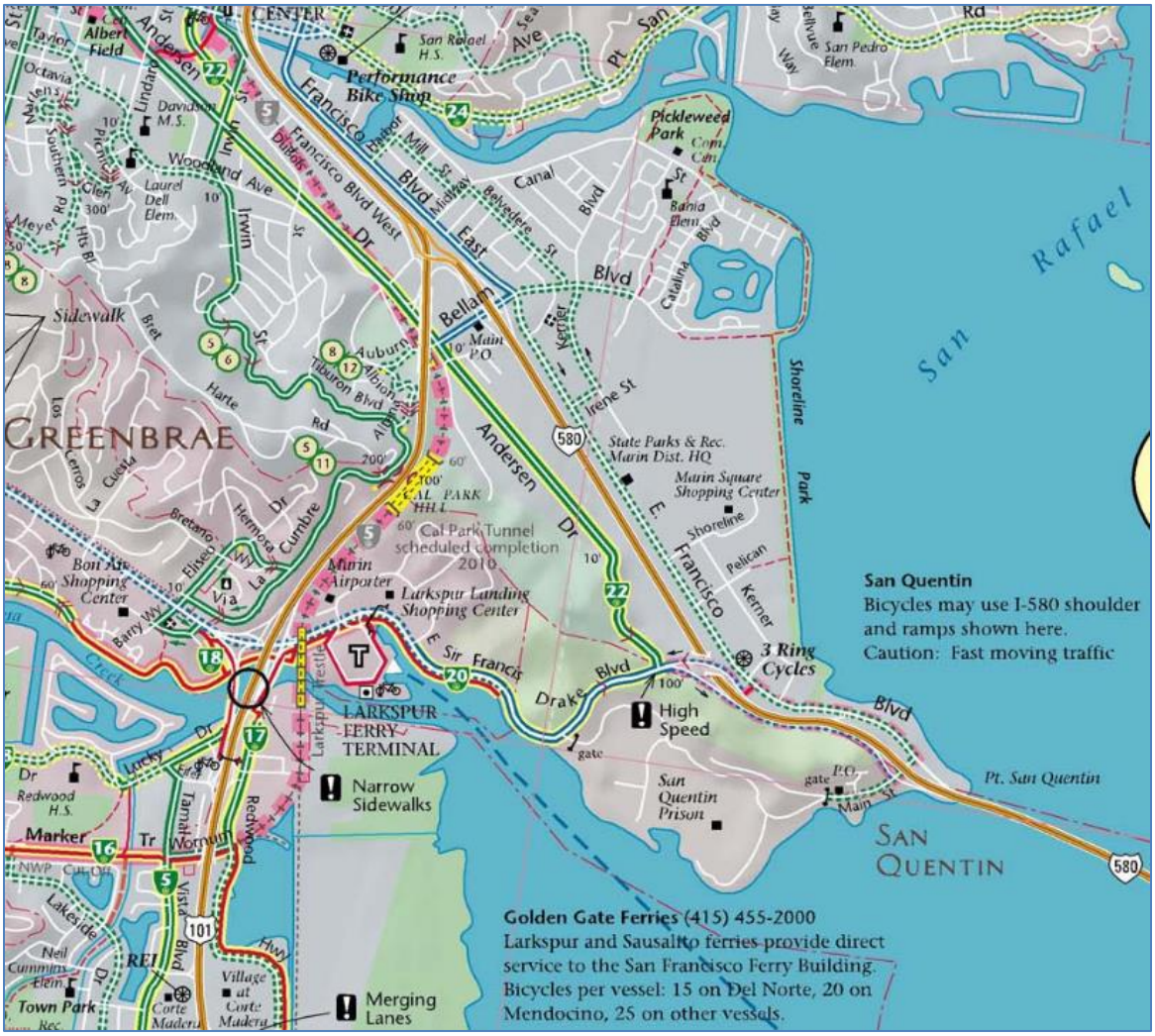


Figure 9-1: Existing Bicycle Infrastructure (Marin)

Map Courtesy of *Walk Bike Marin*

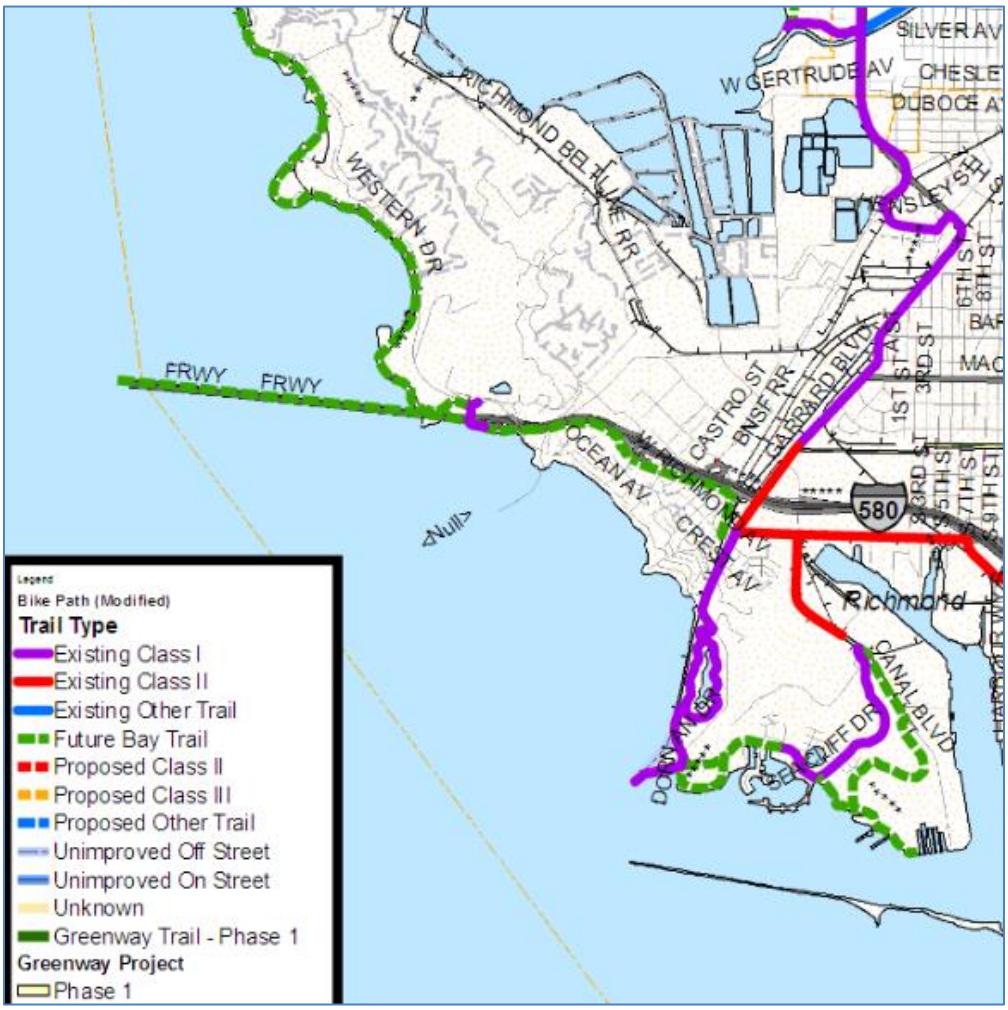


Figure 9-2: Existing Bicycle Infrastructure (Richmond)
Map Courtesy of the *Richmond Bicycle / Pedestrian Coalition – Bike East Bay*

9.2. BICYCLE ON TRANSIT BUSES

Golden Gate Transit (GGT), a local bus transit provider, has bike racks mounted on the front of their commuter buses enabling riders to use their bicycles to solve the first mile-last mile problem. One of their routes, #40, crosses the Richmond-San Rafael Bridge and originates at the transit center in San Rafael and terminates at the Del Norte BART station in El Cerrito, just to the east of Richmond. The route also utilizes two local streets analyzed in this report, Francisco Boulevard in San Rafael and Cutting Boulevard in Richmond. There are 24 buses per day, concentrated during the morning and evening commutes. Figures 10-3 and 10-4 shows maps from GGT showing Route 40 and a slight variant called 40X that skips some stops.

Figure 9-3: GGT Bus Routes in Marin County

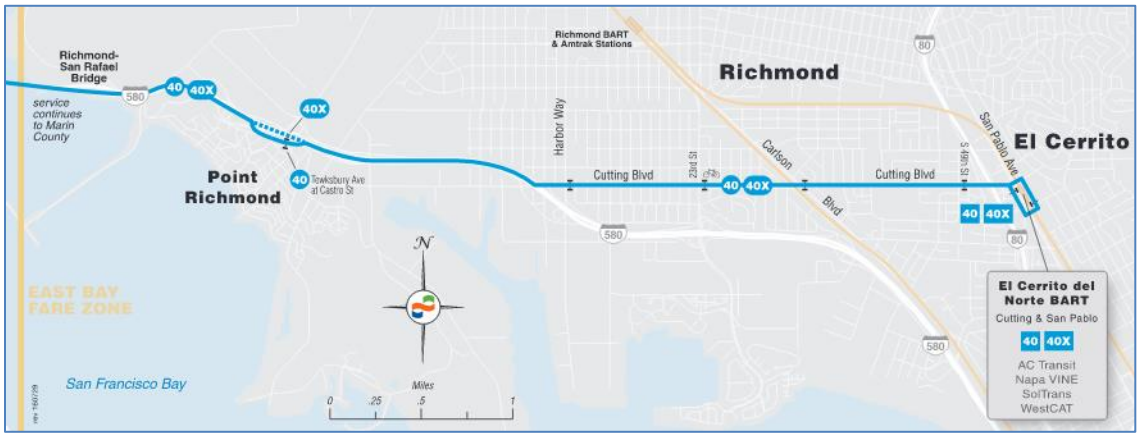


Figure 9-4: GGT Bus Routes in the East Bay

GGT provided the research team with bicycle counts that they took during the study period (Summer 2015 to Summer 2016). During that time period, GGT had pilot project of another route, called the 580, that also carried passengers across the bridge. Also, during that time, GGT was in the process of combining Routes 40 and 42. Figure 10-5 shows the bicycle volumes on the three routes (40, 42, and 580) during the study period. Figure 10-6 compares the overall summer 2015 numbers with 2016.

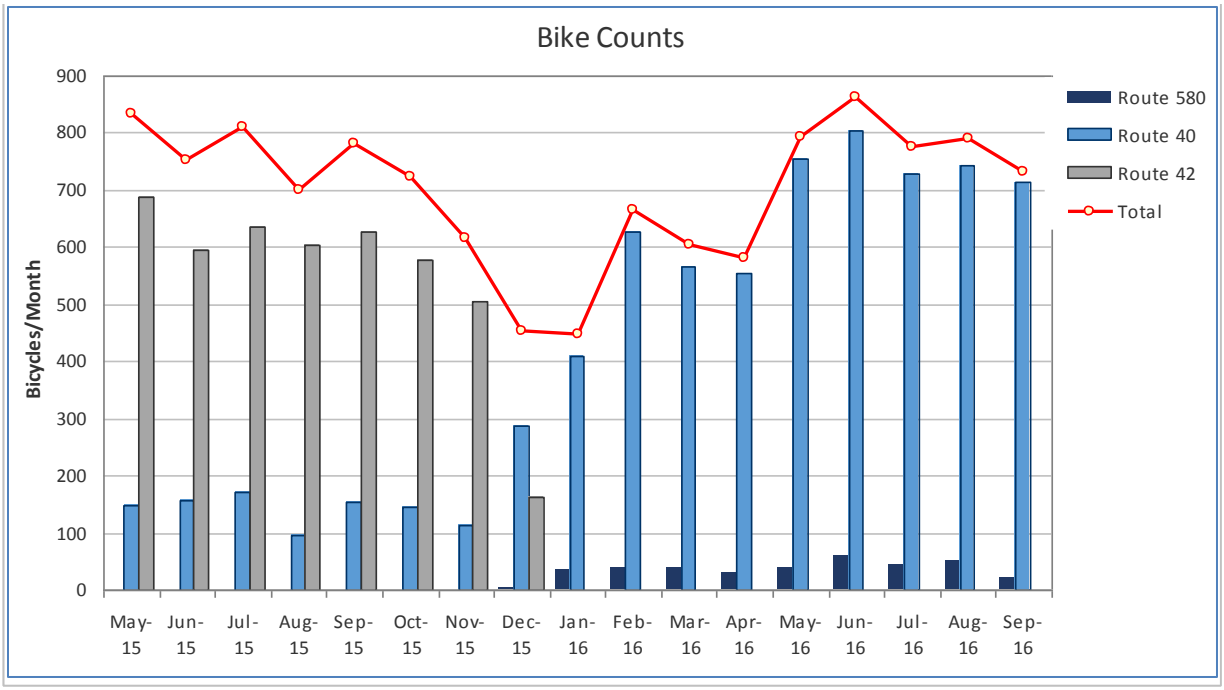


Figure 9-5: GGT Bicycle Counts by Route

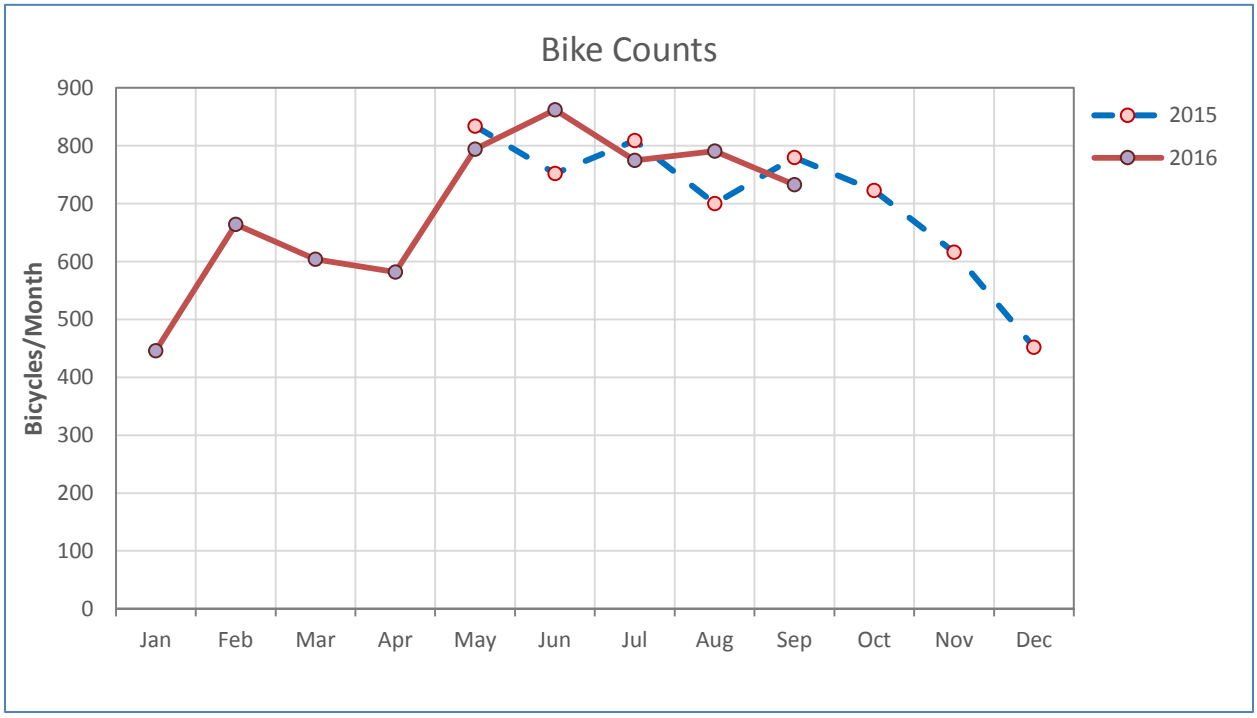


Figure 9-6: Comparison of 2015 to 2016

Bicycle counts per month ranged from in the 400's during the winter to as high as 850 in June 2016. Assuming 30 days for June, this averages to nearly 30 bicycles per day, or just over 0.5 bicycles per bus, taking into account that that there are likely fewer bicycles on the weekends.

9.3. NON-TRANSIT BICYCLE DEMAND

The research team addressed three additional small topics in regards to the usage of bicycles in and around the Richmond – San Rafael Bridge. They are as follows:

- Report on meetings with bicycle/pedestrian groups or surveys of bicycle/pedestrian groups
    - The research team plans to interview cyclists after the bicycle lane is installed, and will possibly meet with the Caltrans Bicycle and Pedestrian Advisory Committee at that time.
- Report on bicycle/pedestrian special events in the vicinity of the bridge
    - The research team found that there were no large bicycle events to monitor in the vicinity of the Richmond-San Rafael Bridge at present.
- Count the number of bikes at the CC end of the bridge (e.g. at Point Molate)
    - The research team and Caltrans decided against manual counts prior to construction and will address the bicycle volumes once the automatic counters are installed.

9.4. PEDESTRIANS

At this time, pedestrians are not allowed on the bridge at any hour. For the study after construction is complete, the research team will need to consider how to accurately count pedestrians using the bridge.

10. QUALITY OF LIFE

The research team assessed "Quality of Life" by conducting a series of interviews with businesses in Marin County. These businesses were located on local streets that are regularly used as alternate routes to the Richmond-San Rafael Bridge. As will be revealed in the stakeholder comments, local street congestion is of great concern to these businesses. In the "After Study," the quality of life impacts will be evaluated by visiting the same businesses (assuming they are all still viable) and determining if the project improved the quality of life for employees or customers of the businesses. The metric for measuring "quality of life" was largely confined to traffic congestion on local streets.

Sixteen businesses were visited in total on one of three days, April 21, 2016, August 3, 2016, or December 1, 2016. The date, the businesses visited, and the location are shown in Table 12-1 through 12-3.

Table 10-1: Businesses visited in April 2016

Date of Visit	Name of Business	Street Location
April 21, 2016	Target	Shoreline / E. Francisco
April 21, 2016	Home Depot	Shoreline / E. Francisco
April 21, 2016	FedEx	E. Francisco
April 21, 2016	Ace Printing	E. Francisco
April 21, 2016	Bay Café	E. Francisco

Table 10-2: Businesses visited in August 2016

Date of Visit	Name of Business	Street Location
August 3, 2016	Orchard Supply Hardware	Andersen
August 3, 2016	Smart and Final	Andersen
August 3, 2016	Westamerica Bank	E. Francisco
August 3, 2016	Marin Airporter	Andersen
August 3, 2016	United Parcel Service (UPS)	Kerner
August 3, 2016	US Postal Service	Bellam

Table 10-3: Businesses Visited in December 2016

Date of Visit	Name of Business	Street Location
December 1, 2016	Extended Stay America	E. Francisco
December 1, 2016	Marin Honda	Shoreline / E. Francisco
December 1, 2016	U-Haul	E. Francisco
December 1, 2016	PG&E Service	Andersen
December 1, 2016	Central Marin Sanitary District	Andersen

10.1. QUESTIONNAIRE

The following questions were asked of each business. Since some questions were repetitive or answered in another question every question will not necessarily have complete information in the answer tables.

a. How does traffic on I-580 and the surrounding roads affect your business and customer/employee access?
b. What days/times are the worst (i.e. weekdays, weekends, specific days, and/or specific times)?
c. Does freeway traffic back up or divert on to local roads surrounding your business?
d. What, if any, types of comments do you hear from employees or customers regarding traffic issues?
e. Do you know where employees live and which on-ramps they use?
f. Do you know of any employees that may bicycle to work once the improvements on the bridge are constructed?

10.2. RESULTS OF SURVEY

Results of the business surveys were as expected. A summary is show in the following bullet points:

- Most of the interviewees expressed that congestion during the afternoon commute period spills over to the local streets as commuters use alternative routes to the bridge. All of the major alternate routes appear to be affected, including Bellam, E. Francisco, Andersen, and Sir Francis Drake. The time intervals most cited were 3:00pm to 7:00pm or 4:00pm to 7:00pm.
- Interviewees expressed that they believe that their businesses are adversely affected this daily afternoon traffic congestion spillover.
- Due to housing costs in Marin County that are approaching or exceeding one million dollars, many employees of these businesses live in Richmond or on the Richmond side of the bridge and as far away as Vallejo or San Leandro. The decreasing reliability of the morning travel time (due to congestion at the toll plaza merge) has resulted in employees arriving at work late.
- In certain circumstances, it could be hard to exit the businesses themselves due to traffic congestion on local streets, particularly on E. Francisco Blvd or Andersen Avenue.
- Businesses that rely on trucks or delivery service (e.g. UPS) pad their schedules to accommodate the anticipated delays.
- Commute travel times in the afternoon/evening can be double those in the morning. Traffic has affected employee commute times.
- Only one business commented that their employees might use the new bicycle lane. Otherwise, consensus was that their employees wouldn't use it.

The raw interviews can be found in Appendix A.

11. PREPARING FOR FUTURE STUDIES

A final but important detail in the "before" study is to highlight key components for future work, both after the implementation of the proposed changes and after the selected time frame for the pilot is over. By being able to compare the before with future periods, key stakeholders will be able to assess whether the downstream consequences of the physical changes to the bridge (shoulder lane use for traffic eastbound and the addition of the multi-use path westbound) merit making these changes permanent.

Some of these key components to consider include the following items:

- Generically, monitor I-580 within the study area as well as other arterials noted previously such as Sir Francis Drake, Bellam Boulevard, and the Richmond Parkway. Try to stay in contact with Caltrans to hear about any serious concerns, possibly through quarterly meetings after the pilot begins.

- Compare travel times and volumes from the "before" study to data received a selected period after construction is complete, specifically trying to identify the influence of the physical changes
- Evaluate new equipment, e.g. cameras and electronic signs that are installed as part of the project.
- Monitor changes in incident duration, location, severity, time to clear, and queues that develop due to accidents, and accidents at the I-580 ramps using data at the midpoint of the pilot. Assess the effect of the physical changes on clearance times for major incidents.
- Engage with bike and walking groups in Marin and CC to assist with evaluation of data and preparation of the future studies. Specifically, the research team will need to get accurate bicycle and pedestrian count data for the multi-use path.
- Recommend additional business visits and/or info-gathering for the future studies.
- Utilize similar methodology in all three reports to ensure quality control.

12. SUMMARY AND RECOMMENDATIONS

This report has summarized the existing conditions and documented existing travel times, volumes, and incident responses as well as interviews with local businesses. When compared with conditions after the pilot project has commenced, it is the hope that sufficient data will be available to provide guidance to the stakeholders. As stated previously, it is the expectation that after the pilot physical modifications are finished there will be observable changes in delays and queues in relation to the additional capacity in the eastbound direction during the PM commute. Similarly, there are likely to the changes, possibly negative, in response time to incidents due to the removal of the shoulder lane. The researchers recommend using methodology similar to this report in order to provide a proper comparison between before during, and after the project.

The following is a summary of key findings from this report:

1. Traffic volumes:
    - Westbound I-580 volumes, as measured on the bridge to the west of the toll plaza, exceed 4,000 vehicles per hour from 6:30 AM to 9:00 AM.
    - Eastbound I-580 volumes, as measured on the bridge to the west of the toll plaza, exceed 3,600 vehicles from 3:00 PM to 7:00 PM.

2. Delays / travel times:
    - During the AM commute, westbound Travel Time Indices (TTI) range from 1.7 to 2.6, Planning Time Indices range from 3.4 to 6.2. This indicates that during the AM commute travel time typically double in length. Average speeds drop to approximately 25 mph.

- During the PM commute, Eastbound TTIs range from 2.9 to 4.4 with planning from 7.9 to 9.4. Travel times during this period can triple or quadruple in length. Average speeds drop to nearly 10mph.

3. Traffic condition on local streets:
    - Richmond: During the AM commute, delays are minor on the Richmond Parkway and Castro Street. Moderate delays sometimes occur on Cutting Boulevard in the vicinity of the I-580 interchange.
    - Marin: Heavy delays during the PM commute on Bellam Boulevard and Sir Francis Drake Boulevard as the road approaches I-580. Queues on I-580 eastbound sometimes back up to US 101 in San Rafael.

4. Incidents
    - There were more incidents westbound than eastbound, with many of these incidents occurring near the toll plaza.
    - The bridge itself was largely free of severe crashes, with only one severe crash occurring over the one year study period.
    - There were a number of minor crashes on local streets in Marin County, particularly during the afternoon peak.

5. Incident clearance times
    - Clearance times were relatively low, with all categories averaging under 20 minutes.
    - Although maximum clearance times did exceed 100 minutes for crashes and maintenance specifically, these situations appeared to be anomalous.

6. Bicycles:
    - There are no off-street grade separated multi-use paths to the bridge at either approach.
    - Bicycle counts on bus routes that cross the bridge ranged from 450 per month in the winter to as high as 850 in the summer.

7. Quality of life:
    - On the Marin side, businesses expressed concern over the spillover of traffic onto local streets during the PM commute. Managers noted that it affected the commutes of their employees and the ability of customers to reach their respective stores.

APPENDIX A: COMMENTS FROM BUSINESSES IN MARIN COUNTY

A summary of the comments received are in the following tables:

Business	***How does traffic on I-580 and the surrounding roads affect your business and/or customer/employee access?***	***What days/time are the worst (weekdays, weekends, specific days, and/or specific times)?***	***Does freeway traffic back up or divert on to local roads surrounding your business?***
Target	Employees are often late due to traffic. When an employee is late, customers are not being served as well, and if they can't find what they are looking for, the sale is lost. It can take anywhere from 20 minutes to 1 hour to get home from work (employee lives in Richmond). In the morning, he leaves before 6:30 am to avoid the traffic.	Weekday afternoons are the worst. The back-up can start as early as 2:30 until about 7 pm.	
Home Depot	Employees are late.	Mornings are bad. 60% of the time on weekdays; 40% weekends.	Traffic backs up onto Francisco.
FedEx Shipping Center	Freight trucks can run late due to traffic in and around the center.	Weekends going westbound on I-580 to get to the bridge. Mid-day Saturdays are busy.	
Bay Café	They close at 3 pm before most of the back-up occurs; so they are not as impacted. Not open on the weekends.		
Orchard Supply Hardware	A major accident on the bridge will affect employees. Traffic is bad eastbound in the afternoons. Traffic is bad eastbound in the afternoon; try to avoid 4 to 7 pm; also 7 to 9 am is bad. Employee schedules are somewhat flexible and he tries to schedule Easy Bay employees to miss traffic. Early shift starts at 5 am so traffic is not an issue at this time. The 7 am start time is more difficult re: traffic.	4 to 7 pm weekdays is the worst; 7 to 9 am is bad.	
Smart and Final	It definitely affects employees, but 60% of the customers are from the surrounding area, so they wouldn't be affected by the R-SR Bridge traffic.	The store is open from 6 am to 10 pm. Traffic is bad for the employees "a lot of the time." Eddie lives in Union City. It takes him about 30 to 45 to get to work in the morning, but it can take up to 2 hours to get home.	Accidents on and around Bellam can cause problems.

Westamerica Bank	Not a huge problem as they have a small number of employees and start time is 10 am. Not open on the weekends.	They can see the freeway from the bank; it is "crawling" any time after 3 pm.	They are on the north end of Francisco so it doesn't tend to back up in this section.
Marin Airporter	Employees are sometimes late due to traffic.	3 pm to 6:30 pm on weekdays is the worst traffic.	
UPS Customer Service and Delivery	It's not a big problem for their employees as most drivers are from the Marin side and don't use the bridge. The customer service center doesn't open until 11 am. It affects Kim (the manager) mostly in the afternoon when it can take 30 minutes longer to get home (she lives in Danville). She leaves between 4 and 6:30 pm. The trucks go out at 8:30 but deliver in Marin; they don't go across the bridge.	During a big accident on the bridge last weekend, the delays were so long that supervisors had to go and take over the shift for the drivers as they had reached their maximum work hours.	
US Postal Service	For the carriers that start at 7 am, a 30 minute "window" is built into their schedule for them to get to work to account for traffic fluctuations. The Postmaster said that the employees are "used to the traffic."	The Postmaster lives in Fairfield. She gets to work at 4 am (it takes 45 minutes and she does not use the bridge; she uses Highway 37). In the afternoon at 4:30 or 5 pm she uses the R-SR Bridge to get home and it takes 1.5 to 2 hours. At 7 pm it takes 1 to 1.25 hours to get home. One employee lives in Union City and it can take up to 3 hours to get home in the afternoon.	The traffic is bad on Bellam getting in and out of their facility.
Extended Stay America	She doesn't hear a lot of complaints from customers; but employees complain, especially in the afternoons. Employees say the traffic is bad coming over the R-SR Bridge.	Afternoons after 3 pm on Francisco; can go to 8 or 9 pm. She goes to the bank in Larkspur around 4 pm and it can take her 45 minutes to get back to work.	When Francisco Blvd. is backed up, it's difficult to exit the hotel.
Honda Dealership	Shawn works 9 am to 6 pm so it doesn't affect him too much unless there is an accident. 580 backs up onto 101 so the frontage roads are used as a bypass. Francisco Blvd. often backs up all the way to Bellam.	After 3:30 or 4 on the weekdays to 6:30 or 7 pm. Weekends are ok.	
U-Haul	Afternoons are bad. It's hard to exit the business; Francisco Blvd. is bumper to bumper.	It can start backing up as early as 1:30 in the afternoon and can go to 8:30 pm. It is backed up on the weekends from 3 to 6 pm.	A lot of people use Francisco Blvd. as an alternate to the freeway, and get onto the bridge at San Quentin.
PG&E Service Center	This site doesn't have customers, only employees (more than 100). Andersen Drive is backed up in the mornings and afternoons.	After 4 pm the traffic is bad on Andersen Drive; not as bad on the weekends.	

Central Marin Sanitary District	Steve said that the traffic on Andersen Drive is backed up after 3 pm during the week and also that Sir Francis Drake is bad in the mornings. He uses the Richmond Parkway and after 7:15 am, the traffic getting to 580 and the bridge can back up onto the Parkway.	The traffic starts to back up on Andersen Drive at 3 pm. After noon it's bad on the weekends.	
Business	***Does the congestion affect your customers?***	***Where do your employees live?***	***Do any employees use a bicycle to commute?***
Target	Lots of complaints from employees; customers may be more from the immediate area.	Many live in the East Bay.	
Home Depot		90% live in the East Bay.	
FedEx Shipping Center			
Bay Café			
Orchard Supply Hardware	Haven't looked at sales to see if they are lower during congested times.	Half of the employees live in CC; half live in Marin.	It's possible that some employees may bicycle to work.
Smart and Final		Employees want to work at this store because the pay is higher, so 55% of the employees live in CC (San Pablo, Vallejo, Richmond for example) and commute to Marin.	Probably not.
Westamerica Bank			Probably not as they don't have shower or locker facilities.
Marin Airporter		15 to 20% live in CC.	
UPS Customer Service and Delivery		Most employees are from Marin (Terra Linda to Sausalito).	
US Postal Service		Of the 178 employees, 65% use the bridge to get to work (they live in Hercules, Pinole, El Sobrante, Fairfield, etc.).	
Extended Stay America	(See comments in previous questions)	60% of the employees live in the East Bay (Richmond and beyond).	No
Honda Dealership	(See comments in previous questions)	They have 74 employees; the majority live in the East Bay. A few live in Petaluma, San Rafael, etc.	No

U-Haul	(See comments in previous questions)	There are only 4 employees at this location. Most live in the San Rafael area.	No
PG&E Service Center	(See comments in previous questions)	There are over 100 employees at this site and they live on both sides of the bridge.	No. The bike lane on the bridge is unsafe.
Central Marin Sanitary District	(See comments in previous questions)	There are 42 employees here. Approximately 50% live in the East Bay and 50% on the Marin side.	No

APPENDIX B: ADDITIONAL CHP CAD DATA

Appendix B provides additional information not captured in the main body of Section 8. This includes incidents and crashes-only categorized by location (e.g. mainline or off ramp) and incidents for landside segments categorized by type. Note categories that did not have any incidents were not included in the table.

All Incidents

AM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	2	30	2	0	10	**44**
Bridge	8	0	0	0	0	**8**
Richmond 1	3	19	9	37	0	**68**
Richmond 2	27	29	16	0	0	**72**

PM Peak

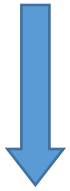
	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	0	34	10	0	14	**58**
Bridge	12	0	0	0	0	**12**
Richmond 1	0	22	7	31	0	**60**
Richmond 2	40	39	12	0	0	**91**

Off-Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	4	48	18	0	22	**92**
Bridge	17	0	0	0	0	**17**
Richmond 1	1	28	19	85	0	**133**
Richmond 2	86	127	28	0	0	**241**

All Day

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total



AM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	2	16	3	0	0	**21**
Bridge	7	0	0	0	0	**7**
Richmond 1	0	6	5	7	0	**18**
Richmond 2	10	17	17	0	0	**44**

PM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	2	37	21	0	0	**60**
Bridge	15	0	0	0	0	**15**
Richmond 1	1	22	5	5	0	**33**
Richmond 2	13	39	24	0	0	**76**

PM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	4	41	18	0	0	**63**
Bridge	25	0	0	0	0	**25**
Richmond 1	1	38	13	13	0	**65**
Richmond 2	20	96	45	0	0	**161**

All Day

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total

Marin	6	112	30	0	46	**194**
Bridge	37	0	0	0	0	**37**
Richmond 1	4	69	35	153	0	**261**
Richmond 2	153	195	56	0	0	**404**
	200	376	121	153	46	896

Marin	8	94	42	0	0	**144**
Bridge	47	0	0	0	0	**47**
Richmond 1	2	66	23	25	0	**116**
Richmond 2	43	152	86	0	0	**281**
	100	312	151	25	0	588

Traffic Collisions and Hit-and-Run Only

AM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	0	10	0	0	4	**14**
Bridge	2	0	0	0	0	**2**
Richmond 1	2	7	5	18	0	**32**
Richmond 2	17	15	6	0	0	**38**
						86

PM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	0	14	8	0	6	**28**
Bridge	3	0	0	0	0	**3**
Richmond 1	0	8	0	9	0	**17**
Richmond 2	16	17	5	0	0	**38**
						86

Off-Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total

AM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	0	5	2	0	0	**7**
Bridge	2	0	0	0	0	**2**
Richmond 1	0	1	2	1	0	**4**
Richmond 2	9	7	2	0	0	**18**
						31

PM Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	0	17	10	0	0	**27**
Bridge	6	0	0	0	0	**6**
Richmond 1	0	9	1	2	0	**12**
Richmond 2	5	13	6	0	0	**24**
						69

Off Peak

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total

Marin	2	16	10	0	6	**34**
Bridge	5	0	0	0	0	**5**
Richmond 1	1	8	4	35	0	**48**
Richmond 2	44	45	7	0	0	**96**
						183

Marin	0	20	9	0	0	**29**
Bridge	5	0	0	0	0	**5**
Richmond 1	1	15	4	4	0	**24**
Richmond 2	15	23	11	0	0	**49**
						107

All Day

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	2	40	18	0	16	**76**
Bridge	10	0	0	0	0	**10**
Richmond 1	3	23	9	62	0	**97**
Richmond 2	77	77	18	0	0	**172**
						355

All Day

	Mainline	Off-Ramps	On-Ramps	Toll Plaza	101 Ramps	Total
Marin	0	42	21	0	0	**63**
Bridge	13	0	0	0	0	**13**
Richmond 1	1	25	7	7	0	**40**
Richmond 2	29	43	19	0	0	**91**
						207

Table A0-1: Classification of Incidents on Marin Segment

Type	I-580 E						I-580 W					
	AM Peak		PM Peak		Total		AM Peak		PM Peak		Total	
	#	Min	#	Min	#	Min	#	Min	#	Min	#	Min
1125 Hazard	14	27.9	25	17.7	*65*	*18.6*	22	21.7	28	27.2	*98*	*30.4*
1125A Animal			4	28.3	*98*	*30.4*			2	21.0	*6*	*8.7*
1166 Signal							2	1.0			*2*	*1.0*
1179 Crash	1	104.0	3	100.3	*9*	*78.4*			6	56.7	*12*	*53.0*
1181 Crash			1	3.0	*1*	*3.0*						
1182 Crash	1	21.0	14	26.6	*29*	*29.1*	4	13.0	14	42.7	*28*	*34.4*
1183 Crash	2	33.0	6	32.8	*16*	*77.7*	10	33.0	8	62.8	*28*	*65.4*
1184 Control					*1*	*36.0*						
20002 H&R	3	23.0	3	371.7	*8*	*159.6*					*8*	*31.5*
ANIMAL			1	65.0	*1*	*65.0*	2	17.0			*2*	*17.0*
BREAK							2	5.0			*2*	*5.0*
CZP Work Zone			1	566.0	*5*	*264.0*						
DOT Request					*1*	*29.0*	2	12.0			*4*	*7.5*
FIRE Other			2	10.5	*2*	*10.5*					*2*	*4.0*
Quantity Totals	21		60		*144*		44		58		*194*	

Table A0-2: Classification of Incidents on Freeway Segment Richmond 1

Type	I-580 E						I-580 W					
	AM Peak		PM Peak		Total		AM Peak		PM Peak		Total	
	#	Min	#	Min	#	Min	#	Min	#	Min	#	Min
1125 Hazard	9	76.8	14	19.8	*53*	*53.7*	28	22.7	34	35.3	*133*	*23.9*
1125A Animal	4	16.0	1	6.0	*9*	*9.7*	5	13.5	3	28.3	*17*	*16.3*
1179 Crash			3	27.3	*9*	*44.0*	3	47.0	2	17.0	*12*	*53.8*
1181 Crash					*1*	*83.0*						
1182 Crash	4	18.8	5	25.8	*14*	*27.0*	18	38.9	9	45.4	*45*	*38.0*
1183 Crash			3	54.0	*13*	*23.6*	9	38.3	6	20.2	*30*	*41.8*
20002 H&R			1	24.0	*3*	*12.0*	2	19.0			*10*	*83.7*
ANIMAL			2	30.0	*2*	*30.0*	1	255.0	1	4.0	*2*	*129.5*
BREAK			1	4.0	*1*	*4.0*	1	160.0			*1*	*160.0*
CFIRE					*2*	*16.5*	1	33.0	2	55.0	*5*	*47.2*
CZP Work Zone			2	72.0	*5*	*58.0*						
FIRE Other			1	42.0	*3*	*21.3*			1	2.0	*1*	*2.0*
FLOOD Advisory	1	92.0			*1*	*92.0*						
WIND Advisory											*1*	*7.0*
WW Driver									1	2.0	*2*	*9.5*
Quantity Totals	18		33		*116*		68		59		*259*	

Table A0-3: Classification of Incidents on Freeway Segment Richmond 2

Type	I-580 E						I-580 W					
	AM Peak		PM Peak		Total		AM Peak		PM Peak		Total	
	#	Min	#	Min	#	Min	#	Min	#	Min	#	Min
1125 Hazard	20	22.9	37	26.0	*144*	*24.2*	26	20.4	45	32.3	*186*	*21.6*
1125A Animal	4	17.3	7	25.3	*26*	*26.0*	7	7.6	3	11.7	*25*	*20.2*
1166 Signal							1	13.0			*1*	*13.0*
1179 Crash	1	1.0	5	50.0	*18*	*43.9*	7	71.0	9	104.4	*27*	*140.8*
1181 Crash											*1*	*31.0*
1182 Crash	5	23.0	3	127.0	*17*	*39.4*	17	30.6	7	82.3	*49*	*36.9*
1183 Crash	9	17.3	15	46.1	*49*	*37.4*	11	21.9	20	48.8	*83*	*43.0*
20001 H&R											*1*	*40.0*
20002 H&R	3	39.0	1	6.0	*7*	*25.8*	3	36.3	2	67.5	*11*	*43.9*
ANIMAL			2	3.0	*3*	*3.0*			1	26.0	*3*	*9.7*
BREAK			1	29.0	*2*	*114.0*			1	23.0	*3*	*17.7*
CFIRE			3	5.0	*3*	*5.0*					*4*	*94.3*
CLOSURE							1	1.0			*1*	*1.0*
CZP Work Zone											*3*	*478.5*
DOT Request	1	2.0			*3*	*4.7*						
FIRE			2	40.5	*8*	*22.0*			1	10.0	*5*	*11.8*
Wrong Way					*1*	*22.0*			1	1.0	*1*	*1.0*
Quantity Totals	43		76		*281*		72		90		*404*	