ATTACHMENT B

PARTNERS FOR ADVANCED TRANSPORTATION TECHNOLOGY
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

After Study for the Richmond-San Rafael Bridge (Phase II)

May 8, 2024

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16. ABSTRACT

This report evaluates the impacts associated with the following pilot changes that were made on and around the Richmond-San Rafael Bridge: (1) opening to traffic of the eastbound shoulder on the bridge’s lower deck between 2 PM and 7 PM every day (April 2018); (2) conversion of the westbound shoulder on the upper deck into a barrier-separated bike/pedestrian path (November 2019); and (3) conversion of an existing one-way bicycle path on the I-580 West Sir Francis Drake off-ramp overcrossing into a barrier-separated two-way path. Specific evaluations include the level of use by cyclists and pedestrians, impacts on traffic conditions and vehicle emissions, traffic compliance with the eastbound shoulder open/close periods, impacts on incident frequency, types, severity, and clearance times, and impacts on maintenance activities. These elements are to be used by Caltrans to determine whether the changes should be kept, in whole or in part. Evaluations show that the opening of the eastbound shoulder to traffic has significantly reduced travel times and incidents in Marin County through the elimination of the congestion that used to affect the I-580 East approach. While the addition of the path on the upper deck has slightly decreased peak bridge capacity and increased travel time variability on the Richmond approach, congestion on the approach remains close to historical averages. Bicycle traffic on the bridge path is highest on weekends, with an average of 483 cyclists entering the bridge on Saturdays and 355 on Sundays. Weekday traffic is much lower, at around 90 trips per day. Pedestrian traffic is usually very low, at less than 25 individuals per day. Some slight impacts from the addition of the path were also found on incident response and maintenance activities, but no significant impacts on incidents. A user survey further shows a positive perception of the path by cyclists, but a more negative view from motorists. The use of the modified path on the Sir Francis Drake overcrossing seems to mirror the use of the bridge path.

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BEFORE EVALUATION REPORT

The work documented in this report is a compilation of a multi-year project aiming to assess the impacts of the modifications made to the Richmond-San Rafael bridge on traffic, safety, and bridge operations. Under contract 65A0529 - *Richmond-San Rafael Bridge Access Improvements Project Before Study Evaluation and Report*, a preliminary set of evaluations was made focusing on operational conditions that existed in 2015-2016 before the modifications. Findings from this study were detailed in a 2018 report bearing the project name as its title (Report 18CA-2997).

PHASE I AND PHASE II AFTER EVALUATIONS

Evaluation results presented in this document cover both Phase I and Phase II of the pilot modifications made around the Richmond-San Rafael bridge. Phase I evaluations, under Contract 65A0684 (Task 3141) - *Richmond San-Rafael Bridge After Study*, focused on assessing the impacts of converting the shoulder on the upper deck of the bridge into a multi-use bike/pedestrian path and converting the shoulder on the lower deck into a part-time traffic lane. Phase II evaluations, under Contract 65A0804 (Task 3839) - *Richmond San-Rafael Bridge and Sir Francis Drake Pilot (Phase II)*, continued the evaluation of the upper deck modifications and expanded the study to also cover modifications made to an existing bike path on a nearby I-580 West off-ramp overcrossing connecting the bridge path to Sir Francis Drake Boulevard in Marin County.

DISCLAIMER

The research reported herein was performed by a research team within the California Partners for Advanced Transportation (California PATH) within the Institute of Transportation Studies at the University of California – Berkeley, for the Division of Research, Innovation and System Information (DRISI) at the California Department of Transportation.

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Primary Author

Francois Dion, Ph.D., PE (Michigan)
Project Manager
Senior Development Engineer
California PATH
University of California, Berkeley

Contributing Authors

Michelle Harrington
Communications Specialist
California PATH
University of California, Berkeley

Lisa Hammon
Project/Policy Analyst
California PATH
University of California, Berkeley

Joe Butler
Project Manager
California PATH
University of California, Berkeley

Joshua Seeherman, Ph.D., PE (Massachusetts)
Project Engineer
California PATH
University of California, Berkeley

Project Advisory Panel Members

Ali, Akber; Project Manager, DRISI, Caltrans
Blair, Scott; Design/Design TAP Coordinator, Caltrans Headquarters
Broadbent, Jack; Design/Design PSC, Caltrans Headquarters
Brown, Kenneth; Caltrans Maintenance
Buffenbarger, Jacob (Jake); Pedestrian & Bicycle Branch, Marin County; Customer representative for the Sir Francis Drake portion of the project
Burnworth, Sarah; Metropolitan Transportation Commission/BATA
Chen, Kevin; Metropolitan Transportation Commission/BATA
Cherrier, Dan; Transportation Authority of Marin
Culik-Caro, Helena; Deputy Director, Project Development East/Customer, Caltrans District 4
Currey, Gregory; Pedestrian and Bicycle Branch, Caltrans District 4
Effinger, Robert; Caltrans District 4
Fernandez, Steve; Bridge Maintenance Operation Manager, Caltrans District 4
Gestuvo, Evelyn; Highway Operations, Caltrans District 4
Go, James; Metropolitan Transportation Commission/BATA
Hale, Charles; Maintenance, Caltrans District 4
Hsai, Josephine; System Planning Office
Kerns, Michael; Highway Operations, Caltrans District 4
Kim, Inho (Eddie); California High-Speed Rail Authority
Lee, Peter; Metropolitan Transportation Commission/BATA
Lopez, Luisa; System Planning Office
Louie, Angela; Metropolitan Transportation Commission/BATA
Mao, Lulu; Metropolitan Transportation Commission/BATA
Mowry, Rebecca; Bicycle, Pedestrian and ADA Design Standards, DOD
Naseer, Amjad; Caltrans District 4
Nyaz, Wajahat; Deputy Director, Caltrans District 4; Primary Customer on the Richmond-San Rafael bridge portion of the project
Omran, Muthanna; Project Manager, Caltrans District 4; Primary Customer on the Richmond-San Rafael bridge portion of the project
Oto, Rodney; Highway Operations, Caltrans District 4
Ruiz, Sergio; Complete Streets Coordinator, Caltrans District 4; Customer Representative for the Sir Francis Drake portion of the project
Soria, Gregorio; Maintenance, Caltrans District 4
Tarlok, Balwinder; DRISI, Caltrans
Tellez, Kimberly; Caltrans District 4
Tseng, Chris; Ramp Metering, Caltrans District 4
Wang, Karen; HNTB
Whitney, Bill; Transportation Authority of Marin
Woods, Mark; Maintenance, Caltrans
Xu, John; System Planning Office, Caltrans
Zhongping, Xu; Caltrans District 4

Additional Contributors

Dhaliwal, Jagtar; Chief, Office of Transportation Technology Research (OTTR), DRISI, Caltrans
Horan, Laura; Maintenance Manager, Toll Bridge Region
Jetta, Steven; Design Coordination Branch, Division of Design, Caltrans District 4
Ma, Paul; Chief, Office of Highway Operations, Caltrans District 4
Man, David; Chief, System Operations, Division of Traffic Operations, Caltrans District 4
Nesmith, Chris; Maintenance Manager, Caltrans
Pazooki, Mo; Project Manager, Caltrans
Sadrai, Hamid; Asset Manager, Caltrans District 4
Simi, Brian; Chief, Office of Traffic Operations Research, DRISI, Caltrans
Szibbo, Nicola; Metropolitan Transportation Commission/BATA
Widmann, Joshua; Customer Relations Assistant, Golden Gate Transit

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LIST OF ACRONYMS

ADT	Average Daily Traffic
BAIRS	Bay Area Incident Response System
BATA	Bay Area Toll Authority
Caltrans	California Department of Transportation
CARB	California Air Resource Board
CCTA	Contra Costa Transportation Authority
CHP	California Highway Patrol
CHP-CAD	California Highway Patrol Computer-Aided Dispatch
DRISI	Division of Research, Innovation, and System Information
EMFAC	Emission Factor Model
EPA	Environmental Protection Agency
HOV	High-occupancy vehicle
IMMS	Integrated Maintenance Management System
LCS	Lane Closure System
MIDB	Major Incident Database
MTC	Metropolitan Transportation Commission
NDS	National Data and Surveying Services
PeMS	Performance Measuring System
RSR	Richmond-San Rafael
SafeTREC	University of California Safe Transportation Research and Education Center
SWITRS	Statewide Integrated Traffic Report System
TAM	Transportation Authority of Marin
TASAS	Traffic Incident and Surveillance Analysis System
TIMS	Transportation Injury Mapping Systems
VMT	Vehicle miles traveled

EXECUTIVE SUMMARY

This report presents an evaluation of the operational impacts associated with the following changes that were made around the Richmond-San Rafael bridge:

- Opening to traffic as a part-time lane of the eastbound shoulder on the lower deck of the bridge between 2 PM and 7 PM every day (opened April 2018).
- Conversion of the westbound shoulder on the upper deck of the bridge into a barrier-separated shared bike/pedestrian path (opened November 2019).
- Conversion of an existing one-way bike path on the I-580 West Sir Francis Drake Boulevard off-ramp overcrossing into a barrier-separated two-way bike path with slightly narrower than standard lanes (opened summer 2020).

Specific elements that were evaluated include:

- Traffic compliance with the open period of the eastbound shoulder
- Use of bridge paths by cyclists and pedestrians
- Impacts on eastbound and westbound traffic conditions on the bridge and its approaches
- Impacts on frequency, type, and severity of incidents occurring on and around the bridge
- Impacts on incident clearance times
- Impacts on maintenance activities on the bridge
- Impacts on quality of life in Marin County areas near the bridge

Below is a summary of the key findings from the study for the two bridge modifications evaluated.

IMPACTS OF SHOULDER MODIFICATIONS ON BRIDGE LOWER DECK

- **OVERALL ASSESSMENT:**
    - **Traffic impacts:** The conversion of the lower deck shoulder into a part-time traffic lane positively impacted the eastbound traffic. Afternoon congestion on I-580 East in Marin County has disappeared, leading to a reduction of up to 17 minutes in travel time from the US-101 to the toll plaza. Travel times and flow output have also improved along Sir Francis Drake Boulevard, and significantly less traffic is using other local arterials to bypass I-580 East.
    - **Safety impacts:** The frequency of incidents on the approach to the bridge has been reduced by 70%. No significant impacts were further observed on the type, severity, duration, and location of incidents.
- **Compliance of traffic with open/close periods:**
    - On average, 99.6% of traffic observed on the bridge before 2 PM and after 7 PM is compliant with the shoulder closure.
    - Non-compliant use is highest 20 minutes before its opening and up to 30 minutes following its closure. Pre-opening non-compliance varies between 0.3% and 0.6% of traffic while post-closing non-compliance varies between 0.5% and 1.1% of traffic.

  - Some vehicles use the shoulder as a passing or travel lane when a red or yellow X is displayed above it. This suggests that current lane control signs, particularly the yellow X, may not be fully understood by all motorists.

- **Traffic conditions on I-580 East and US-101 North traffic:**
  - The availability of an extra traffic lane during peak hours has increased hourly flows across the bridge by 13-25%, from 3,300-3,600 vehicles/hour before the modification to 3,750-4,500 vehicles/hour after. This is not due to an increase in traffic demand but simply to the removal of the bottleneck at the entrance of the bridge.
  - Less than 25% of traffic is using the part-time lane during weekday peak periods, and less than 20% on weekends.
  - The added peak-hour capacity has ended congestion on the Marin County approach to the bridge, resulting in peak travel time reductions from the US-101 to the toll plaza by 14-17 minutes on midweek days, 10-14 minutes on Saturdays, and 6-8 minutes on Sundays. Peak travel times are also significantly less variable than before.
  - Traffic improvements along I-580 East may have partly contributed to the observed 1-2 minutes reduction in average peak weekday travel times on US-101 North between the Sir Francis Drake Boulevard and I-580 interchanges since 2017.
  - Fewer vehicles are using the Main Street off-ramp and on-ramp as a congestion bypass. Such use of the ramps during the afternoon peak has dropped from an average of 56 vehicles/hour in 2016 to 1 vehicle/hour in 2022.
- **Vehicle emissions along I-580 East**
  - The elimination of the congestion on the bridge approach has led to reductions in pollutant emission rates per mile traveled varying between 3.6% and 23.4% depending on the pollutant considered and season (summer/winter).
  - Mixed results were obtained on weekends due to conflicting effects from the elimination of the congestion on the approach (reduction of emissions due to low speeds) and enabling a higher proportion of vehicles to travel above 60 mph (increase in emissions due to higher engine output).

- **Traffic on local arterials in Marin County:**
  - Compared to 2016, weekday afternoon peak travel times along Sir Francis Drake Boulevard have dropped by up to 4 minutes, while traffic volumes have increased by over 300 vehicles/hour.
  - Fewer vehicles are using local arterials as a bypass to I-580 to save time while traveling towards the bridge in the afternoon. Peak traffic on Francisco Boulevard has for instance dropped from 730 to 227 vehicles/hour between May 2016 and March 2022.

- **Traffic safety on I-580 East:**
  - On the approach, the rate of incidents on the approach to the bridge, on a per million miles traveled basis, has reduced by 69% since the opening of the eastbound shoulder to traffic. This can be linked to the elimination of the heavy congestion that used to affect I-580 East traffic from the US-101 interchange to the entrance of the bridge. This

was largely associated with the three-to-two-lane drop at the Main Street off-ramp just before the bridge. In terms of incident types, this change has further translated into an 80% reduction in the rate of rear-end collisions, a 57% reduction in sideswipes, and a 59% reduction in vehicles hitting fixed objects.

- On the bridge, the rate of rear-end collisions has reduced by 32% since the opening of the shoulder to traffic. This can be linked to lower peak traffic densities as traffic can now spread over three lanes instead of two. However, the modification also provides more opportunities for lane changes and could be partly responsive to the observed 24% increase in the rate of sideswipes and a 7% increase in vehicles hitting objects.
- In terms of severity, the data indicate a reduction from 41% to 32% in the proportion of incidents with severe injury, complaints of pain, or other visible injuries occurring on the bridge. While this may be related to the lower traffic densities, it mainly indicates a lack of negative impacts as other contributing factors could be involved.
- There is no evidence that the modifications are producing longer incidents or changing the location where incidents tend to occur on the bridge.
- There is no evidence that the bridge modifications are increasing the time needed to clear incidents. More precisely measuring the period during which an incident affects traffic would be required to provide a more definitive answer.

- **Lower deck incident response times:**
  - The tow truck and CHP dispatch logs do not provide evidence that the modifications have changed the time needed for responding to incidents on the bridge.

- **Lower deck maintenance activities:**
  - Because vehicles are occasionally seen using the lower deck shoulder when closed, maintenance crews must always treat it as an active lane to ensure their safety.

IMPACTS OF NEW PATH ON BRIDGE UPPER DECK

- **OVERALL ASSESSMENT:**
  - **Cyclist use:** Since January 2022, daily entries onto the path during summer, from either end of the bridge, have averaged 465 on Saturdays, 352 on Sundays, and 132 on weekdays. During winter, entries have averaged 311 on Saturdays, 258 on Sundays, and 90 on weekdays.
  - **Pedestrian use:** Pedestrian use is generally low, with an average of 15 individuals entering the path from the Richmond side on Saturdays, 12 on Sundays and 8 on weekdays during summer, and 13 on Saturdays, 20 on Sundays, and 7 on weekdays during winter. No data is available for the Marin side.
  - **Traffic impacts:** Due to the shorter merge downstream of the toll plaza and narrower bridge roadway, the maximum flow across the bridge has been reduced by 7%, on weekdays and 4% on weekends. In parallel, peak-hour travel times across the bridge have only increased by less than a minute, due to slightly slower speeds on the bridge, and been more variable due to the inability of disabled vehicles to move out of a traffic

lane. However, these impacts have not translated into significantly increased congestion upstream of the bridge compared to the 2015 to 2018 average conditions. This appears to be due to traffic levels on the approach remaining below 2018 levels.

  - **Safety impacts:** The path is generally perceived as safe by its users, although some concerns exist about the risk of being hit by objects flung over from the adjacent traffic lanes. On the vehicular side, the installation of the path has not affected the frequency, type, and severity of incidents, nor has it significantly affected incident responses.

- **Use by cyclists:**
  - In the most recent peak season, bicycle traffic on the bridge was the highest of all State-owned toll bridge paths, including the San Francisco-Oakland Bay Bridge multi-use path.
  - Bicycle traffic typically follows an annual cyclical pattern, with the highest volumes occurring in the summer (June-September) and the lowest in winter (November-March), when it is colder and rainier. Traffic also follows a weekly pattern, with the highest traffic typically observed on Saturday, the second highest on Sundays, and relatively constant lower volumes on weekdays.
    - Since January 2022, Saturday summer traffic has averaged 264 cyclists/day westbound and 219 eastbound, with peaks up to 435, while Sunday summer traffic has averaged 188 westbound and 167 eastbound, with peaks up to 285.
    - Winter Saturday traffic has averaged 177 cyclists/day westbound and 135 eastbound, with peaks near 300, while Sunday traffic has averaged 145 cyclists/day westbound and 120 eastbound, with again with peaks near 300.
    - Summer weekday has averaged 75 cyclists/day westbound and 66 eastbound, with peaks near 100, and winter traffic 50 westbound and 41 eastbound, with peaks near 60.
  - Westbound traffic is usually greater than the eastbound traffic, with a 55%/45% split.
  - Westbound traffic peaks between 10 AM and 11 AM on both weekends and weekdays. Eastbound traffic peaks between 1 PM and 2 PM on weekends and 3-4 PM on weekdays with notable volumes between 12 Noon and 3 PM.
  - A 2021 survey of path users indicated that 1.9% used it more than four times per week, 10.7% up to four times per week, 29.8% up to four times a month, 31.8% less than once a month, and 25.8% less than four times since its opening.
  - 85.1% of path users have indicated using it for recreation (63.1%) or exercise (22.0%). Only 14.0% have used it for commuting, either to work (4.9%) or other locations (9.1%). The remaining 0.9% used it for other, non-specified, reasons.
  - 83.9% of path users indicated having completed one or more round trips on the path while cycling or walking. Of these, 90.6% reported fully crossing the bridge both ways, 6.9% turning back mid-way, and 2.5% having both fully crossed the bridge or turned back mid-way depending on the occasion.
  - While there has been a significant drop in the number of bicycles carried across the bridge by Golden Gate Transit buses, with monthly counts remaining at 51%-63% of the 2015-2019 average, it is unclear what part might be a byproduct of the COVID-19

pandemic and what part could be linked to the path opening, as the overall ridership for Golden Gate Transit remains at around 45%-48% of the 2019 level.

  - Overall, trips with bicycles across the bridge, either being carried on a bus or ridden, are higher than before the path opening. Summer traffic went from 700-900 trips/month when Golden Gate Transit buses were the only option, to 6,000-8,000 trips/month during the summer of 2023.

- **Use by pedestrians:**
  - Observed pedestrian traffic is low. On average, only 11 pedestrians are seen each weekday crossing the bridge eastbound, and 8 going westbound. Weekend traffic is slightly higher, with 24 pedestrians going eastbound and 14 westbound.
  - Pedestrian use is likely underestimated as the reported counts are based on a single sensor on the Richmond side. This sensor does not capture individuals accessing the path from Marin County and turning back partway.
  - The 4-mile length of the bridge likely explains the low pedestrian demand, and why less than 25% of pedestrians indicated completing a full round trip on the bridge and 57% turned around partway.
  - Fishers have been observed using the path to access locations from where to cast fishing lines, either on the shore or the path itself. Such individuals are more often seen on the Marin County side, where they use the vista parking lot as a staging area.

- **Traffic conditions on I-580 West:**
  - Average weekday peak-hour flows across the bridge have dropped by 7%, from 3,500-3,850 to 3,250-3,600 vehicles/hour.
  - Weekend peak-hour flows have similarly dropped by 4%, from 3,200-3,500 to 3,100-3,300 vehicles/hour.
  - The closeness of the path's barrier to the right traffic lane appears to have caused 1-2% of peak-hour traffic to shift to the left lane, and up to 20% of the evening and night traffic to do the same. This has resulted in an average 57%/43% split across the left and right lanes during weekday peaks and a 55%/45% split during weekend peaks.
  - Frictions from the significantly shorter merge downstream of the toll plaza (325 ft instead of 850 ft), in addition to unbalanced lane use and lower speeds on the bridge, may explain the reduction in bridge capacity. However, these negative impacts may have partly been compensated by the elimination of the toll cash collection activities.
  - Despite the slight bridge capacity reduction, the extent of the congestion upstream of the toll plaza and average peak travel times from I-80 to the end of the bridge on weekdays, Saturdays, and Sundays have remained similar to the before conditions.
  - Before the modifications, upper deck traffic generally flowed on weekday mornings at or above 50 mph following the first mile of the bridge. In the fall of 2021, speeds between 40 and 50 mph were typically observed across the bridge, resulting in a slight increase in travel time of less than one minute. Some slight speed reductions were also observed on Saturdays and Sundays but with negligible impacts on travel times.

- Peak weekday travel times on the bridge's approach are now more variable, i.e., less reliable, than before the path installation, mainly due to the barrier now preventing disabled vehicles from pulling out of a traffic lane. The reliability of peak weekend travel times remains similar to before.
- Many of the traffic impacts described above may still be affected by lingering reductions in traffic caused by an increase in the proportion of individuals working from home following the COVID-19 pandemic.
- Evaluations regarding the possibility of a third traffic lane on the upper deck of the bridge must consider capacity constraints in the existing road network in Marin County.

- **Vehicle emissions along I-580 West**
  - Depending on the pollutant and season, reductions in emissions varying between 0.2% and 12.7% are estimated to have resulted from the bridge modification, primarily due to a reduction in the share of vehicles traveling above 60 mph.
  - On weekends, increases in emissions varying between 0.4% and 4.4% are contrarily estimated. This is due to pushes for higher emissions from (a) a higher proportion of vehicles traveling above 60 mph; (b) the documented slight reduction in bridge capacity; and (c) the historically high traffic demand observed in 2023. The last item is important to consider as it is the result of changes in traffic demand and indicates that some emission increases could have occurred in the absence of the bridge modification.

- **Traffic conditions on local arterials in Richmond:**
  - The bridge modifications do not appear to have had significant impacts on local arterials on the Richmond side of the bridge.

- **Safety of new bridge paths for cyclists and pedestrians:**
  - No incidents involving cyclists or pedestrians were recorded by the CHP or reported on the University of California's Street Story community platform during the evaluation period. However, anecdotal evidence suggests that some incidents have occurred.
  - Users generally have a positive view of the safety offered by the path, as evidenced by a safety rating of 8.19 out of 10 assigned by users in the summer of 2021.
  - The low height of the barrier puts path users at risk of being hit by debris flung from the adjacent traffic lanes or being blinded at night by vehicle lights when traveling east.
  - Only 3% of surveyed path users commented on its narrowness.

- **Traffic safety on I-580 West:**
  - There is no compelling evidence that the modifications have negatively impacted traffic safety. All the analyses produced estimates of change that were not statistically significant at the 95%, 90%, or 85% level, meaning that all observed changes could be the result of normal variability in the quarterly data.
  - Collision rates either increased or decreased, depending on how the data is considered. When considering all known incidents, the data points to a 13% decrease in overall collisions east of the toll plaza and a 19% drop on the bridge. When focusing only on the weekday AM peak period, increases of 16% and 40% respectively were observed.

- No clear impacts are observed on incident types. When considering all logged incidents, relatively similar proportions of incident types are observed before and after the modification. However, during the weekday AM peak (6 AM to 9 AM), the proportion of sideswipes on the approach appears to have reduced (from 51% to 40%) while rear ends and vehicles hitting objects have increased. On the bridge, sideswipes have further increased slightly (40% to 44%) while rear-ends have decreased (58% to 48%).
- No clear impacts are observed on incident severity. Before the modification, incidents without injury represented 72%-76% of all incidents on the approach depending on whether al logged incidents are considered or only those occurring during the weekday AM peak, and 67%-68% of incidents on the bridge. After, these incidents accounted for 70%-79% of all incidents on the approach and 68-70% on the bridge.
- There is no statistical evidence that the bridge modifications are producing longer crash-related incidents or changing the location where crashes tend to occur on the bridge.
- There is no statistical evidence that the modifications are increasing the time needed to clear crashes. In this case, data measuring more precisely the period during which an incident affects traffic would be required to provide a more definitive answer.

- **Upper deck incident response times:**
  - Tow truck and CHP dispatch logs do not provide evidence that the modifications may have changed the time needed for responding to incidents on the bridge.

- **Upper deck maintenance activities:**
  - The barrier may force maintenance crews to close the right traffic lane when they need to do maintenance on the bridge.
  - Closing of a traffic lane for path maintenance mainly occurs for routine monthly cleanings when the barrier must be moved. To minimize traffic impacts, this is typically done at night, with bulletins published by MTC/511 well ahead of time.
  - Emergency realignment to the barrier only occurs if the width of the path is reduced to less than 10 feet. This occurred twice between November 2019 and April 2022. In such cases, maintenance crews will generally try to use tools to manually realign the barrier or wait for the monthly machine re-alignment of the barrier to fix the issue.

IMPACTS OF MODIFIED BICYCLE PATH ON SIR FRANCIS DRAKE OVERCROSSING

- **OVERALL ASSESSMENT:**
  - **Cyclist use:** Utilization of the path significantly mirrors the bridge path, suggesting that a sizable portion of users are coming from the bridge or traveling toward it. Since January 2022, daily entries during summer, from either end of the overcrossing, have averaged 315 on Saturdays, 200 on Sundays, and 93 on weekdays. During winter, entries have averaged 318 on Saturdays, 263 on Sundays, and 58 on weekdays.
  - **Traffic impacts:** No constraining impacts on traffic were found.

   - **Safety impacts:** No significant safety risks have been assessed for the path itself. However, some potential safety issues are associated with how cyclists cross the roadway at the intersection with Andersen Drive.

- **Use by cyclists:**
   - Peak travel periods are similar to what has been observed on the bridge.
   - Bicycle traffic is seasonal, with the highest volumes typically observed between June and September and the lowest between November and March when it is colder and rainier.
      - Since January 2022, Saturday traffic during summer months (June-September) has averaged 189 cyclists/day westbound and 126 eastbound, while Sunday traffic has averaged 125 and 88 cyclists/day respectively.
      - Winter weekend traffic (November-March) has expectedly ranged lower, with Saturday westbound and eastbound averages of 119 and 77 cyclists/day, and Sunday averages of 92 and 60.
      - Weekday traffic is much lower, with peak summer averages of 56 and 37 cyclists/day westbound and eastbound, and winter averages of only 37 and 24.
   - Eastbound traffic (toward the bridge) is generally lower than westbound traffic (away from the bridge). This is partly explained by the presence of an alternate eastward path running along the eastbound shoulder of I-580 East between the Sir Francis Drake Boulevard on-ramp and the Main Street exit.
   - The conversion of the overcrossing path into a two-way path has enticed some eastbound travelers to switch from using the I-580 East shoulder path to using the overcrossing path, likely associated with the uneasiness of traveling along freeway traffic on a path only delimited by painted lines, resulting in more crossings of Sir Francis Drake Boulevard at Andersen Drive.
   - Westbound path traffic typically corresponds to 75-90% of westbound bridge traffic while eastbound traffic corresponds to 50-60% of eastbound bridge traffic. This suggests that a majority of path users are also users of the bridge path.

- **Use by pedestrians:**
   - While the overcrossing path is restricted to bicycle use, pedestrians are on relatively rare occasions seen walking on the path.

- **Traffic conditions on the overcrossing:**
   - No constraining impacts have been observed on the overcrossing traffic.

- **Safety for cyclists:**
   - No path-related incidents were recorded by the CHP or on the Street Story community reporting platform after the path's modification.
   - The narrower lane width does not appear to affect behavior, as cyclists going down the overcrossing are seldom seen noticeably slowing down when crossing cyclists going up.
   - At the bottom of the overcrossing, cyclists going toward the bridge generally cut into the opposing lane to negotiate the 90-degree turn, creating a potential for collision.

- A significant proportion of cyclists traveling east along Sir Francis Drake Boulevard cross the arterial at Andersen Drive to access the path. This requires them to do the equivalent of a permitted left-turn across traffic coming off the freeway or going to it.
- A significant proportion of cyclists traveling south along Andersen Drive cross it upstream of the intersection with Sir Francis Drake Boulevard to access the path.

- **Traffic safety:**
  - The very low number of incidents occurring on the Sir Francis Drake overcrossing does not lead to conclusions on the impacts on incident occurrence, type, or severity.
- **Overcrossing maintenance activities:**
  - All barrier repairs are done manually due to the inability to bring the barrier-moving machine from the bridge. This can easily be done and occurs very infrequently.
  - The relatively small length of the overcrossing path does not create significant issues for maintenance crews to access the site.

OTHER ASSESSMENTS

- **Impacts on businesses in Marin County**
  - According to 8 surveyed businesses in March 2022, morning congestion on the Richmond side of the bridge continues to affect the ability of businesses in Marin County to hire and retain staff from the East Bay. This is a problem that pre-existed the upper bridge modifications. However, travel time reductions to access Richmond from the Marin side during the afternoon peak following the lower deck improvements may have helped reduce the impacts of the morning commute.
  - For one business, which provides on-demand transportation services, less traffic using local streets to bypass I-580 East in the afternoon is significantly easing corporate fleet movements around San Rafael and Larkspur.
  - None of the small number of surveyed business managers were aware of employees using the new bridge bicycle/pedestrian path for commute purposes.

ITEMS FOR FUTURE CONSIDERATIONS

While the final determination of the future of each element of the pilot project is to be made by Caltrans based on the findings documented in this report, the following are items for future considerations that have been brought to the research team during the project:

- While the objective of the project was to look at operational issues associated with the various modifications evaluated, there may be a need to conduct a more formal analysis of the equity issues associated with them, particularly with the impacts associated with the multi-use path that was installed on the upper deck of the bridge.
- Given that the use of the multi-use path varies significantly between weekdays and weekends, a possible option might be to have the path open on weekends only, when its use is the highest,

and have the barrier move to the side on weekdays to re-establish the shoulder. A potential benefit of such a configuration could be the recovery of a portion, if not all, of the capacity drop that was estimated to be caused by the path.

1. INTRODUCTION

This report presents an evaluation of the operational and safety impacts associated with changes that were made between 2018 and 2020 to the Richmond-San Rafael bridge and I-580 West off-ramp overcrossing in the northern portion of the San Francisco Bay Area as part of a four-year pilot project. Three specific changes are evaluated:

- Opening of the eastbound shoulder on the bridge lower deck to traffic between 2 PM and 7 PM every day (opened April 2018).
- Conversion of the westbound shoulder on the upper deck into a barrier-separated bike/pedestrian path (opened November 2019).
- Conversion of an existing one-way bike path on the I-580 West Sir Francis Drake Boulevard off-ramp overcrossing into a barrier-separated two-way bike path with narrower than usual lanes (opened summer 2020).

The impacts associated with the modifications are evaluated through a study comparing operational conditions before and after the changes. For the bridge modifications, the before conditions were assessed in 2015-2016, at the beginning of the project, while the after conditions were assessed between 2019 and 2024. For the overcrossing modifications, the evaluations primarily focus on the after conditions due to the extremely limited availability of usable data to assess conditions before the summer 2020 modifications. In both cases, efforts were made to avoid conducting evaluations between March 2020 and June 2021 due to the significant impacts of the COVID-19 pandemic on business activities and travel.

Specific elements that were evaluated through the before/after study include:

- How traffic utilizes the eastbound part-time traffic lane that was set up on the bridge's lower deck shoulder
- How many bicyclists and pedestrians use the new multi-use path that was installed on the bridge's upper deck
- Changes in bicycle traffic around the modified bike path running along the I-580 West Sir Francis Drake off-ramp overcrossing
- Changes in vehicular traffic conditions on the eastbound and westbound approaches to the bridge, as well as the bridge itself, during peak weekday and weekend traffic conditions.
- Impacts on the number, type, and severity of incidents occurring on the bridge and its approaches.
- Impacts on the ability to respond to incidents occurring on the bridge and the overcrossing
- Impacts on bridge and overcrossing maintenance activities
- Impacts on business activities in Marin County

The results of the above evaluations are to be used by Caltrans at the end of the pilot project to determine whether the various modifications should be kept, modified, or removed. It is not the goal of this study to provide recommended courses of action as other considerations need to be evaluated. Its goal is simply to report on the impacts of the modifications.

The remainder of this report is divided into the following sections:

- **Section 2:** Project background
- **Section 3:** Evaluation objectives

- **Section 4:** Description of the study area and roadways of interest
- **Section 5:** Description of data collected and analyzed
- **Section 6:** Bicycle traffic on the new bridge path and modified Sir Francis Drake overcrossing path
- **Section 7:** Pedestrian traffic on the new bridge path
- **Section 8:** Impacts on traffic conditions along I-580 and nearby local streets
- **Section 9:** Impacts on vehicle emissions along I-580
- **Section 10:** Safety of new bridge and modified overcrossing paths for cyclists and pedestrians
- **Section 11:** Impacts on traffic safety
- **Section 12:** Impacts on incident response activities
- **Section 13:** Impacts on maintenance activities
- **Section 14:** Evaluation of impacts on quality of life through business and user surveys
- **Section 15:** Summary of observations

2. PROJECT BACKGROUND

This section provides background information about the pilot projects evaluated in this report. Specific elements covered include:

- Project stakeholders
- Description of Richmond-San Rafael Bridge
- Initial traffic setup across the bridge
- Initial pedestrian/cyclist access to the bridge
- San Francisco Bay Trail project
- Pilot modifications to the bridge
- Pilot modifications to the I-580 West Sir Francis Drake off-ramp overcrossing

2.1. PROJECT STAKEHOLDERS

In addition to the University of California being responsible for performing the evaluations reported in this document, stakeholders in the pilot projects included the following entities:

- **Project Proponents:** Bay Area Toll Authority (BATA), Contra Costa Transportation Authority (CCTA), and Transportation Authority of Marin (TAM). These organizations have provided the funding for the modifications, in addition to having expedited the permitting process.

- **Project Overseer:** Caltrans District 4, responsible for approving the design and providing quality assurance during construction.

- **Project Designer:** CH2M Hill (formerly HNTB Corporation), responsible for the design and implementation of the improvements.

2.2. RICHMOND-SAN RAFAEL BRIDGE

Figure 2-1 locates the Richmond-San Rafael Bridge within the context of the San Francisco Bay Area. The bridge connects the city of Richmond in Contra Costa County with the city of San Rafael in Marin County, through a narrow section of water between the San Francisco and San Pablo bays. It opened to traffic in September 1956 as the second-to-last major bridge to be constructed in the Bay Area. While it initially carried State Route 17 across the water, State Route 17 was renamed Interstate 580 in 1984. The bridge remains the second-longest bridge in California, with a length of four miles, behind the San Mateo-Hayward crossing further south.

Figure 2-2 further provides a picture of the bridge. As illustrated, it features two identical cantilever spans with a lower section in between. Both spans are 1,070 feet long, with a 185-foot clearance over water at the highest point. For much of its length, the structure has upper and lower decks rather than side-by-side decks. Westbound traffic is carried on the upper deck while eastbound traffic is carried on the lower deck.

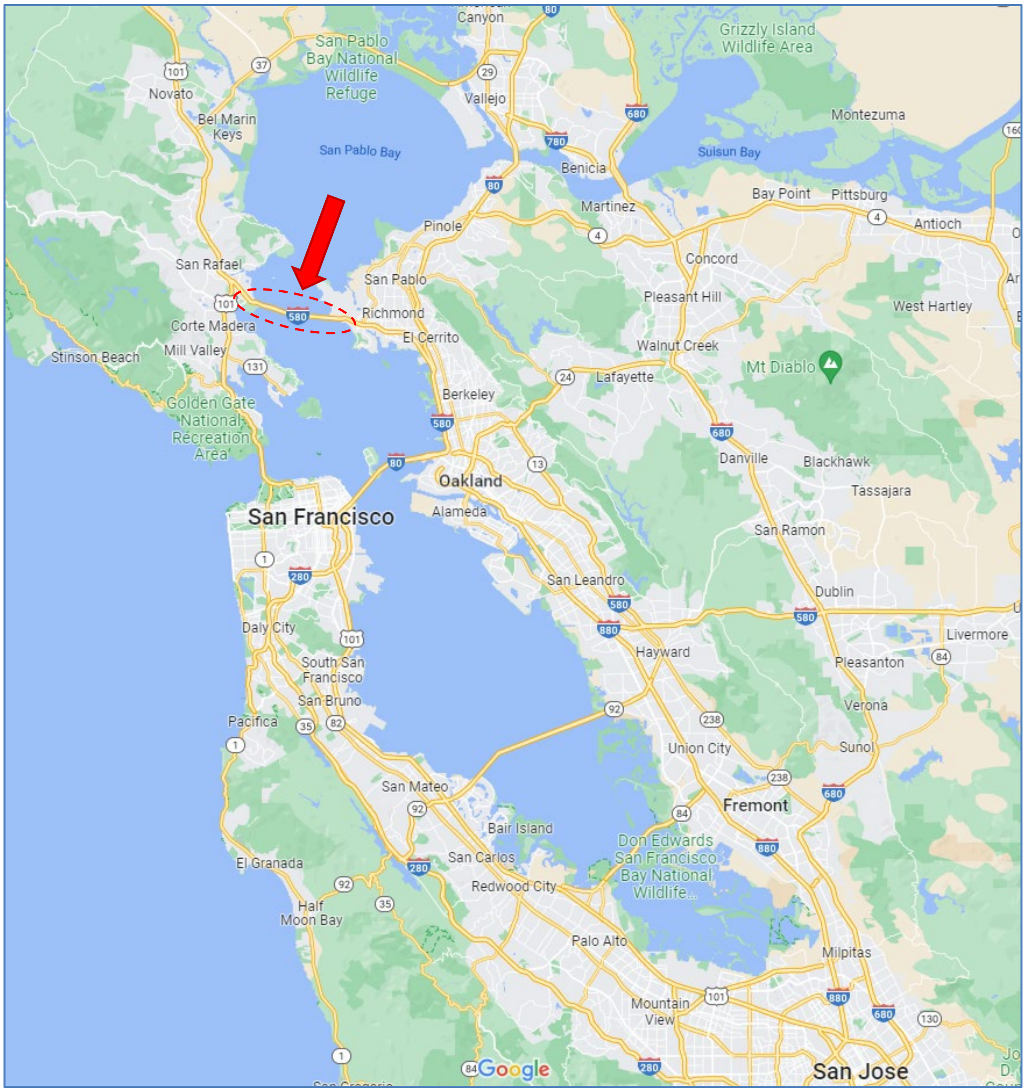

Figure 2-1: Location of Richmond-San Rafael Bridge within the San Francisco Bay Area

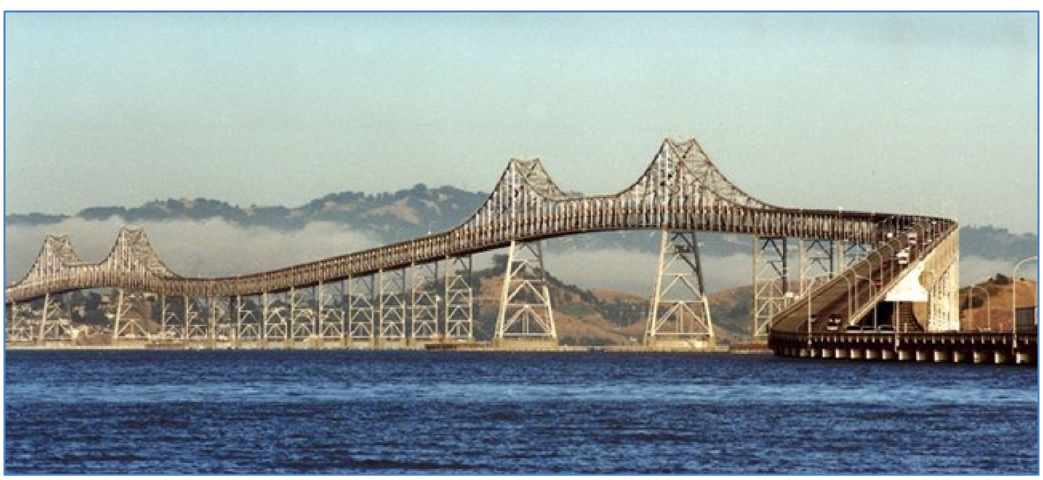

Figure 2-2: Richmond-San Rafael Bridge

2.3. INITIAL TRAFFIC SETUP ACROSS BRIDGE

This section presents a brief overview of the traffic setup and traffic conditions that existed on and around the Richmond-San Rafael Bridge at the beginning of the study. Comparisons to the current setup are made where appropriate to highlight modifications that were made over time not related to the pilot study.

Specific elements discussed include:

- Lane configuration on bridge approaches
- Lane configuration on the bridge's upper and lower decks
- Westbound tolling operations
- Initial traffic conditions

2.3.1. LANE CONFIGURATION ON BRIDGE WESTBOUND APPROACH

Figure 2-3 illustrates the lane configuration leading to the bridge on the Richmond side of the bridge as it existed in 2015. As indicated, three traffic lanes were carrying the approaching traffic along I-580 West. All available lanes were general traffic lanes, i.e., none were lanes with specific occupancy or vehicle type restrictions. Near the toll plaza, the number of lanes increases from three to seven to accommodate the number of available tool booths. One of these lanes was restricted to vehicles having two or more occupants, while the remaining lanes were open to general traffic. Downstream of the toll plaza, the number of lanes then quickly dropped back to two over a distance of approximately 350 feet.

Figure 2-3: Initial Conditions – Westbound Bridge Approach in Richmond

2.3.2. LANE CONFIGURATION ON BRIDGE EASTBOUND APPROACH

Figure 2-4 illustrates the lane configuration leading to the bridge on the Marin County side before the pilot project. In this case, while I-580 East carried three lanes of traffic on the approach to the bridge, one of the lanes was dropped at the Main Street off-ramp, leaving only two lanes to go across the bridge. Similar to the westbound approach, all available traffic lanes were open to general traffic.

Figure 2-4: Initial Conditions – Eastbound Bridge Approach in Marin County

2.3.3. LANE CONFIGURATION ON THE BRIDGE

On the bridge, two lanes were stripped on both the upper deck and lower deck. This is illustrated in Figure 2-5. While the width of the bridge can accommodate on each deck three lanes with no emergency shoulder, Caltrans typically striped each direction for only two lanes for safety reasons, leaving the third lane for emergencies or maintenance vehicles. This shoulder 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 without disrupting traffic.

Figure 2-5: Initial Conditions – Bridge Upper and Lower Decks

2.3.4. WESTBOUND TOLLING OPERATIONS

Like other east-west Bay Area bridges, a toll is currently assessed for vehicles crossing in the westbound direction, while no toll is charged in the reverse direction. The toll is collected at a plaza located on the Richmond side of the bridge, approximately 550 feet from its foot. Figure 2-6 provides an aerial view of the toll plaza area, while Figure 2-7 provides close-up views of the toll booth setup before March 2020.

The toll plaza allows traffic to pay the bridge toll through seven tool booths. Not all booths are necessarily open at a given time, as one or two lanes may be closed during low-traffic periods. Before March 2020, the traffic lanes at the toll plaza were configured as follows:

- The left lane was dedicated as a high-occupancy vehicle (HOV) lane. Its use was restricted to vehicles equipped with an electronic FasTrak toll transponder and carrying two or more passengers (HOV 2+ lane)
- The second and third lanes from the left were restricted to any vehicle equipped with an electronic transponder.
- The last four remaining lanes on the right were dedicated to general traffic and had toll collectors handling cash payments in addition to electronic toll readers.

Since then, tollbooth operators have been eliminated and replaced with a license-plate reading electronic toll collection system, leading to the configuration illustrated in Figure 2-8:

- The left lane is still designated as an HOV lane and restricted to vehicles having a FasTrak transponder. However, occupancy requirements have been upped to vehicles carrying three or more passengers (HOV 3+ lane).
- The second and third lanes from the left remain restricted to any vehicle equipped with an electronic transponder.
- The last four remaining lanes on the right now can read either FasTrak transponders or vehicle license plates. In the latter case, the toll is charged through an invoice mailed to the registered vehicle owner.

Eventually, it is planned to remove the toll booths and replace them with an open tolling structure.

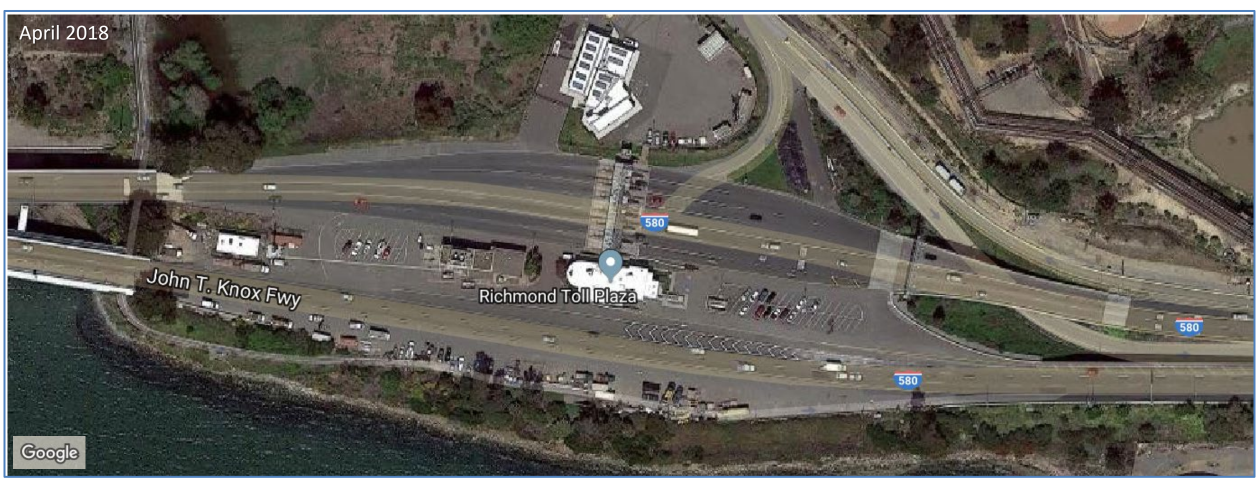

Figure 2-6: Aerial View of Richmond-Toll Plaza Before Modifications

Figure 2-7: Approach to Richmond-Toll Plaza before March 2020

Figure 2-8: Approach to Richmond-Toll Plaza in April 2023

2.3.5. INITIAL TRAFFIC CONDITIONS

As indicated in Table 2-1, the Richmond-San Rafael bridge carried an average daily traffic flow (AADT) of approximately 78,000 vehicles in 2015, when planning for the pilot project was initiated. This increased to 82,000 vehicles in 2017 but decreased to 76,400 in 2019 before returning to 78,000 in 2022. As further shown in the table, this AADT is noticeably lower than other Bay Area bridges, except for the Dumbarton Bridge. This is in great part due to the lower number of lanes on the bridge (two instead of three, four, or five) and its location relative to the main traffic destinations in the region.

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

Bridge Name	Connections	Route	Lanes per Direction	2015 AADT	2017 AADT	2019 AADT	2022 AADT
Carquinez Strait	Martinez – Benicia	I-680	4	115,000	128,100	123,000	118,000
Richmond-San Rafael	Richmond – San Rafael	I-580	2	78,000	82,000	76,400	78,000
San Francisco Bay	Oakland – San Francisco	I-80	5	260,000	278,000	274,000	231,000
Golden Gate	Marin County – San Francisco	US-101	3	110,000	117,600	117,000	92,000
San Mateo	Hayward – San Mateo	SR-92	3	103,000	112,400	117,000	103,000
Dumbarton	Fremont – Palo Alto	SR-84	3	70,000	74,600	74,000	68,000

(Source: 2015, 2017, 2019, and 2022 Caltrans Traffic Census)

During a typical weekday, travel demand on the bridge is highly directional, with traffic mainly moving westbound towards Marin County in the morning and eastbound towards the city of Richmond during the afternoon peak. Peak westbound traffic typically occurs between 7 and 8 AM, while peak westbound traffic typically occurs between 4 and 6 PM. A similar directional pattern is observed on weekends, with peak eastbound traffic between 11 AM and 2 PM, and peak westbound traffic around 5 PM.

Over time, increased volumes have led to increasing congestion on the westbound approach to the bridge. As indicated in Figure 2-3, the two main congestion-contributing factors were the toll collection activities and the fact that the bridge only carried two lanes of traffic while the freeway approach had three. While it was often hypothesized that the toll collection activities were the primary cause of congestion, merging activities downstream of the plaza was the likely culprit. Following a continuous reduction in the number of vehicles paying the toll with cash, the expectation was that congestion upstream of the plaza would reduce. This did not happen. By increasing the rate at which vehicles were able to go through the toll plaza, the adoption of electronic toll transponders by motorists resulted in more vehicles entering the merge area downstream of the plaza. This, in turn, caused increased friction and slower speeds at the entrance of the bridge that propagated back through the toll booths.

The eastbound approach in Marin County, shown in Figure 2-4, also experienced a significant increase in congestion during the PM peak period due to increased traffic. In this case, the congestion was primarily caused by a reduction in the number of traffic lanes from three to two as the right-most lane converts to an exit lane approximately 2,000 feet from the foot of the bridge. Traffic merging from Main Street onto the freeway through a very short acceleration lane also contributed to the problem.

2.4. INITIAL PEDESTRIAN/CYCLIST BRIDGE ACCESS

Before the pilot project, there were no physical accommodations on the bridge for bicycles or pedestrians. To cross the bridge, the only option had been to take transit buses.

The only regular transit service across the bridge was, and is currently still, offered by Golden Gate Transit, a local transit agency serving Marin and Sonoma counties, with limited service to San Francisco and Contra Costa County. To accommodate bicyclists, most of the Golden Gate Transit buses are equipped with exterior bike racks at the front of the bus or underbelly bike racks, as shown in Figure 2-9.

Figure 2-9: Golden Gate Bus Carrying Bikes on Front Rack

Between 2015 and December 2021, primary service across the bridge was offered by buses on Route 40. As shown in Figure 2-10, this route provided service between the El Cerrito Del Norte BART Station on the east side of the bay to the San Rafael Transit Center on the west side. Before January 2016, two other routes also ran across the bridge: Routes 42 and 580. Route 42 was eventually merged with Route 40, while Route 580 was a pilot service that only ran from December 2014 to December 2015, from Emeryville to the San Rafael Transit Center via San Pablo Avenue in Berkeley and I-580, as shown in Figure 2-11. Between 2017 and mid-2020, Route 40X also ran from the same origin to the same destination as Route 40 during the afternoon peak, but with fewer stops.

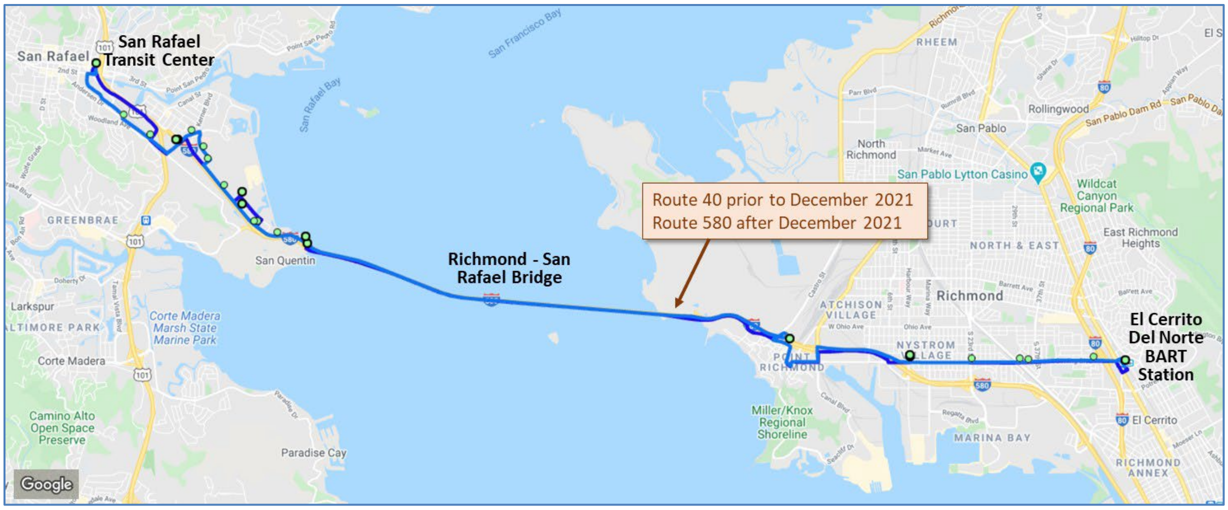

Figure 2-10: Golden Gate Transit Service across the Richmond-San Rafael Bridge

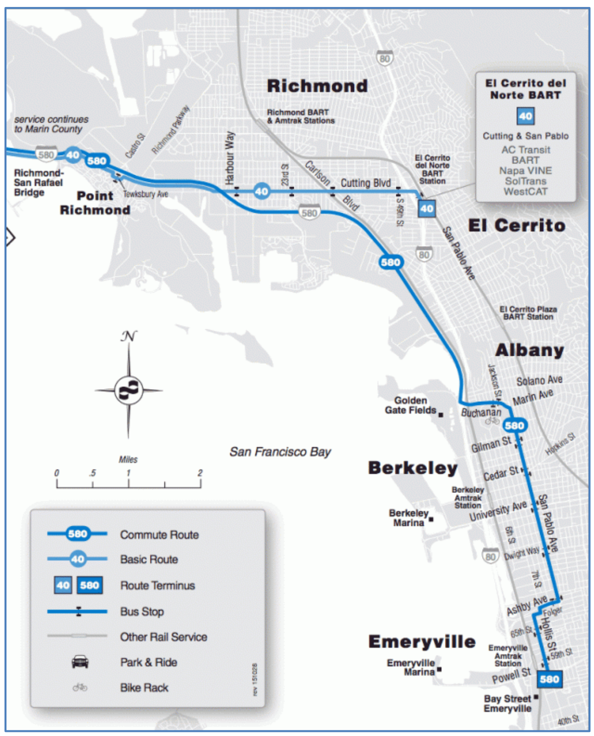

Figure 2-11: Golden Gate Transit Pilot Route 580 Service

In response to a significant drop in demand due to the COVID-19 pandemic, service on Route 40 was reduced in the summer of 2020, while Route 40X was suspended. In December 2021, to help the customers better distinguish between routes offered by Golden Gate Transit from those offered by other agencies, Route 40 was renamed Route 580, without any service change. As of April 2024, Route 40x has not been reinstated. It appears to have been permanently discontinued, likely because of low transit demand, leaving only one route crossing the bridge.

2.5. SAN FRANCISCO BAY TRAIL PROJECT

The San Francisco Bay Trail is a project from the Metropolitan Transportation Commission (MTC) and the Association of Bay Area Governments that calls for the development of a continuous 500-mile network of biking and hiking trails encircling the San Francisco Bay, San Pablo Bay, and Carquinez Strait. By 2021, about 350 miles of trails had already been completed. As shown in Figure 2-12, plans were made to use, if possible, all Bay Area bridges to connect various sections of the networks on each side of the bay. This vision provided strong advocacy for converting one of the shoulders on the Richmond-San Rafael bridge into a bike/pedestrian path.

Figure 2-12: San Francisco Bay Trail Network (2019 Brochure)

2.6. PILOT BRIDGE MODIFICATIONS

To address the traffic and pedestrian/bicycle issues identified above, a consortium comprised of Caltrans, the Bay Area Transportation Authority (BATA), the Metropolitan Transportation Commission (MTC), and local agencies started formulating in 2014 a pilot project that would allow for vehicular traffic to use the eastbound shoulder on the bridge lower deck during the afternoon peak periods while at the same time constructing a multi-use path for bicycles and pedestrians on the westbound shoulder on the upper deck. The objectives of this pilot were twofold:

- To reduce congestion on eastbound I-580
- To provide a bike/pedestrian link between the two counties.

The proposed pilot, known as the *Richmond-San Rafael Bridge Access Improvements Pilot Project*, was formally approved in the summer of 2015. As illustrated in Figure 2-13 and Figure 2-14, it included the following key modifications to be made to the bridge and its approaches:

- **Bridge upper deck (westbound direction):**
    - Conversion of the existing shoulder into a two-way bike/pedestrian path.
    - Addition of a movable zipper barrier from the foot of the bridge in Richmond to the Main Street intersection in Marin County, to separate the multi-use path from the vehicular traffic while allowing maintenance vehicles to retain the ability to access the path.
    - Shortening of traffic merge area downstream of the toll plaza from 850 ft to 325 ft.
    - Construction of a connecting bike/pedestrian path separated by a fixed barrier between Marine Street in Richmond and the bridge, along the right side of the freeway and the Stenmark Drive off-ramp.

- **Bridge lower deck (eastbound direction):**
    - Conversion of the existing shoulder into a part-time traffic lane, opened each week and weekend day between 2 PM and 7 PM.
    - Installation of electronic traffic signs above the traffic lanes indicating whether a lane is opened (green arrow), closed (red X), or still open at the entrance of the bridge but closed at some point further down (yellow X indicating that traffic should merge to the next lane).
    - Installation of electronic traffic signs on the bridge approach to indicate when the shoulder is operating as a traffic lane.
    - Conversion of the auxiliary lane between Sir Francis Drake and the Main Street off-ramp in Marin County into a general-purpose traffic lane.
    - Addition of a third traffic lane between the Main Street exit in Marin County and the bridge.
    - Addition of a third traffic lane between the bridge and the Marine Street on-ramp in Richmond.

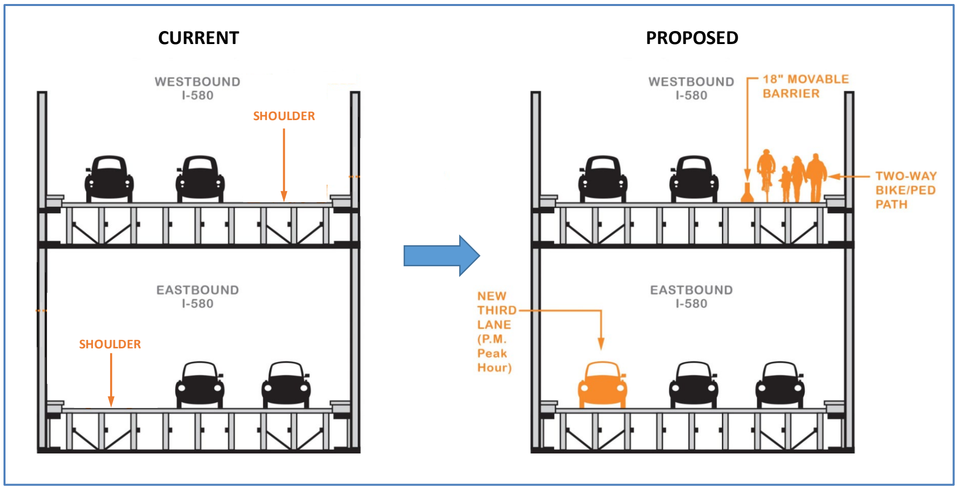

Figure 2-13: Proposed Bridge Modifications

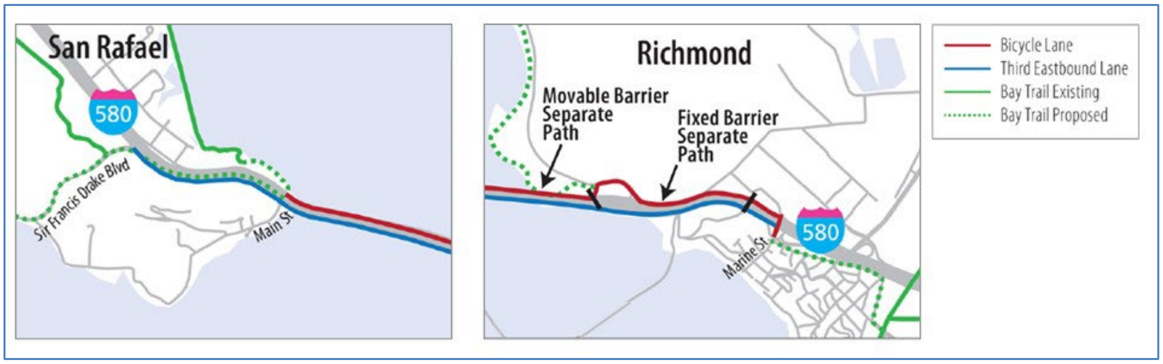

Figure 2-14: Bike Trail Modifications on Eastern and Western Bridge Approaches

The eastbound modifications on the bridge were completed in early 2018, with the shoulder opening to traffic on Friday, April 20, 2018. Construction of the multi-use path on the upper deck was completed in March 2019, with the path officially opened for use on Monday, November 18, 2019.

Figure 2-15 through Figure 2-21 present illustrations of the completed work. Figure 2-15 provides a Google Street View snapshot of the bridge's lower deck with the installed overhead lane control signs, while Figure 2-16 provides a snapshot of the roadside sign explaining the lane control symbols used. Figure 2-17 presents snapshots of the electronic message signs that have been installed on the eastbound approach to indicate whether the shoulder is open or closed. Figure 2-18 further presents a view of the upper deck with the bikeway and moveable barrier, while Figure 2-19 presents a snapshot of the western end of the path along the Main Street off-ramp in Marin County. The aerial pictures of Figure 2-20 and Figure 2-21, finally, indicate the various modifications that were made to the eastern and western approaches to the bridge to accommodate the changes made on the bridge.

Figure 2-15: Electronic Lane Control Signs on Lower Deck

Figure 2-16: Sign Explaining Electronic Lane Control Displays

Figure 2-17: Dynamic Sign Indicating Shoulder Open Status

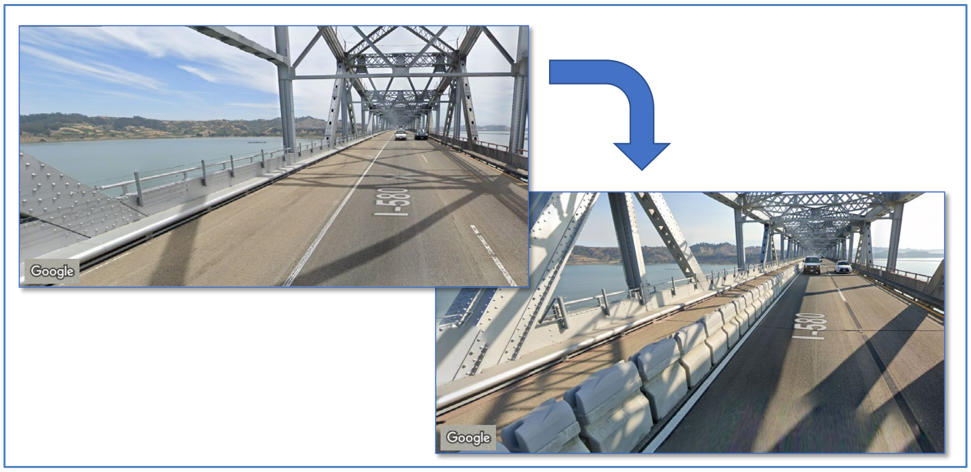

Figure 2-18: Upper Deck Modifications for the Bike/Pedestrian Path

Figure 2-19: Bike/Pedestrian Path Western End Along Main Street Off-Ramp

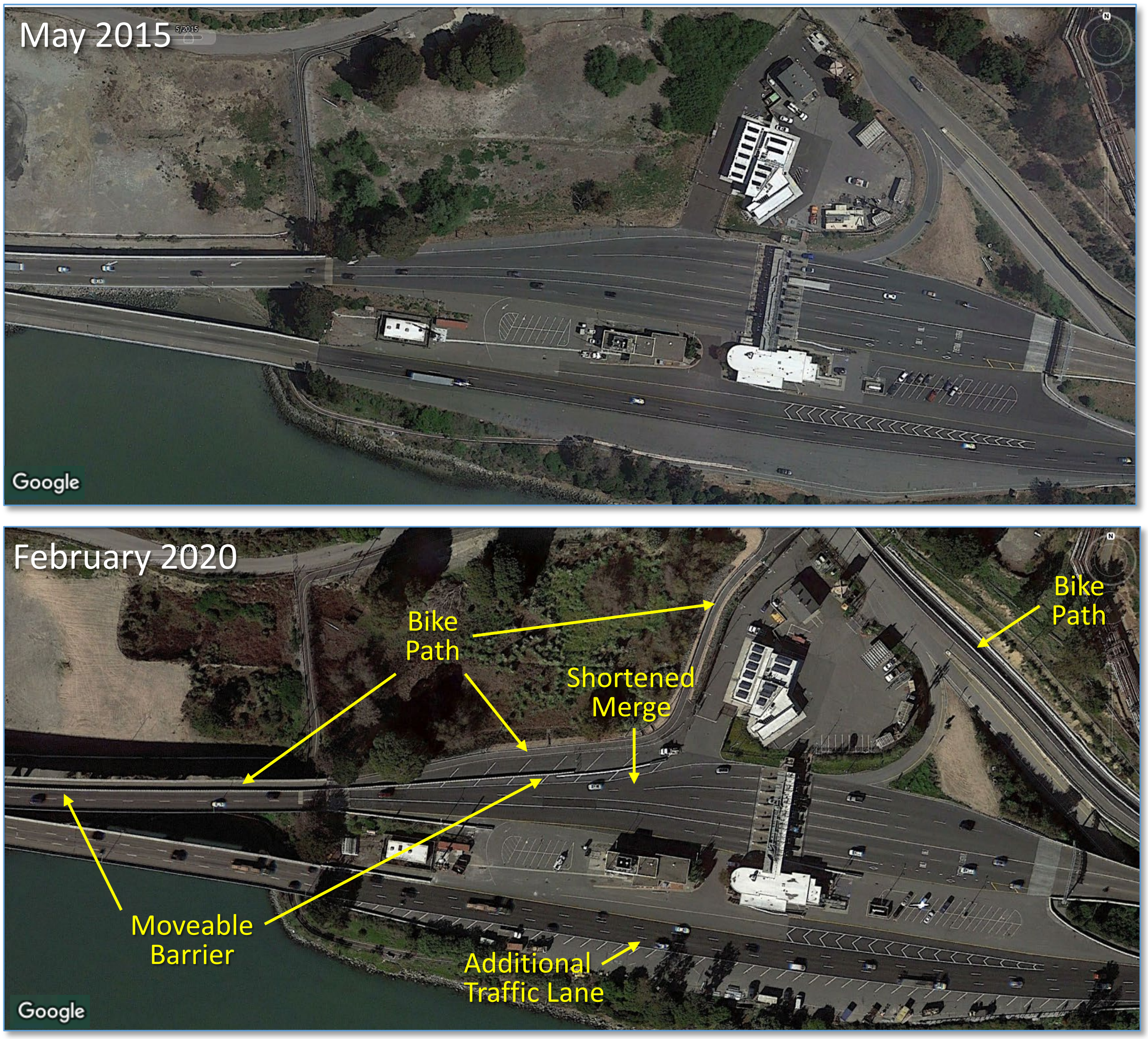

Figure 2-20: Modification of Richmond Approach

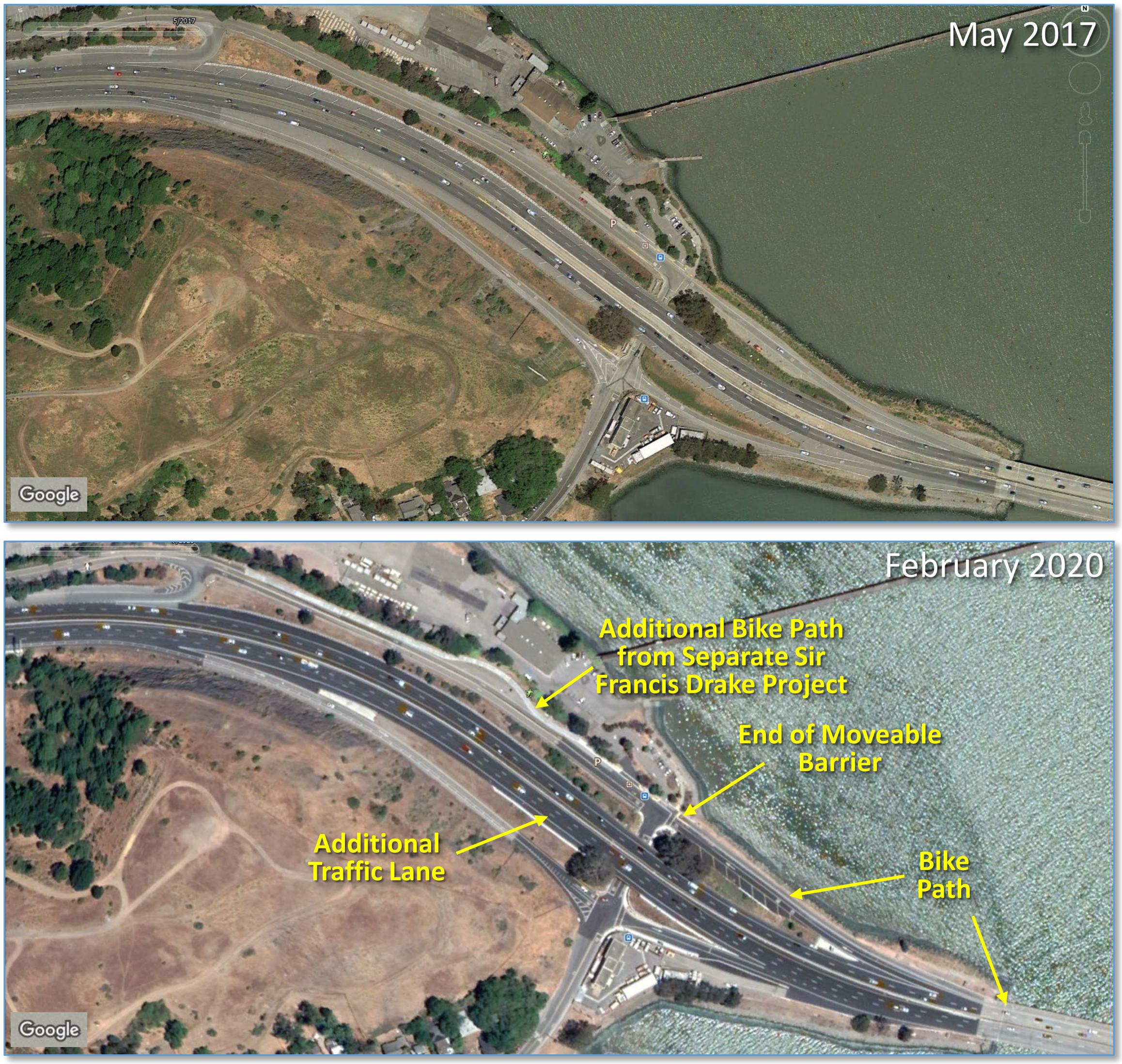

Figure 2-21: Modifications of Marin County Approach

2.7. PILOT SIR FRANCIS DRAKE OVERCROSSING CORRIDOR MODIFICATIONS

In addition to the bridge modifications, changes were made in the summer of 2020 to resolve connectivity gaps between the bridge and the existing Andersen Drive bike path corridor on the Marin County side of the bridge. Figure 2-22 illustrates the key elements of the corridor before the modifications. These included:

- A 6-foot wide, one-way Class II bike lane between Francisco Boulevard and Andersen Drive that allows cyclists traveling westbound to cross I-580 along the Sir Francis Drake off-ramp overcrossing (photos #1, #2, and #3).
- A path allowing cyclists to use the I-580 East on-ramp at Sir Francis Drake Boulevard and then the I-580 East freeway shoulder to reach San Quentin's Main Street (photos #4, #5, and #6).
- Bike lanes on each side of Andersen Drive (photo #3).

Figure 2-22: Before Conditions – Sir Francis Drake Overcrossing Path

To improve connectivity, the following changes were made to the corridor to produce the situation illustrated in Figure 2-23:

- Conversion of the existing one-way Class II bike lane on the Sir Francis Drake overcrossing into an 8-foot wide, barrier-separated, two-way Class IV bike path connecting Francisco Boulevard and Andersen Drive (photos #1 and #2).
- Reduction of the shoulder width for vehicular traffic on the overcrossing to 1 foot, together with a reduction of the width of the traffic lane from 12.0 feet to 11.5 feet.
- Changes to the Sir Francis Drake Boulevard /Andersen Drive intersection to improve the channelization of both bike and vehicular traffic (photo #3).
- Enhanced marking for the bike route running along the I-580 shoulder between the Sir Francis Drake on-ramp and the Main Street off-ramp (photos #4, #5, and #6).
- Construction of a Class I bike path along Francisco Boulevard, between the end of the bridge path at Main Street and the start of the Sir Francis Drake overcrossing path at Grange Avenue.

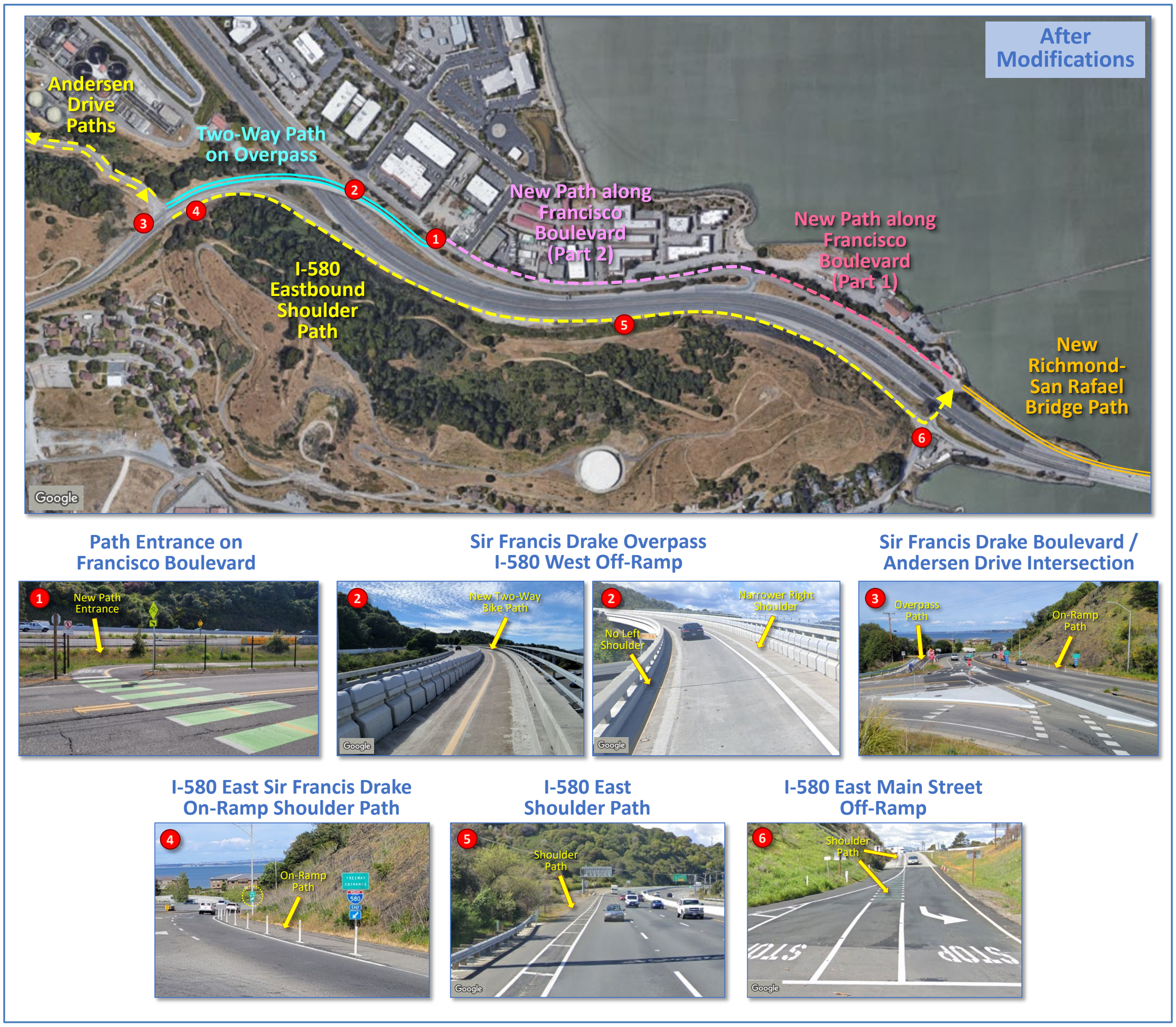

Figure 2-23: After Conditions – Sir Francis Drake Overcrossing Path

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3. EVALUATION OBJECTIVES

The conversion of the eastbound shoulder into a part-time traffic lane and the conversion of the westbound shoulder into a barrier-separated bike/pedestrian path was expected to change how the bridge operates. In both directions, a key concern was the fact that the loss of the shoulder could significantly reduce bridge accessibility for emergency and maintenance vehicles. Another concern was that the installation of a physical barrier on the upper deck could cause the westbound traffic to travel slower on the bridge and increase congestion on the Richmond side of the bridge. Finally, some individuals argued that opening the bridge to pedestrians and cyclists could also generate additional emergency responses on the bridge and negatively impact westbound traffic, particularly if the problems occur during peak traffic periods.

Similarly, to the bridge modifications, some concerns existed regarding the conversion of the existing one-way bicycle path on the I-580 West Sir Francis Drake off-ramp overcrossing west of the bridge into a two-way bike path. A key concern was whether the narrowness of the new bike path would create some safety hazards for cyclists. There were also concerns about how the removal of the traffic shoulder and the addition of a barrier would affect traffic and maintenance operations on the overcrossing.

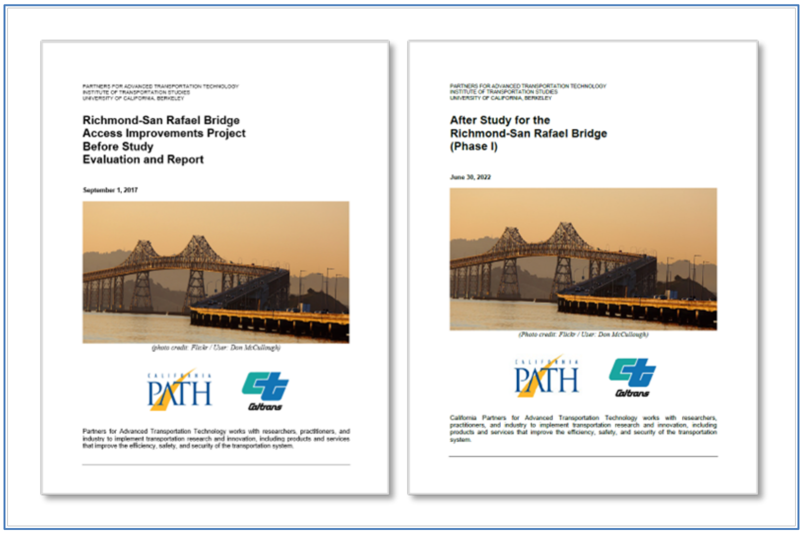
To assess the extent of these potential impacts, Caltrans commissioned the University of California, Berkeley to monitor the changes in bridge and overcrossing operations that may result from the modifications. The results of this evaluation are to be used by Caltrans to assess whether the improvements are to be kept, in whole or in part, at the end of the four-year evaluation period, or removed altogether. This meant first assessing operations before the changes and then reassessing them at various points in time after the completion of the modifications.

Specific elements that were to be evaluated included:

- Use of the eastbound shoulder on the bridge's lower deck during periods of authorized and unauthorized use
- Use of the new multi-use path on the bridge's upper deck by cyclists and pedestrians
- Use of the modified two-way path on the Sir Francis Drake overcrossing by cyclists, including potential shifts in traffic from the I-580 East shoulder path
- Congestion on the eastbound and westbound approaches to the bridge
- Traffic conditions on the bridge itself
- Traffic on local arterials near the freeway
- Rate and severity of major traffic incidents occurring on the bridge and its approaches
- Clearance time of incidents occurring on the bridge
- Impacts on maintenance activities on the bridge
- Impacts on quality of life in Marin County areas near the bridge

A "before evaluation" report covering the first part of the evaluation was completed and released in September 2017. See Figure 3-1. Another report detailing initial findings from the upper and lower deck bridge modifications was subsequently released in June 2022. The present report presents updated findings assessing impacts surrounding the installation of the multi-use path on the upper deck of the bridge and evaluations of the modifications made to the existing bike path along the I-580 West Sir Francis Drake Boulevard off-ramp overcrossing on the Marin County side of the bridge.

No additional findings are presented regarding the conversion of the eastbound shoulder into a part-time traffic lane on the lower deck of the bridge as the findings of the previous report were unambiguously established. The focus of this report is thus on the impacts surrounding the bike/multiuse paths.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INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

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

September 1, 2017

(photo credit: Flickr / User: Don McCullough)

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INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

After Study for the
Richmond-San Rafael Bridge
(Phase I)

June 30, 2022

(Photo credit: Flickr / User: Don McCullough)

California Partners for Advanced Transportation Technology works with researchers, practitioners, and industry to implement transportation research and innovation, including products and services that improve the efficiency, safety, and security of the transportation system.

Figure 3-1: Covers of Previous Before and Phase I After Evaluation Reports

4. STUDY AREA

The evaluation of the changes brought over by the bridge modifications was not strictly limited to what happened on the bridge and its eastern and western approaches. It also included an assessment of potential impacts on important local arterials on both the Marin County and Richmond sides of the bridge. Below is a more detailed listing of the roadway segments that were considered in the evaluation:

- **I-580 segments (Figure 4-1):** Sections from US-101 to the bridge in Marin County, on the bridge, around the toll plaza, from the toll plaza to Cutting Boulevard in Richmond, and from Cutting Boulevard to I-80.
- **US-101 segments (Figure 4-1):** Segments from Madera Boulevard to Second Street interchanges, covering the I-580 and Sir Francis Drake Boulevard interchanges.
- **Sir Francis Drake overcrossing (Figure 4-21):** Section of Sir Francis Drake Boulevard between Andersen Drive and I-580 in Marin County.
- **Local streets in Richmond (Figure 4-2):** Stenmark Drive, Marine Street, Castro Street, Richmond Parkway, Cutting Boulevard, and Harbour Way.
- **Local streets in Marin County (Figure 4-3):** Stenmark Drive, Marine Street, Castro Street, Richmond Parkway, Cutting Boulevard, and Harbour Way.

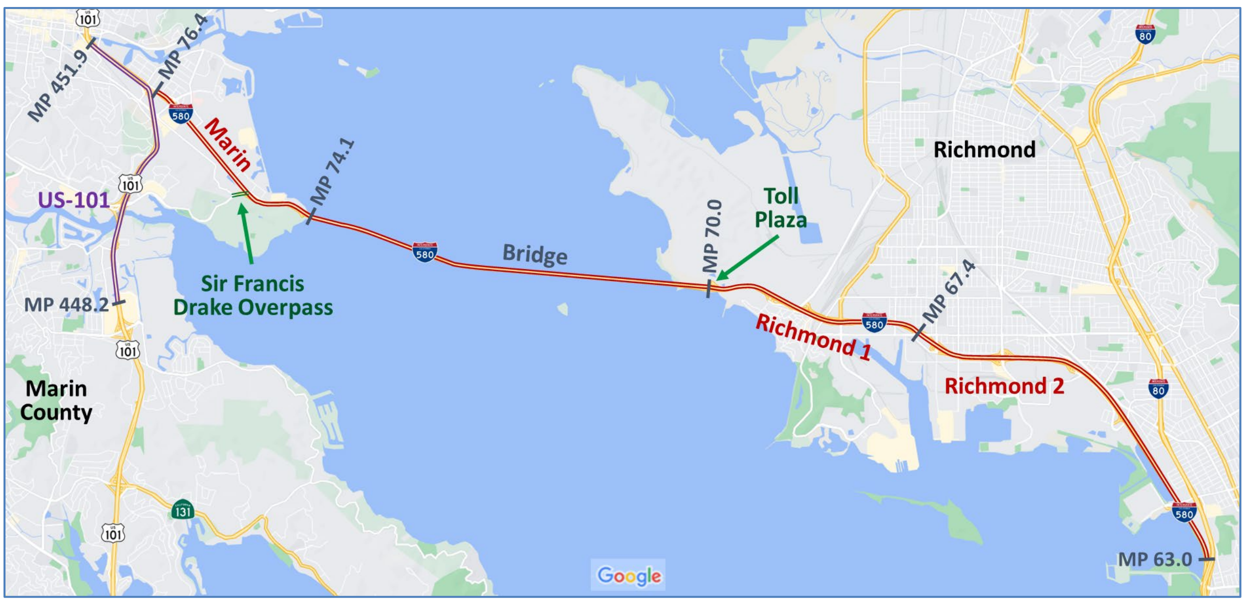


Figure 4-1: Freeway Segments of Interest

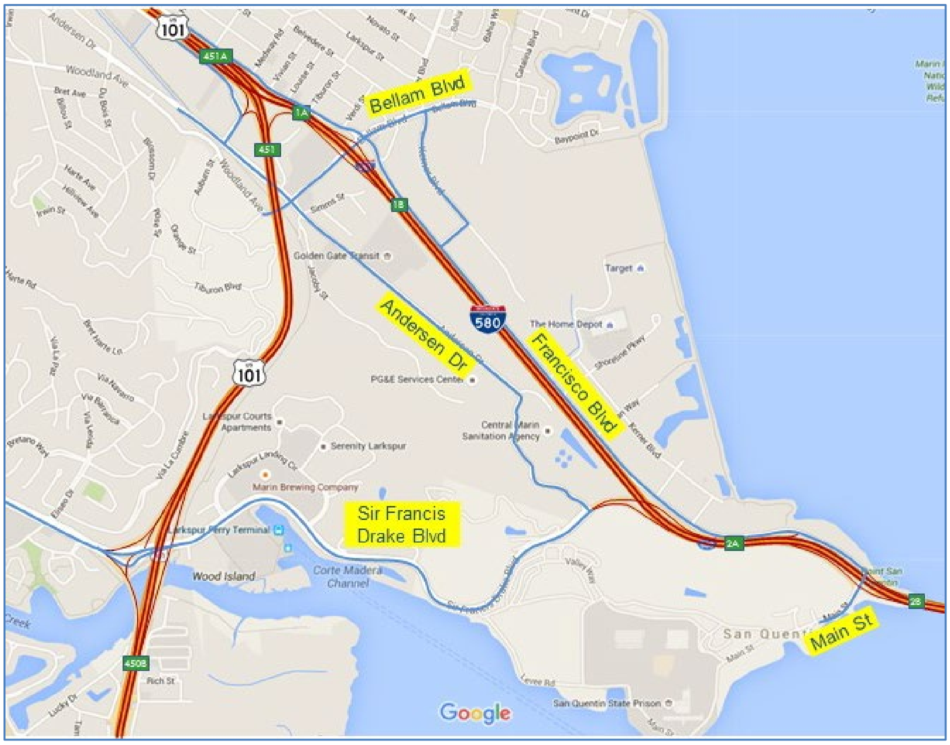


Figure 4-2: Arterials of Interest on Marin County Side

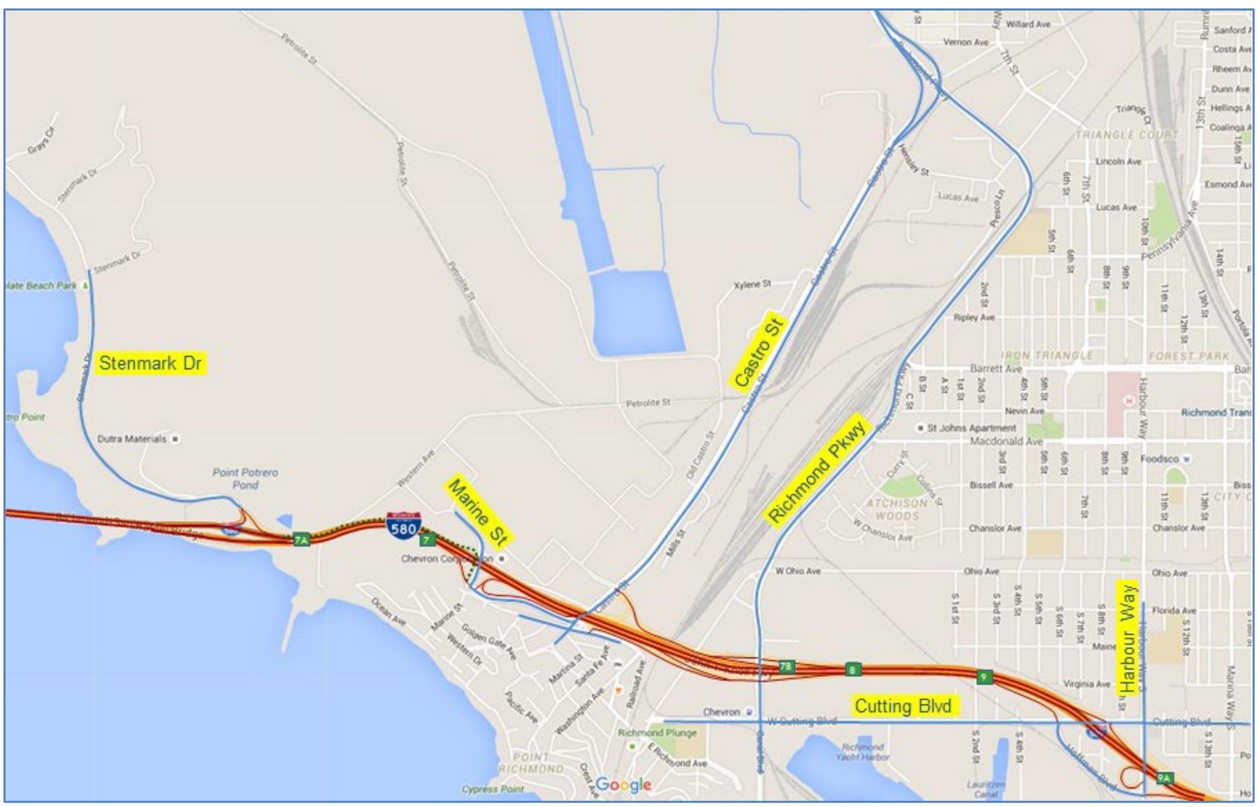


Figure 4-3: Arterials of Interest on the Richmond Side

5. DATA COLLECTED

This section presents a summary of the data that was collected to evaluate the impacts of the implemented modifications on traffic, safety, maintenance, and quality of life. The following sections provide more detailed information about:

- Data collection periods
- Traffic count data
- Travel time data
- Bike and pedestrian counts
- Incident data
- Incident response data
- Maintenance activity data
- Bridge path user survey
- Business surveys

5.1. DATA COLLECTION PERIODS

Figure 5-1 illustrates the various data collection periods that were considered for the evaluations. With construction initially scheduled to start in late 2016 or early 2017, the period between July 2015 and June 2016 was selected as the preferred one for assessing bridge operations before the implementation of the proposed changes. This was the closest one-year period during which bridge operations would not have been disturbed by construction activities. However, the selection of this period did not preclude the collection of additional data outside this period should the need arise.

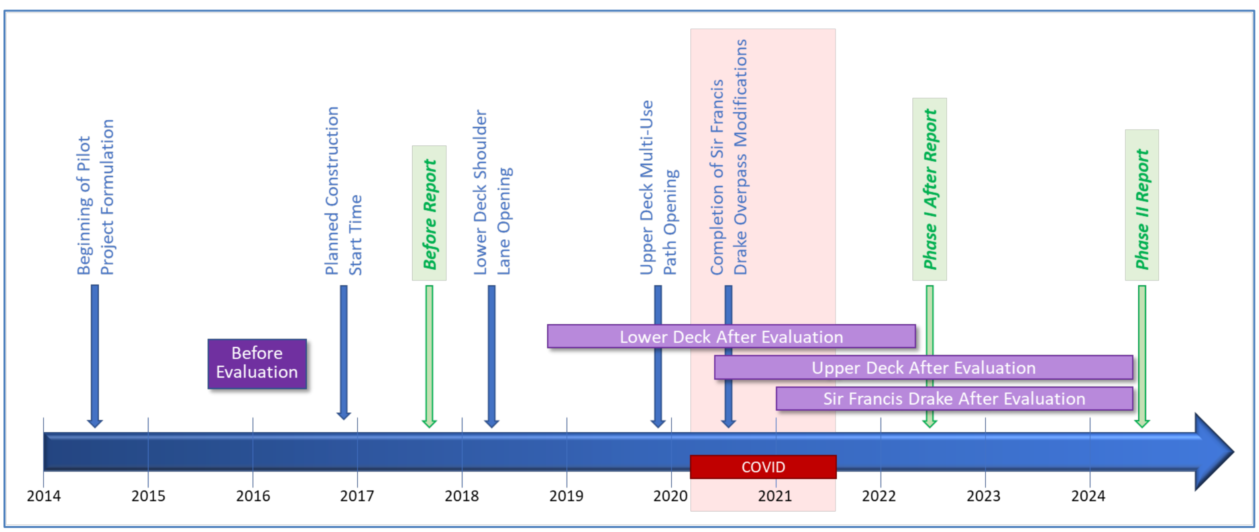


Figure 5-1: Data Collection Periods

For the after period, data collection was initially set to start approximately 6 months after completion of construction activities, to allow enough time for traveler behavior to settle following the introduction of the new elements. This evaluation was again set to cover at least one year. Based on the expected April 2018 opening of the eastbound path-time traffic lane on the lower deck of the bridge, this meant starting data collection for the lower deck evaluation no earlier than October 2018. For the upper deck, this further meant starting data collection no earlier than May 2020 based on the path's anticipated November 2019 opening.

The above data collection plans were derailed by the COVID-19 pandemic. Following the imposition of a stay-at-home order in mid-March 2020, vehicle traffic across the bridge dropped by more than 50% in April and May 2020. This likely affected bicycle and pedestrian traffic across the bridge as well. Because of these unusual changes, the data collection for the after period had to be postponed until traffic would return close to pre-COVID conditions. By the end of June 2021, most work-related COVID restrictions had been lifted and both weekday and weekend peak time traffic had returned close to pre-COVID levels, even slightly exceeding them in some time intervals. However, off-peak traffic remained significantly below pre-COVID levels, with night traffic still ranging between 30 and 50% below pre-COVID levels. While off-peak traffic continued to adjust back towards pre-COVID conditions throughout 2022 and 2023, some lingering effects remained at the end of 2023.

Despite COVID-19's effects, sufficient data were deemed to have been collected by early 2022 to adequately assess the impacts of the part-time traffic lane on the bridge's lower deck. This was not the case for the multi-use path on the upper deck and bicycle path on the Sir Francis Drake overcrossing as COVID forced a delay in the start of after evaluations. Representative data could not start to be collected before 2022. Data from 2023 were then required to establish adequate trends.

5.2. TRAFFIC COUNTS

The following is a summary of the several types of traffic data that were gathered, or attempted to be gathered, to support the intended evaluations. These include:

- PeMS sensor data
- Toll plaza counts
- Traffic counts for local jurisdictions
- Manual traffic counts executed as part of the project

5.2.1. PEMS COUNTS AND SPEED DATA

Vehicle counts and speed data were collected from the Caltrans Performance Measurement System (PeMS) online application throughout the project. While it was initially thought that PeMS data could fulfill most of the evaluation needs, several continuous or periodical issues affected the ability to use the collected data for the before/after evaluation:

- Most of the stations along I-580 have significant reliability problems. This is illustrated in Figure 5-2, Figure 5-3, and Figure 5-4, which show the percent of direct measurements supplied by each station along the freeway between January 2016 and December 2023, ranging from 0% (red) to 100% (green). A 100% value means that direct measurements are provided for all time intervals, while a 0% value means that all counts are estimated based on an analysis of information from surrounding sensors. Because of potential errors associated with estimated data, only counts having at least 80% observed data were considered valid. This meant that useful data could typically be retrieved only from a small subset of stations.

- On the Richmond side, the two mainline stations on I-580 near Canal Boulevard (stations 400638 and 400739) were the only ones to almost consistently provide reliable data.

- In Marin County, the station on I-580 West upstream of the Bellam Boulevard off-ramp (station 403266) was the most reliable.
- Many of the stations along I-580 and US-101 that produced data in 2016-2017, during the before evaluation, ceased to produce data by 2019, limiting their usefulness to the before evaluation only.
- The three new stations on the bridge installed as part of the pilot project only started to produce data in February 2018, restricting their usefulness to the after-evaluation.
- Several new mainline and ramp stations on each side of the bridge only started to produce data in the fall of 2019, restricting again their usefulness to the after-evaluation.
- Several stations along US-580, both on the Marin County and Richmond sides of the bridge had data collection problems in 2022, likely due to area-wide communication issues.
- The detectors installed on the part-time lane on the bridge's lower deck have had difficulty recognizing that the lane is opened to traffic only during specific periods. Since PeMS assumes that a zero volume might be an error, estimated flows are often provided for the lane when it is closed, resulting in an overestimation of the overall bridge traffic. This problem was remedied by retrieving and processing the raw count data instead of the supplied processed data.

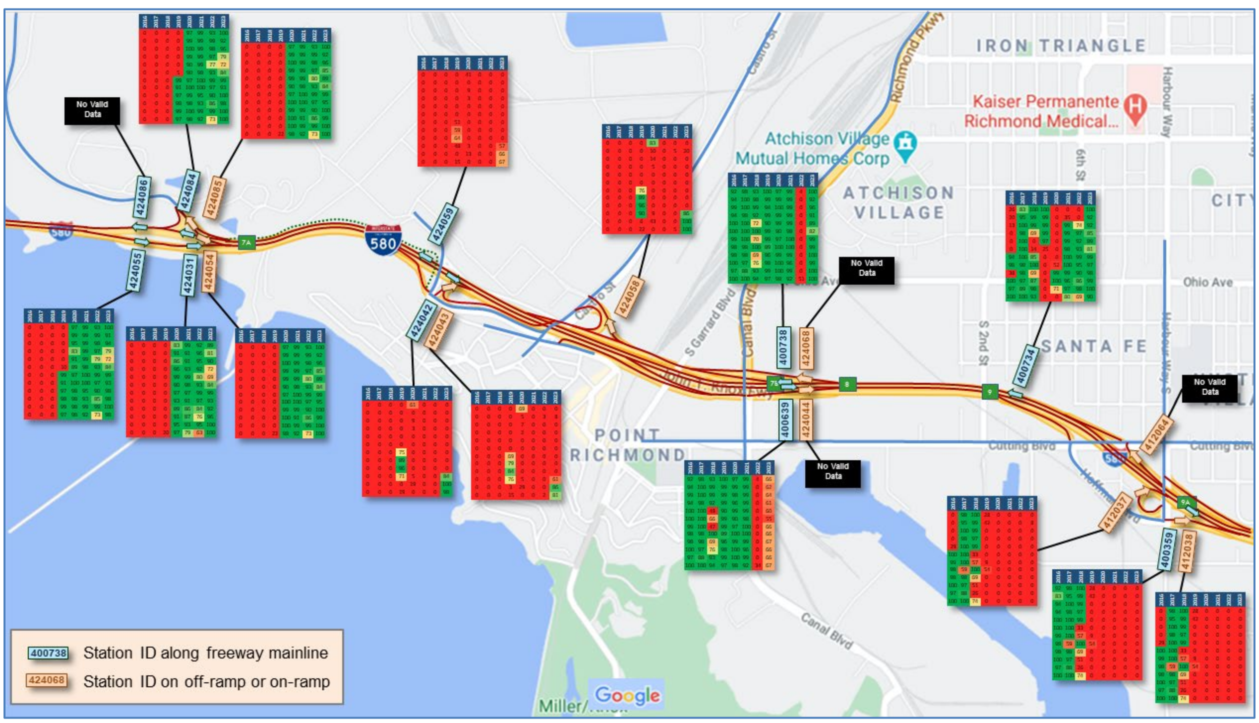


Figure 5-2: Percentage of Observed Data from PeMS Stations on I-580 in Richmond, 2016-2023

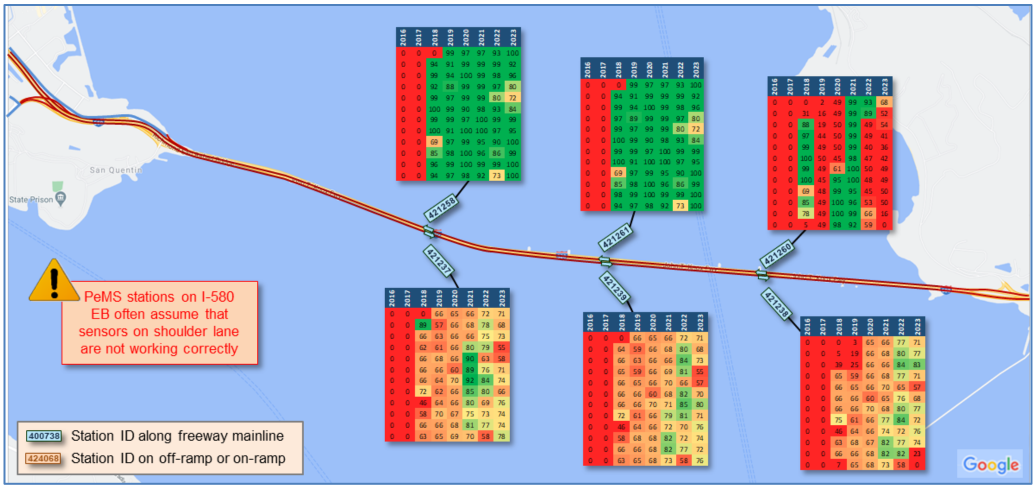


Figure 5-3: Percentage of Observed Data from PeMS Stations on Bridge, 2016-2023

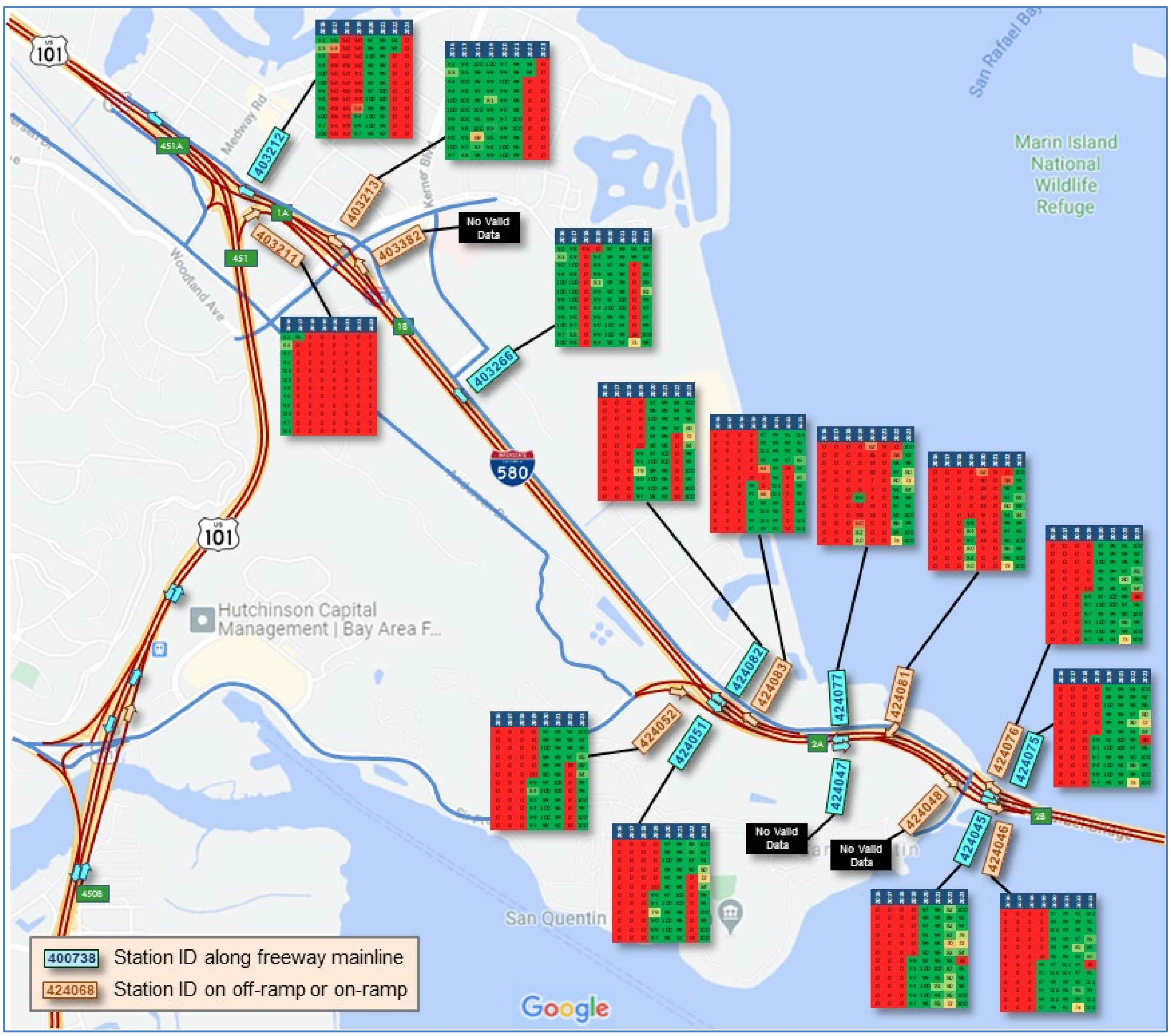


Figure 5-4: Percentage of Observed Data from PeMS Stations on I-580 in Marin County, 2016-2023

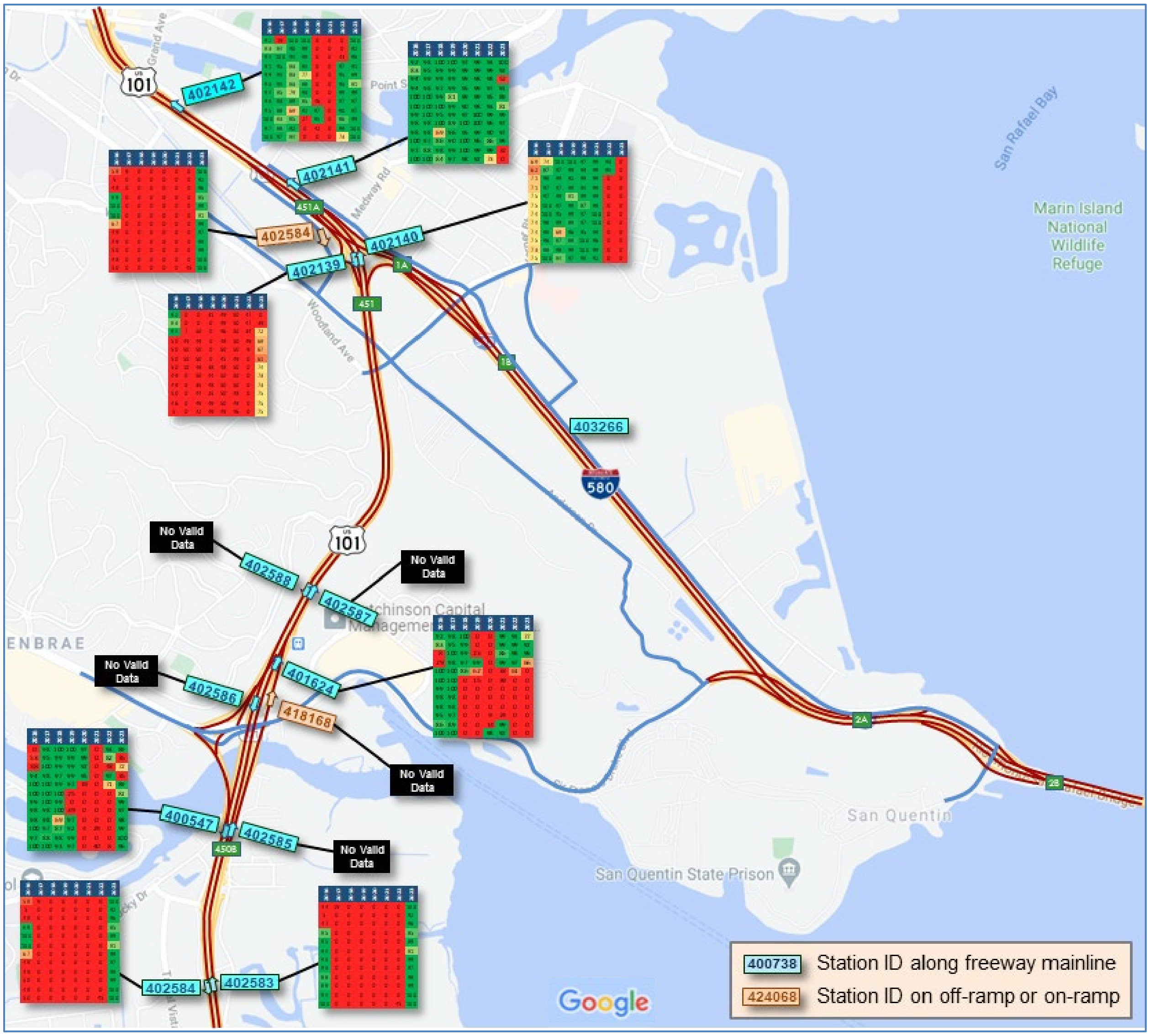


Figure 5-5: Percentage of Observed Data from PeMS Stations on US-101, 2016-2023

5.2.2. TOLL PLAZA COUNTS

The number of vehicles crossing the Richmond toll plaza on I-580 West for each hour of the day between January 2010 and September 2023 was provided by the Bay Area Toll Authority. These counts are from the vehicle detection system used to detect and categorize vehicles across each of the seven toll lanes at the plaza. Because the data can be considered fully accurate, it was used as a reference for the assessment of the westbound traffic accessing the upper deck of the bridge.

5.2.3. TRAFFIC COUNTS FROM LOCAL JURISDICTIONS

Neither Richmond nor the multiple jurisdictions in Marin County had detailed information about traffic on local streets.

5.2.4. MANUAL TRAFFIC COUNTS

To supplement existing data and cover areas without information, National Data and Surveying Services (NDS) was contracted by PATH to conduct manual traffic counts at strategic locations within the study area. The same firm was used for both the before and after data collection as follows:

- For the before evaluation, data were collected between May 10 and May 19, 2016, at the locations shown in Figure 5-6 and Figure 5-7. This included turning counts at 9 intersections and through traffic counts at 4 freeway mainline or interchange-related locations in Marin County, in addition to 11 turning counts and 7 through counts in Richmond, as detailed in Table 5-1
- For the after evaluation, data were collected at the same locations shown in Figure 5-6 and Figure 5-7, except for the two I-580 mainline sites in Marin County, between March 22 and March 24, 2022. Data collection was not repeated at the two I-580 sites in Marin County as traffic detectors installed in the summer of 2019 along the freeway mainline near the Sir Francis Drake Boulevard and Main Street interchanges provided desired freeway volumes.

Table 5-1: Manual Traffic Count Locations

Location	Turning Counts	Through Counts
Marin County	• Main St @ I-580 East Ramps • Francisco Blvd @ Main St • Francisco Blvd @ Irene St • Bellam Blvd @ Francisco Blvd • Bellam Blvd @ I-580 West Ramps • Bellam Blvd @ I-580 East Ramps • Sir Francis Drake Blvd @ Andersen Dr • Sir Francis Drake Blvd @ Larkspur Landing Cir • Sir Francis Drake Blvd @ US-101 North Ramps	• I-580 East, near Irene St • I-580 West, near Irene St • US-101 South off-ramp to Sir Francis Drake Blvd • Sir Francis Drake Blvd East, before US-101 overcrossing
Richmond	• Marine St @ Standard Ave • Castro St @ Standard Ave • Castro St @ I-580 West ramps • Castro St @ Hensley St • Richmond Pkwy @Hensley • Richmond Pkwy @ Ohio Ave • Richmond Pkwy @ I-580 West ramps • Richmond Pkwy @ I-580 East ramps • Cutting Blvd @ I-580 East ramps • Cutting Blvd @ I-580 West ramp • Stenmark Dr @ I-580 West ramps	• I-580 East, west of Toll Plaza • I-580 West, west of Toll Plaza • I-580 East on-ramp near Standard Ave @ Marine • I-580 West on-ramp from Castro St • I-580 West Frontage Road, between off-ramp and on-ramp to Castro Street • I-580 East on-ramp from Tewksbury Ave • I-580 East off-ramp to Richmond Pkwy

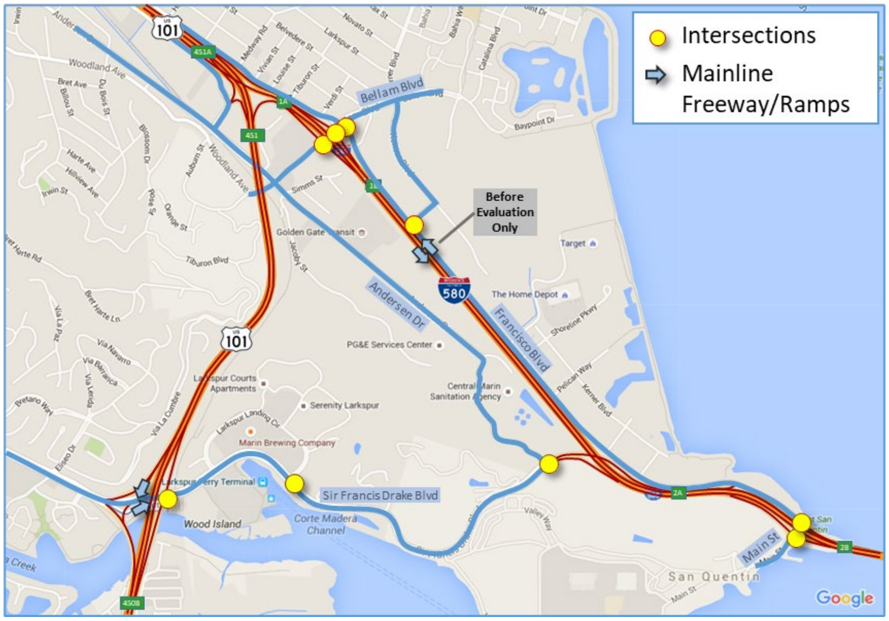


Figure 5-6: Before/After Marin County Manual Count Locations

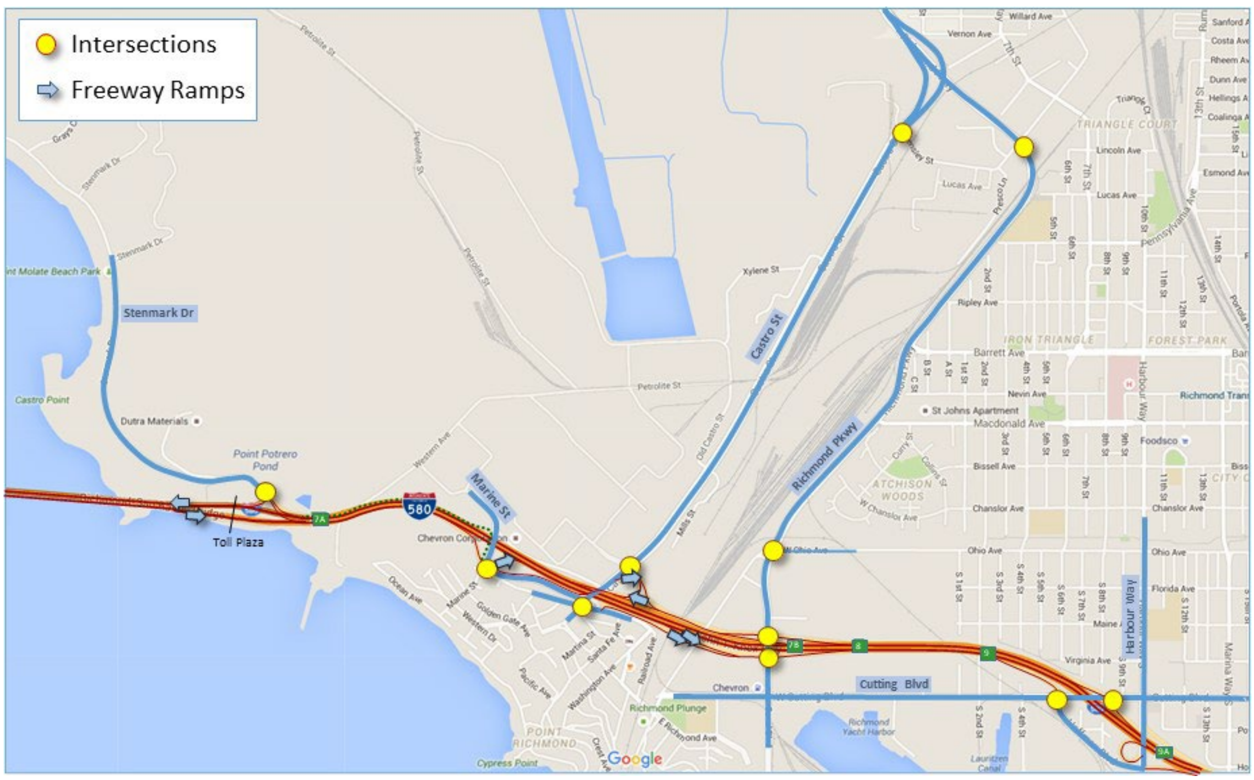


Figure 5-7: Before/After Richmond Manual Count Locations

5.3. TRAVEL TIME DATA

Travel times along key freeway and arterial segments were obtained from the Roadway Analytics module from the INRIX online data analysis platform through a login provided by the MTC. Specific segments for which travel times were collected are shown in Figure 5-8. This includes segments along I-580, US-101, and key arterials within the study area.

Figure 5-8: INRIX Travel Time Study Segments

While the project team initially hoped that Bluetooth data would be available to supplement speeds and travel times obtained from PeMS and INRIX, no such data were found to be available for the study area.

5.4. BIKE/PEDESTRIAN DATA

The following data were collected to characterize the bike and pedestrian demand for the multi-use path on the upper deck of the bridge:

- Automated bicycle and pedestrian counts
- Bicycle Counts from Golden Gate Transit
- Spot pedestrian/bicycle counts at the Sir Francis Drake Boulevard/Andersen Drive intersection
- Video recordings of activity on the Sir Francis Drake overcrossing from a nearby high-resolution I-580 CCTV camera operated by Caltrans.

More details about the collected data are provided in the subsections that follow.

5.4.1. AUTOMATED COUNTS FROM ECO-COUNTER SENSORS

To help monitor bicycle and pedestrian activities along the new bridge multi-use path, BATA installed in November 2019 new automated Eco-Counters around the bridge. The purpose of these counters, which are also used to monitor bicycle and pedestrian traffic at other bridges within the Bay Area, was to provide the agency with continuous counts. Depending on settings, counts could be analyzed on a 15-minute, hourly, daily, monthly, or annual basis.

As indicated by the typical layout of Figure 5-9, Eco-Counter devices rely on a combination of in-pavement loops and a passive infrared sensor to detector bicycles and pedestrians:

- Inductive loops embedded in the pavement are used to detect the metal in bicycles passing in front of them. Following a detection, an algorithm then analyzes the recorded bicycle's electromagnetic signal to determine whether a bicycle should be counted and its direction of travel. This is like systems using pavement loops to detect and count traffic.
- The passive infrared sensor is used to detect the heat of human bodies passing in front of the sensor. Like the bicycle data, an algorithm is then used to determine how many pedestrians have been observed and their direction of travel.

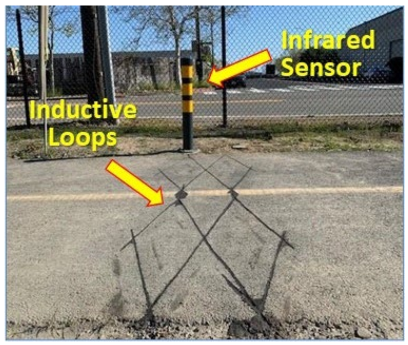


Figure 5-9: Typical Eco-Counter Sensor Installation

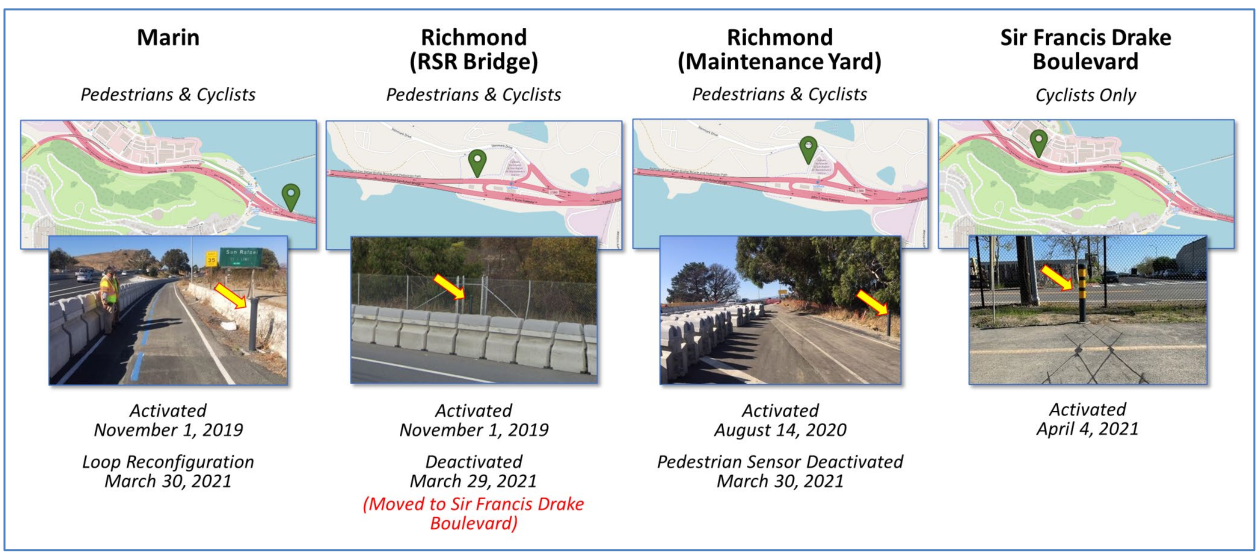


Figure 5-10: Locations of Bike/Pedestrian Eco-Counter Sensors

Figure 5-10 maps the locations from which pedestrian and bike counts have been collected. As indicated at the bottom of the figure, various changes were made to the placement of sensors throughout the study to adjust to technical issues or expand the coverage provided by the procured sensors:

- The first two sensors, dubbed the "Marin" and "Richmond (RSR Bridge)" sensors, were installed on each side of the bridge in November 2019.
- In August 2020, an additional sensor was added near the Caltrans Maintenance Yard at the Richmond toll plaza.

- At the end of March 2021, the initial Richmond sensor was removed to be used along the path going across the Sir Francis Drake of-ramp overcrossing on I-580 West in Marin County, leaving only the Maintenance Yard sensor on the east side of the bridge.
- During the March 2021 reconfiguration, the Marin sensor had its bicycle loop reconfigured to address an eastbound/westbound misdetection issue that was identified through the analysis of the collected data. The pedestrian sensor for the Maintenance Yard sensor was also deactivated, leaving the Marin sensor to be the only remaining one recording pedestrians.

A comparison of the sensor data to video recordings has shown that the sensors generally produce reliable counts. The only identified issue was a potential undercounting of bicyclists traveling in tight groups. This indicates that the actual number of cycles passing in front of each station may be slightly higher than what is reported, particularly on Saturdays and Sundays, when groups of cyclists are more frequently observed.

5.4.2. GOLDEN GATE TRANSIT DATA

Information about the number of bicycles carried over the bridge by Golden Gate Transit buses on their front rack was provided by the agency. This included monthly counts of bicycles by bus route between January 2015 and March 2024. The purpose of collecting this data was to help ascertain whether the traffic observed on the bridge path might be displaced by buses.

5.4.3. CALTRANS MIOVISION TEST RECORDING OF SIR FRANCIS DRAKE OVERCROSSING ACTIVITIES

To help assess potential safety issues associated with the narrower than usual lanes on the Sir Francis Drake overcrossing path, an attempt was made in May 2021 by Caltrans to record a video of activities on the path. To this end, as shown in Figure 5-11, a Miovision camera was placed on a pole in the proximity of the path at a short distance from the intersection with Andersen Drive to provide a view of both the overcrossing path and the I-580 East on-ramp shoulder path.

Test videos were recorded on May 15-16 (Saturday-Sunday) and May 18-19 (Tuesday-Wednesday). Once completed, each recording was uploaded to a Miovision website for post-processing, where a pattern recognition algorithm would identify and count cyclists and pedestrians on the video. For each day, counts were only retrieved from 7 AM to 6 PM as little bicycle traffic is typically observed outside this period. For each 15-minute interval, the post-processing returned the number of cyclists and pedestrians going east and west on the overcrossing path, as well as on the I-580 East on-ramp shoulder path.

Figure 5-11: Snapshot of Sir Francis Drake Overcrossing Video

To validate the video counts, comparisons were made with the bicycle counts from the Eco-Counter installed at the bottom of the overcrossing path. The video-based counts were found to be in general agreement with the Eco-Counter data, except in a few cases. In some cases, the Miovision post-processing mischaracterized cyclists walking beside their bikes, particularly when traveling up the ramp, as pedestrians. Cyclists riding slowly uphill were also occasionally considered pedestrians. Conversely, it was also determined that the Eco-Counters might be missing cyclists traveling in compact groups, as the videos consistently showed slightly higher counts in intervals in which groups could be observed.

While the above analysis was originally intended to help assess whether near misses were occurring on the overcrossing path, the quality of the video did not allow us to see clearly what was happening on it. The retrieved counts were deemed as the only valuable information. A decision was then made to try to look at other means of obtaining visuals of activities on the path.

5.4.4. CALTRANS CCTV VIDEOS OF SIR FRANCIS DRAKE OVERCROSSING

Following the May 2021 video recording test, the project team was informed that it would be possible to periodically record activities on the path using a new high-resolution CCTV camera located east of the overcrossing along I-580 that was installed to periodically check messages displayed on a nearby dynamic sign indicating whether the shoulder on the bridge lower deck is open or closed. Figure 5-12 presents a snapshot of the camera. As shown in Figure 5-13, the high resolution of the camera allowed us to get a fairly detailed zoomed view of the overcrossing path, including the sharp curve at the bottom of the overcrossing. While cyclists appear small, the videos have high enough resolution to assess whether cyclists are slowing down or swerving to avoid individuals traveling in the opposite direction.

Following the establishment of a pre-set view, videos were captured over several periods to try to capture potential seasonal effects, particularly between summer and winter users. Each capture period further spanned weekdays and weekend days to assess potential behavioral differences between the path's weekday and weekend users. Specific periods during which videos were captured are as follows:

- **Winter 2022:** February 14-21 (Monday to the following Monday)
- **Summer 2022:** June 23-26 (Thursday to Sunday)
- **Winter 2022:** December 17-20 (Saturday to Tuesday)
- **Fall 2023:** October 14-17 (Saturday to Tuesday)

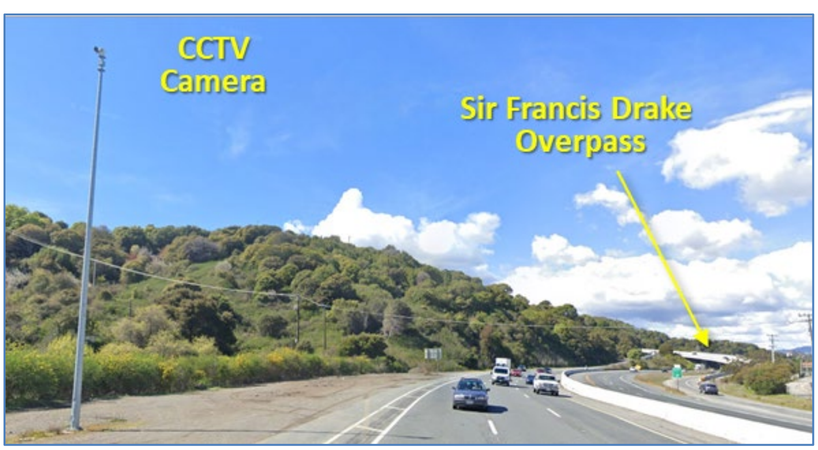


Figure 5-12: Locations of Caltrans CCTV Camera used for Path Safety Evaluations

Figure 5-13: Pre-set View from Caltrans CCTV Camera

5.4.5. NDS SIR FRANCIS DRAKE BOULEVARD / ANDERSEN DRIVE VIDEO COUNTS

To better understand how the conversion of the existing one-way path into a two-way path might have affected trip patterns around the overcrossing, NDS was commissioned to conduct periodic turning counts at the intersection between Sir Francis Drake Boulevard and Andersen Drive. As indicated in Figure 5-14, this is the intersection at the top of the overcrossing, linking the overcrossing path with Sir Francis Drake Boulevard, the existing bike path on Andersen Drive, and the eastbound bike path running along the I-580 East shoulder from the Sir Francis Drake Boulevard on-ramp to the Main Street off-ramp.

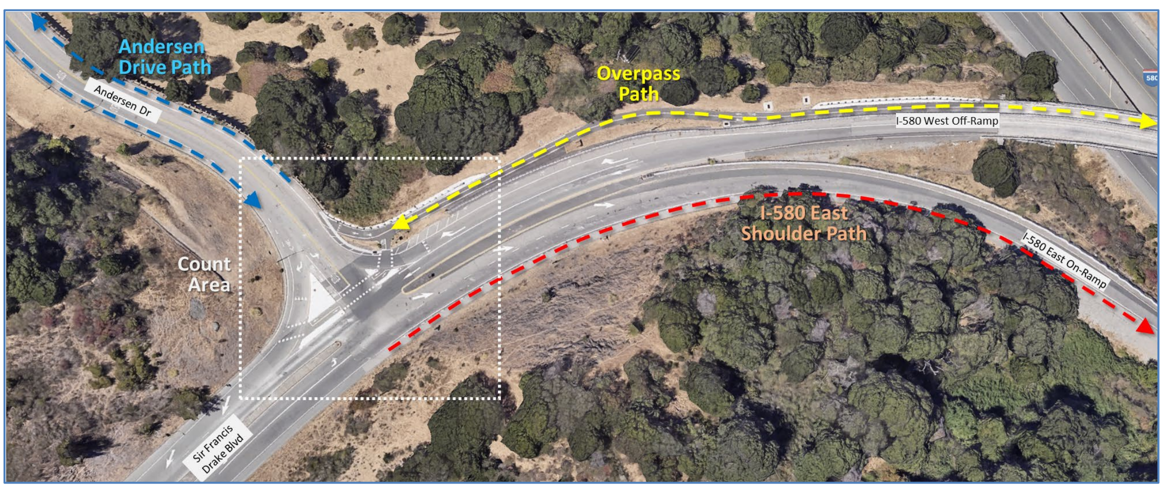


Figure 5-14: Turning Count Location for Sir Francis Drake Overcrossing Evaluation

All turning counts were captured by processing video recordings of traffic movement through the intersection. Counts were conducted during the following periods:

- **Fall 2023:** October 2-8 (Sunday to Saturday)
- **Spring 2023:** February 4-10 (Saturday to Friday, with Wednesday missing due to technical issues)
- **Summer 2023:** July 14-20 (Friday-Thursday)

For each period, turning movements were observed from approximately 7 AM to 6 PM.

5.5. INCIDENT DATA

To assess the impacts of the modifications on the frequency, type, and severity of incidents occurring around the bridge, attempts were made to collect data from the following sources:

- Statewide Integrated Traffic Report System (SWITRS)
- Traffic Incident and Surveillance Analysis System (TASAS)
- Transportation Injury Mapping Systems (TIMS)
- California Highway Patrol Computer-Aided Dispatch (CHP CAD) log data within PeMS
- Processed data from the Bay Area Traffic Incident Management Dashboard
- Incident reports logged by travelers on the Street Story online platform

Attempts were also made to collect and use data from the following sources:

- Bay Area Incident Response System (BAIRS)
- Major Incident Database (MIDB)
- Call Box data
- Incident data from local police agencies

The subsections below describe in more detail the data collection efforts, or issues, associated with each of the above sources.

5.5.1. STATEWIDE INTEGRATED TRAFFIC REPORT SYSTEM (SWITRS) DATA

SWITRS is a CHP database containing information about highway incidents. It essentially aggregates information about incidents that have been submitted by officers on Traffic Collision Reports. It is generally considered to be the definitive source of incident data for state highways. For each collision, this database details its location, time of occurrence, severity, type, number of vehicles implicated, and roadway condition at the time of the incident, among many other parameters. However, incident duration is normally not included.

Where needed, information about specific incidents was retrieved from the CHP's iSWITRS online portal at https://iswitrs.chp.ca.gov/Reports/jsp/CollisionReports.jsp. A snapshot of the incident query page is shown in Figure 5-15. Access to this query tool is open to the public but requires obtaining login credentials from the CHP. It allows obtaining PDF reports detailing all the incidents occurring between specific dates, within a specific county, city, or police jurisdiction. However, it does not allow to perform queries for specific roads. To retrieve incidents associated with I-580, a manual scan of all reported incidents must be performed.

An element of note with this dataset is that a significant lag can exist between the time an incident occurs and the time it shows up in the database. This is due to the time taken by the CHP to verify all the submitted information. Information about incidents typically becomes public one to one-and-a-half years after their occurrences.

Figure 5-15: iSWITRS Incident Query Webpage

5.5.2. TRAFFIC ACCIDENT AND SURVEILLANCE ANALYSIS SYSTEM (TASAS) DATA

The Traffic Accident and Surveillance Analysis System (TASAS) is a database developed by Caltrans based on information contained in SWITRS. This database links incident data from SWITRS to roadway feature data to facilitate the analysis of their traffic impacts.

This is the primary database that was used to compile incident statistics for the project. Data for mainline and ramp incidents along sections of I-580 within Contra Costa County and Marin County between January 2016 and December 2023 were graciously compiled by Caltrans staff and provided to the research team in Excel format.

5.5.3. TRANSPORTATION INJURY MAPPING SYSTEM (TIMS) DATA

The Transportation Injury Mapping System (TIMS) is an online analytical tool developed by SafeTREC at the University of California, Berkeley to provide quick, easy, and free access to crash data contained in the SWITRS database and facilitate the display of incidents on maps. This tool can be accessed at https://tims.berkeley.edu, but requires obtaining login credentials from the manager of the site. Its focus is on crashes with injury. As such, it does not map crashes with no reported injuries. A particularly useful feature of this data source is that it allows mapping incidents that have occurred in a specific direction on a specific roadway, as illustrated in the snapshot of Figure 5-16.

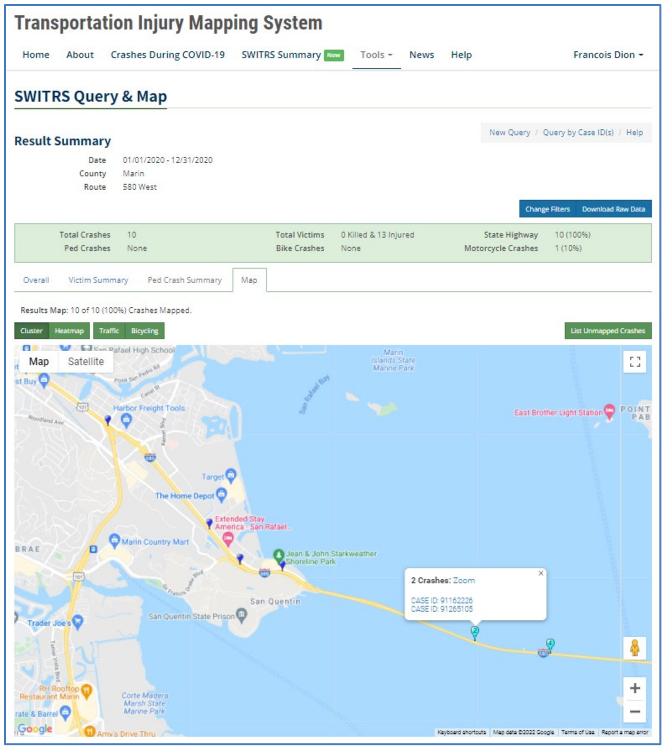


Figure 5-16: TIMS I-580 Incident Query Result Example

5.5.4. CALIFORNIA HIGHWAY PATROL COMPUTER-AIDED DISPATCH (CHP CAD) LOGS

Data from the CHP Computer-Aided Dispatch (CAD) system was used to supplement incident information obtained from the SWITRS and TASAS databases. This data can be retrieved from the California Performance and Monitoring System (PeMS), as illustrated in Figure 5-17. It details the time of occurrence, location, duration, and type of events for which a dispatch log exists. This not only includes information about traffic collisions, but also information about roadway hazards, weather events, maintenance activities, and roadway closures that involved the dispatching of CHP officers.

An item of particular interest in this database is the ability to access the detailed messages that were posted to manage incidents. An example is shown in Figure 5-18. These message logs are used by various applications as the basis for estimating incident durations. In most cases, incident durations are simply estimated as the interval between the first and last recorded messages.

While useful, the logs must always be considered carefully as their accuracy is subject to the diligence of CHP dispatchers in recording the various actions taken. For instance, actual event start times are generally not captured. Start times are usually taken as the time a dispatcher is notified of an existing event. End times are also often missing or unclearly identified, making it difficult to determine accurately the actual time taken to clear an incident. The last recorded message may correspond to the moment a note has been entered to indicate when the congestion generated by an incident has dissipated when the last incident-related message has been turned off on nearby changeable message signs, or to the last remark about the location where a vehicle has been towed. Some feeds also terminate abruptly, with no information about how an incident was cleared.

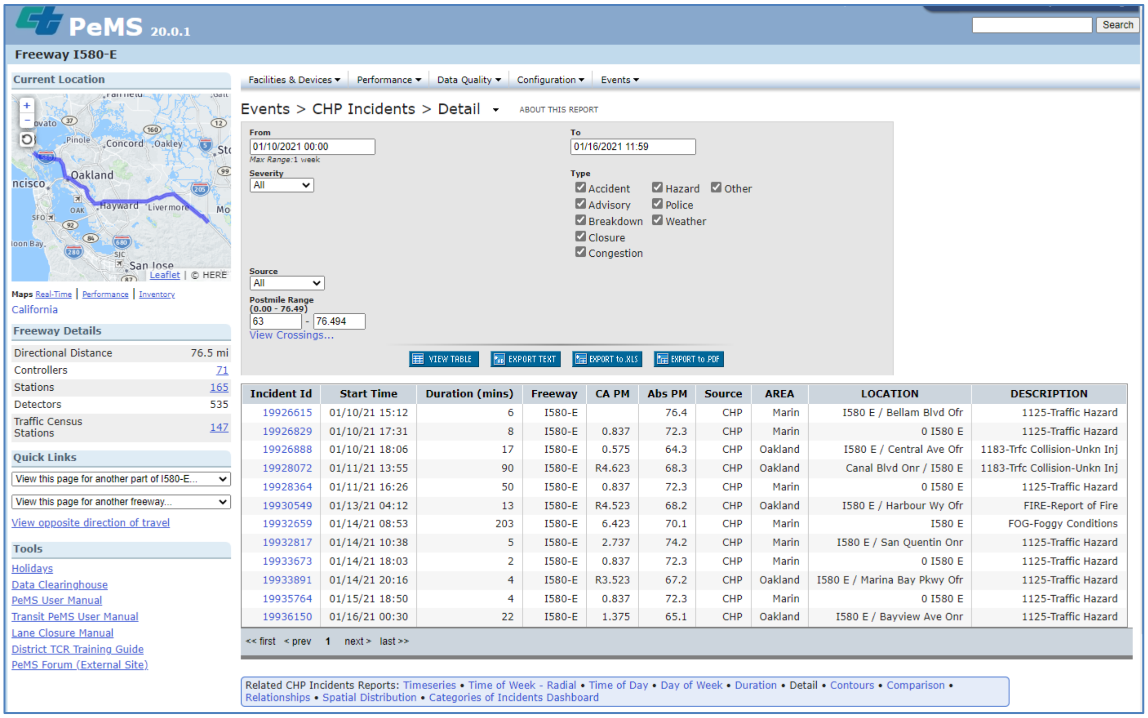


Figure 5-17: CHP-CAD Query Output Example

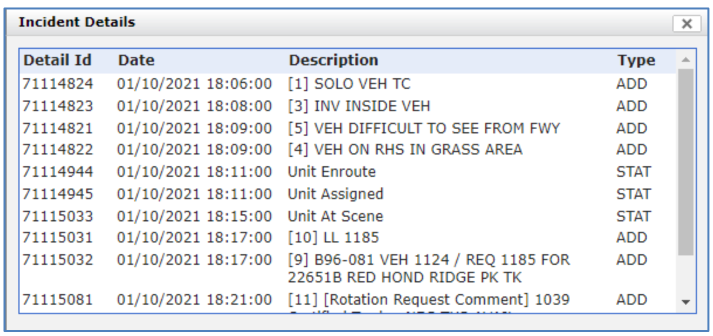


Figure 5-18: CHP-CAD Incident Log Example

While the logs do not necessarily provide clear incident start and end times, they are the only source of information allowing us to ascertain incident durations. To reduce possible biases, the message logs associated with all incidents considered in the analyses were reviewed to determine whether an adjustment should be made to the reported durations to more accurately reflect the period during which an incident affected traffic, particularly in the case of incidents with very long reported durations.

5.5.5. BAY AREA TRAFFIC INCIDENT MANAGEMENT DASHBOARD DATA

The Bay Area Traffic Incident Management Dashboard is a web-based application developed by the MTC to facilitate the viewing of crash-related data associated with various Bay Area corridors. Access to this dashboard requires obtaining credentials from the MTC. A snapshot of the page associated with the Richmond-San Rafael bridge corridor is shown in Figure 5-19, with the map at the bottom illustrating the area for which incident statistics are compiled.

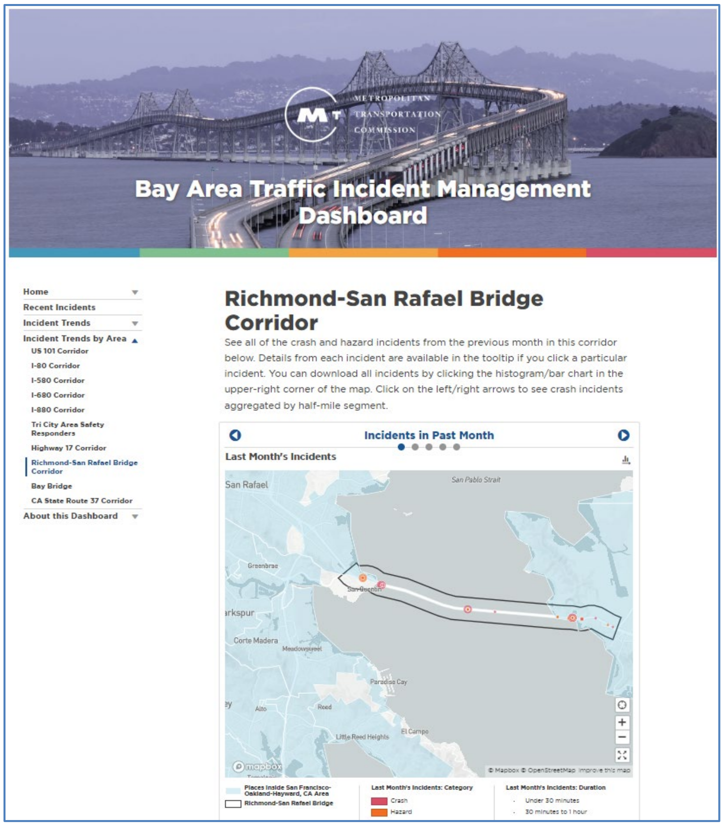


Figure 5-19: Bay Area Traffic Incident Management Dashboard

This dashboard uses CHP CAD data contained within PeMS to identify crash-related incidents within each corridor, estimate their clearance time, and produce summary monthly statistics. Similar to the CHP CAD data processed by PeMS, incident clearance times are estimated based on the first and last messages associated with a particular event. The first message generally corresponds to the time an incident is reported. While the last message often corresponds to a note that a unit has left the scene, this is not always the case. As indicated in the previous section, some incident feeds terminate abruptly while others may include messages posted after an incident has been cleared. As a result, the reported clearance times do not necessarily correspond to actual incident clearance times. To reduce potential large discrepancies, messages associated with all incidents lasting more than one hour were reviewed to verify the accuracy of their reported duration and adjust them if necessary.

5.5.6. STREET STORY ONLINE PLATFORM DATA

Street Story is an online platform created by the University of California Safe Transportation Research and Education Center (SafeTREC) on the Berkeley campus. This tool allows residents, community groups, and agencies to collect community input about transportation crashes, near-misses, general hazards, and safe locations to travel. Figure 5-20 shows a screenshot of the page used to enter new reports, while Figure 5-21 shows the maps that can be used to explore logged reports. For the evaluations, all reports about the bridge logged between October 2018, when the site was activated, and November 2023 were retrieved and analyzed.

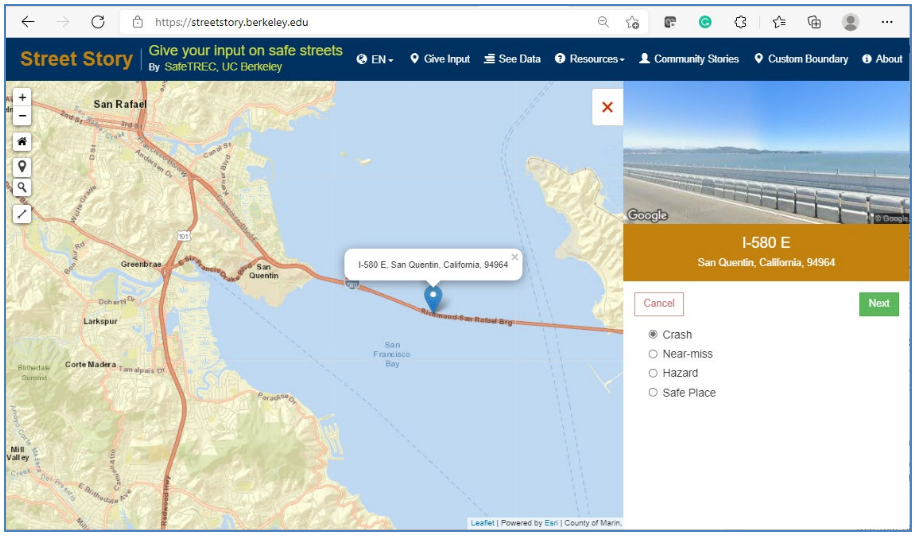


Figure 5-20: SafeTREC Street Story Incident Reporting Online Platform

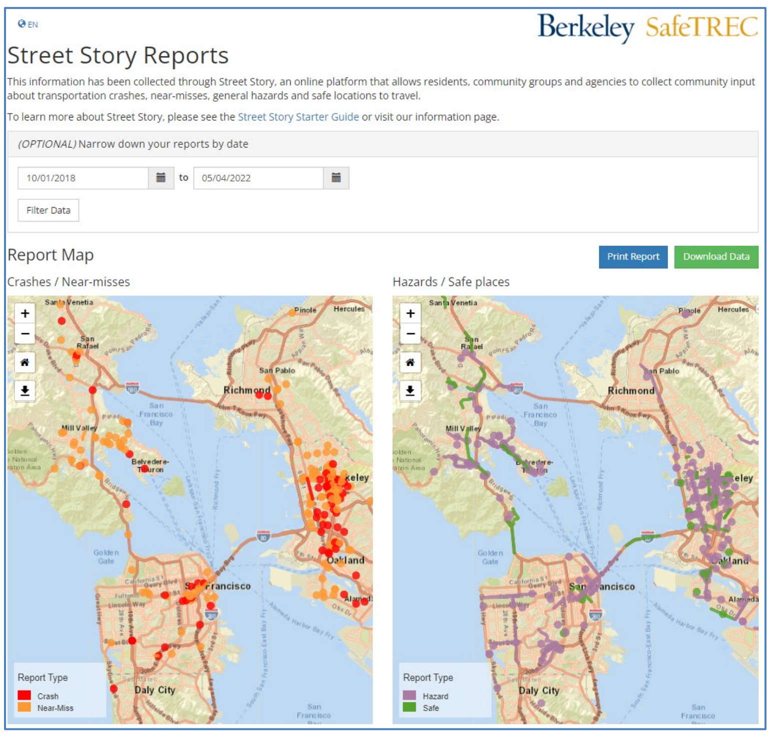


Figure 5-21: SafeTREC Street Story Online Platform for Exploring Reports

5.5.7. BAIRS DATA

BAIRS data were initially obtained for 2015 and 2016. After reviewing the data, it was determined that the information contained in this dataset often duplicated what could be retrieved from SWITRS and the CHP-CAD system. For this reason, no further data were collected from this dataset.

5.5.8. MIDB DATA

Attempts were made to retrieve data from the Major Incident Database (MIDB) in 2015 and 2016. However, these were unsuccessful, in great part due to the difficulty of extracting electronic data from the system. Additional efforts to retrieve data were abandoned after it was determined that the SWITRS data would provide a comprehensive enough record of incidents occurring within the study area.

5.5.9. CALLBOX DATA

A summary of calls made from Call Boxes was obtained for 2011, 2012, 2013, and 2014. While the Call Box data provided information about how frequently the boxes were used to report incidents on each bridge within the Bay Area, the data was found of relatively little use as it did not provide information about the location of the specific box that was used to report each incident, or the type of incident reported. This made it difficult to try to correlate the incidents contained in the database with incidents included in other databases. For these reasons, no further effort was made to use this type of data in the analyses.

5.5.10. DATA FROM LOCAL POLICE DEPARTMENTS

To obtain information about incidents occurring outside the freeway, the police departments of the cities of Richmond and San Rafael as well as the Sheriff's Office of Marin County were contacted in 2016 and 2017. Since electronic data could only be obtained from the San Rafael Police Department, and since the primary focus of the evaluations was on incidents occurring on the freeway, this potential source of incident data was not pursued further.

5.6. INCIDENT RESPONSE DATA

In addition to information about the number and type of incidents, attempts were made to collect data characterizing the time taken by emergency or service vehicles to respond to incidents on the bridge. The goal was to collect data enabling an assessment of the difficulty that emergency services faced reaching incident locations under the various bridge configurations. Efforts were more specifically directed at exploring how such information could be retrieved from the following two sources:

- Caltrans tow truck activity logs
- CAH CAD log data

5.6.1. CALTRANS TOW TRUCK LOGS

Tow truck activity reports were sought from Caltrans to obtain information about instances in which tow trucks were dispatched to help vehicles on the bridge or its immediate vicinity. This did not include obtaining information about towing activities beyond the immediate vicinity of the bridge as these activities would normally be provided by the Freeway Service Patrol and should not have been significantly impacted by the bridge modifications.

Collected data include tow truck activity reports for the following periods:

- Before modifications:
    - January to July 2016 (75 logs, 75 with dispatch times)
    - January to September 2018 (244 logs, none with dispatch times)
    - March 21-31, 2019 (26 WB logs, 12 with dispatch times)
- After modifications:
    - March 21-31, 2019 (100 EB logs, 9 with dispatch times)
    - January and February 2020 (119 logs, none with dispatch times)
    - February and March 2022 (645 logs, 77 with dispatch times)
    - January to October 2023 (5,035 logs, 277 with dispatch times)

Logs from 2016 and 2018 were provided in an electronic format and included summary information about tow truck activities. Logs from 2019 to 2023 were provided as scans of handwritten log sheets covering all bridges within the Bay Area. Each sheet thus had to be visually inspected to determine which logs were relevant and to manually transcribe data from relevant logs into an Excel spreadsheet that would facilitate analyses.

Almost all collected log records include the time a vehicle arrived on the scene (10-97 code) and the time service was completed (10-98 code). However, only a fraction also includes a dispatch time that can be used to assess the time needed to reach the location of the requested service. This is in part because many of the logs simply record regular activities, such as periodical patrols to check whether there is debris on the bridge or if the lane signals on the lower deck at correctly set. Such activities would not require a dispatch. In addition, many of the logs likely capture activities that may have been executed as part of a routine patrol, such as logs detailing short stops to pick debris.

In many of the logs, finally, while service locations were generally entered, there were often coded as general reference points, such as “midspan bridge”, “just east of Toll Plaza”, “just west of San Quentin”, etc. Based on the entered general locations, all transcribed logs were determined to belong to either the bridge itself, the toll plaza area, the approach of the bridge, or its exit.

5.6.2. CHP CAD LOGS

Explorations were made into the ability to use the CHP CAD logs to determine the time taken by response vehicles to reach an incident since many logs indicate when a unit has been assigned to an incident, is on the way (en route), and has arrived at the scene. As an example, in the log snapshot of Figure 5-18 presented earlier, it could be determined that a unit was assigned to the incident at 6:11 PM, started to travel towards it at that time, and reached the incident location four minutes later at 6:15 PM.

While the “Unit Assigned,” “Unit Enroute” and “Unit at Scene” logs provide some insights about response times, they do not indicate from where a unit has been dispatched. This makes it difficult to assess whether long recorded travel times are due to difficult traffic conditions on the way to an incident or simply because of a farther starting point. For many incidents, multiple vehicle dispatches and arrivals are also recorded in short succession. Since the logs do not provide information about the specific vehicles being dispatched, it is often unclear to which dispatch each scene arrival corresponds, making it difficult to determine actual response times. Many logs also indicate an assignment but no subsequent arrival time, or an arrival without a prior logged assignment. As a result, estimated response times based on incident logs can only be viewed as crude, potentially inaccurate, estimates.

5.7. MAINTENANCE DATA

Maintenance activity data were sought to assess the frequency at which repairs would be required on the new barrier and, if possible, the time taken by maintenance crews to reach a given site and complete a given task. For this purpose, the following two data sources were considered:

- Caltrans Lane Closure (LCS) System
- Integrated Maintenance Management System (IMMS)

5.7.1. CALTRANS LANE CLOSURE SYSTEM (LCS) DATA

The LCS is used by Caltrans staff to report all approved closures planned for the next seven days, in addition to all lane, ramp, and road closures that are currently in place due to maintenance, construction, special events, or other reasons. The system also retains a record of all past closures.

As shown in Figure 5-22, LCS data can be retrieved directly from PeMS. For each closure request, the data indicates whether the request was approved, rejected, or canceled, the proposed start and end locations, the proposed start and end times, the actual start and end times if implemented, as well as the number of lanes closed. The reason for the closure may also be provided in the remarks section.

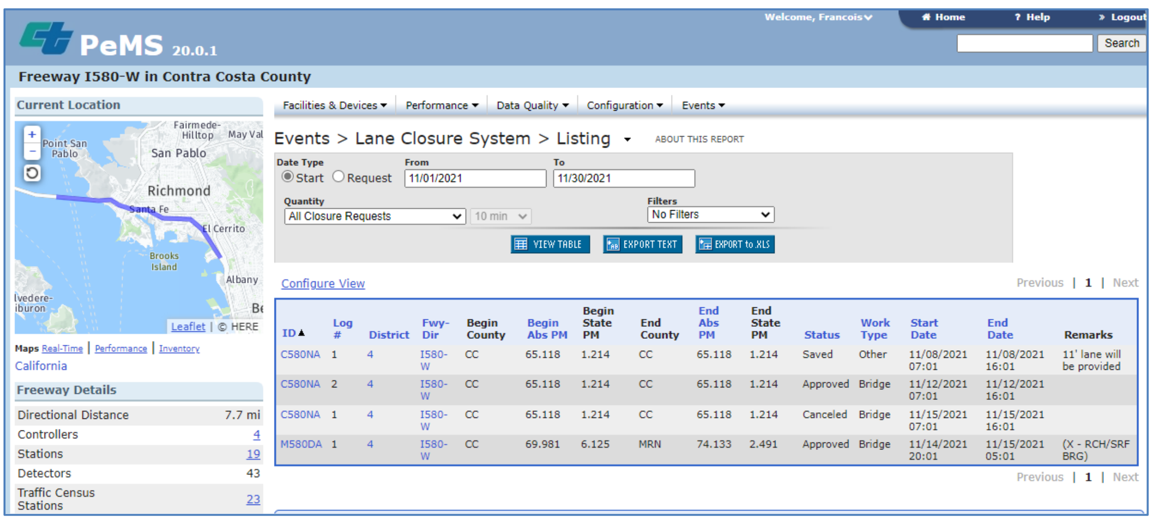


Figure 5-22: Lane Closure System Data Retrieval within PeMS

5.7.2. INTEGRATED MAINTENANCE MANAGEMENT SYSTEM (IMMS) DATA

The Caltrans Integrated Maintenance Management System (IMMS) is used to record, report, and monitor maintenance work planned and performed. A log is normally created for each incident for which maintenance is required. This includes an assessment of the damage to any state property.

An analysis of an IMMS data sample that was provided to the team in 2016 only showed the total number of hours needed to complete a given task and the associated cost to the agency. While this information could be used to assess the magnitude of maintenance work completed, there was no specific information about the time needed to reach a given site. For this reason, it was determined that data from this system would likely not provide useful information for the evaluation and no additional data were sought.

5.8. BRIDGE PATH USER SURVEY

This section provides information about a user survey that was conducted from June 16, 2021, to August 13, 2021, to assess how users of the new bike/pedestrian path on the bridge view its usefulness and safety. Specific information presented includes:

- Survey development
- Survey dissemination
- Survey results

5.8.1. SURVEY DEVELOPMENT AND DISSEMINATION

The user survey was developed in TypeForm, an application allowing for posting online surveys. A key criterion behind the setup was for path users to be able to answer questions on their mobile phones or at home. Table 5-2 and Table 5-3 detail the questions that were asked. The first set specifically pertained to the new bike/pedestrian path on the bridge, while the second set was included to gain some insights about the trips made on the bridge or overcrossing and how users have heard about the survey. Survey respondents did not necessarily have to answer all the questions. For instance, respondents who indicated in Question #1 that they did not use the new bridge path were not shown questions #2 to #7.

Table 5-2: Survey Questions Related to Improvements on the Richmond-San Rafael Bridge

Question	Answer Choices
1. Have you used the bike/pedestrian path on the upper deck of the Richmond-San Rafael Bridge since its opening in November 2019?	• Yes, as a bicyclist • Yes, as a pedestrian • Yes, as both a bicyclist and pedestrian • No
2. If yes, how frequently do you use the path?	• 1-4 times a week • More than 4 times a week • 1-4 times a month • Occasionally (less than once a month on average) • Seldom (Used only 1-4 times total since opening)
3. Which day(s) do you predominantly use the path (check all that apply)?	• Weekdays • Saturdays • Sunday
4. Which of the following is the most likely reason you currently use the ped/bike path?	• Commuting/traveling to or from work • Commuting/traveling to locations other than work • Recreation • Exercise • Other (please specify)
5. When using the bike/ped path, do you usually (check all that apply)	• Complete a round trip on the path • Use the path one way and return home on a different route • Use the path one way and use a motor vehicle or bus the other way across the bridge to complete your trip • Do not go completely across the bridge, but turn around mid-way
6. How safe do you feel on the bridge path?	• A number between 1 and 10, with 1 being not safe at all and 10 very safe
7. What is the primary factor you think of when considering your safety:	• Open text box
8. How beneficial do you think the path improvements are to you?	• A number between 1 and 10, with 1 being not beneficial at all and 10 very beneficial

Table 5-3: Additional Survey Questions

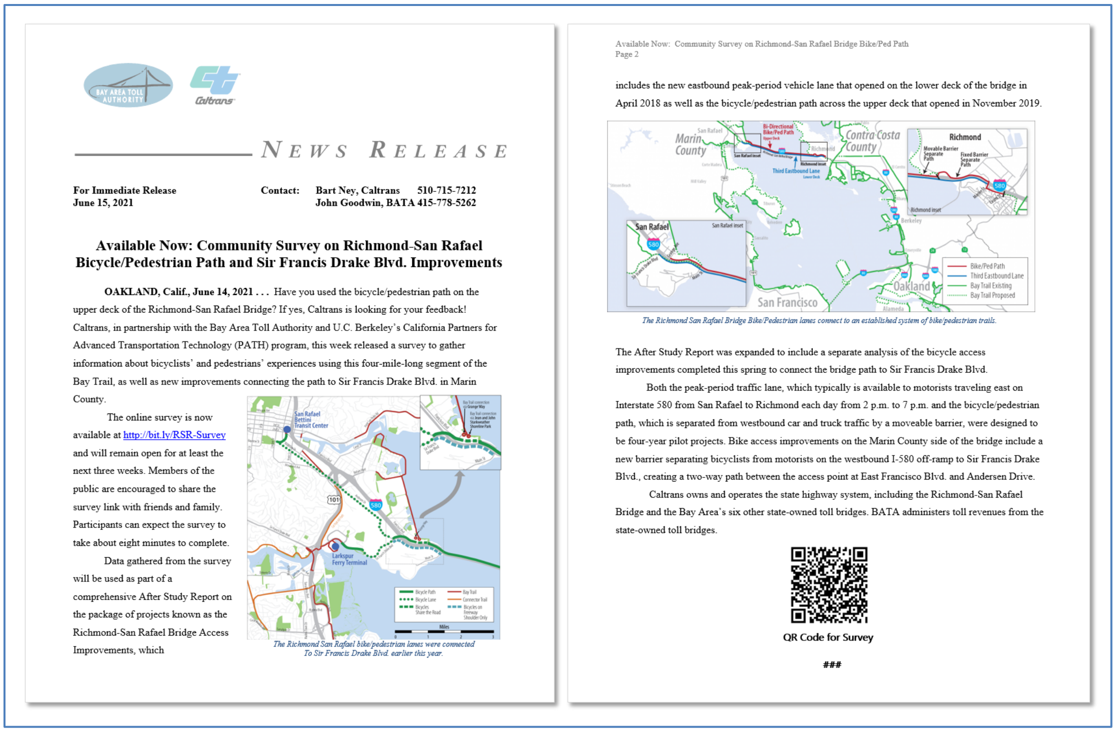
Question	Answer Choices
9. When making your trip across the Richmond-San Rafael Bridge, is your **starting destination** on the	• Richmond/Contra Costa side of the bridge • San Rafael/Marin side of the bridge
10. Please provide the closest intersection or neighborhood to describe your usual starting destination	• Open text box
11. When making your trip across the Richmond-San Rafael Bridge, is your **ending destination** on the:	• Richmond/Contra Costa side of the bridge • San Rafael/Marin side of the bridge
12. Please provide the closest intersection or neighborhood to describe your usual ending destination	• Open text box
13. Any comments you would like to add about your experience with the bike/pedestrian improvements?	• Open text box
14. Any comments you would like to add about your experience with Richmond-San Rafael Bridge?	• Open text box
15. How did you hear about the survey?	• Sign on bike/ped path • Social media post • Local news source • Caltrans or MTC press release • Bike advocacy or other community groups • Other

5.8.2. SURVEY DISSEMINATION

Information about the survey was disseminated to the public through:

- A formal Bay Area Toll Authority / Caltrans press release (Figure 5-23)
- Posts on websites maintained by the Metropolitan Transportation Commission/Association of Bay Area Governments and University of California Berkeley (Figure 5-24)`
- Mentioning the survey on local news outlets, such as on the KRON 4 television channel
- Email blast to bike advocacy groups
- Signs posted at various key locations along the path (Figure 5-25 to Figure 5-28)

A QR code linked to the survey was embedded in press releases and posters to facilitate access from mobile phones. On web pages, a hyperlink was used instead to bring users to the survey.



BAY AREA TOLL AUTHORITY Caltrans

NEWS RELEASE

For Immediate Release
June 15, 2021

Contact: **Bart Ney, Caltrans 510-715-7212**
John Goodwin, BATA 415-778-5262

Available Now: Community Survey on Richmond-San Rafael Bicycle/Pedestrian Path and Sir Francis Drake Blvd. Improvements

OAKLAND, Calif., June 14, 2021 . . . Have you used the bicycle/pedestrian path on the upper deck of the Richmond-San Rafael Bridge? If yes, Caltrans is looking for your feedback! Caltrans, in partnership with the Bay Area Toll Authority and U.C. Berkeley's California Partners for Advanced Transportation Technology (PATH) program, this week released a survey to gather information about bicyclists' and pedestrians' experiences using this four-mile-long segment of the Bay Trail, as well as new improvements connecting the path to Sir Francis Drake Blvd. in Marin County.

The online survey is now available at http://bit.ly/RSR-Survey and will remain open for at least the next three weeks. Members of the public are encouraged to share the survey link with friends and family. Participants can expect the survey to take about eight minutes to complete.

Data gathered from the survey will be used as part of a comprehensive After Study Report on the package of projects known as the Richmond-San Rafael Bridge Access Improvements, which

The Richmond San Rafael bike/pedestrian lanes were connected To Sir Francis Drake Blvd. earlier this year.

Available Now: Community Survey on Richmond-San Rafael Bridge Bike/Ped Path
Page 2

includes the new eastbound peak-period vehicle lane that opened on the lower deck of the bridge in April 2018 as well as the bicycle/pedestrian path across the upper deck that opened in November 2019.

The Richmond San Rafael Bridge Bike/Pedestrian lanes connect to an established system of bike/pedestrian trails.

The After Study Report was expanded to include a separate analysis of the bicycle access improvements completed this spring to connect the bridge path to Sir Francis Drake Blvd.

Both the peak-period traffic lane, which typically is available to motorists traveling east on Interstate 580 from San Rafael to Richmond each day from 2 p.m. to 7 p.m. and the bicycle/pedestrian path, which is separated from westbound car and truck traffic by a moveable barrier, were designed to be four-year pilot projects. Bike access improvements on the Marin County side of the bridge include a new barrier separating bicyclists from motorists on the westbound I-580 off-ramp to Sir Francis Drake Blvd., creating a two-way path between the access point at East Francisco Blvd. and Andersen Drive.

Caltrans owns and operates the state highway system, including the Richmond-San Rafael Bridge and the Bay Area's six other state-owned toll bridges. BATA administers toll revenues from the state-owned toll bridges.

QR Code for Survey

###

Figure 5-23: BATA/Caltrans Press Release for the User Survey

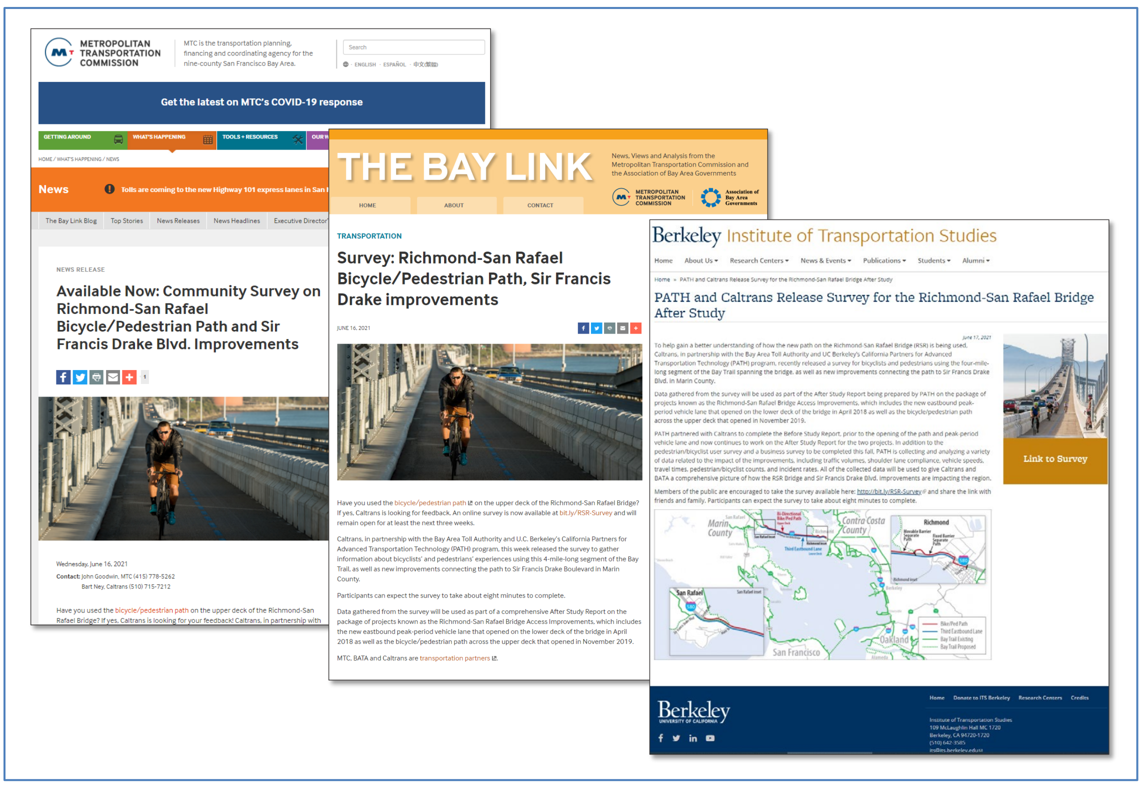


Figure 5-24: Online Posts for the User Survey

Figure 5-25: User Survey Signs Along Path – Richmond Side

Figure 5-26: User Survey Signs Along Path – Marin County Side

Figure 5-27: User Survey Signs Along Path – Vista Point on Marin County Side

Figure 5-28: User Survey Signs Along Path – Sir Francis Drake Overcrossing Access

5.8.3. SURVEY RESPONSE RATE

A total of 4,608 individuals viewed the survey splash page over its 8-week active period. Of these individuals, 2,833 started answering questions but only 2,166 individuals completed the survey. This means that 76% of respondents who started answering the survey completed it and 47% of individuals who became aware of it completed it.

A summary of the responses provided by the individuals who completed the survey is provided in Appendix A. More detailed discussions of the survey results are provided in Section 14.2.

5.9. BUSINESS SURVEY

To assess the impacts on business activities associated with the bridge modifications, a series of interviews were conducted with businesses in Marin County located on local streets that were extensively used as alternate routes to the bridge before the modifications. These interviews focused primarily on assessing how congestion leading to the bridge affected the businesses and their employees. No interviews were conducted on the Richmond side as very few businesses were located on streets exhibiting significant bridge-related congestion.

Interviews for the before-evaluation were conducted between April, August, and December of 2016. Interviews for the after-evaluation were conducted in the first week of May 2022. The following subsections provide more details about the businesses that were visited, and the questions asked.

5.9.1. BUSINESSES INTERVIEWED – BEFORE-STUDY

A total of sixteen businesses were visited for the before study. Table 5-4 lists the various businesses visited and the date the visit occurred. These businesses were selected based on their high number of employees or customers and their location along key local arterials running parallel to I-580. In each case, efforts were made to talk to managers.

Table 5-4: Businesses Visited in 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
August 3, 2016	Orchard Supply Hardware	Andersen
August 3, 2016	Smart and Final	Andersen
August 3, 2016	West America Bank	E. Francisco
August 3, 2016	Marin Airporter	Andersen
August 3, 2016	United Parcel Service (UPS)	Kerner
August 3, 2016	US Postal Service	Bellam
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

5.9.2. QUESTIONNAIRE – BEFORE STUDY

The following questions were asked of each business during the before-study survey. Since some questions were repetitive or answered in another question, every question did not necessarily have complete information in the answer tables.

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

5.9.3. BUSINESSES INTERVIEWED – AFTER-STUDY

For the after-study, attempts were made to revisit the same businesses that were targeted for the before-study. Visits were made in the first week of May 2022. As shown in Table 5-5, comments were obtained from only 8 businesses. First, not all businesses could be revisited as some had permanently closed since 2016. One was still listed as temporarily closed due to the COVID-19 pandemic. Two businesses where the questionnaire was left to staff with instructions to forward it to managers due to them being unavailable ended up not responding to the survey. The remaining businesses that declined to participate in the after-study survey did so because of corporate policies preventing employees not working at a corporate office from commenting on questions submitted to them.

Table 5-5: Businesses Visited in May 2022

Name of Business	Street Location	Response Provided
Target	Shoreline / E. Francisco	Yes
Home Depot	Shoreline / E. Francisco	No – Did not return the questionnaire
FedEx	E. Francisco	No – Did not return the questionnaire
Ace Printing	E. Francisco	No – Permanently closed
Bay Café	E. Francisco	No – Temporarily closed
Orchard Supply Hardware	Andersen	No – Permanently closed
Smart and Final	Andersen	No – No soliciting policy
West America Bank	E. Francisco	No – No soliciting policy
Marin Airporter	Andersen	Yes
United Parcel Service (UPS)	Kerner	Yes
US Postal Service	Bellam	Yes
Extended Stay America	E. Francisco	Yes
Marin Honda	Shoreline / E. Francisco	Yes
U-Haul	E. Francisco	Yes
PG&E Service	Andersen	No – No soliciting policy
Central Marin Sanitary District	Andersen	Yes

5.9.4. QUESTIONNAIRE – AFTER STUDY

The after-survey was conducted more like a discussion than an administration of specific questions. The goal of the discussion was to try to obtain answers to the following questions:

1. Does traffic on I-580 and the surrounding roads affect your business and customer/employee access?
2. What days/times are the worst (i.e., weekdays, weekends, specific days, and/or specific times)?
3. Have there been noticeable changes in travel times to come from Richmond since the addition of the bicycle/pedestrian path on the upper deck (November 2019), particularly in the morning?
4. Have there been noticeable changes in travel times to get to Richmond since the opening of the lower deck shoulder to traffic (April 2018), particularly in the afternoon?
5. Does freeway traffic still back up onto local roads surrounding your business?
6. Do you know if some freeway traffic still uses local roads as a freeway bypass?
7. Do you know if some employees live on the Richmond side of the bridge?
8. What, if any, types of comments do you hear from employees or customers about traffic issues?
9. Do you have to consider potential delays due to bridge congestion when planning business activities or employee schedules?
10. Do you know of any employees using the bicycle/pedestrian path on the Richmond-San Rafael Bridge to come to work?
11. Any comments you would like to add about your experience with the bridge improvements?

Not all questions were necessarily answered with each discussion as some of the responses provided may have indicated that some questions were not relevant. Some businesses indicated for instance that they do not have employees coming from the Richmond side of the bridge or do not have business activities requiring them to use the bridge. In such cases, it would have been difficult for the businesses to comment on the impacts that the bridge modifications may have had on their activities or employees. The two-year COVID-related delay in administering the after-survey has also made it harder for interviewed individuals to recall all the specific conditions that existed in the corridor before the bridge modifications. Many businesses have also had a significant turnover of personnel in the past few years, resulting in many employees being unaware of previous traffic conditions in the corridor.

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6. BICYCLE TRAFFIC

This section presents the results of the evaluations assessing the demand for bicycle travel across the new path installed on the upper deck of the bridge. The following specific elements are discussed:

- Average daily directional bicycle traffic on the bridge path
- Average daily directional bicycle traffic on the Sir Francis Drake overcrossing corridor
- Bicycles carried across the bridge on Golden Gate Transit buses
- Daily directional bicycle flow profiles on the bridge path
- Summary of observations

6.1. BICYCLE TRAFFIC - BRIDGE PATH

Figure 6-1, Figure 6-2, and Figure 6-3 present the average number of cyclists observed entering the bridge path each day on non-holiday weekdays, Saturdays, and Sundays from November 2019, when the path was opened, to April 2024. Separate data is presented for the traffic entering the bridge from the Richmond and San Rafael sides, as the Richmond counts are generally slightly higher. The three figures further distinguish three data collection periods based on the number of sensors used to monitor bicycle traffic (see Figure 5-10):

- **November 2019 – August 2020:** Observations based on the Richmond and Marin sensors.
- **August 2020 – March 2021:** Observations based on the Maintenance Yard, Richmond, and Marin sensors.
- **April 2021 – April 2024:** Observations based only on the Maintenance Yard and Marin sensors after the Richmond sensor was relocated to the Sir Francis Drake overcrossing path. This period also marks a change in the placement of in-pavement sensors at the Marin location in response to reports of possible inversion of the eastbound and westbound counts.

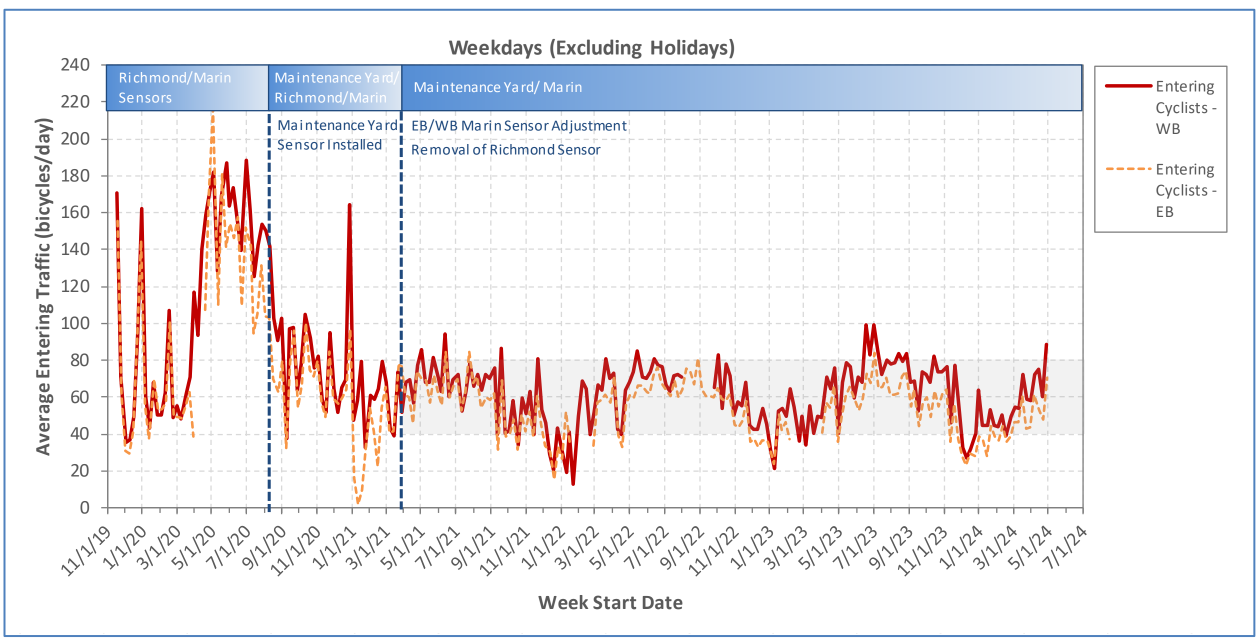

Figure 6-1: Daily Entering Bicycle Traffic – Bridge Path – Weekdays, 2019-2024

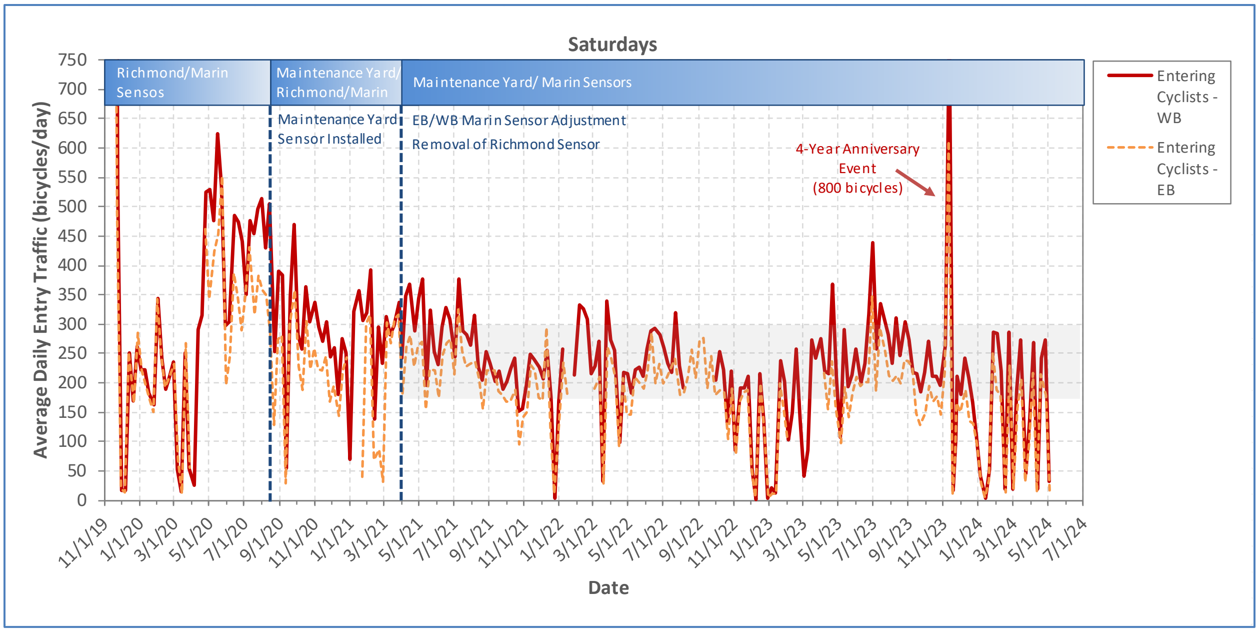

Figure 6-2: Daily Entering Bicycle Traffic – Bridge Path – Saturdays, 2019-2024

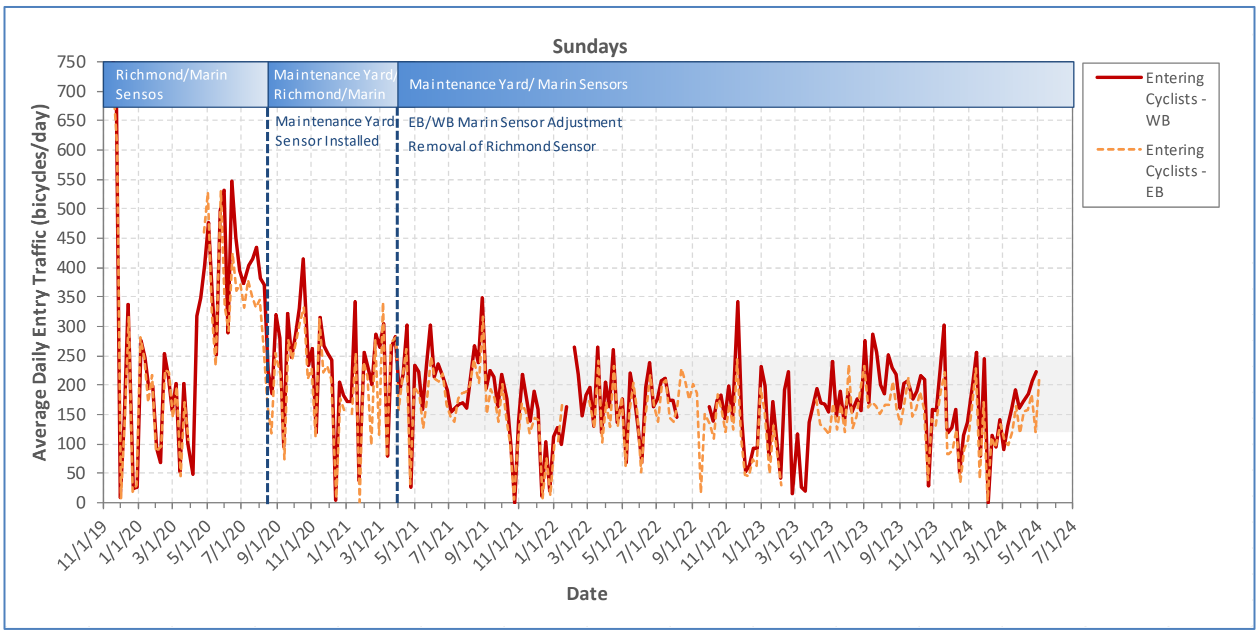

Figure 6-3: Daily Entering Bicycle Traffic – Bridge Path – Sundays, 2019-2024

Figure 6-4 further recompiles the data of Figure 6-1, Figure 6-2, and Figure 6-4 to highlight monthly variations in average trips entering the bridge path from both ends of the bridge since January 2020. Figure 6-5 further presents daily variations in average directional path traffic across weekdays since January 2022.

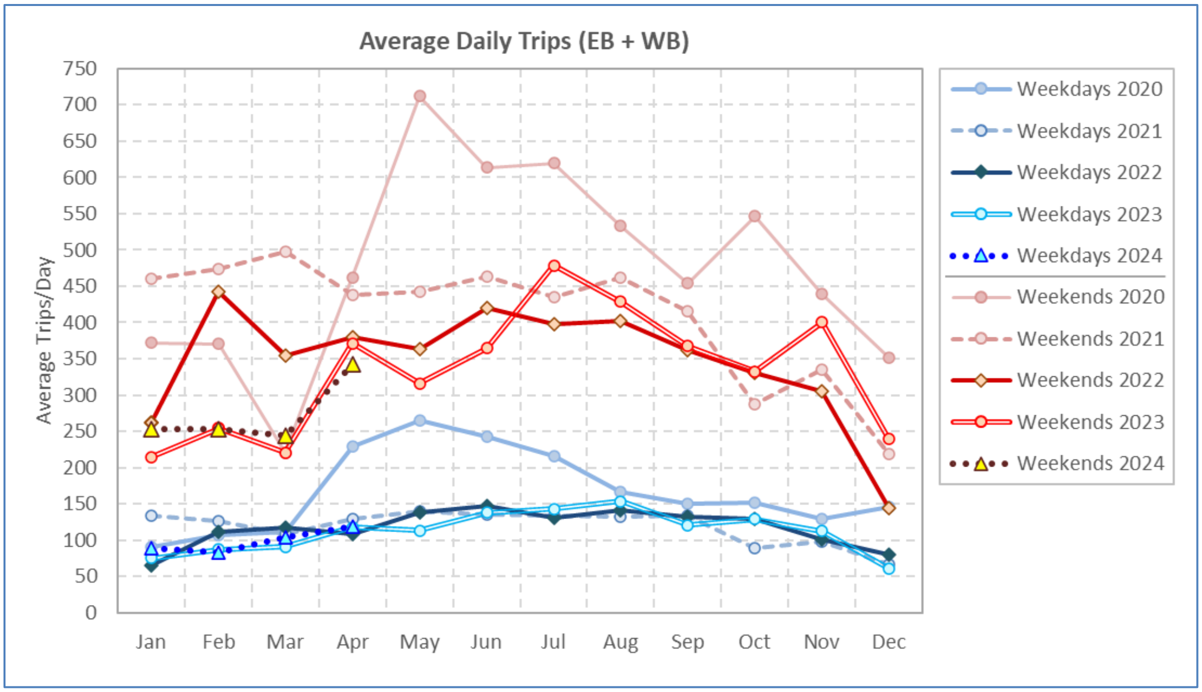

Figure 6-4: Average Daily Entering Bicycle Trips by Months – Bridge Path, 2019-2024

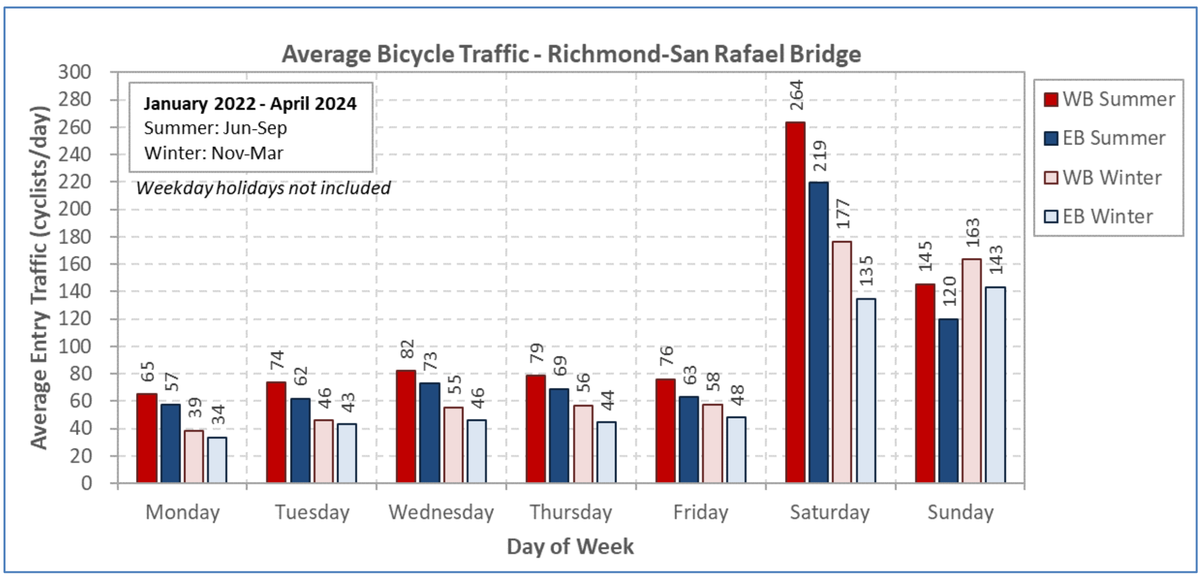

Figure 6-5: Average Daily Entering Bicycle Trips by Day of Week – Bridge Path, 2022-2024

Based on the illustrated data, the following observations can be made:

- The highest recorded traffic, both on weekdays and weekends, appeared to have occurred between April and August 2020, during the path's first summer. Initial curiosity may have contributed to this high traffic. Following the March 2019 COVID-19 stay-at-home order, some individuals may also have decided to go on bike rides to break the monotony of staying home. Sensor issues may have further affected the early measurements, as suggested by the significant drop in measured traffic after the sensor at the Caltrans Maintenance Yard was activated and adjustments were made to the other sensors to reduce the capture of nearby vehicular traffic.

- Observed peak summer traffic (June-September) since January 2022:
  - **Saturdays:** Westbound and eastbound averages of 264 and 219 cyclists/day, respectively, with peaks up to 435.
  - **Sundays:** Westbound and eastbound averages of 188 and 167 cyclists/day, respectively, with peaks up to 285.
  - **Non-holiday weekdays:** Westbound and eastbound averages of 75 and 88 cyclists/day, respectively, with peaks up to 99.
- Observed winter low traffic (November to March) since January 2022:
  - **Saturdays:** Westbound and eastbound averages of 177 and 135 cyclists/day, respectively, with peaks up to 440.
  - **Sundays:** Westbound and eastbound averages of 145 and 120 cyclists/day, respectively, with peaks up to 340.
  - **Non-holiday weekdays:** Westbound and eastbound averages of 50 and 41 cyclists/day, respectively, with peaks up to 69.
- The use of the path is seasonal. When ignoring the 2020 data due to the reasons cited above, the highest traffic is typically observed during the summer months (June to September), and the lowest traffic is during the winter months (November to March) when the weather is colder and rainier.
- As expected, traffic is generally higher on weekends than on weekdays, with Saturdays usually having the highest traffic and Sundays the second highest. There are only small variations in non-holiday weekday traffic, with days later in the week appearing to have slightly higher traffic than Mondays and Thursdays.
- Westbound traffic is generally higher than eastbound traffic, with a typical 55%/45% westbound/eastbound split on both weekends and weekdays.
- Weekend traffic shows significantly more variations basis than weekday traffic. This is likely due to variations in the composition of the bicycle traffic. During weekends, traffic is primarily recreational, and thus heavily influenced by the weather. During weekdays, a portion of path users may be individuals commuting to work. While the weather may still affect the decision to ride, weekday riders may be more accustomed to inclement weather and thus less inclined to ditch their bike on rainy or windy days.
- Following the March 2021 adjustments to the Marin sensor, eastbound and westbound counts generally appear to follow similar patterns. While some discrepancies remain, this may be due to some riders traveling only along a section of the bridge before turning back. This is likely to occur more often with recreational weekend riders than work-related weekday riders, thus explaining the larger observed weekend discrepancies compared to the weekday data.
- The more recent data suggests that there are generally slightly more riders traveling westbound towards Marin County than eastbound towards Richmond during the day. This imbalance is observed at all counting locations. Based on data collected from path users in the summer of 2021 (see Section 14.2) and the fact that morning trips tend to be westbound crossings, this unbalance can be explained by a proportion of riders following a circuit not taking them back to the bridge or using a different mode of transportation to return to their starting point.

6.2. BICYCLE TRAFFIC - SIR FRANCIS DRAKE OVERCROSSING CORRIDOR

This section presents an analysis of bicycle traffic along the Sir Francis Drake overcrossing corridor. Specific elements discussed include:

- Average daily directional bicycle traffic on the overcrossing during weekdays and weekends.
- Trip patterns at the intersection between Sir Francis Drake Boulevard and Andersen Drive.
- Traffic distribution between the overcrossing path and path running along I-580 East between the Sir Francis Drake Boulevard on-ramp and Main Street off-ramp.
- Percent of overcrossing/I-580 East shoulder traffic coming from or traveling toward the bridge.

6.2.1. AVERAGE DAILY TRAFFIC

Figure 6-6, Figure 6-7, and Figure 6-8 illustrate the average daily eastbound and westbound bicycle traffic on non-holiday weekdays, Saturdays, and Sundays measured at the entrance of the Sir Francis Drake overcrossing path since April 2021, when the path's sensor was installed.

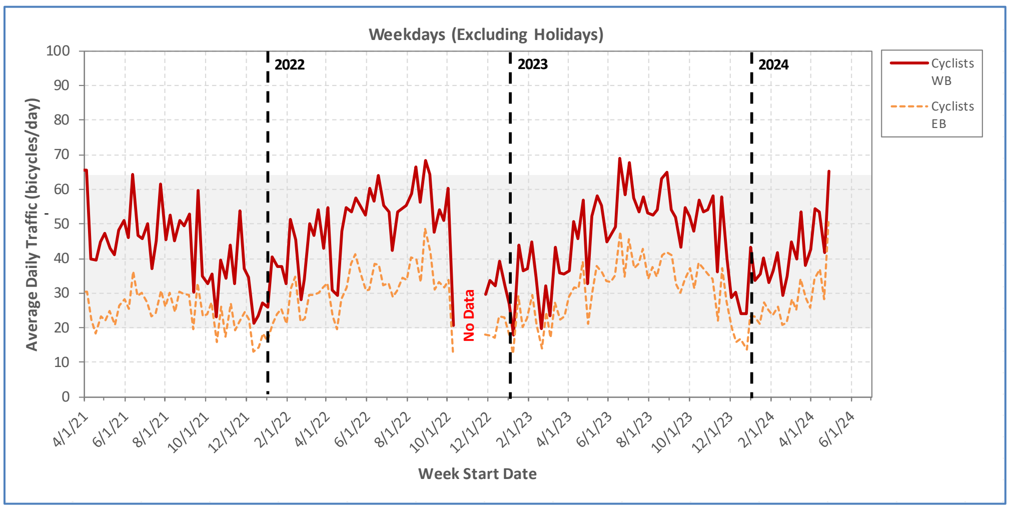

Figure 6-6: Daily Bicycle Traffic – Sir Francis Drake Overcrossing Path – Weekdays, 2021-2024

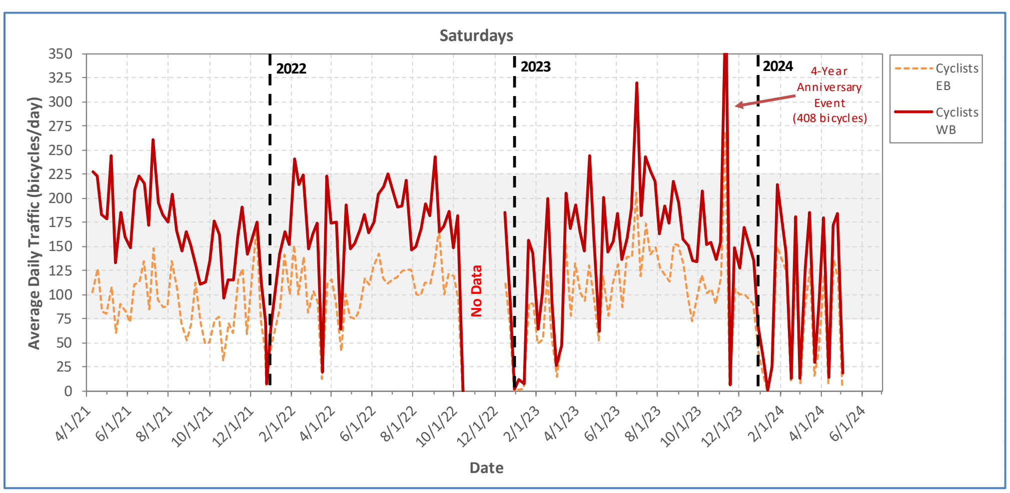

Figure 6-7: Daily Bicycle Traffic – Sir Francis Drake Overcrossing Path – Saturdays, 2021-2024

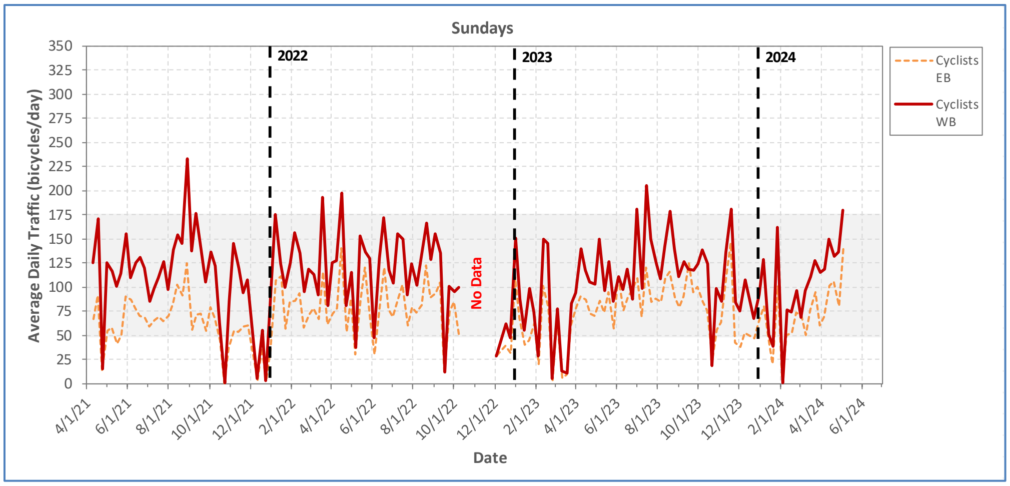

Figure 6-8: Daily Bicycle Traffic – Sir Francis Drake Overcrossing Path – Sundays, 2021-2024

The following key observations can be made from the illustrated data:

- Use of the path is seasonal, with the highest recorded traffic typically observed during summer and the lowest traffic in November and February when it is colder and rainier.
- As expected, weekend traffic is higher than weekday traffic, with Saturdays being typically the day with the highest observed traffic.
- Observed peak summer traffic (June-September) since January 2022:
    - **Saturdays:** Westbound and eastbound averages of 189 and 126 cyclists/day, respectively, with peaks up to 320.
    - **Sundays:** Westbound and eastbound averages of 125 and 88 cyclists/day, respectively, with peaks up to 205.
    - **Non-holiday weekdays:** Westbound and eastbound averages of 56 and 37 cyclists/day, respectively, with peaks up to 69.
- Winter daily traffic (November-March) since January 2022:
    - **Saturdays:** Westbound and eastbound averages of 119 and 77 cyclists/day, respectively, with peaks up to 240.
    - **Sundays:** Westbound and eastbound averages of 92 and 60 cyclists/day, respectively, with peaks up to 190.
    - **Non-holiday weekdays:** Westbound and eastbound averages of 37 and 24 cyclists/day, respectively, with peaks up to 49.
- Westbound traffic (away from the bridge) is generally higher than eastbound traffic (towards the bridge). Similar to the bridge traffic, this can partly be explained by a proportion of riders following a circuit not taking them back to the overcrossing or using a different transportation mode to return. The ability for eastbound cyclists to travel along either the overcrossing or the I-580 East on-ramp shoulder to reach the bridge, as shown in Figure 2-23, may also be a factor.
- Eastbound traffic is split between the overcrossing path and the I-580 East shoulder path. With a 68% weekday and 74% weekend split, a strong preference is for using the overcrossing path, likely due to its perceived higher safety compared to traveling on the shoulder of a busy freeway.

6.2.2. TRIP PATTERNS AT ANDERSEN DRIVE INTERSECTION

Figure 6-9 illustrates the average distribution of trips at the intersection between Sir Francis Drake Boulevard and Andersen Drive, at the end of the overcrossing path, based on data from the October 2022, February 2023, and July 2023 counts. The graph on the right illustrates the average observed distribution on weekdays while the one on the right presents the weekend distribution. Based on the illustrated data, the following general observations can be made:

- Trip distributions are similar between weekdays and weekend days.
- Approximately 50% of all observed trips involve cyclists coming from the overcrossing path. Of these, 67-69% of trips (34% of overall trips) continue on Sir Francis Drake Boulevard while 31-33% (15-17% of overall trips) turn onto Andersen Drive.
- Cyclists traveling eastbound from Sir Francis Drake Boulevard either continue on the overcrossing path (17-18% of overall trips) or the I-580 East shoulder (11-13% of trips), with an approximate preference toward using the overcrossing path.
- A small proportion of cyclists turn west on Sir Francis Drake Boulevard from Andersen Drive

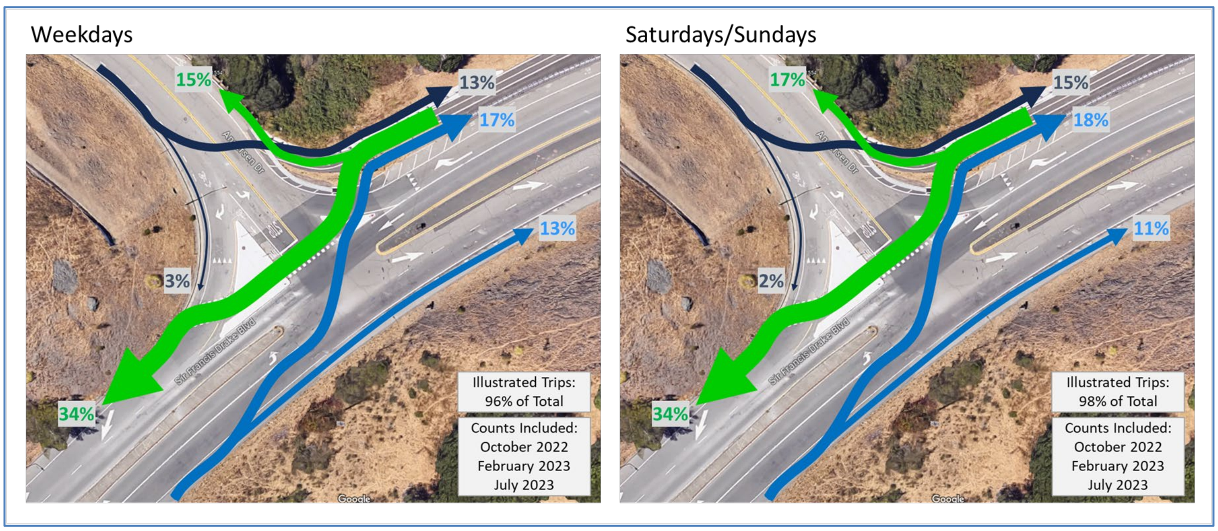

Figure 6-9: Trip Distribution – Sir Francis Drake Boulevard and Andersen Drive Intersection

6.2.3. TRAFFIC DISTRIBUTION BETWEEN THE OVERCROSSING AND I-580 EAST SHOULDER PATHS

To evaluate whether cyclists tend to use the Sir Francis Drake overcrossing path or the I-580 East shoulder path, Table 6-1 provides a breakdown of directional bicycle counts associated with each path over the four periods for which counts have been collected. The data show that:

- The westbound traffic, moving away from the bridge, is almost entirely carried on the overcrossing path. Only a few cyclists are seen traveling westbound on the I-580 East shoulder. This was expected as traveling on the I-580 East shoulder path would involve going against traffic.

- On average, 74% of the eastbound weekend traffic traveling from Sir Francis Drake Boulevard towards the bridge, and 68% of the weekday traffic, is observed using the overcrossing path.

- The share of eastbound traffic using the overcrossing path represents a shift in behavior from the before conditions. Initially, the path was marked as a one-way, westbound-only, path, forcing all eastbound traffic to use the I-580 East shoulder path. The modifications opened a new path for these individuals.

- Some of the observed shift toward the overcrossing path within the eastbound traffic likely comes from the perceived higher safety of using the barrier-separated path compared to using a path running along high-speed freeway traffic and delimited only by simple pavement markings.

Table 6-1: Comparison of Counts between Sir Francis Drake Overcrossing and I-580 East Soulder Paths

Observation Period	Westbound (From)				Eastbound (To)			
	SFD Overcrossing	I-580 Shoulder	Total	Overcrossing Share	SFD Overcrossing	I-580 Shoulder	Total	Overcrossing Share
Weekdays								
May 2021	72	1	73	98.6%	41	25	66	62.1%
October 2022	283	5	288	98.3%	150	101	251	59.8%
February 2023	163	1	164	99.4%	101	41	142	71.1%
July 2023	265	2	267	99.3%	189	61	250	75.6%
All Periods	**783**	**9**	**792**	**98.9%**	**481**	**228**	**709**	**67.8%**
Weekends								
May 2021	231	0	231	100.0%	110	43	153	71.9%
October 2022	280	3	283	98.9%	176	79	255	69.0%
February 2023	99	0	99	100.0%	74	17	91	81.3%
July 2023	437	0	437	100.0%	280	80	360	77.8%
All Periods	**1,047**	**3**	**1,050**	**99.7%**	**640**	**219**	**859**	**74.5%**

6.2.4. VOLUME COMPARISON TO BRIDGE PATH TRAFFIC

Figure 6-10 and Figure 6-11 compare the bicycle traffic on the Sir Francis Drake overcrossing to the traffic on the San Rafael side of the bridge. Figure 6-10 compares traffic in each direction of travel over weekdays from April 2021, when the overcrossing sensor was installed, to mid-April 2024. Figure 6-11 provides the same comparison over weekends and holidays. In both cases, a ratio less than 1.0 indicates that the overcrossing traffic is less than the bridge traffic while values greater than 1.0 indicate higher counts.

Based on the illustrated data, the following observations can be made:

- Eastbound and westbound traffic on the overcrossing is generally less than the bridge's traffic. Traffic going towards the bridge (eastbound) typically corresponds to 50%-65% of the bridge traffic, while traffic going away from the bridge (westbound) corresponds to 75-90%.
- The lower proportion of eastbound traffic is likely due to the option of using either the overcrossing path or the I-580 shoulder. This is supported by the data of Table 6-1, which indicates that 68% of eastbound and 74% of weekend/holiday eastbound cyclists along the Sir Francis Drake corridor opt to use the overcrossing path over the I-580 shoulder path.
- The relatively high proportions obtained in each direction indicate that a high fraction of cyclists traveling along the Sir Francis Drake corridor are likely to be traveling to or from the bridge.
- The above observation suggests a strong incentive to provide for a continuous path between the bridge and Sir Francis Drake Boulevard.

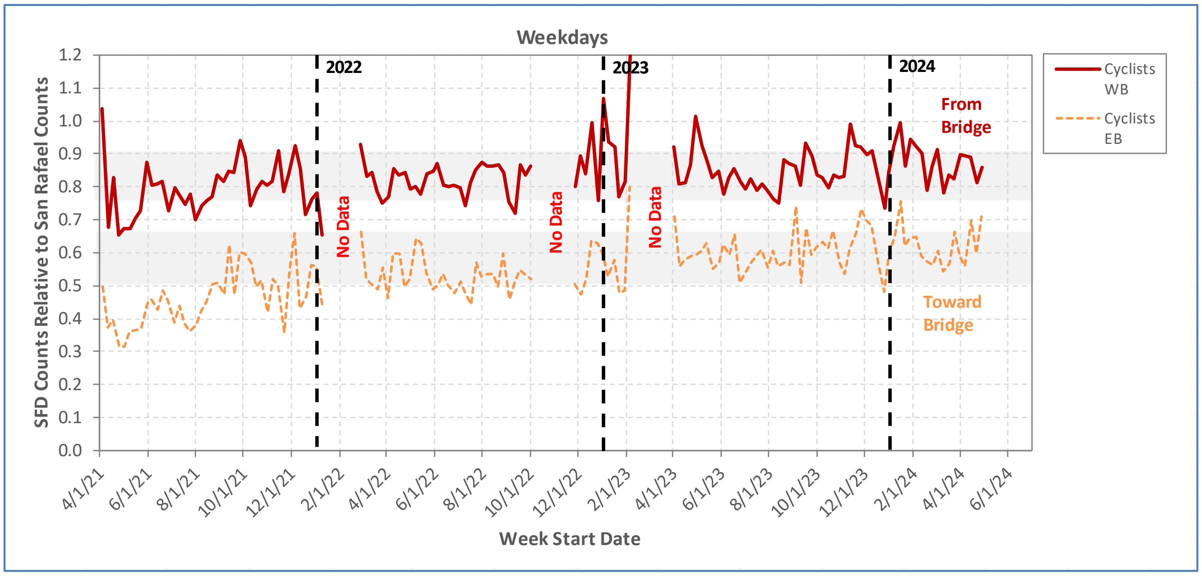

Figure 6-10: Comparison of Sir Francis Drake Overcrossing Traffic to Bridge Traffic - Weekdays

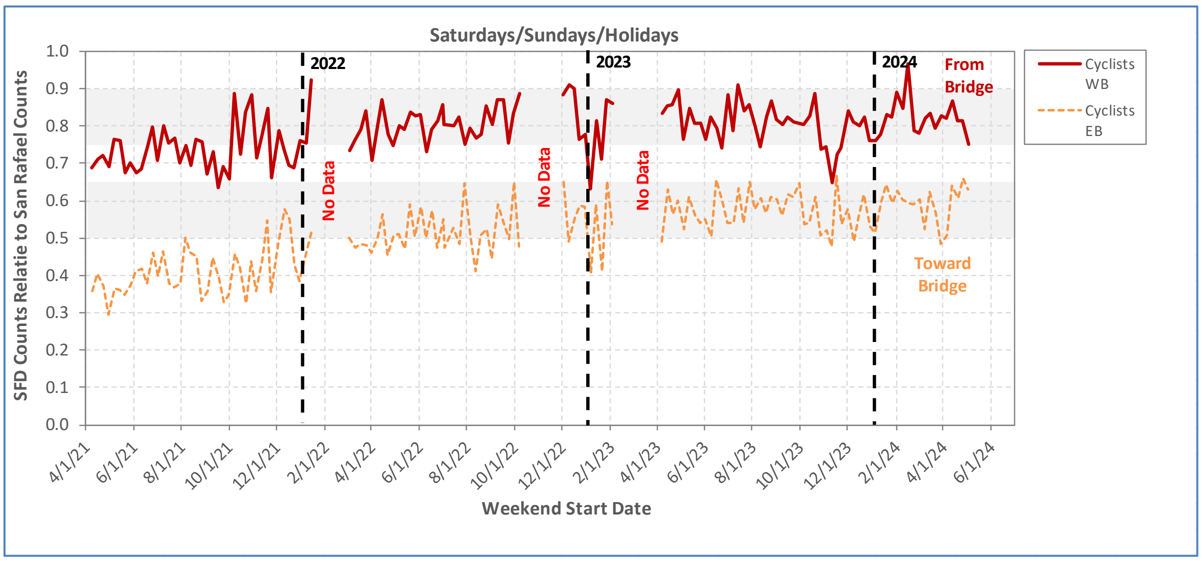

Figure 6-11: Comparison of Sir Francis Drake Overcrossing Traffic to Bridge Traffic – Weekends

6.3. BICYCLES CARRIED ON GOLDEN GATE TRANSIT BUSES

Before the opening of the bridge path, cyclists wishing to cross the Richmond-San Rafael bridge only had the option of using Golden Gate Transit buses crossing across. To assess the impact that the new bridge path might have had on the need to use Golden Gate buses, counts of bikes carried across the bridge each month by Golden Gate Transit buses were obtained from the agency. These counts, covering May 2015 to September 2023, are shown in Figure 6-12.

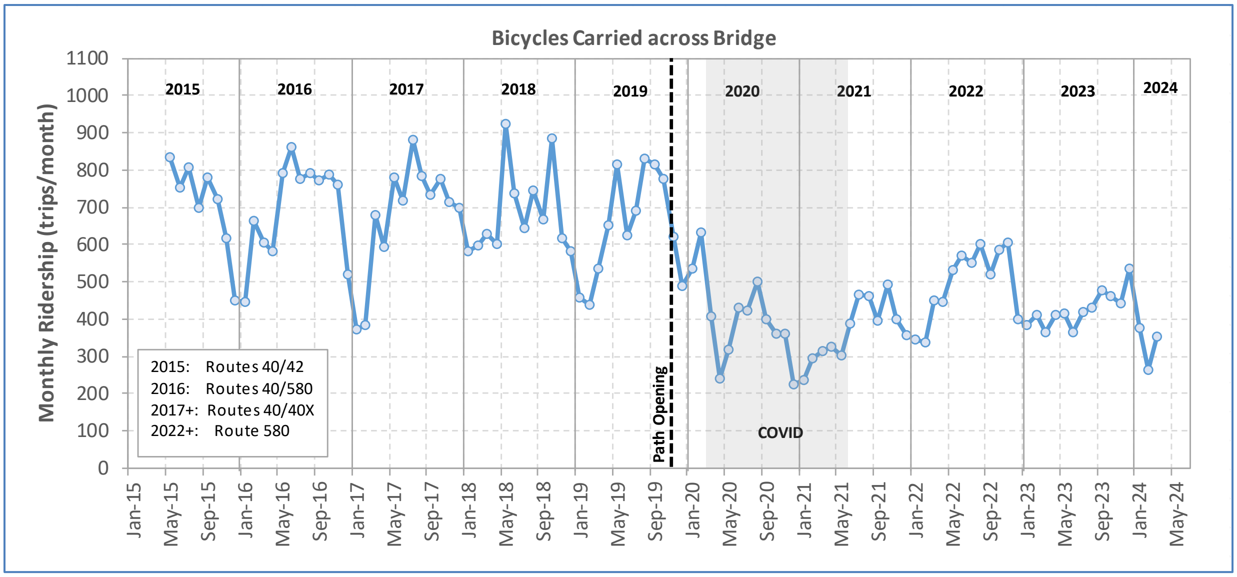

Figure 6-12: Bicycles Carried across Bridge on Golden Gate Transit Buses, 2015-2024

Based on the illustrated data, the following observations can be made regarding the number of bikes carried across the bridge by Golden Gate Transit buses:

- Before the path opening, the number of bikes carried on buses followed an annual cyclical pattern, with the highest counts observed in May, June, July, or August, when the weather is warm and sunny, and the lowest counts in December or January when it is colder and rainier. This is similar to the counts from the bridge path.
- Before the path opened, buses carried between 780 and 925 bikes across the bridge during summer, corresponding to 25-30 bicycles/day. During winter, only 375 to 550 bikes were typically carried each month, corresponding to 12-18 bicycles/day.
- After the path opening in November 2019, bike counts for December 2019, January 2020, and February 2020 appear to stay within the 2015-2019 historical cycle.
- Following the imposition of the first COVID-19 stay-at-home order in March 2020, the number of bikes carried across the bridge significantly dropped, reaching a low of 239 in April 2020.
- Following the official end of the COVID-19 pandemic in the summer of 2021, counts have partly recovered, gradually reaching 600 bicycles/month, or 19-20 bicycles/day, in the fall of 2022.
- 2023 saw another significant drop in counts, with the number of bicycles carried across each month remaining below 500 for most of the months.

Based on the above observations, it could be hypothesized that the opening of the multi-use path on the upper deck of the bridge might have led to a reduction in the number of bicycles carried across the bridge by Golden Gate Transit buses as recent counts remain below observations from before the path's opening. However, it is also possible that the drop might be the result of an underlying reduction in transit ridership, and thus, not entirely related to the path's opening.

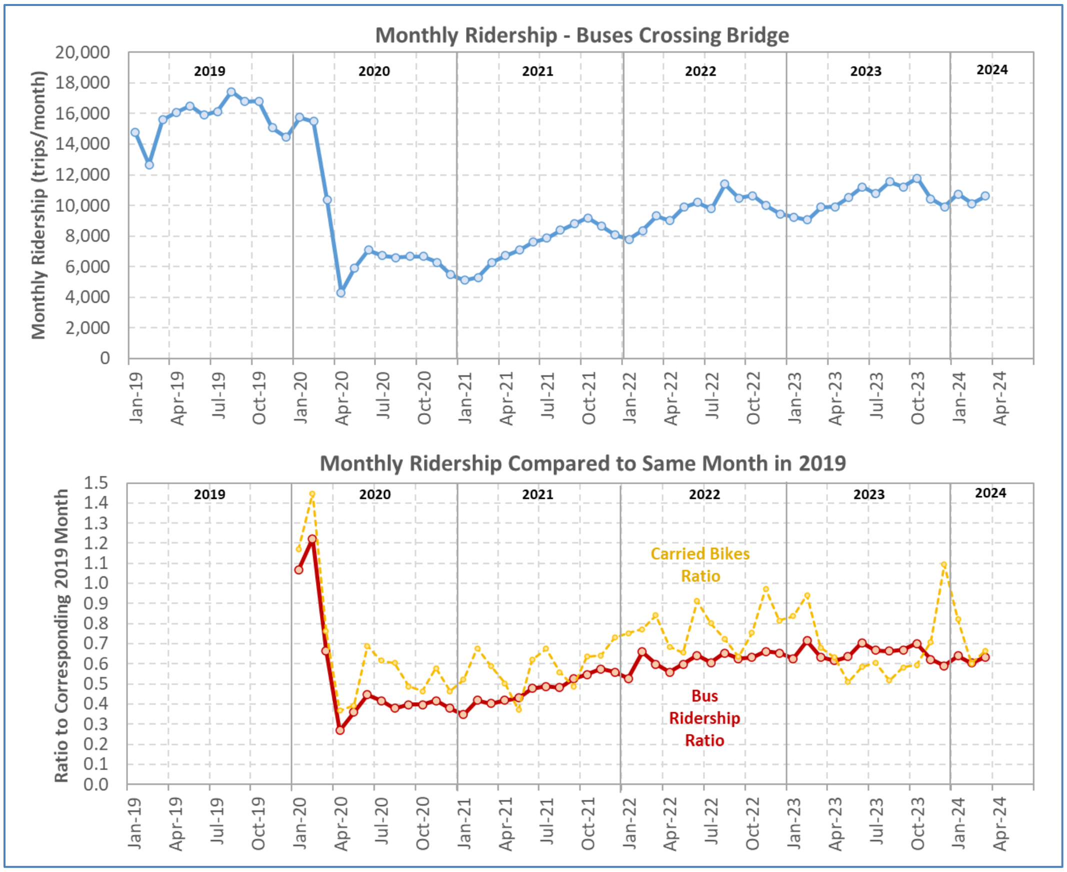

Figure 6-13: Golden Gate Transit Monthly Ridership, 2018-2023

To determine whether the post-2019 drop in bicycles carried across the bridge could be linked to the availability of the multi-use path, the bicycle counts were compared to the ridership of buses running across the bridge for the agency. This analysis is shown in Figure 6-13. In the figure, the top diagram illustrates the observed ridership over the bridge between January 2019 and March 2024, while the bottom diagram compares ridership levels from 2020 to 2024 to the 2019 ridership in the same month. To facilitate data interpretation, the ratio of bicycles carried over based on the same reference is also presented.

Based on the illustrated data, the following observations can be made:

- Following the COVID-related drop of March/April 2020, which saw bus ridership levels across the bridge drop to 27% of 2019 levels, bus ridership has gradually reached back to around 70% of 2019 levels in late 2023 before dropping back around 60% in early 2024.
- From mid-2020 to early 2023, the ratio of bikes carried on buses compared to 2019 generally appears to follow the gradual increase in the overall ridership ratio. This suggests a potential strong correlation between bus ridership and bicycle counts, and thus, a potential low impact from the bridge path up to this point.
- From April 2023 to October 2023, the bicycle count ratios suddenly dip below the overall ridership ratios. This is linked to the unexpectedly low monthly bicycle counts observed throughout the summer of 2023 as shown in Figure 6-12. Since these low counts occur while the bus ridership is increasing, this suggests that external factors may have enticed bicycle riders

not to use buses. Since counts from the bridge path show a noticeable increase in bicycle traffic over the summer of 2023, a logical conclusion could be that some bus riders have switched to using the path. However, more data would be needed to provide a more definitive conclusion, and in particular, to explain why the hypothesized switch did not occur in 2022 or earlier years.

- Between November 2023 and March 2024, the increase in bicycle ratios could simply be due to changes in the proportion of rainy/cold days during this period compared to 2019.

Based on the illustrated data, it is difficult to determine with certainty whether the opening of the multi-use path on the bridge's upper deck might have caused a shift in travel demand from the buses to the path. This is in great part due to the opening happening right before the COVID-19 pandemic. While the number of bicycles currently carried across the bridge on buses is lower than before the path's opening, the overall bus ridership is also lower as the overall transit demand has yet to fully recover from the behavioral changes induced by the COVID-19 pandemic. While the data suggests that a potential switch away from using buses toward riding on the path might have occurred in 2023, such a conclusion lacks clear supporting arguments. It remains possible that any of the observed changes are simply the results of seasonal or annual fluctuations playing on top of residual pandemic effects.

6.4. TIME-OF-DAY USE PROFILES – BRIDGE PATH

Figure 6-14 illustrates the daily eastbound and westbound bicycle traffic profiles across the bridge for an average weekday, Saturday, and Sunday between April 2021 and April 2024. This is an average of the data recorded by sensors at both ends of the bridge. For each day, the diagrams show the fraction of the total daily flow within each hour. The dotted line further represents the eastbound traffic and the solid line the westbound traffic.

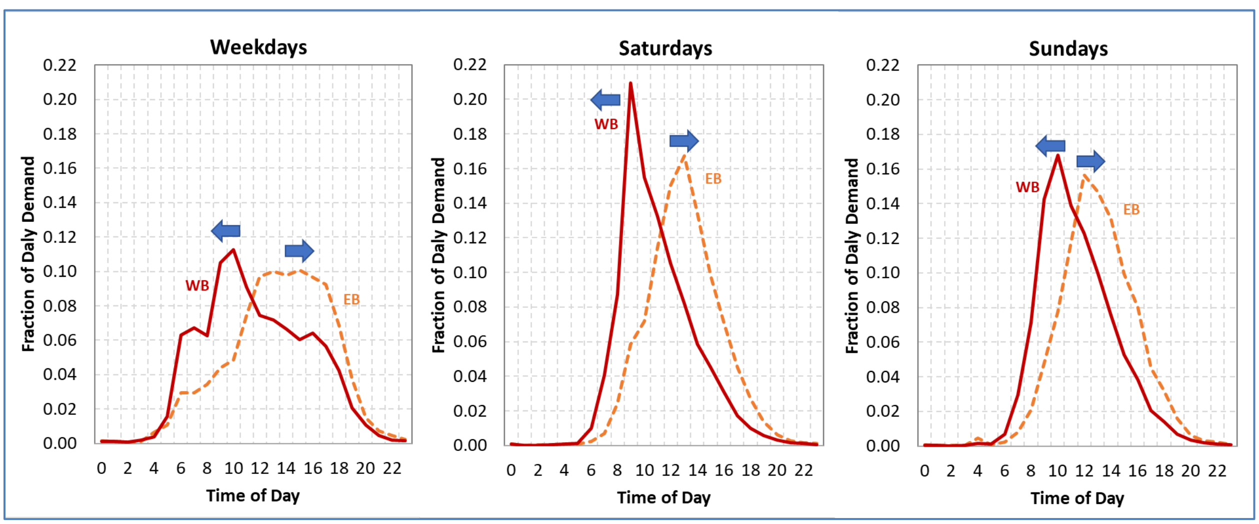

Figure 6-14: Time-of-Day Bicycle Traffic Profiles – Bridge Path

The following observations can be made from the illustrated data:

- On all days, cyclists mainly travel westbound in the morning and eastbound in the afternoon.
- On weekdays, westbound traffic generally peaks between 10 and 11 AM, while eastbound traffic peaks between 12 Noon and 4 PM.

- On weekends, westbound traffic tends to peak between 9 and 10 AM on Saturdays, and slightly later on Sundays, between 10 and 11 AM. On Saturdays, eastbound traffic peaks between 1 and 2 PM, while Sunday traffic peaks a bit earlier, between 12 Noon and 1 PM.
- Weekday bicycle traffic is more spread out across the day, while both Saturday and Sunday traffic show very pronounced peaks.

6.5. TIME-OF-DAY USE PROFILES – SIR FRANCIS DRAKE OVERCROSSING CORRIDOR

Figure 6-15 illustrates the daily eastbound and westbound bicycle traffic profiles on the Sir Francis Drake overcrossing path for an average weekday, Saturday, and Sunday between April 2021 and April 2024. For each day, the diagrams show the fraction of the total daily flow within each hour. The dotted line further represents the eastbound traffic and the solid line the westbound traffic.

The following observations can be made from the illustrated data:

- Similar to the bridge traffic, cyclists mainly travel westbound in the morning and eastbound in the afternoon on weekdays, Saturdays, and Sundays. This is likely a reflection of the fact that most of the path users either come from or are going to the bridge.
- On weekdays, westbound traffic generally peaks between 10 and 11 AM, while eastbound traffic typically peaks between 12 Noon and 1 PM
- On weekends, Saturday traffic tends to peak between 9 and 10 AM, while Sunday traffic peaks between 10 and 11 AM. On Saturdays, eastbound traffic peaks between 1 and 2 PM, while Sunday traffic peaks a bit earlier, between 12 Noon and 1 PM.
- Weekday bicycle traffic is more spread out across the day, while both Saturday and Sunday traffic show very pronounced peaks.

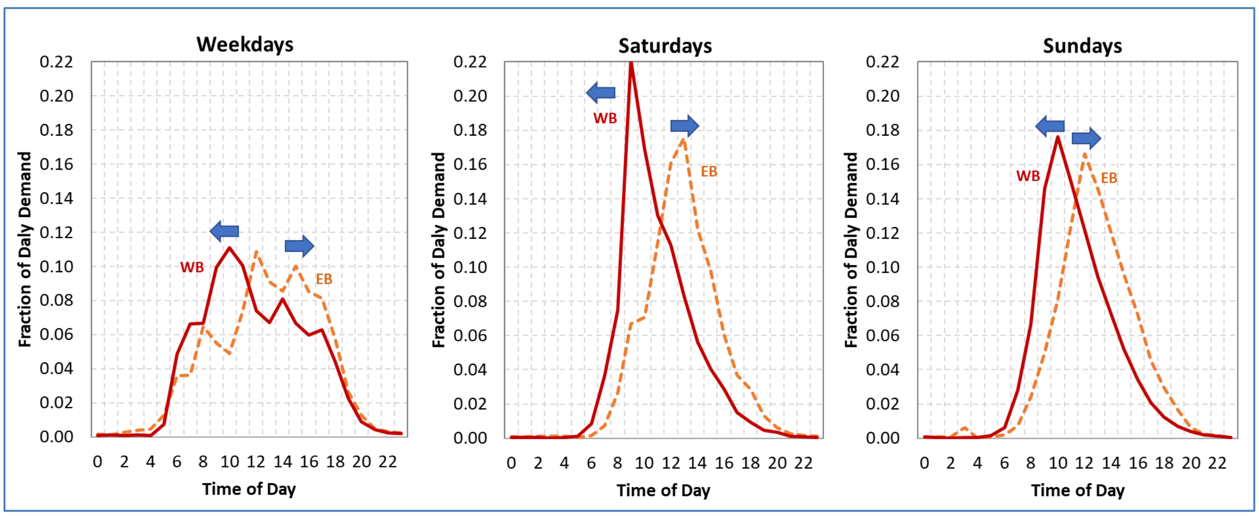

Figure 6-15: Time-of-Day Bicycle Traffic Profiles – Sir Francis Drake Overcrossing Path

6.6. COMPARISONS TO OTHER BAY AREA BRIDGES

Figure 6-16 compares the monthly bicycle counts across the various Bay Area bridges with multi-use paths from January 2021 to April 2024, as captured by the Eco-Counters sensors operated by the Bay Area Transportation Authority. These are bidirectional counts, summing traffic in both directions. This data is presented to assess the relative popularity of the Richmond-San-Rafael bridge path to other bridges. Missing data points reflect months during which problematic data or no data at all was collected.

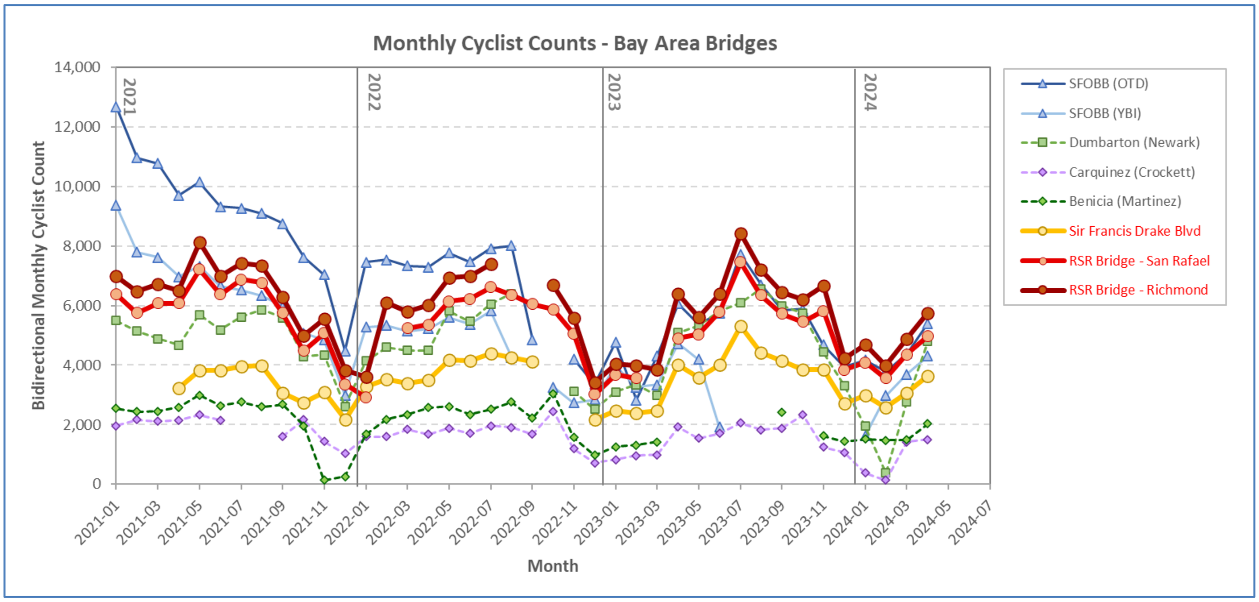

Figure 6-16: Monthly Bicycle Counts across Bay Area Bridges, 2021-2024

Based on the illustrated data, the following observations can be made:

- Bicycle traffic on the bridge is currently the highest of all State-owned toll bridge paths, including the San Francisco-Oakland Bay Bridge multi-use path.
- Across 2023 and 2024, if ignoring data from November 2023 due to the artificially high demand that resulted from the fourth-anniversary event, the monthly traffic entering the multi-use path from the Richmond side has corresponded to between 85% and 140% of the San Francisco-Oakland Bay Bridge traffic, for an average of 107%. On the San Rafael side, the entering traffic has corresponded to between 77% and 125% of the San Francisco-Oakland Bay Bridge traffic, for an average of 96%.
- Traffic on the Sir Francis Drake overcrossing path is generally lower than on the Dumbarton Bridge but higher than on the Benicia or Carquinez bridges.

6.7. SUMMARY OBSERVATIONS

The following are key observations regarding the use of the bridge's upper deck path by cyclists:

- Bicycle traffic on the bridge is currently the highest of all State-owned toll bridge paths, including the San Francisco-Oakland Bay Bridge multi-use path.

- Bicycle traffic is seasonal, with the highest volumes typically observed between June and September and the lowest between November and March when it is colder and rainier.
    - **Saturday traffic:** Since January 2022, westbound Saturday traffic has averaged 264 cyclists/day during summer while eastbound traffic has averaged 219 cycles per day, with peaks near 440. Winter traffic has averaged 177 cyclists/day westbound and 135 cyclists/day eastbound, with peaks near 300.
    - **Sunday traffic:** Sunday traffic is usually lower than on Saturdays. Summer westbound traffic has averaged 188 cyclists/day and eastbound traffic 167, with peaks of up to 285. Winter traffic has averaged 145 cyclists/day westbound and 120 eastbound, with peaks near 300.
    - **Weekday traffic:** Weekday traffic is much lower than on weekends, with peak summer averages of 75 and 66 cyclists/day westbound and eastbound, respectively, with peaks near 100, and winter averages of only 50 and 41 cyclists/day with peaks near 60.
- Westbound traffic is usually greater than the eastbound traffic, with a typical 55%/45% split.
- Weekend traffic is more noticeably affected by weather conditions than weekday traffic.
- Path users generally travel westbound in the morning and eastbound in the afternoon.
- There has been a significant drop in the number of bicycles carried across the bridge by Golden Gate Transit buses, with monthly bike counts remaining at 51%-63% of the 2015-2019 average for each month. However, it is unclear what part might be a byproduct of the COVID-19 pandemic and what part, if any, could be linked to the path opening, as the overall ridership for Golden Gate Transit remains at around 45%-48% of the 2019 level.
- Overall, trips with bicycles across the bridge, either being carried on a bus or ridden, are higher than before the path opening. Summer traffic went from 700-900 trips/month when Golden Gate Transit buses were the only option, to 6,000-8,000 trips/month during the summer of 2023.

Additional observations regarding the use of the Sir Francis Drake overcrossing path:

- Similar to the bridge path, bicycle traffic on the overcrossing path is seasonal, with the highest traffic occurring in the summer and the lowest between November and February.
    - **Saturday traffic:** Since January 2022, peak summer Saturday traffic has averaged 189 cyclists/day westbound and 125 eastbound, with directional peaks of up to 320 and 206 cyclists/day respectively. Winter traffic has averaged 119 cyclists/day westbound and 77 eastbound.
    - **Sunday traffic:** Sunday traffic is usually lower than on Saturdays. Summer traffic has averaged 125 cyclists/day westbound and 88 eastbound, with directional peaks of 205 and 125 respectively. Winter traffic has averaged 92 cyclists/day westbound and 60 eastbound.
    - **Weekday traffic:** Weekday traffic is much lower than on weekends, with peak summer averages of 56 and 37 cyclists/day westbound and eastbound, and winter averages of only 37 and 24 cyclists/day.
- Peak travel periods are similar to what has been observed on the bridge, with westbound traffic peaking in the morning and eastbound in the early afternoon.

- Eastbound traffic (going toward the bridge) is generally significantly less than westbound traffic (going away from the bridge). This is explained by the presence of an alternate eastward path on the I-580 East on-ramp and along the freeway mainline up to the Main Street exit.
- Eastbound traffic is split between the overcrossing path and the I-580 East shoulder path. With a 68% weekday and 74% weekend split, a strong preference is for using the overcrossing path, likely due to its perceived higher safety compared to traveling on the shoulder of a busy freeway.
- The conversion of the overcrossing path from a one-way into a two-way path has likely enticed some eastbound travelers to switch from using the I-580 East shoulder, resulting in more crossings of Sir Francis Drake Boulevard at Andersen Drive.
- The counts suggest that a majority of overcrossing users are also bridge path users, as westbound overcrossing traffic typically corresponds to 75-90% of westbound bridge traffic while eastbound traffic corresponds to 50-60% of the bridge traffic.

7. PEDESTRIAN TRAFFIC

This section presents the results of the evaluations assessing pedestrian traffic across the bridge. The specific elements discussed include:

- Pedestrian traffic on the bridge path
- Pedestrian traffic on the Sir Francis Drake overcrossing path
- Time-of-day pedestrian flow profiles on the bridge path
- Summary observations

7.1. PEDESTRIAN TRAFFIC – BRIDGE PATH

Figure 7-1 and Figure 7-2 illustrate the average daily eastbound and westbound pedestrian traffic that was recorded by the sensor near the Caltrans Maintenance Yard on the east side of the bridge from August 2020 to mid-April 2024 on non-holiday weekdays and weekend and holiday days. This is the only sensor that provided valid pedestrian data during the study. Both figures distinguish two data collection periods based on which sensors returned data (see Figure 5-10):

- **November 2019 – Mid-August 2020:** No valid pedestrian data available.
- **Mid-August 2020 – April 2024:** Pedestrian counts from the Maintenance Yard counter only.

While data were collected between November 2019 and mid-August 2020 from the initial Richmond and current San Rafael sensors, the counts that were returned during this period were unrealistically high, often in the thousands of pedestrians per day. This problem was attributed to placements that caused the sensors to capture vehicles passing in the nearby traffic lane. This led to the disabling of the pedestrian counting capability at both stations in March 2021, leaving only data collected by the Maintenance Yard station from August 2020 onward.

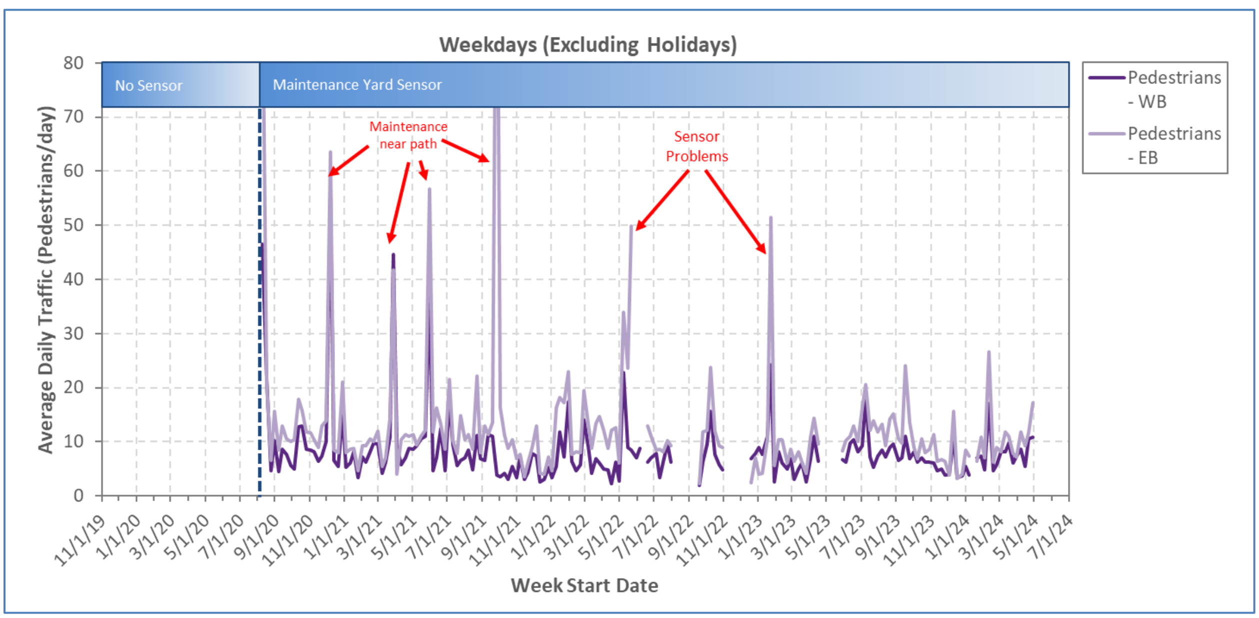

Figure 7-1: Daily Pedestrian Traffic – Richmond Bridge – Weekdays, 2020-2024

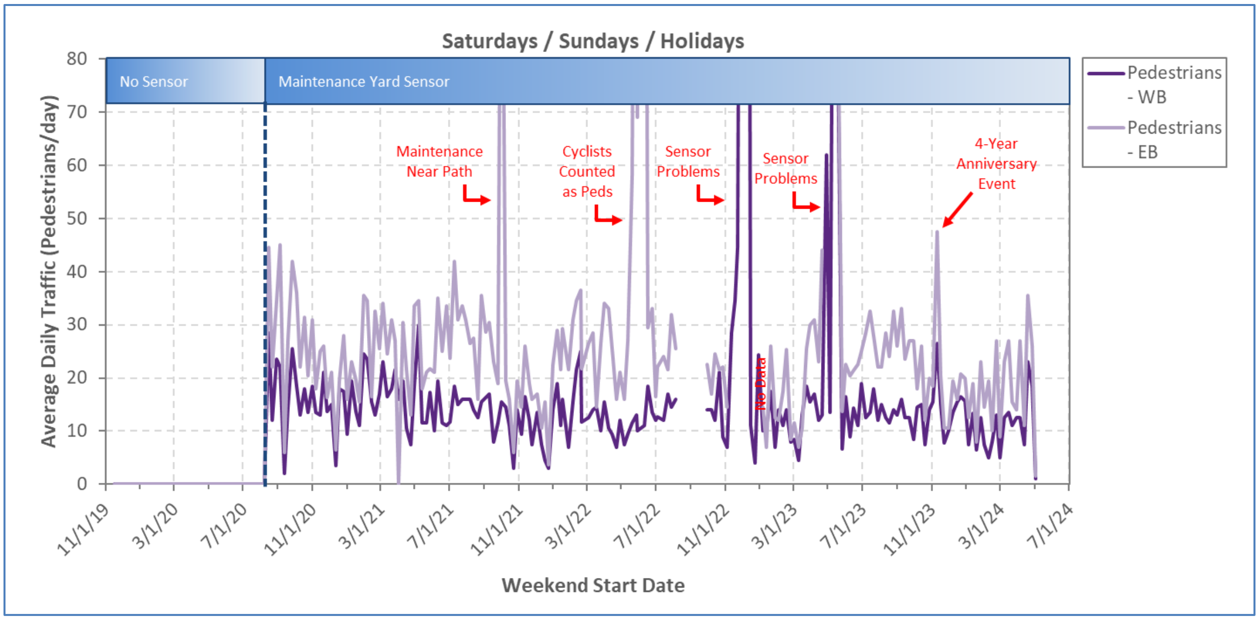

Figure 7-2: Daily Pedestrian Traffic – Richmond Bridge – Weekends, 2020-2024

Comparisons of the eastbound travel profiles captured by the Maintenance Yard counter to the eastbound profile extracted from the San Rafael counter in the fall of 2020 further suggested that the assumed travel direction might have been incorrect at one of the two counters. This led to further adjustments being carried out at the end of March 2021 on both the Marin and the Maintenance Yard sensors to correct the recorded direction of travel and adjust the compiled data.

Finally, the various spikes in traffic shown in both figures are often attributed to maintenance activities occurring near the Caltrans Maintenance Yard. In most instances, the sensors likely captured workers walking near them. For this reason, data from all marked traffic spikes have been excluded from all the analyses further reported.

Based on the illustrated data, the following observations can be made about the observed pedestrian use of the bridge path:

- Relatively few pedestrians use the bridge path. Since January 2022, daily weekday traffic has typically ranged between 5 and 20 pedestrians/direction, for a westbound average of 11 pedestrians/day and an eastbound average of 8 pedestrians/day.
- Weekend traffic has ranged between 10 and 40 pedestrians/direction, with occasional higher and lower peaks, for a westbound average of 24 pedestrians/day and an eastbound average of 14 pedestrians/day.
- Eastbound pedestrian counts are generally higher than westbound counts. It is unclear whether this is due to different directional volumes or some sensor setup.
- Weekday pedestrian traffic appears to be relatively stable throughout the year, suggesting that a significant portion of the observed pedestrians may be regular users.
- Both weekday and weekend traffic exhibit some cyclical pattern, with slightly higher observed traffic in the summer than in winter. This may likely be due to weather effects.

- The 4-mile length of the bridge may explain the relatively low pedestrian use of the path, as this length may be longer than what most people are willing to walk. It may also explain why some pedestrians may only walk a portion of the bridge.
- The lack of parking close to the bridge also likely hinders pedestrian traffic, as individuals may have to walk a significant additional distance on either side of the bridge to access it.
- Based on field observations, some of the travelers seen going in one direction may be the same individuals seen traveling in the opposite direction, such as individuals using the path to access fishing locations on the path or near the bridge.

In the above assessment, the number of pedestrians using the path is likely to be underestimated. This is because all the collected data is based on a single sensor located on the Richmond side of the bridge. Due to the presence of the vista point and its parking area, some individuals likely access the path from the Marin County side and walk a portion of the bridge before returning to the vista point. Unless they have reached the Caltrans Maintenance Yard on the other side of the bridge, none of these individuals were therefore captured in the statistics.

Another unknown is the proportion of individuals walking on the path to reach a fishing location near the foot of the bridge. On the Marin County side of the bridge, individuals are frequently observed walking along the path to set up fishing stations along the shoreline, on or off the path. These individuals would usually park their vehicles at the nearby vista and would rarely fully cross the bridge. Since the only pedestrian counter is located on the Richmond side, these individuals were likely not captured in the pedestrian statistics. Some fishers are also observed walking on the path on the Richmond side but to a much lower frequency than on the Marin County side.

7.2. PEDESTRIAN TRAFFIC – SIR FRANCIS DRAKE OVERCROSSING PATH

Since pedestrians are prohibited from using the Sir Francis Drake overcrossing bike path, only occasional pedestrians were expected to be observed using it. This assumption was confirmed by the various video recordings of the path that were made between May 2021 and February 2023. A total of fewer than 10 pedestrians were observed across all data collection periods.

7.3. TIME-OF-DAY USE PROFILES – BRIDGE PATH

Figure 7-3 illustrates the average eastbound and westbound daily pedestrian traffic profiles near the Caltrans Maintenance Yard in Richmond for weekdays, Saturdays, and Sundays. This is based on data recorded between April 2021 and April 2024. As indicated in the previous section, no valid pedestrian data were collected from the other sensors around the bridge. For each day, the diagrams show the fraction of the total daily flow seen within each hour compared to the total daily flow.

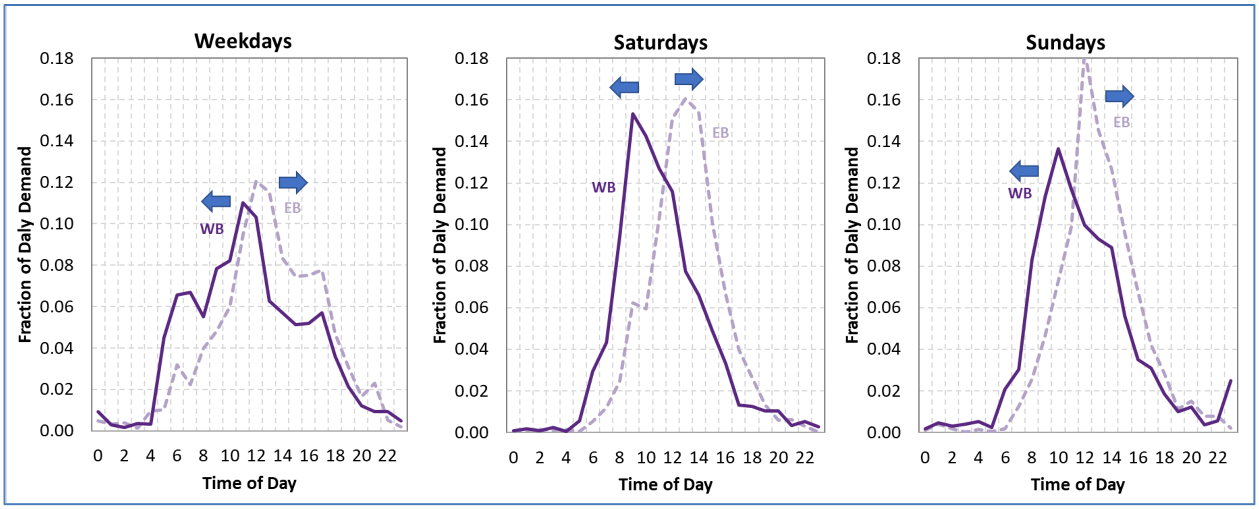

Figure 7-3: Average Daily Pedestrian Traffic Profiles, Maintenance Yard

The following observations can be made regarding the pedestrian traffic:

- More pedestrians travel westbound towards Marin County in the morning and eastbound towards Richmond in the afternoon. This is similar to the observed bicycle traffic.
- Weekday westbound traffic peaks between 11 AM and 1 PM, while eastbound traffic peaks between 12 Noon and 1 PM.
- Saturday westbound traffic peaks between 9 and 10 AM, while Sunday traffic peaks slightly later, between 10 and 11 AM. Both the Saturday and Sunday eastbound traffic peaks between 1 and 2 PM.
- Pedestrian traffic is generally more spread out over time during weekdays than on weekends.

7.4. TIME-OF-DAY USE PROFILES – SIR FRANCIS DRAKE OVERCROSSING CORRIDOR

No time-of-day profiles were developed for pedestrians on the Sir Francis Drake overcrossing corridor as pedestrians are normally not allowed to use the path. Throughout the project, only occasional pedestrians have been observed walking on the path.

7.5. COMPARISONS TO OTHER BAY AREA BRIDGES

Figure 6-16 compares the monthly pedestrian counts across the various Bay Area bridges with multi-use paths, as captured by the Eco-Counters sensors operated by the Bay Area Transportation Authority. These are bidirectional counts from January 2021 to April 2024. This data is presented to assess the relative popularity of the Richmond-San-Rafael bridge path to other bridges. Missing data points reflect months during which problematic data or no data at all was collected.

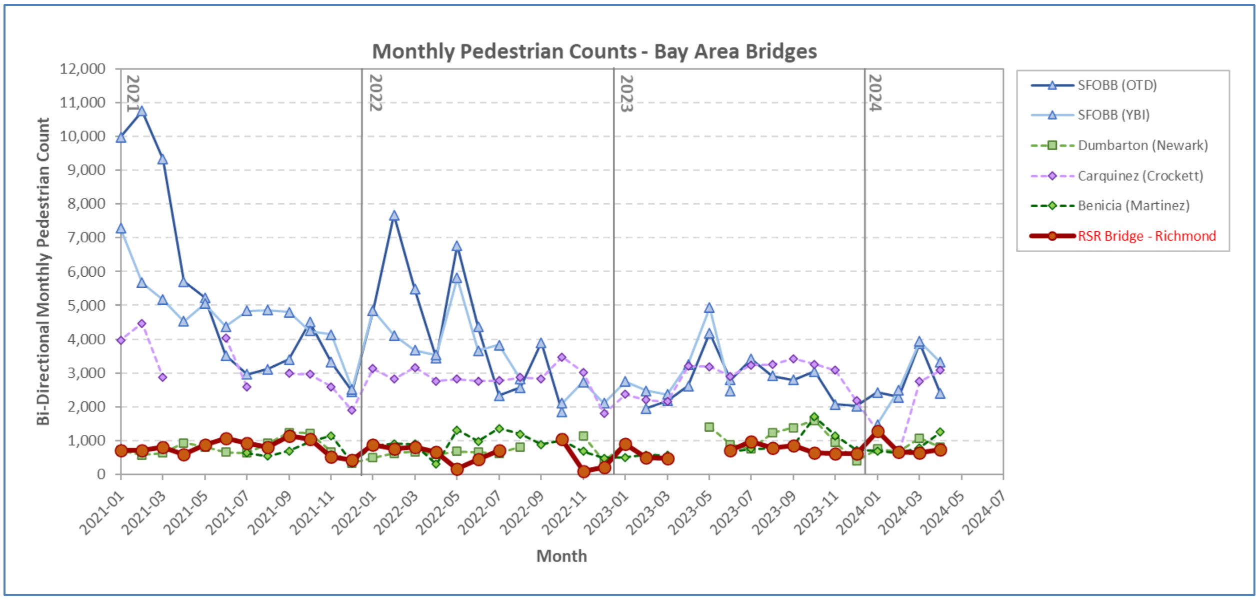

Figure 7-4: Monthly Pedestrian Counts across Bay Area Bridges, 2021-2024

Based on the illustrated data, the following observation can be made:

- Traffic on the Richmond-San Rafael bridge is currently among the lowest across the various Bay Area bridges, with monthly pedestrian counts similar to the Dumbarton and Benicia bridges. As explained earlier, this is likely linked to the length of the bridge and the lack of parking close to it on either side.
- The San Francisco-Oakland Bay Bridge and Carquinez Bridge are usually the two bridges with the highest pedestrian traffic.

7.6. SUMMARY OBSERVATIONS

The following is a summary of key observations from the analysis of pedestrian counts on the Richmond side of the bridge:

- Pedestrian traffic on the bridge is relatively low. On average, only 11 pedestrians are seen entering the bridge path daily from the Richmond side and 8 exiting it daily. During weekdays, 24 are seen on average entering the path and 14 exiting it from the same location.
- A daily directional pattern exists, with pedestrians traveling mainly westbound in the morning and eastbound in the afternoon.
- Both weekday and weekend traffic exhibit some seasonal patterns, with slightly higher observed traffic in the summer compared to winter. This is likely due to weather effects.
- The estimated pedestrian use is likely underestimated as the counts are based on a single sensor located on the Richmond side of the bridge. This sensor would not have captured individuals accessing the path from the vista point in Marin County and turning back before having fully crossed the bridge.
- The 4-mile length of the bridge may explain the low pedestrian demand.

- Fishers have been observed using the path to access a location to cast their fishing lines, either on the shore or the path itself. Such individuals are more often seen on the Marin County side of the bridge, where they use the parking lot at the vista as a staging area.

Additional observations regarding the use of the Sir Francis Drake overcrossing path:

- While the overcrossing path is technically restricted for use by bicyclists, occasional pedestrians are seen walking on the path.

8. TRAFFIC IMPACTS

This section presents the results of the evaluations that were conducted to assess the impacts on traffic of the various modifications made. The specific items covered in the section include:

- Observed changes in traffic demand over the evaluation period.
- Impacts of opening the lower deck shoulder to traffic on eastbound traffic in Marin County.
- Impact of converting the upper deck shoulder into a barrier-separated bike/pedestrian path on westbound traffic in Richmond and the bridge.
- Impact of converting the one-way bicycle path on the Sir Francis Drake Boulevard overcrossing in Marin County into a barrier-separated two-way path.

8.1. UNDERLYING CHANGES IN BRIDGE TRAFFIC DEMAND

Before evaluating the impacts of the various modifications made, traffic volumes around the bridge were reviewed to determine to which extent observed changes in speeds and travel times could be the result of underlying changes in traffic demand. Three specific aspects of traffic demands are evaluated below:

- Changes in daily total traffic volumes
- Changes in daily traffic profiles
- Changes in estimated vehicle miles traveled (VMT)

8.1.1. DAILY TRAFFIC VOLUMES

Changes in the traffic demand around the bridge were first analyzed using data from PeMS stations on I-580 near Canal Boulevard in Richmond (stations 400639 and 400738 in Figure 5-2) as these are the only ones having generally provided good data from 2015 to 2024. While the counts supplied by these stations do not technically represent bridge traffic, most vehicles observed at this location typically travel to the bridge or come from it. Any changes in local traffic would thus be indicative of changes in traffic across the bridge. The westbound station is also sufficiently far from the bridge to be less affected by the congestion that frequently builds up upstream of the toll plaza.

Figure 8-1 to Figure 8-3 illustrates the eastbound and westbound daily flows measured on weekdays, Saturdays, and Sundays from January 2015 to March 2024. Below are key points regarding each figure:

- The dots represent specific day measurements while the solid lines represent moving averages across two weeks for weekdays and four weeks for Saturdays and Sundays.
- Only days with 90% or more observed data are included to avoid biasing results with less accurate estimates from the PeMS imputation process. Days affected by known major incidents are also ignored.
- Westbound data from March to December 2022 were estimated using counts from the upstream station at Cutting Boulevard (station 400734) as the Canal Boulevard station did not produce valid measurements during this interval.
- No eastbound data is provided from March 2022 onward as neither the Canal Boulevard nor Cutting Boulevard stations produced valid data.

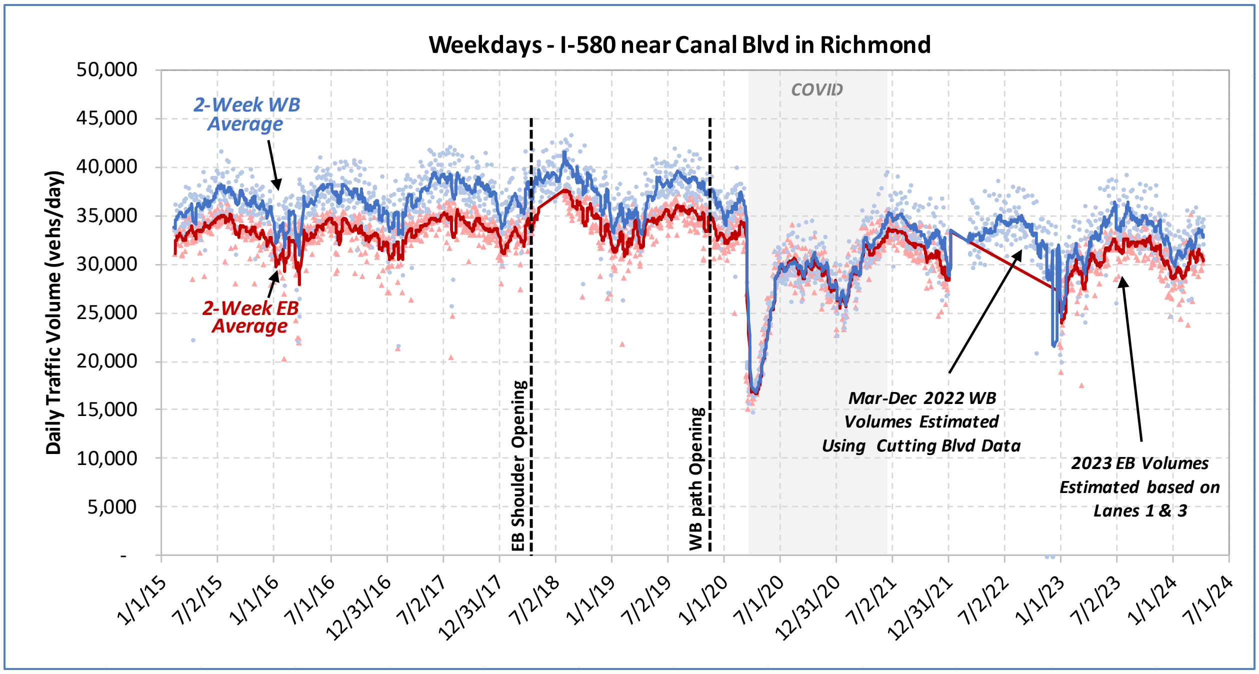

Figure 8-1: Traffic Volumes on I-580 near Canal Boulevard in Richmond – Weekdays, 2015-2024

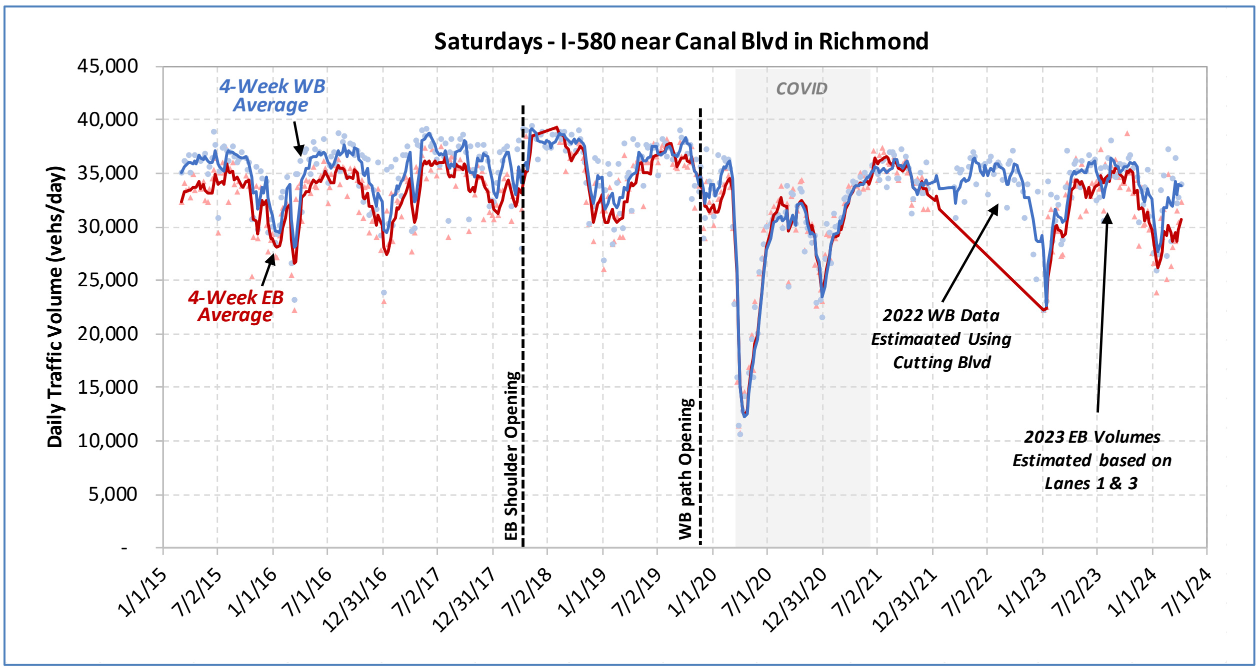

Figure 8-2: Traffic Volumes on I-580 near Canal Boulevard in Richmond – Saturdays, 2015-2024

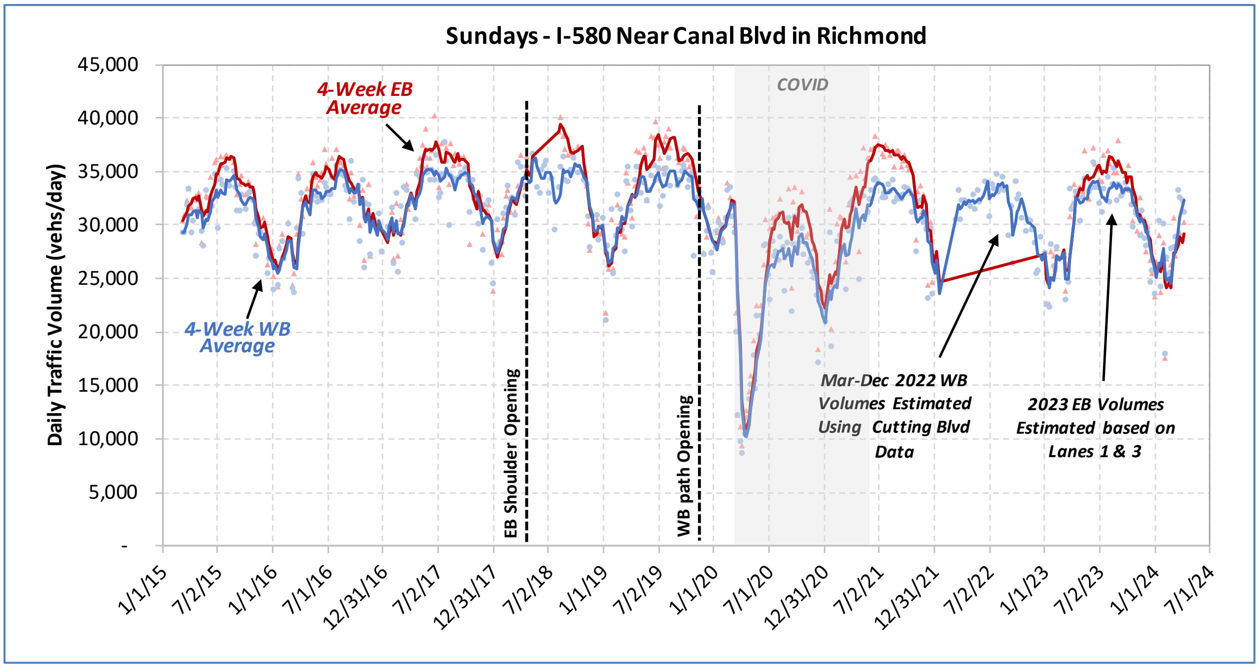

Figure 8-3: Traffic Volumes on I-580 near Canal Boulevard in Richmond – Sundays, 2015-2024

Below are key observations that can be made regarding traffic demand around the bridge:

- Before the COVID-19 pandemic, traffic volumes were slowly increasing year-over-year, with some repetitive seasonal patterns. Pre-pandemic volumes typically ranged between 25,000 and 43,000 vehicles/day, depending on the direction and day of the week.
- Through March and April 2020, daily traffic dropped by roughly 55% on weekdays and 66% on Saturdays and Sundays as a result of the imposed COVID-19 travel restrictions.
- Following a quick partial rebound through June and July 2020, traffic demand went through another dip from December 2020 through February 2021 as a result of the second wave of COVID-19 infections.
- Since March 2021, daily traffic volumes have rebounded significantly but have remained slightly below pre-COVID levels. As explained in Section 8.1.2, and more specifically shown in the profiles of Figure 8-7, this is in part due to the weekday off-peak traffic remaining somewhat below pre-COVID levels.

For comparison purposes, Figure 8-4 through Figure 8-6 illustrate observed traffic volumes between February 2018 and March 2024 near Pier 21 on the west end of the bridge. Earlier data are not plotted due to an absence of sensors. While data from Pier 35 in the middle of the bridge were initially thought to be ideal, a comparison to counts from the toll plaza revealed that the sensors at this location were likely undercounting traffic. The data from Pier 21 generally indicates similar traffic patterns to the Canal Boulevard location but with higher flow levels. This increase in traffic is mainly the result of vehicles entering or exiting the freeway at the Castro Street/Richmond Parkway interchange.

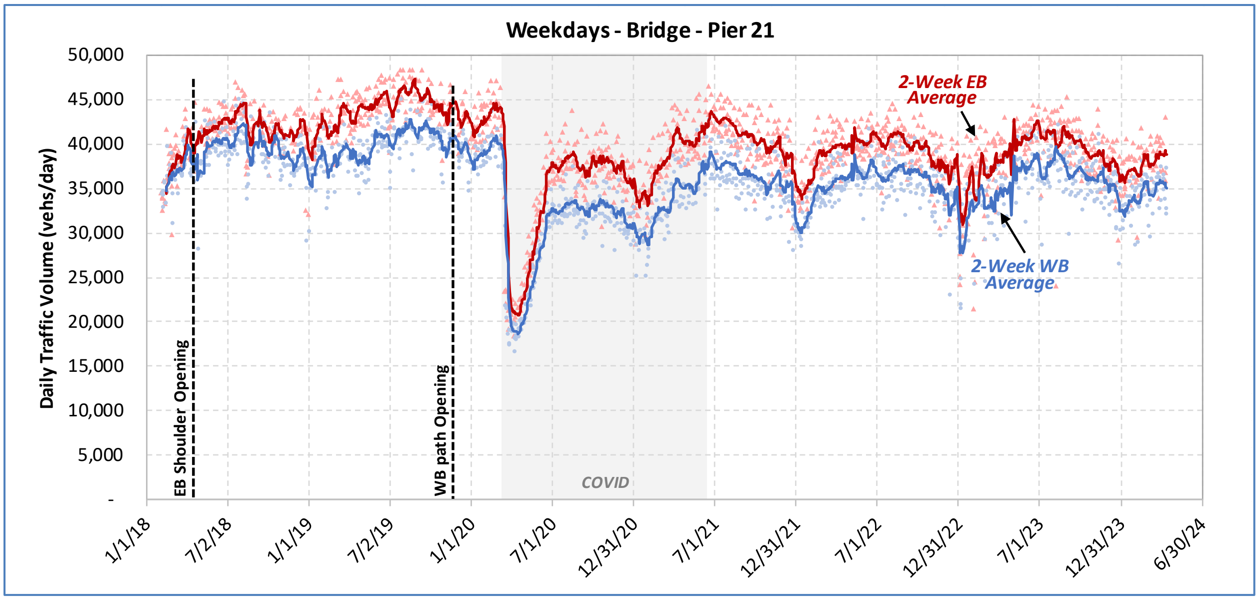

Figure 8-4: Traffic Volumes on Bridge – Weekdays, 2018-2024

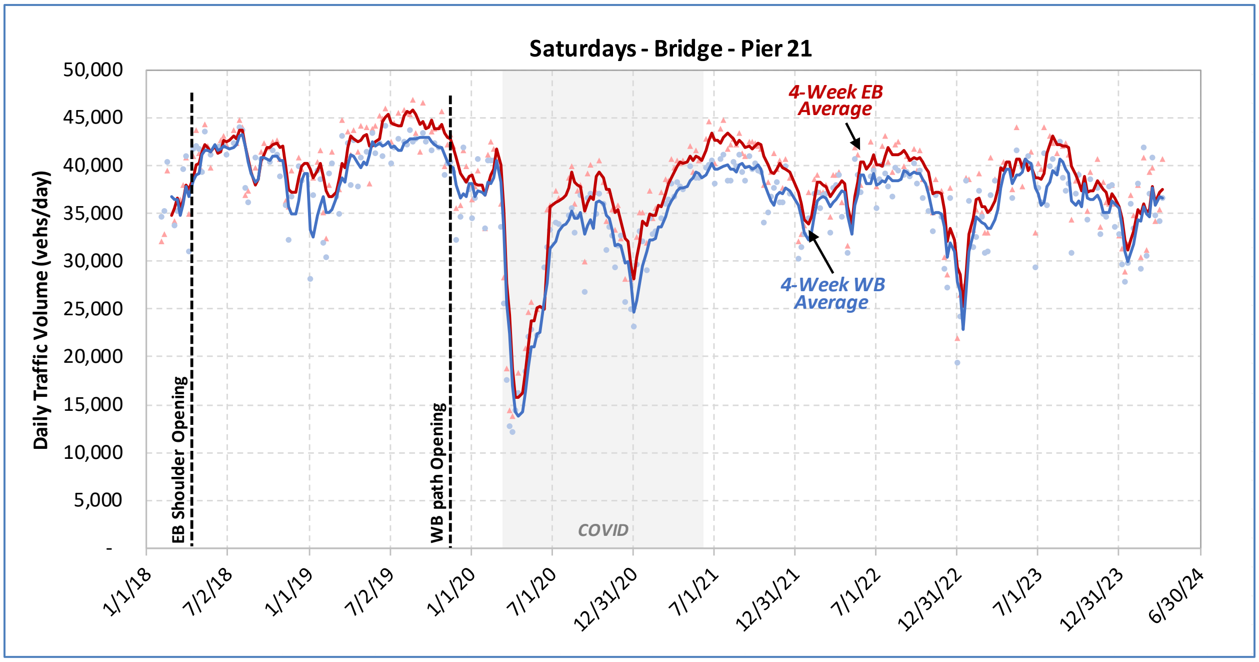

Figure 8-5: Traffic Volumes on Bridge – Saturdays, 2018-2024

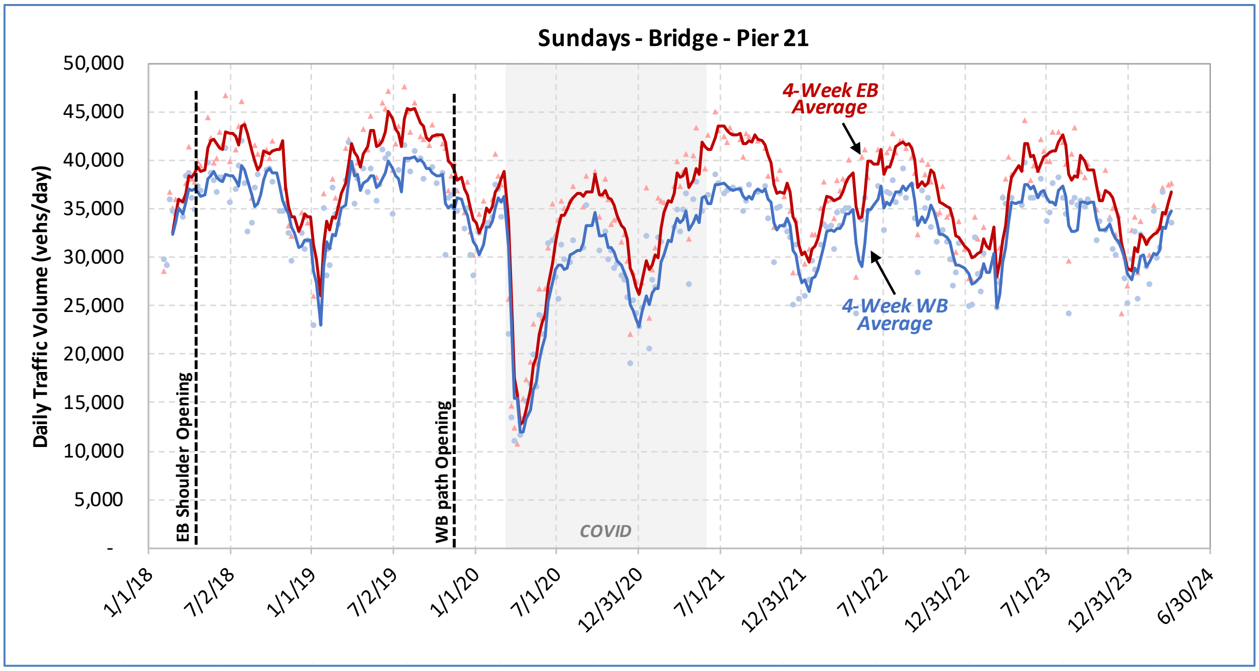

Figure 8-6: Traffic Volumes on Bridge – Sundays, 2018-2024

8.1.2. TIME-OF-DAY TRAFFIC PATTERNS

Figure 8-7 to Figure 8-12 present the average daily flow profiles across the bridge for weekdays, Saturdays, and Sundays for each year with available data between 2015 and 2024. For the eastbound direction, data are from the PeMS station at the start of the bridge (Pier 21), which only came online in February 2018. For the westbound direction, data are from the toll plaza counts. Each figure presents two profiles: one covering February, March, and April, and the other covering mid-September to mid-November. All profiles cover the same weeks year after year, except for the spring of 2020, where data past March 15 are ignored to avoid including the sudden drop in traffic related to the COVID-related stay-at-home order. In each diagram, dotted lines are further used to mark data associated with the before-evaluation period while solid lines mark data for the after-period.

The following key observations can be made from the illustrated daily profiles:

- While the counts presented in Section 8.1.1 indicate that daily traffic across the bridge remains below pre-COVID levels, the hourly flow data indicate that this is largely due to off-peak flows remaining below pre-COVID levels, as marked by the illustrated arrows.
- The reduction in off-peak traffic is particularly noticeable in the non-peak direction of both the morning and afternoon peak periods. As shown in Figure 8-7, peak eastbound morning flows between 8 AM and 9 AM have dropped from 1,900-2,100 vehicles/hour to 1,500-1,600 vehicles/hour, representing at least a 15% drop. In the westbound direction, shown in Figure 8-10, the peak afternoon flows between 4 PM and 5 PM have dropped by at least 10%, going from 2,100-2,250 vehicles/hour up to below 1,900 vehicles/hour.
- Peak eastbound weekday traffic flows for 2022 and 2023 are generally back to around levels observed in late 2018 and 2019, in the first year after the lower deck modifications.

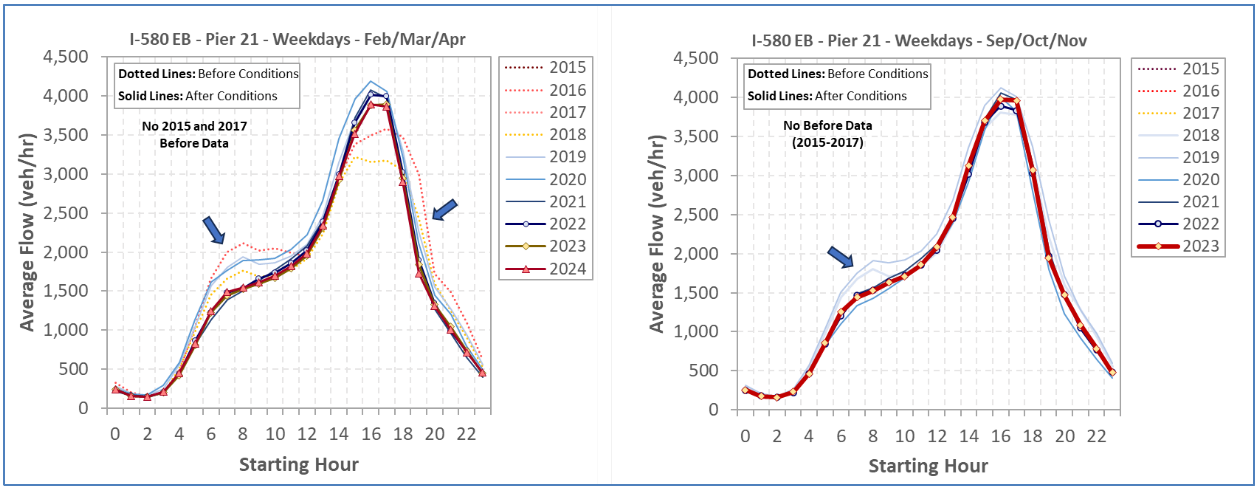

Figure 8-7: Daily Traffic Flow Profile – Bridge EB – Weekdays, 2015-2024

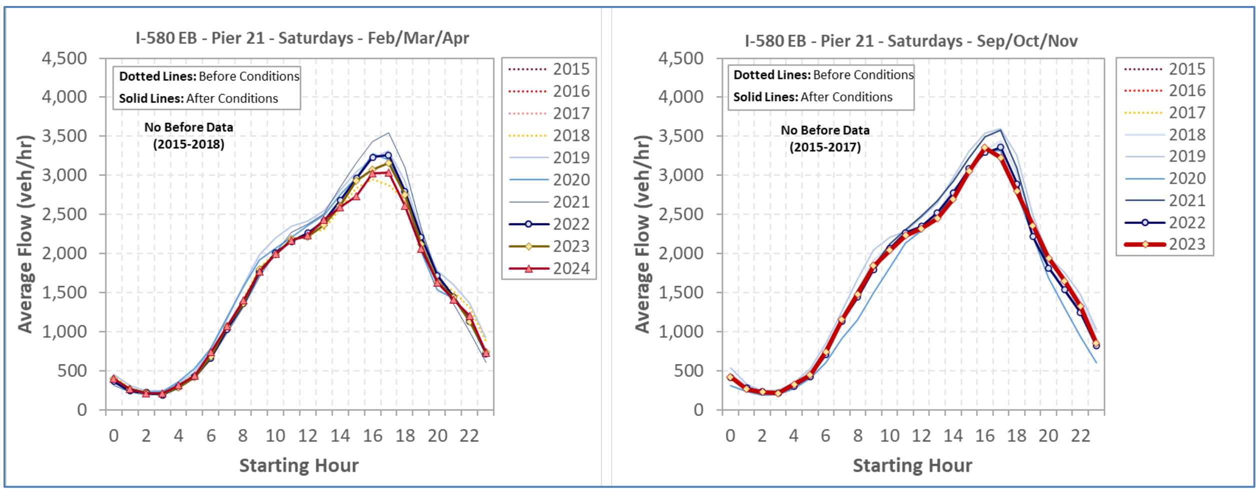

Figure 8-8: Daily Traffic Flow Profile – Bridge EB – Saturdays, 2015-2024

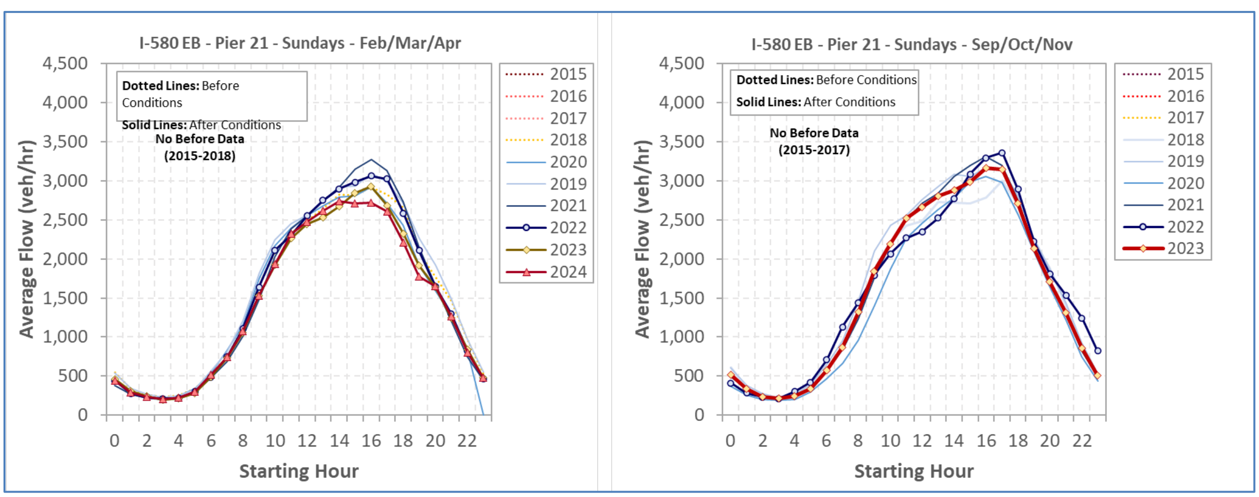

Figure 8-9: Daily Traffic Flow Profile – Bridge EB – Sundays, 2015-2024

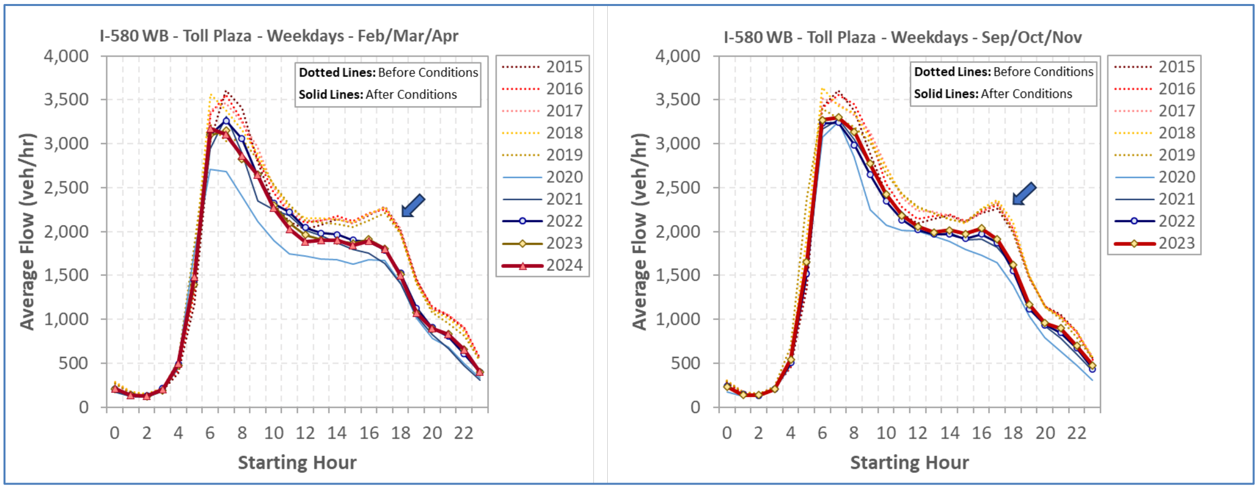

Figure 8-10: Daily Traffic Flow Profile – Bridge WB – Weekdays, 2015-2024

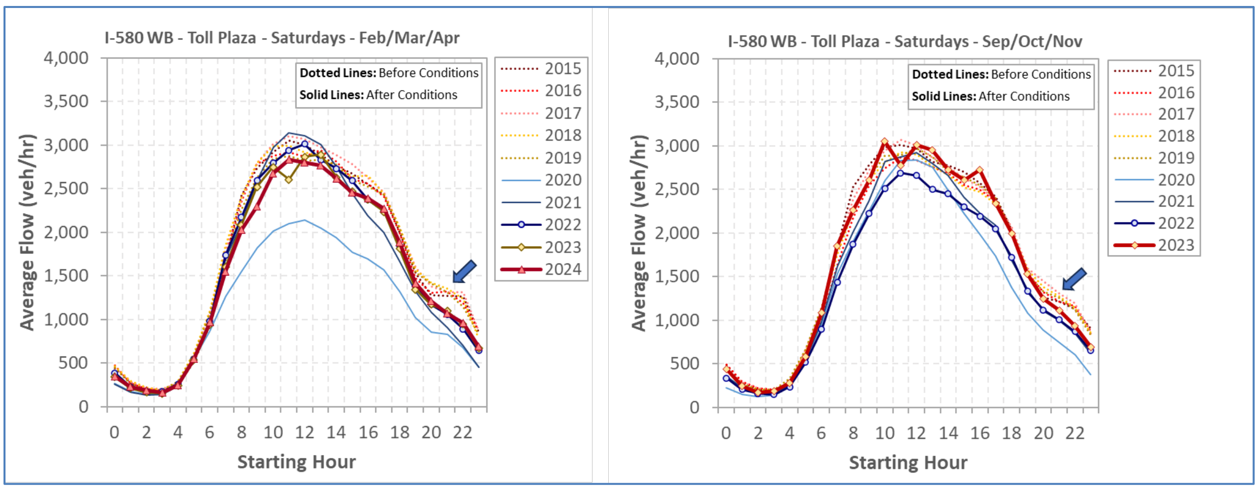

Figure 8-11: Daily Traffic Flow Profile – Bridge WB – Saturdays, 2015-2024

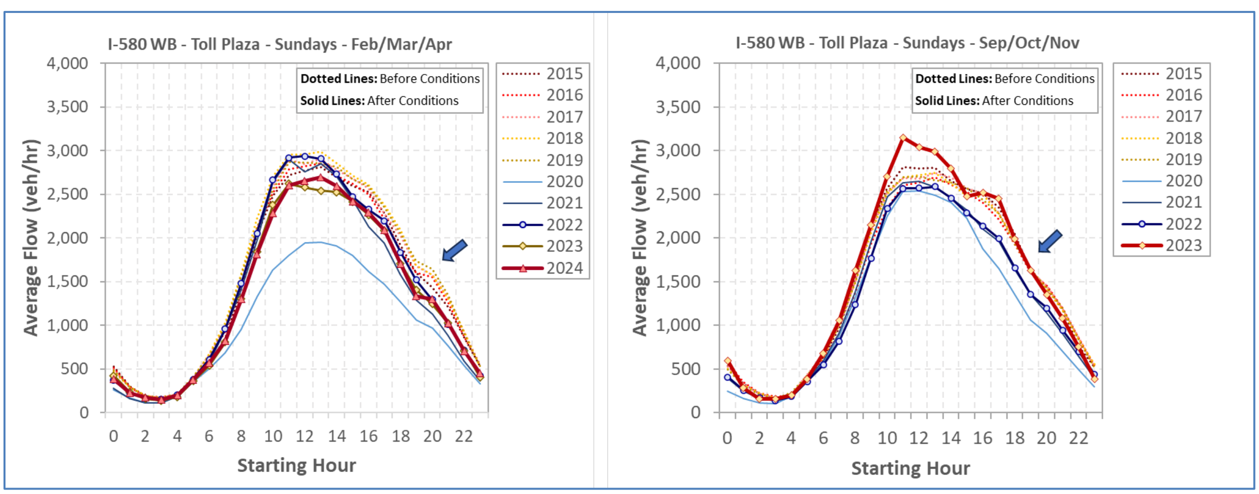

Figure 8-12: Daily Traffic Flow Profile – Bridge WB – Sundays, 2015-2024

- Peak westbound weekday traffic flows for 2022 and 2023 remain below the peak flow levels from 2015 to 2019. While westbound flows peaked at around 3,500 vehicles/hour in 2019 and prior years, peak flows have hovered since then between 3,100 and 3,329 vehicles/hour. As will be explained in Section 8.3.2, this is likely due to a reduced carrying capacity across the bridge caused by the presence of the multi-use path barrier close to the traffic lane and the shortening of the merge area at the foot of the bridge.
- Peak Saturday and Sunday flows in both directions are generally back to pre-COVID levels, and even exceeding these levels in recent instances (see westbound Sunday data, Figure 8-12).
- The spring eastbound profiles show significantly higher afternoon peak flows for 2019-2023 than for 2016 and 2018, the only two years for which data is available before the lower deck modifications. This is due to the availability of an additional lane to cross the bridge. A similar observation cannot be made on the fall profiles as bridge sensors only started to produce data after the April 2018 modification. In addition, while some eastbound flow data were also collected at the toll plaza in May 2016 using radar detectors, these were deemed unrealistically too high for the bridge's capacity and assumed to be invalid.

8.1.3. ESTIMATED VEHICLE MILES TRAVELED (VMT)

To further assess potential underlying changes in traffic demand, VMT estimates along I-580 were calculated for each travel direction for the following sections, as illustrated in Figure 8-13:

- **Bridge**: Sections of I-580 East and West between the toll plaza in Richmond and the foot of the bridge in Marin County.
- **Bridge Approaches**: Section of I-580 West in Contra Costa County extending from the Harbour Way interchange to the toll plaza, and section of I-580 East in Marin County from the US-101 interchange to the foot of the bridge.
- **Bridge Downstream Sections**: Section of I-580 West in Marin County from the Main Street off-ramp to the US-101 interchange, and section of I-580 East in Contra Costa County from the toll plaza to the Harbour Way interchange in Richmond.
- **Corridor**: Combination of all three sections described above.

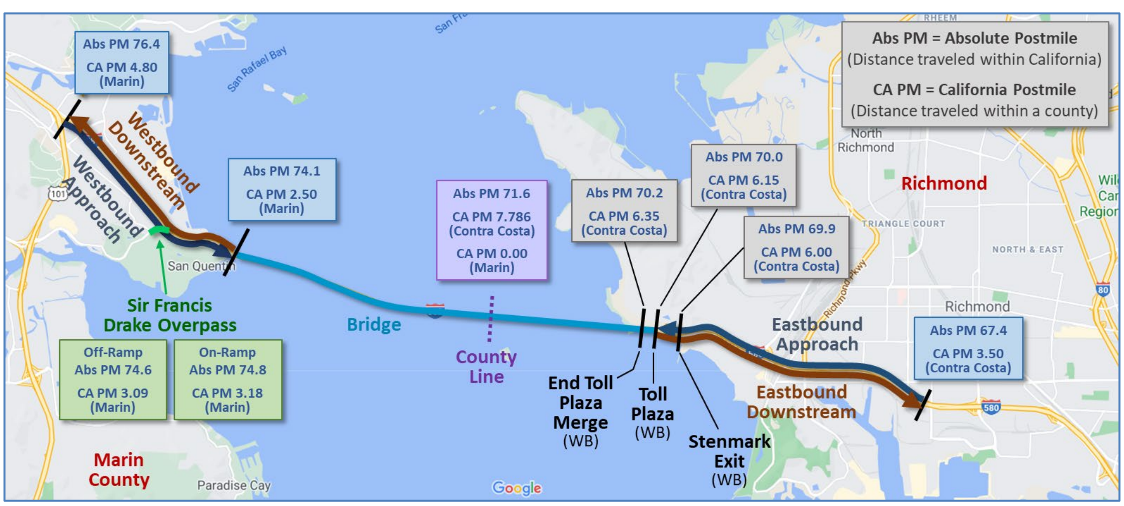

Figure 8-13: VMT Analysis Sections

The estimates are based on traffic counts from PeMS sensors and from the Richmond Toll Plaza. Because of variations over time in sensor setup across the corridor, the following general approaches were used throughout the analysis period to obtain VMT estimates:

- **Before February 2018:** Estimates are based on eastbound and westbound traffic counts from the Canal Boulevard, Harbour Way, and Richmond Parkway PeMS stations in Richmond, eastbound counts from the Bellam station in Marin County, and the westbound toll plaza counts. Referring back to Figure 5-2 to Figure 5-5, this is due to the absence of sensors on the bridge and the fact that many of the other PeMS stations were then not returning data.
- **February 2018 to June 2019**: Estimates are similar to the prior period but add counts produced by the newly installed sensors on the bridge.
- **After June 2019:** data from several additional PeMS stations along the corridor have also been considered, with occasional adjustments to consider sensors temporarily going offline.

In addition to the above, various data adjustments were performed where needed to the counts supplied by PeMS sensors during intervals with data issues, i.e., with low percentages of observed values. In most cases, these adjustments consisted of estimating reasonable counts based on trends observed at nearby stations with valid data.

8.1.3.1. Eastbound Travel Direction (Bridge Lower Deck)

Figure 8-14 to Figure 8-17 present the estimated eastbound quarterly VMT from the first quarter of 2015 to the first quarter of 2024 for the following periods:

- All-day traffic (Figure 8-14).
- When the part-time lane is open, from 2 PM to 7 PM, Tuesdays to Thursdays (Figure 8-15).
- Saturday daytime traffic, from 9 AM to 7 PM (Figure 8-16).
- Sunday daytime traffic, from 9 AM to 7 PM (Figure 8-17).

In each figure, the grey areas further identify the quarter during which the bridge modification for the direction was made and the period affected by COVID-19 stay-at-home orders.

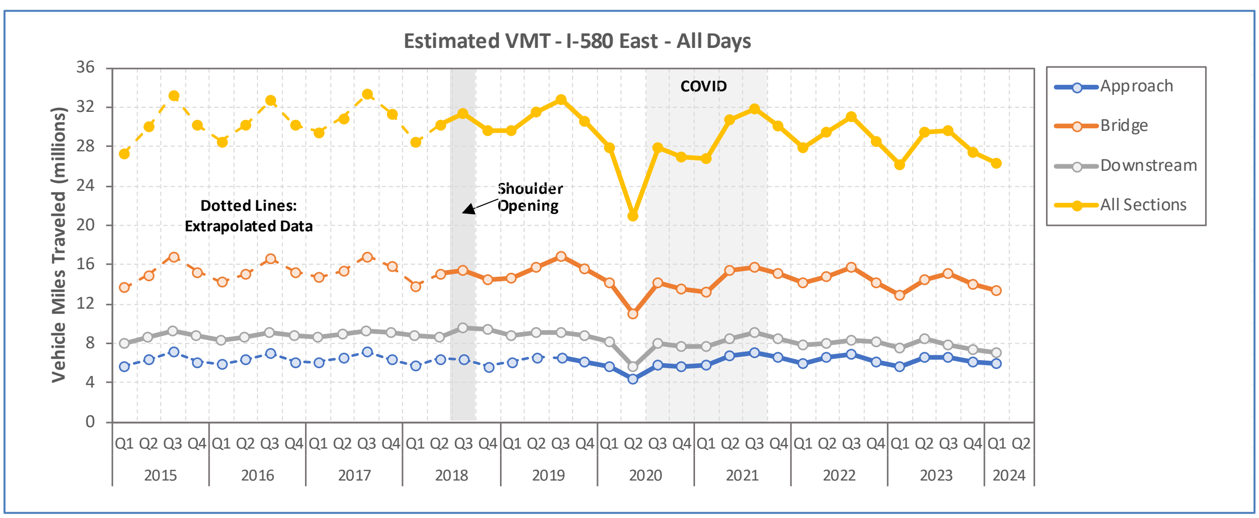

Figure 8-14: Estimated Vehicle Miles of Travel – I-580 East – All Days

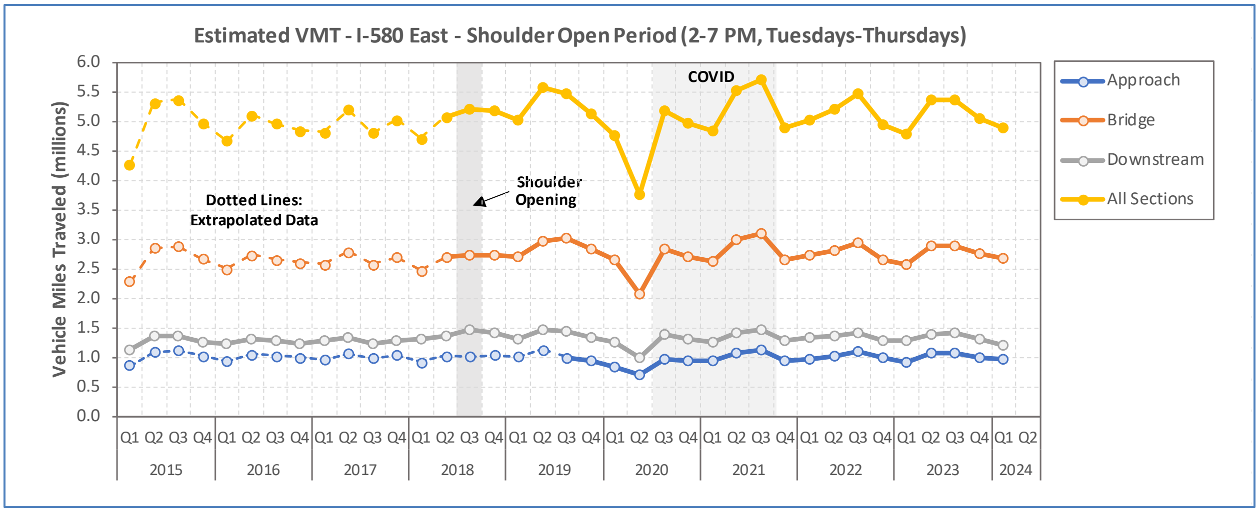

Figure 8-15: Estimated Vehicle Miles of Travel – I-580 East – Shoulder Open Period

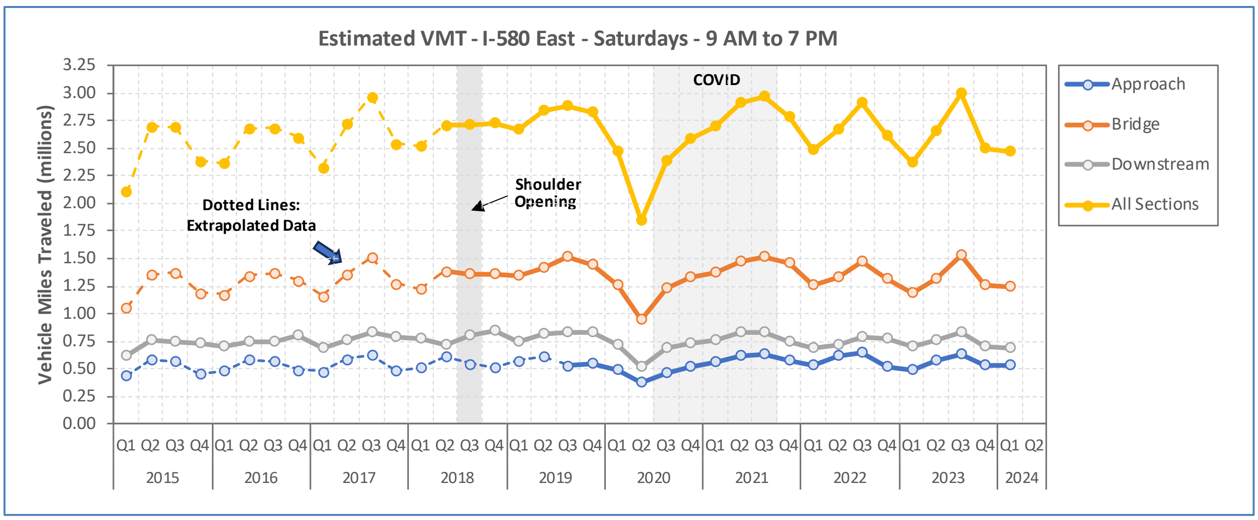

Figure 8-16: Estimated Vehicle Miles of Travel – I-580 East – Saturday Daytime Traffic

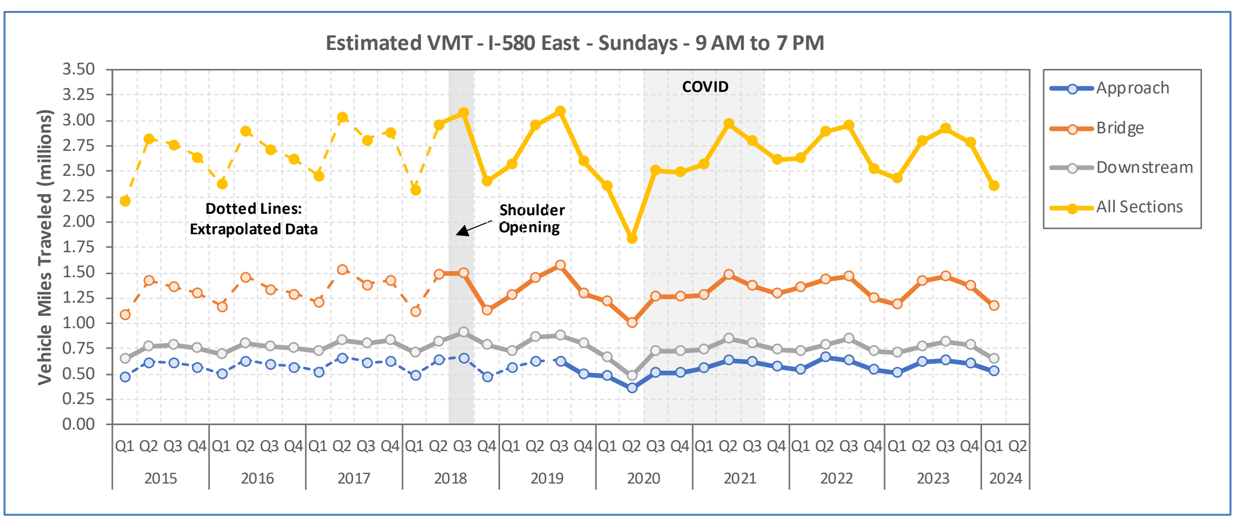

Figure 8-17: Estimated Vehicle Miles of Travel – I-580 East – Sunday Daytime Traffic

In each graph, the dotted line portions show VMT estimates that have been extrapolated using sensors that may be some distance away. This was necessary as no working sensors existed on the approach before June 2019, and sensors on the bridge only started to produce data in February 2018.

Key VMT-related takeaways from the illustrated data regarding eastbound traffic are as follows:

- Data from all four periods indicate that eastbound traffic has generally recovered from the COVID-19 pandemic.
- All-day corridor VMT estimates for 2022 and 2023 are on average 6% below levels from late 2018 and 2019 following the opening of the part-time lane, as well as 6% below the pre-modification levels from 2016 and 2017. The latter case is a rough estimation based on the extrapolated data and should be considered with caution. As presented in the time-of-day profiles of Section 8.1.2., this can be partly explained by an off-peak travel demand that has not yet fully recovered from the pandemic.
- When focusing only when the part-time lane is open (2 PM and 7 PM) on peak midweek travel days (Tuesdays to Thursdays), the corridor VMT estimates for 2022 and 2023 again remain below 2019 levels, but with only a 2% average drop. However, when compared to the estimated pre-modification data, the data suggests that the current VMT in the corridor could be 5% higher than in 2016 and 2017.
- Current Saturday daytime corridor VMT is on average 5% lower than in late 2018 and 2019, and about 2% higher than pre-modification. In this case, it can be noted that peak summer traffic (Q3) in 2021, 2022, and 2023 has been near the estimated historical peak of 2017.
- Current Sunday traffic is on average 2% lower than in 2018 and 2019, and 2% higher than pre-modification.

Overall, no clear general trend can be identified regarding future traffic demand on the corridor. While current VMT estimates are generally lower than in the few quarters following the opening of the part-time lane, weekday AM peak and Saturday traffic appear to be higher than before the modifications. However, the quarterly variation of the data and the fact that pre-modification data have been extrapolated make it difficult to identify a clear growing trend.

8.1.3.2. Westbound Travel Direction (Bridge Upper Deck)

Figure 8-18 to (Figure 8-21 present the estimated westbound quarterly VMT from the first quarter of 2015 to the first quarter of 2024 for the following periods:

- All-day traffic (Figure 8-18).
- Midweek AM peak period, Tuesdays to Thursdays from 6 AM to 9 AM (Figure 8-19).
- Saturday daytime traffic, from 9 AM to 7 PM (Figure 8-20).
- Sunday daytime traffic, from 9 AM to 7 PM (Figure 8-21).

Similar to the graphs shown in the previous section, the grey areas within each figure identify the quarter during which the bridge modification for the direction was made and the period affected by COVID-19 stay-at-home orders. The dotted portion of the approach line further shows VMT estimates that have been extrapolated using data that may be some distance away. In this case, this is the only section that has been subject to significant extrapolation as the availability of toll plaza counts throughout the entire analysis period allowed building a clear picture of the traffic on the bridge.

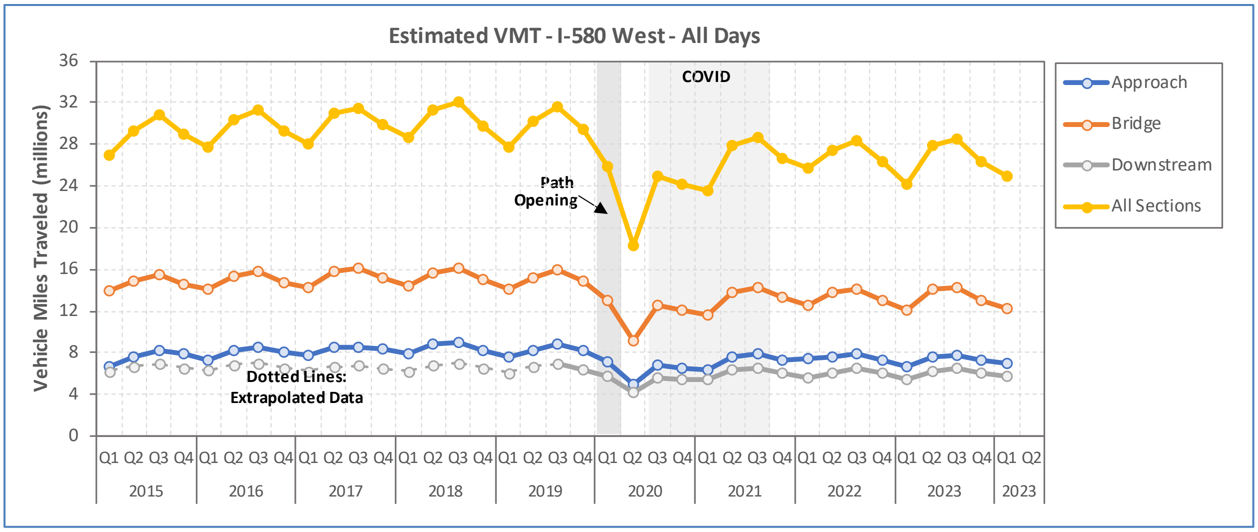

Figure 8-18: Estimated Vehicle Miles of Travel – I-580 West – All Days

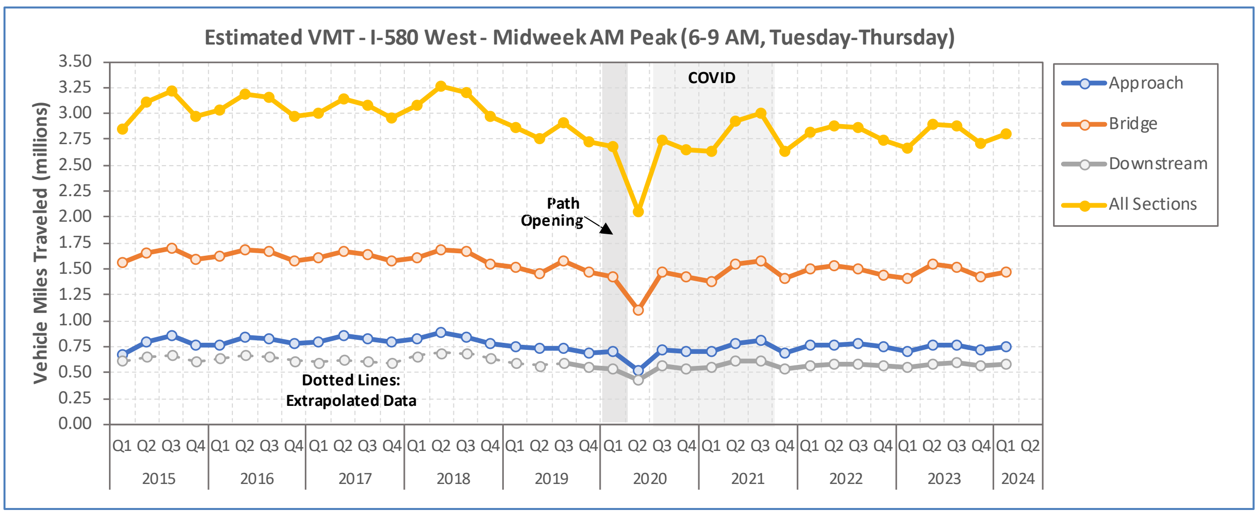

Figure 8-19: Estimated Vehicle Miles of Travel – I-580 West – Midweek AM Peak

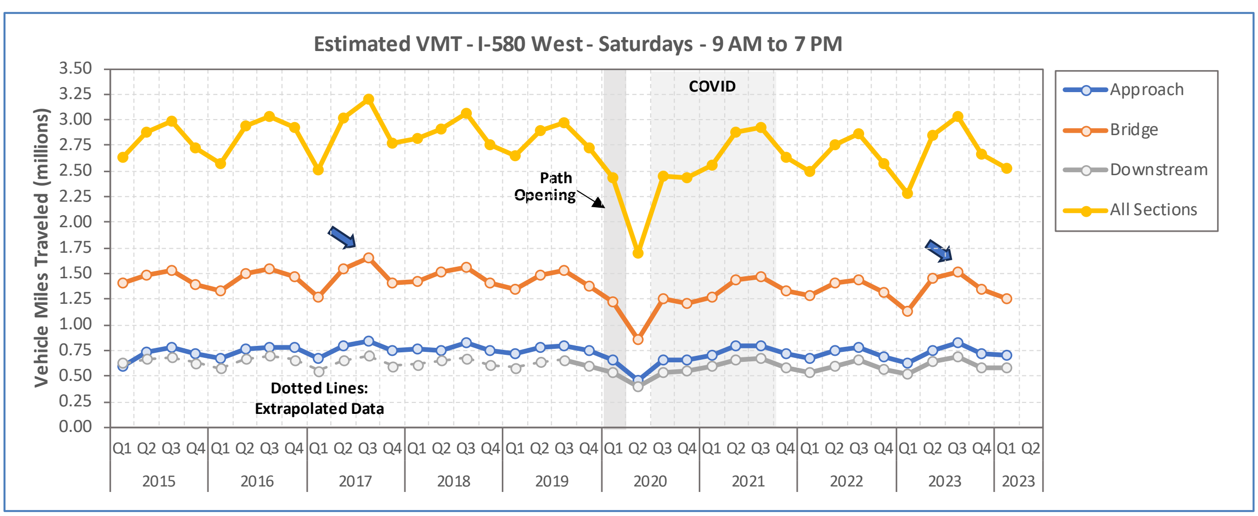

Figure 8-20: Estimated Vehicle Miles of Travel – I-580 West – Saturday Daytime Traffic

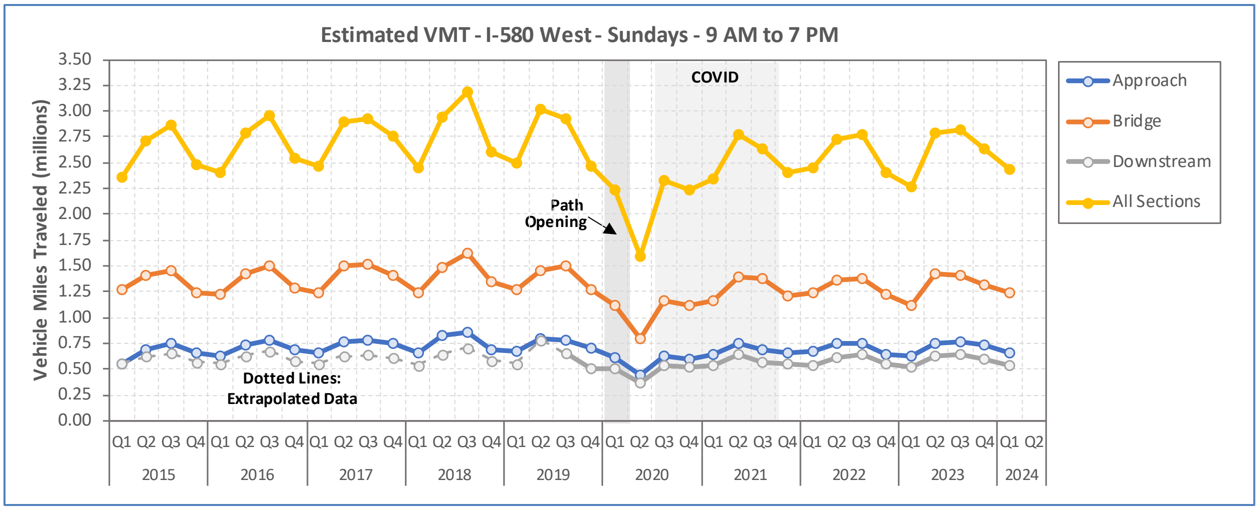

Figure 8-21: Estimated Vehicle Miles of Travel – I-580 West – Sunday Daytime Traffic

Key VMT-related takeaways from the illustrated data regarding westbound traffic are as follows:

- Similar to the eastbound direction, data from all four periods indicate that eastbound traffic has generally recovered from the COVID-19 pandemic.
- Data from all periods indicate lower quarterly VMT estimates on all sections in 2022 and 2023 than before the bridge modification. For the weekday and weekend peak hour periods, when traffic demand exceeds the bridge capacity, this could reflect the reduced capacity on the bridge imposed by the addition of the multi-use path, as will be documented in Section 8.3.2. Another potential contributing factor is the observation that traffic demand in off-peak periods and travel directions still somewhat remain below pre-pandemic levels as detailed in the time-of-day daily traffic profiles of Section 8.1.2.
- Data for daytime Saturday traffic also indicate a drop in the 2022 and 2023 VMT estimates compared to the 2018 and early 2019 data. However, the drop appears in this case less pronounced. In particular, as shown by the two arrows, data from the third quarter (July-September) of 2023 indicates VMT levels on the bridge that approached the historic high that was measured in the third quarter of 2017.

8.2. IMPACTS ON EASTBOUND BRIDGE TRAFFIC

This section evaluates the impacts on traffic of the conversion of the eastbound lower deck shoulder into a part-time traffic lane. This evaluation covers the following elements:

- Eastbound freeway congestion before the modification
- Traffic on the shoulder when open
- Motorist compliance with the shoulder open/close periods
- Impacts of the new lane on the bridge carrying capacity
- Impacts on I-580 East traffic conditions between the US-101/I-580 interchange and the bridge
- Impacts on US-101 North travel times between Sir Francis Drake Boulevard and I-580
- Impacts on Marin County arterials parallel to I-580 East, such as Sir Francis Drake Boulevard, Francisco Boulevard, and Andersen Drive
- Impacts on I-580 East ramp traffic at Bellam Boulevard and Main Street

8.2.1. INITIAL CONDITIONS

Figure 8-22 illustrates the typical extent of the afternoon congestion before the shoulder conversion on I-580 East in Marin County, the section of US-101 North south of the I-580 interchange, and the section of US-101 South north of the I-580 interchange. Data represents average observed speeds between mid-September and mid-November 2017, the last fall before the modification.

At that time, congestion along I-580 East was primarily caused by the number of traffic lanes reducing from three to two near the entrance of the bridge. As illustrated, congestion on I-580 East generally extended up to the US-101 interchange on weekdays, Saturdays, and Sundays. Weekday traffic on the US-101 North between Sir Francis Drake Boulevard and the I-580 interchange also appeared affected. While part of the US-101 congestion could be attributed to the I-580 East congestion, another part could also be explained by traffic frictions between the I-580 and Third Street interchanges caused by the merging of the US-101 North and I-580 West traffic. Congestion on Saturdays and Sundays also typically extended up to the US-101 interchange but did not appear to affect traffic along US-101 North.

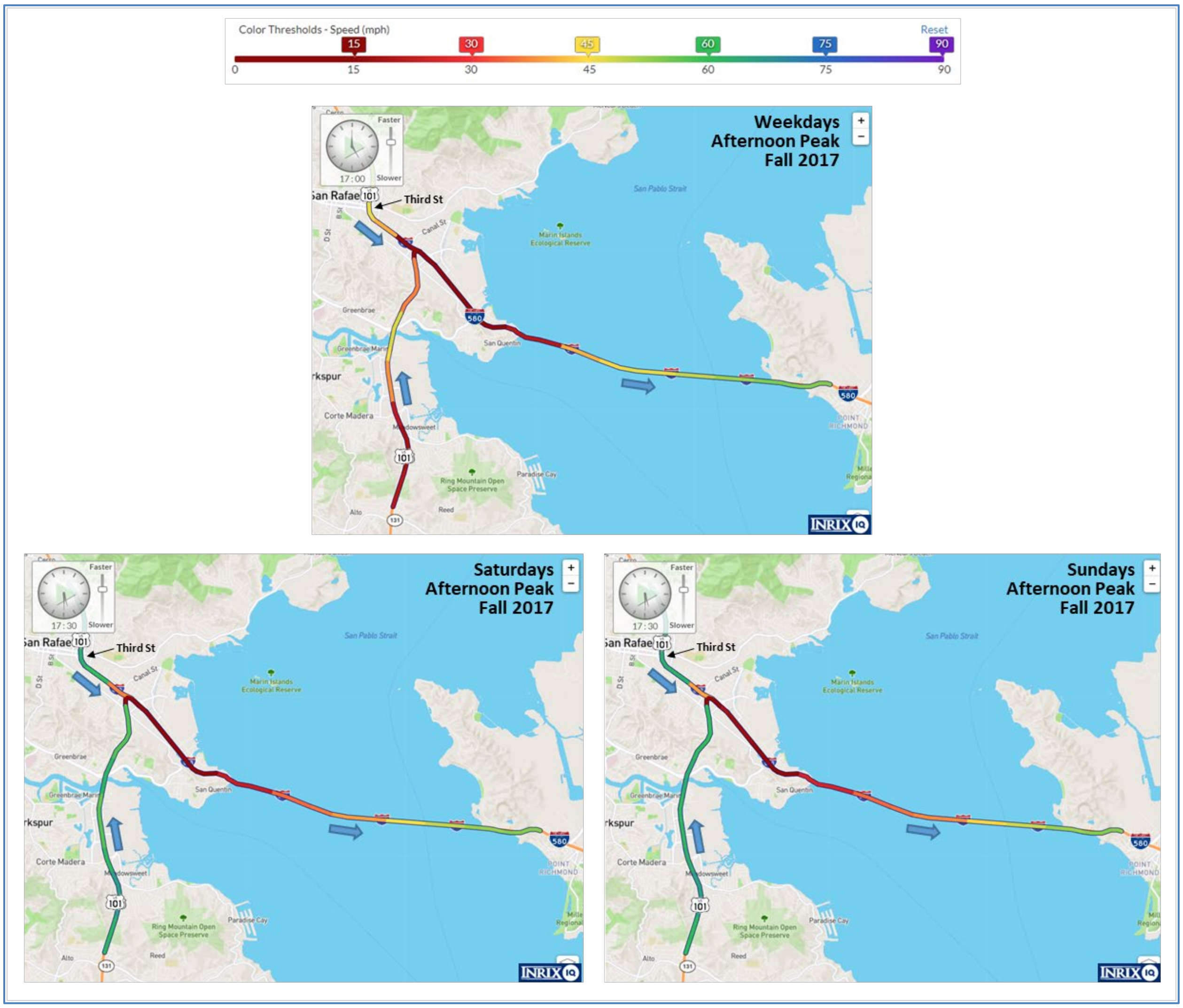

Figure 8-22: Extent of Congestion on I-580 East in Marin County before Modifications

8.2.2. PART-TIME LANE USE

Figure 8-23 illustrates the average flow rates on the eastbound part-time lane between February and April 2021. More recent data are not used, as data past late 2021 are heavily affected by lane closures associated with bridge maintenance activities that often result in vehicles being allowed to use the shoulder at night and during off-peak periods. According to the data, under normal conditions, vehicles typically start traveling on the shoulder at 2:00 PM when it opens and stop using it around 7:00 PM when it closes. Weekday traffic typically peaked around 5:30 PM at a rate of about 1050 vehicles/hour. During weekends, Saturday traffic typically peaks between 4:30 PM and 6:30 PM at around 650 vehicles/hour, while Sunday traffic peaks around 5:00 PM at around 600 vehicles/hour.

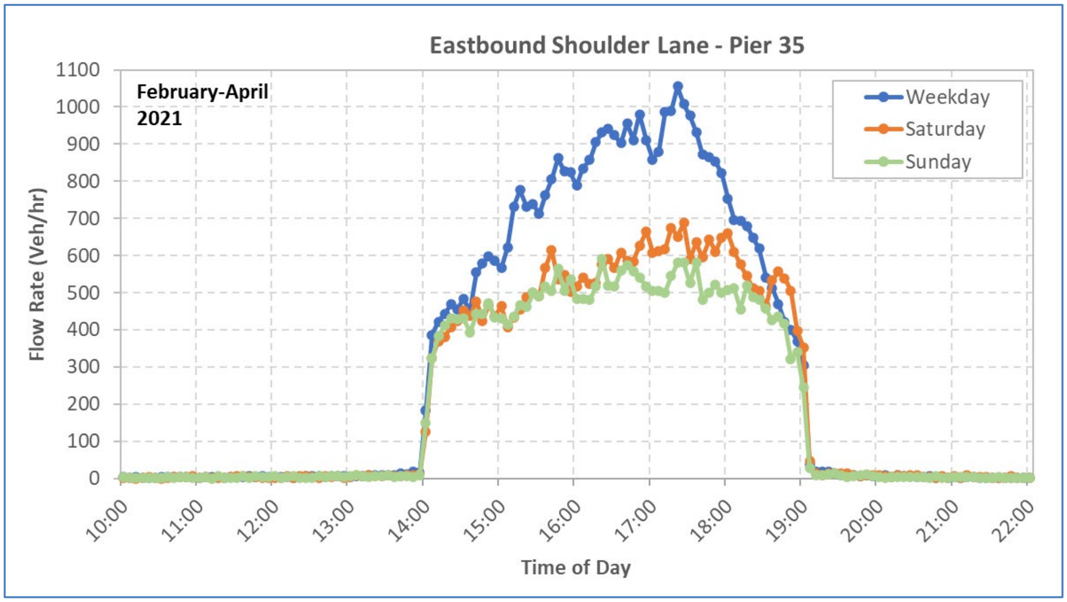

Figure 8-23: Lower Deck Lane on Part-Time Lane/Shoulder - Flow Rate

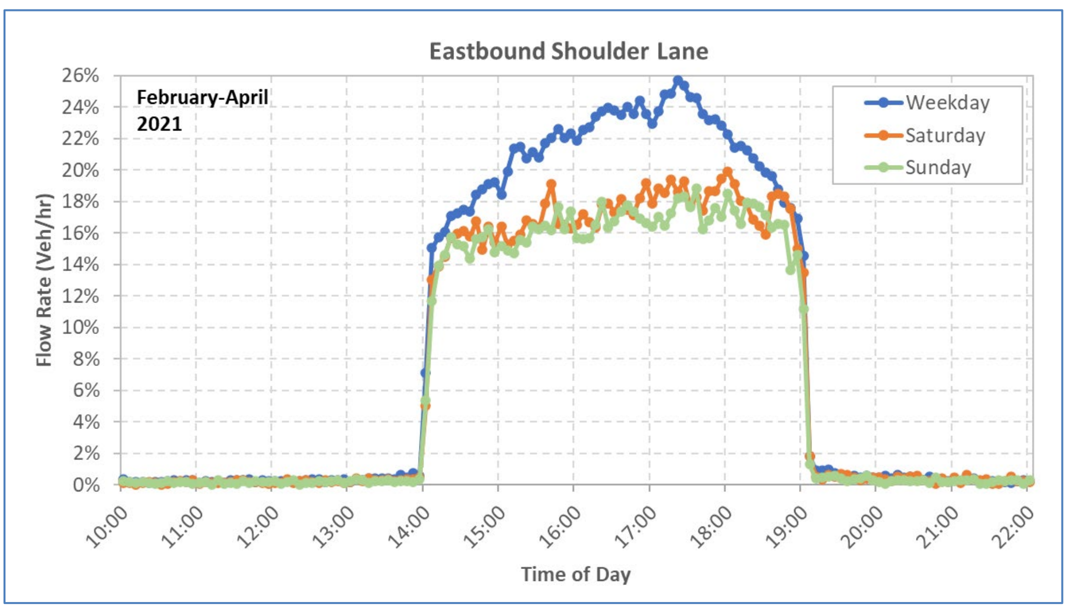

Figure 8-24: Lower Deck Traffic on Part=Time Lane/Shoulder - Percent of Total Eastbound Flow

Figure 8-24 provides another view by illustrating the percentage of vehicles using the part-time lane/shoulder. At opening, about 15% of vehicles are typically observed using the lane across all day types. On weekdays, the proportion of traffic on the lane then rose to about 25% between 5 PM and 6 PM before dropping to 15% before its closure. On weekends, however, less than 20% of them use the lane. If traffic were distributed equally among all eastbound lanes, 33% of the traffic should be observed on each lane. The fact that the use of the part-time lane never rises above 25% indicates that motorists generally prefer to drive on the two regular lanes. This might be due to habits. The delineation of the lane with a solid line may also further entice motorists to stay on the two left lanes.

8.2.3. SHOULDER COMPLIANCE

Based on the data in Figure 8-23, there appears to be relatively high compliance with the open/close periods of the shoulder. When the two regular bridge traffic lanes are not affected by closures relatively few vehicles are seen on the shoulder before 2 PM and after 7 PM. On average, less than one vehicle per hour is observed using it at night, and between 5 and 16 vehicles/hour during other portions of the day when it is formally closed. These observations translate into a 99.6% compliance rate before 2 PM and after 7 PM on weekdays and Saturdays, and a 99.7% compliance rate on Sundays.

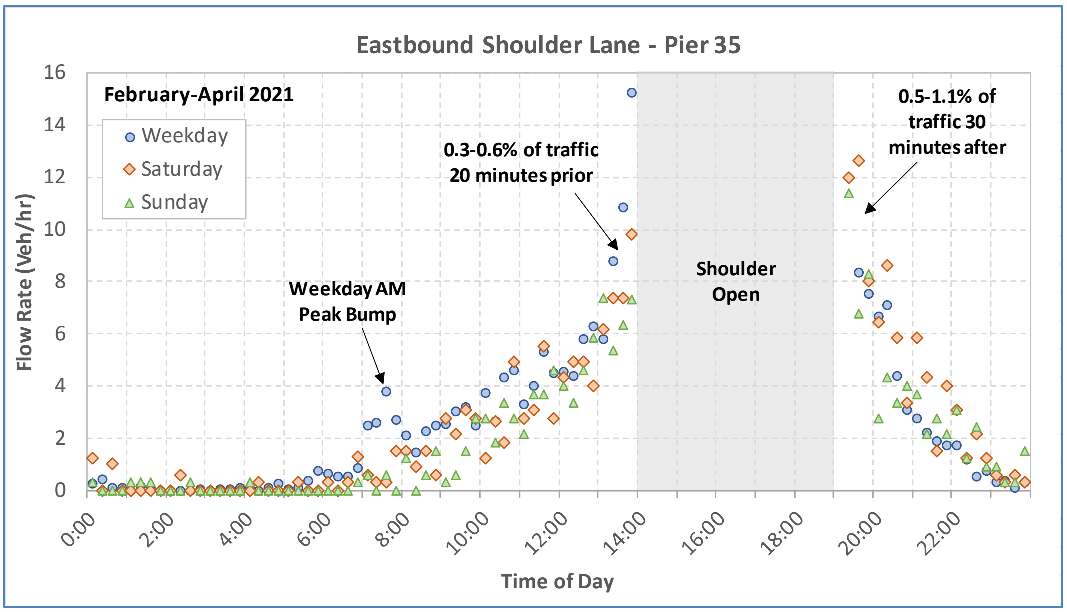

Figure 8-25: Lower Deck Shoulder – Flow Rate When Closed to Traffic

Some of the observed traffic on the shoulder outside its open period might be attributed to maintenance vehicles, tow trucks, and police vehicles. CHP officers have also indicated observing vehicles using the lane to pass other vehicles. There is further a suspicion that some motorists may not understand the significance of the green arrow/yellow X/red X displayed on top of each lane, resulting in some motorists not realizing that the shoulder may be closed at some times.

Figure 8-25 indicates that the periods of highest non-compliance are usually right before the shoulder opens to traffic and after it closes, typically 20 minutes before its opening and up to 30 minutes following its closure. A short peak in part-time lane usage is also observed during the weekday morning AM peak period. On weekdays, shoulder traffic in the 20 minutes before its opening typically represents 0.6% of the total observed traffic. On Saturdays and Sundays, non-compliant traffic represents 0.4% and 0.3% of the 20-minute traffic, respectively. For the 30 minutes following the closing of the shoulder, non-compliant traffic typically represents 1.1% of weekday traffic and 0.5% of Saturday and Sunday traffic.

Non-compliance use of the shoulder outside its opening period is believed to have a minimal impact on traffic operations, largely due to its relatively small share of the overall traffic and because some of the observed traffic might be legitimate use by maintenance, police, or other vehicles. However, the use of the lane by non-authorized users may carry increased safety risks, as motorists traveling on the right lane may be surprised by vehicles traveling on the shoulder.

8.2.4. IMPACT ON LOWER DECK CAPACITY

Figure 8-26 illustrates peak eastbound hourly flows observed at Pier 21 near the bridge entrance on weekdays, Saturdays, and Sundays from February 2018, when the bridge sensors were activated, to March 2024. As expected, the data appears to indicate that the opening of the part-time lane has increased peak flows across the bridge. From February to mid-April 2018, the only period for which data is available before the modifications, between 3,300 and 3,570 vehicles/hour were observed crossing the bridge during the afternoon peak. Since the shoulder opening, peak weekday flows have ranged between 3,750 and 4,500 vehicles/hour, depending on the day, representing a 13-26% capacity increase.

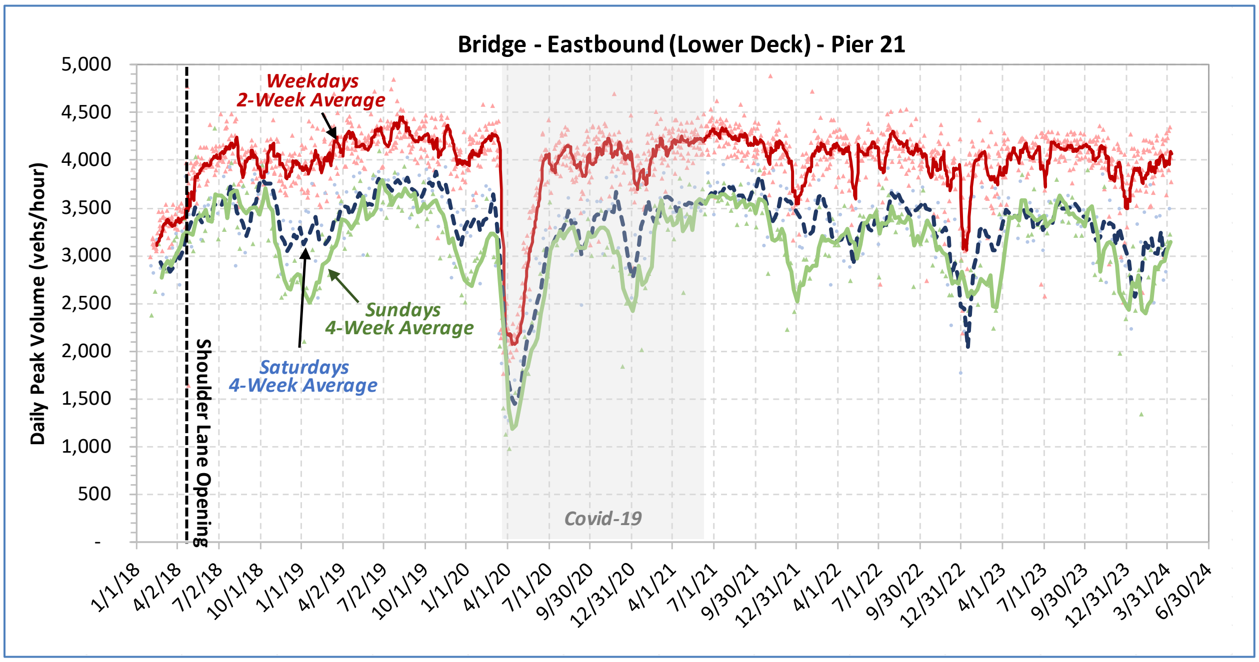

Figure 8-26: Average Peak Traffic Flow at Entrance of Bridge – Eastbound, 2018-2024

Figure 8-27 presents an additional look at the capacity increase by comparing eastbound flows measured in May 2016 at the toll plaza to flows captured at the same location in March 2022. Similar to the previous figure, an increase in peak afternoon flow rate from 3,500-3,600 to around 4,500 vehicles/hour can be observed. The figure also indicates a potential reduction in the duration of the afternoon peak period associated with the elimination of congestion on the Marin side of the bridge. This is illustrated by the earlier drop in traffic after 6 PM. While some of this drop may be due to lower traffic due to the COVID-19 pandemic, a portion may also be due to fewer vehicles being held back on the Marin side of the bridge. Similar to other analyses, morning and evening flow reductions are primarily due to COVID-related effects.

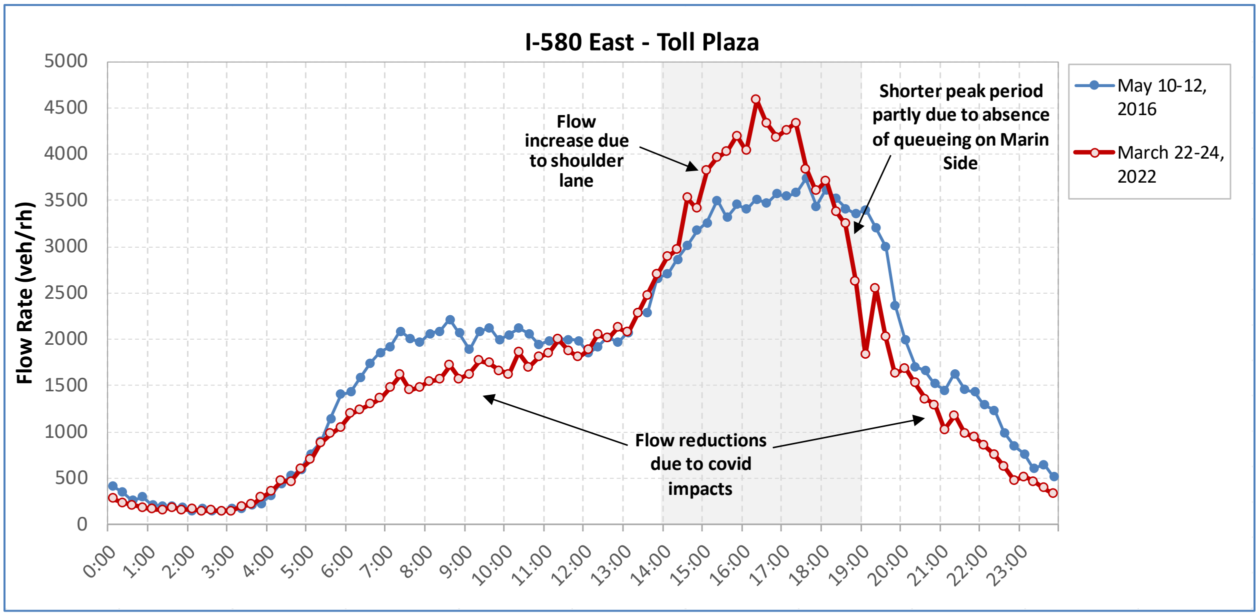

Figure 8-27: Observed Peak Traffic Flow at Toll Plaza – Eastbound, 2016 and 2022

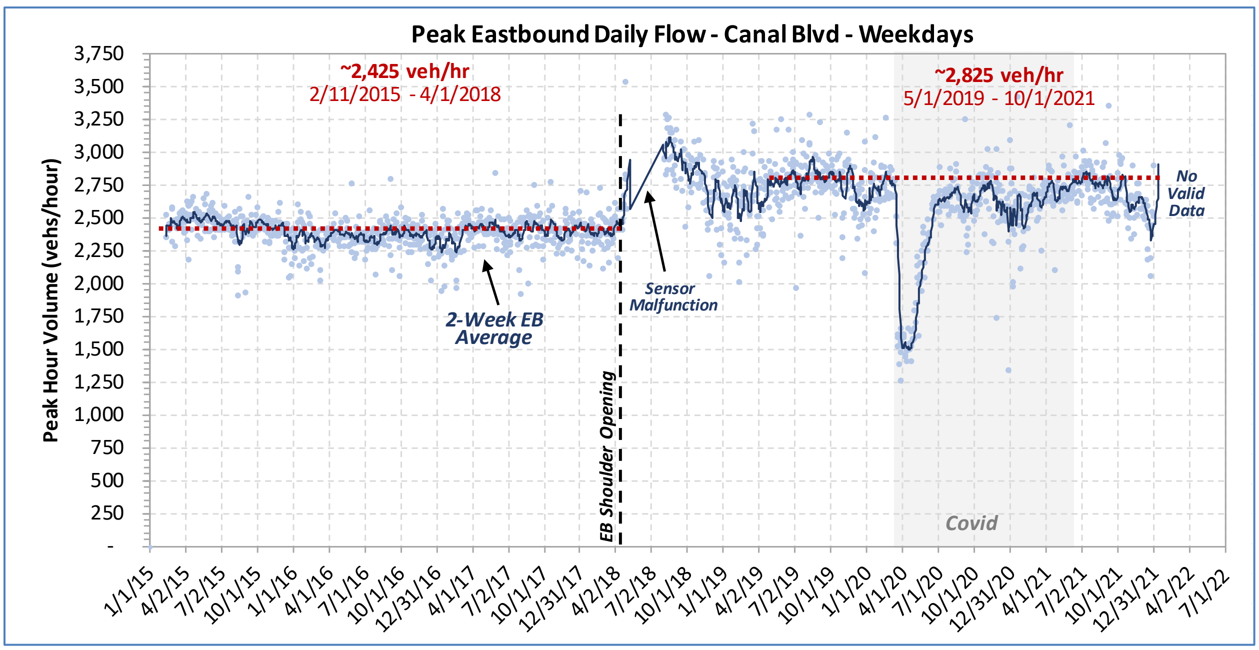

Figure 8-28: Average Peak Traffic Flow on I-580 East near Canal Boulevard, 2015-2022

An additional assessment can be made using peak hourly flows from the PeMS sensors just downstream of the Canal Boulevard off-ramp (station #400639). These sensors have continuously recorded data from 2015 to early 2022. While they do not capture traffic that would have exited at the Castro Street and Richmond Parkway off-ramps, any significant increase in traffic crossing the bridge would normally translate into higher flows at this location. As shown in Figure 8-28, the average peak weekday flows before the opening of the part-time lane hovered at this location at around 2,425 vehicles/hour. After the opening, peak flows of around 2,825 vehicles/hour have more commonly been observed. This represents a 16% increase in line with the data in Figure 8-26. While flows of around 3,250 vehicles/hour have occurred immediately following the opening, motorists adjusting their travel time in response to the absence of congestion on the bridge approach may have resulted in the current lower average level.

PeMS data further suggests that peak hour flows on Saturdays and Sundays near Canal Boulevard have similarly increased by 15-16% following the part-time lane opening. Prior average daily peak flows ranged from 2,250 and 2,750 vehicles/hour, while peak flows now range between 2,750 and 3,200 vehicles/hour.

The observed increases result from the added capacity provided by the third traffic lane. Before the modifications, the two existing lanes did not provide sufficient capacity to accommodate peak traffic on weekdays and weekends. This caused traffic to back up along I-580 East up to the US-101 interchange, as was illustrated earlier in Figure 8-22. With the added capacity, the bridge is now able to better handle the peak traffic, thus explaining the current absence of congestion on the approach.

Another key observation is that the increase in maximum flow does not correspond to the full capacity of a new traffic lane. In the initial two-lane setup, an average peak flow of 3,500 vehicles/hour would translate into 1,750 vehicles/hour/lane. With three lanes of traffic, a peak flow of 4,500 vehicles/hour translates instead into an average flow of 1,500 vehicles/hour/lane. This apparent reduction in lane capacity is explained by vehicles not fully utilizing all the available lanes. As was shown in Figure 8-24, less than 25% of the weekday traffic and 20% of the weekend traffic uses the part-time lane. If traffic were equally distributed along all lanes, each lane would instead carry 33% of the total traffic. A typical distribution is 40% on the left lane, 36-40% on the middle lane, and 20-25% on the part-time lane. Since the part-time lane is not fully utilized, this translates into some unused capacity.

8.2.5. TRAVEL CONDITIONS ON EASTBOUND APPROACH AND BRIDGE

The opening of the eastbound shoulder to traffic during the afternoon peak has significantly reduced congestion on the Marin County approach to the bridge. This change can be observed in Figure 8-29 to Figure 8-31, which illustrates the average observed speeds on I-580 East from the US-101 interchange to the toll plaza on Tuesdays-Thursdays, Saturdays, and Sundays from mid-September to mid-November for each year between 2015 and 2023. Before the April 2018 modification, speeds typically dropped below 15 mph from approximately 3:00 to 7:30 PM, starting at the US-101 and up to about 0.5 miles onto the bridge. After the opening, speeds have remained at or above 50 mph in the absence of disturbances from incidents or bridge/roadway maintenance activities.

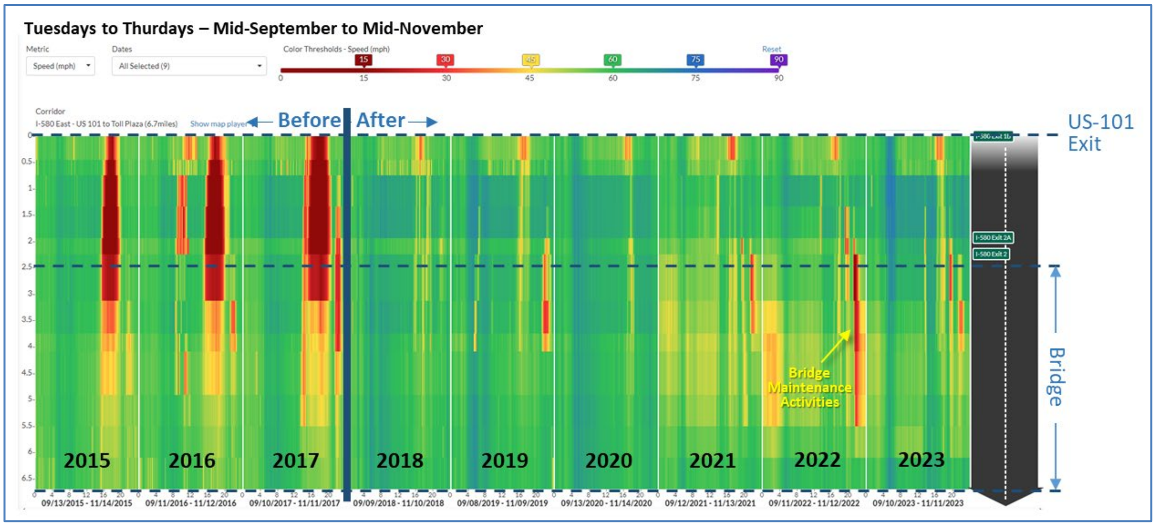

Figure 8-29: Speed Maps – I-580 East – US-101 to Toll Plaza – Midweek, Fall 2015-2023

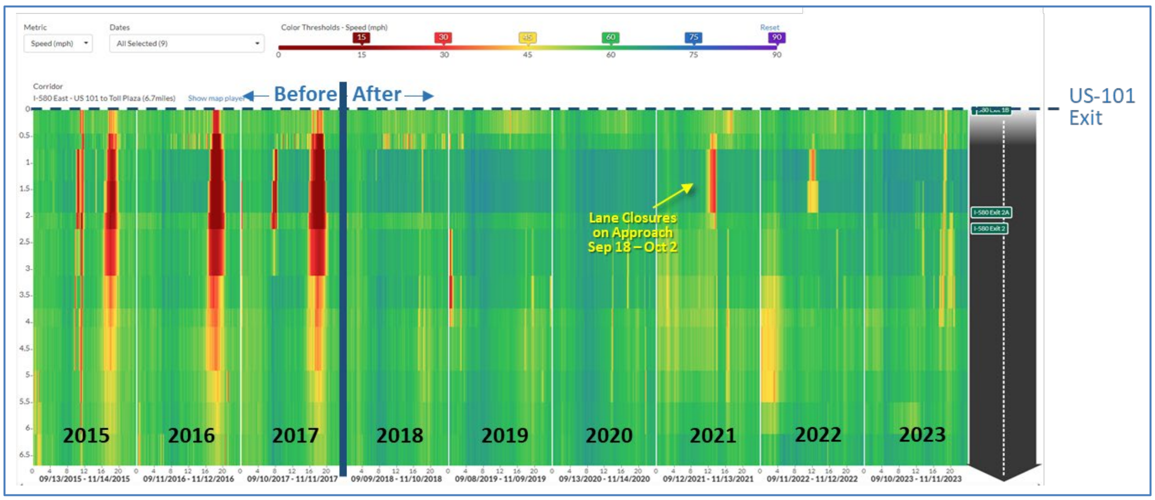

Figure 8-30: Speed Maps – I-580 East – US-101 to Toll Plaza – Saturdays, Fall 2015-2023

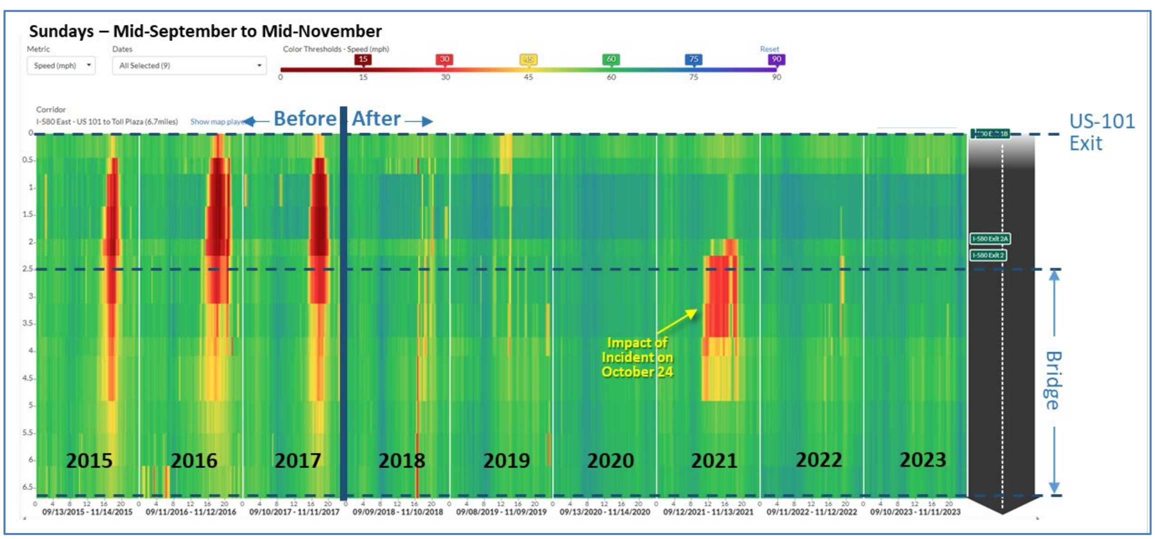

Figure 8-31: Speed Maps – I-580 East – US-101 to Toll Plaza – Sundays, Fall 2015-2023

While the 2020 data may be tainted with COVID-19 effects, this is not the case for 2018 and 2019. The disappearance of the congestion on the approach before the onset of the pandemic is proof that the improved conditions are a direct result of the bridge modifications. Figure 8-32 further enforces this point by illustrating observed midweek speeds from four months before the modification to four months after. As can be observed, the change in traffic conditions unmistakably corresponds to when the modification was made.

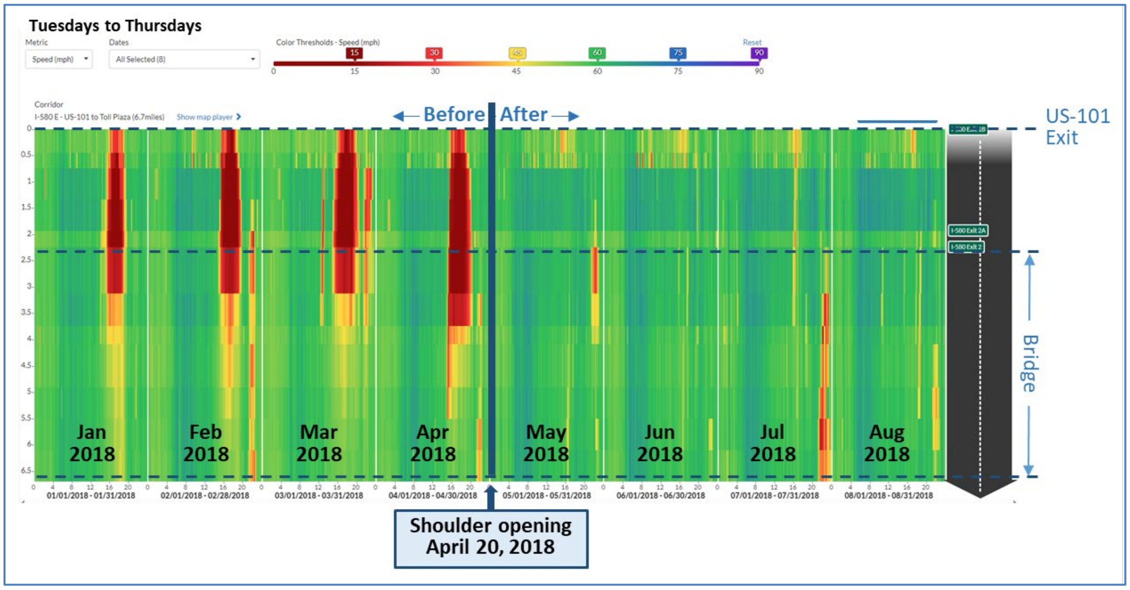

Figure 8-32: Speed Maps – I-580 East – US-101 to Toll Plaza – Midweek, January-August 2018

Figure 8-33 to Figure 8-35 further illustrate the impacts on travel times from the US-101 to the toll plaza. Conditions before the modification are shown with a dotted line and those after with a solid line. Before the modification, peak weekday travel times reached 22-26 minutes, depending on the year. Since then, peak travel times have remained around 8-9 minutes, yielding a reduction of 14-17 minutes. On Saturdays, peak travel times have similarly reduced from 17-21 to about 7 minutes, for a reduction of 10-14 minutes. On Sundays, peak travel times have been further reduced from 13-15 to 7 minutes, for a reduction of 6-8 minutes.

Finally, Figure 8-36 to Figure 8-38 show the buffer time index for the midweek, Saturday, and Sunday conditions illustrated in the previous graphs. This is a measure of reliability. The index represents the additional time that travelers must add to their planned trip to arrive on time 95 percent of the time, expressed as a percentage of the average travel time. For the eastbound bridge approach, the figures indicate that the bridge modifications have significantly reduced the variability of travel times from the US-101 to the toll plaza, particularly on Saturdays and Sundays. This is mainly due to the elimination of congestion on the bridge approach during peak travel periods.

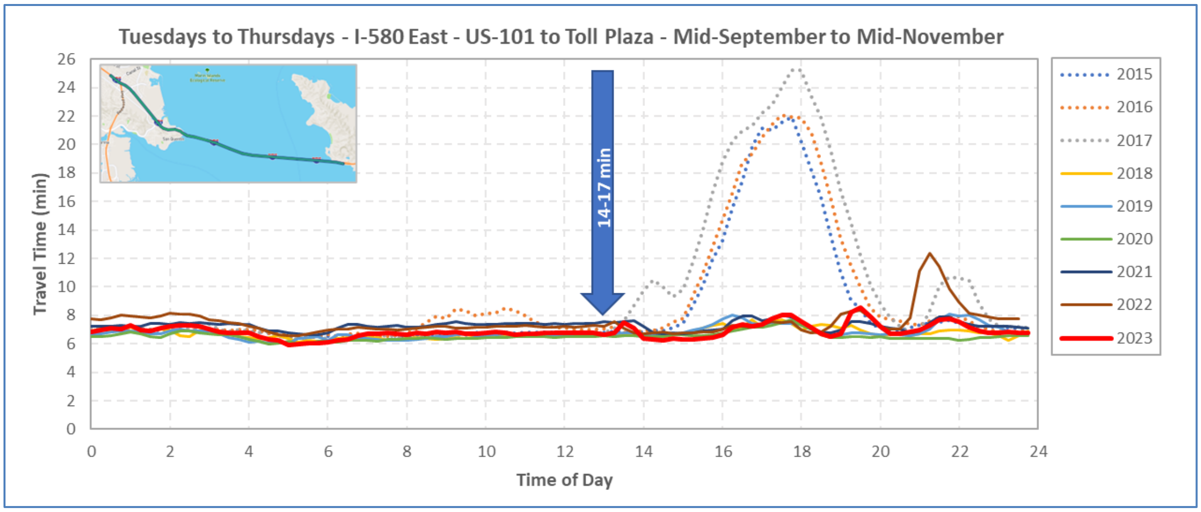

Figure 8-33: Travel Times – I-580 East – US-101 to Toll Plaza – Midweek, Fall 2015-2023

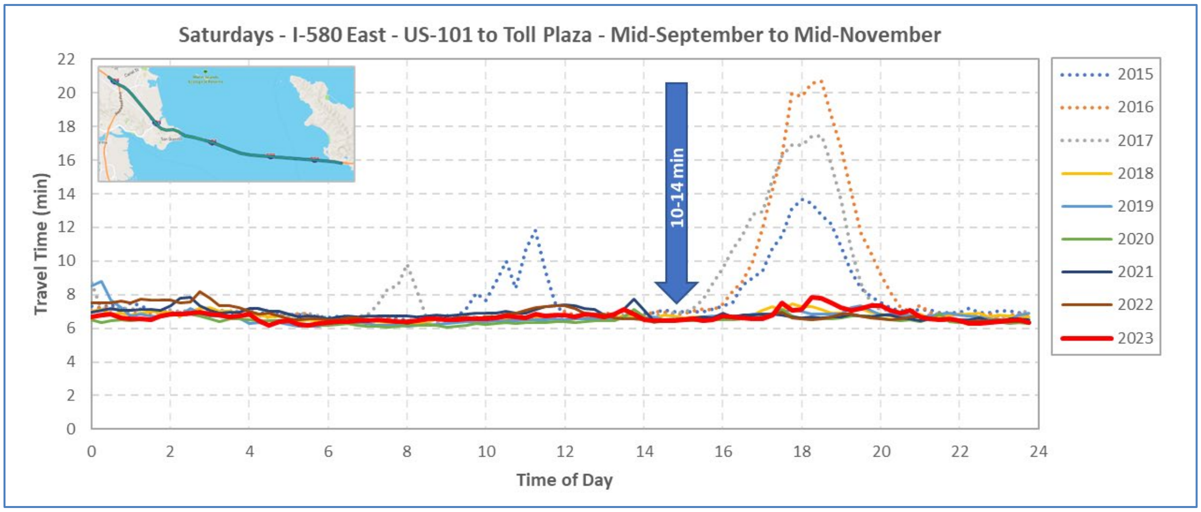

Figure 8-34: Travel Times – I-580 East – US-101 to Toll Plaza – Saturdays, Fall 2015-2023

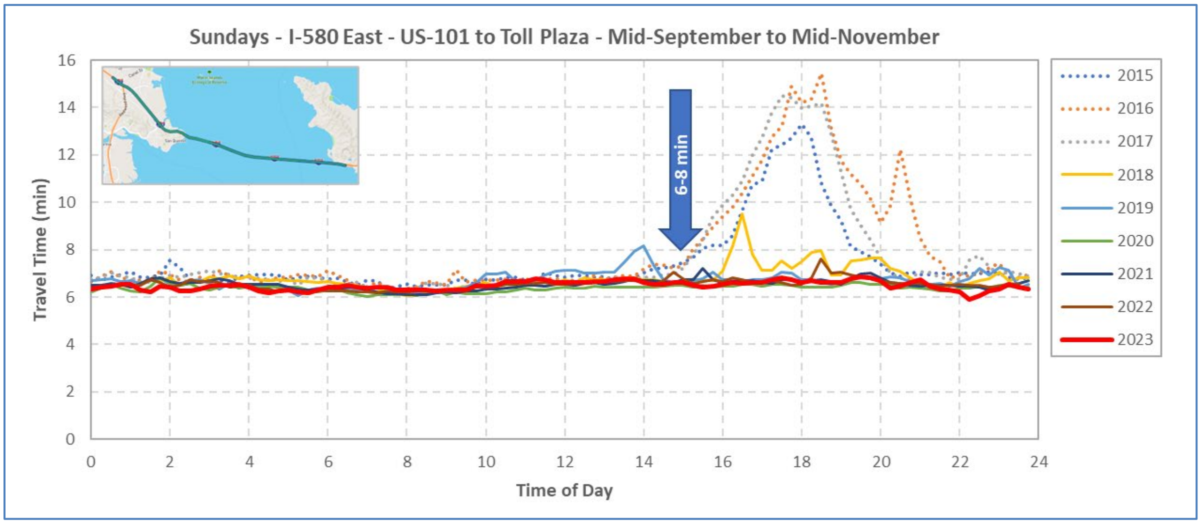

Figure 8-35: Travel Times – I-580 East – US-101 to Toll Plaza – Sundays, Fall 2015-2023

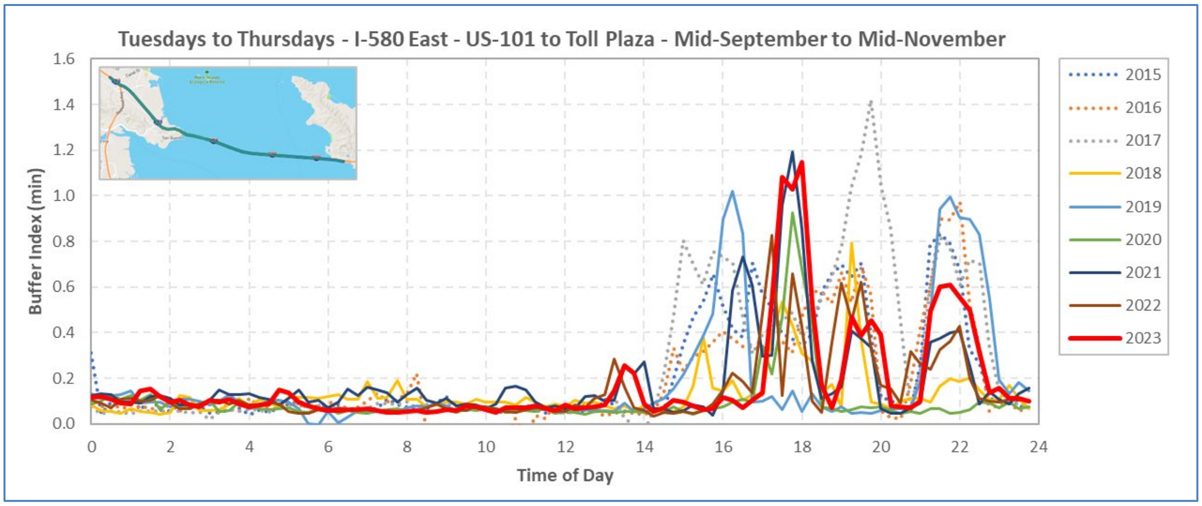

Figure 8-36: Travel Time Reliability I-580 East – US-101 to Toll Plaza – Midweek, Fall 2015-2023

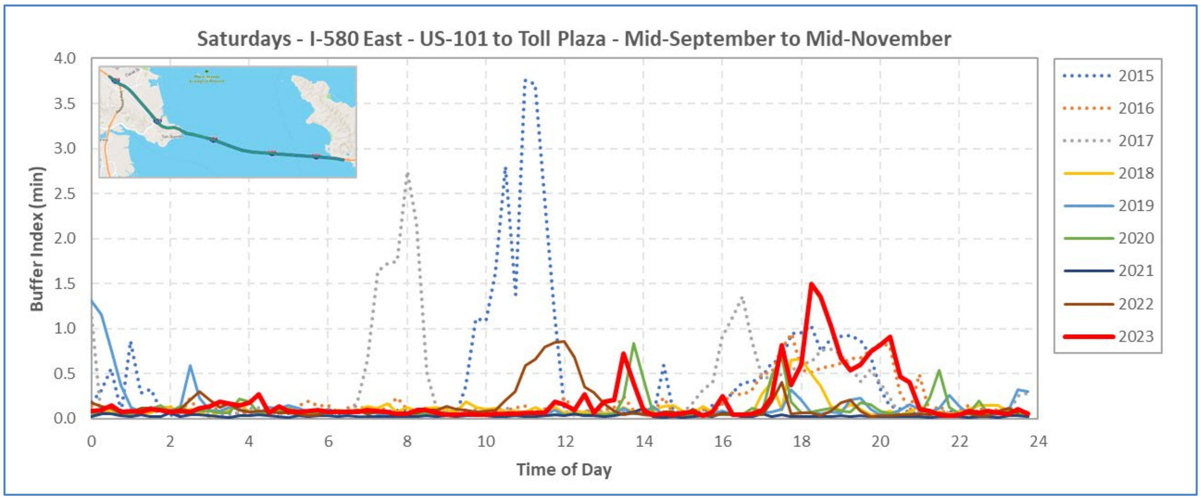

Figure 8-37: Travel Time Reliability I-580 East – US-101 to Toll Plaza – Saturdays, Fall 2015-2023

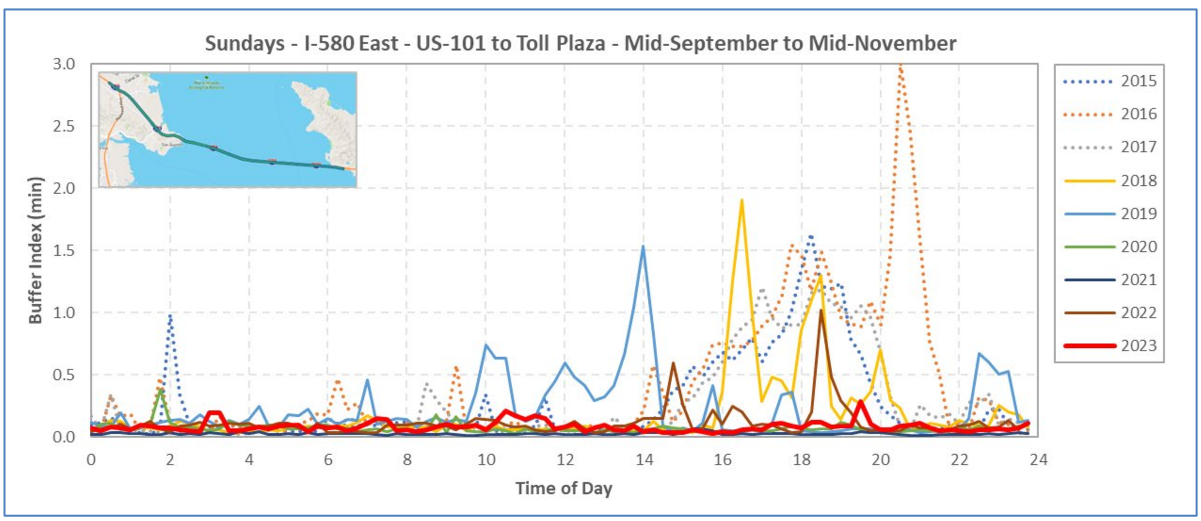

Figure 8-38: Travel Time Reliability I-580 East – US-101 to Toll Plaza – Sundays, Fall 2015-2023

8.2.6. TRAVEL CONDITIONS ON US-101 NORTH

In addition to reducing travel times along I-580 East, the new part-time lane may have contributed to a slight reduction in travel time along US-101 North during weekday afternoon peaks. As previously shown in Figure 8-22, before the modification the congestion generated by the lane drop at the foot of the bridge typically reached the US-101 interchange. On weekdays, this congestion even appeared to spread onto US-101 North between Sir Francis Drake Boulevard and the I-580 exits. However, it did not appear to significantly impact US-101 traffic on Saturdays and Sundays. Without current congestion on I-580 East, the signals at the end of the ramp are now the only element constraining flow on the Francisco Boulevard/I-580 exit. While these signals still cause some vehicle queues to back up onto US-101 during weekdays, they do so to a much lower extent than before.

Figure 8-39 compares the fall average speed profiles along the section of US-101 North extending from the Tamalpais interchange to the Third Street interchange on the other side of the I-580 interchange. The thick vertical blue line indicates the boundary between the before and after periods. As can be observed, significant congestion initially existed on US-101 North between Sir Francis Drake Boulevard and I-580. As noted in Section 8.2.1, this congestion could be attributed to both the I-580 East congestion and traffic frictions north of the interchange resulting from the merging of the US-101 North and I-580 West traffic streams. Following the modifications, reduced congestion has been observed along US-101 in 2018 and 2019, before the COVID-19 pandemic, suggesting a direct potential impact. However, it can also be noted that congestion on US-101 North downstream of the off-ramp was equally reduced. While some congestion reappeared in 2022 between the Sir Francis Drake off-ramp and I-580 interchange, before disappearing again in 2023, this congestion remained less severe than before the modifications.

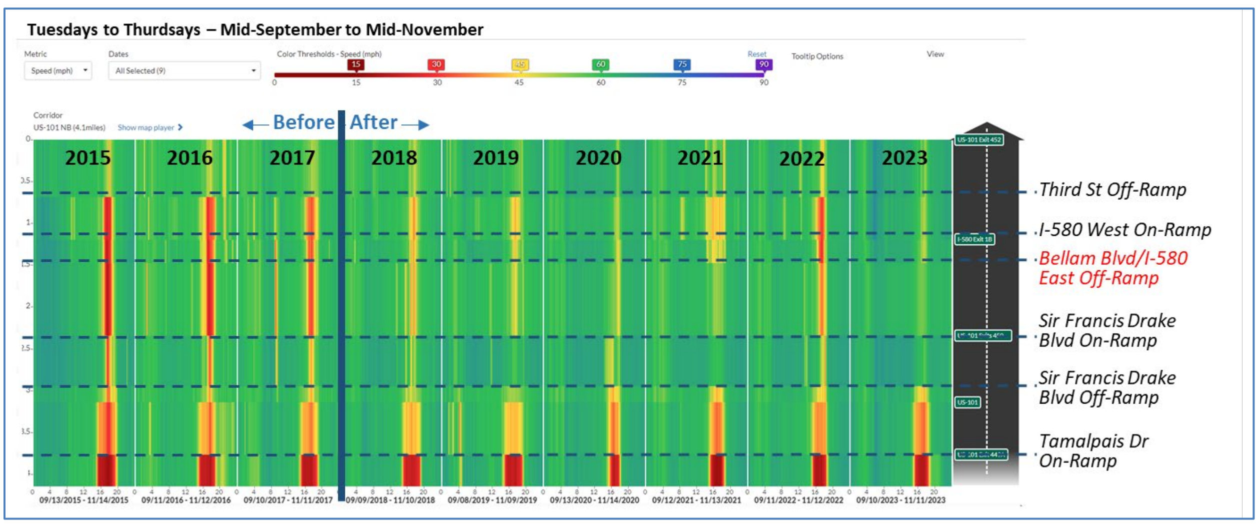

Figure 8-39: Speed Maps – US-101 North –Midweek, Fall 2015-2023

Figure 8-40 further illustrates the average mid-September to mid-November travel times between 2015 and 2022 along the section of US-101 extending from the Tamalpais Drive interchange to the Francisco Boulevard/I-580 exit, as shown in the embedded map. Before the part-time lane opening, peak travel times on this section of US-101 ranged from 5.0 to 6.5 minutes. Since then, average travel times have not exceeded 4.6 minutes. This translates into an average reduction of 0.4 to 1.9 minutes. This is for all vehicles traveling on the section. Unfortunately, a more detailed characterization distinguishing travel time reductions for US-101 and I-580 bound traffic is not possible due to sensor data quality issues near the interchange with I-580, as was highlighted in Section 5.2.1.

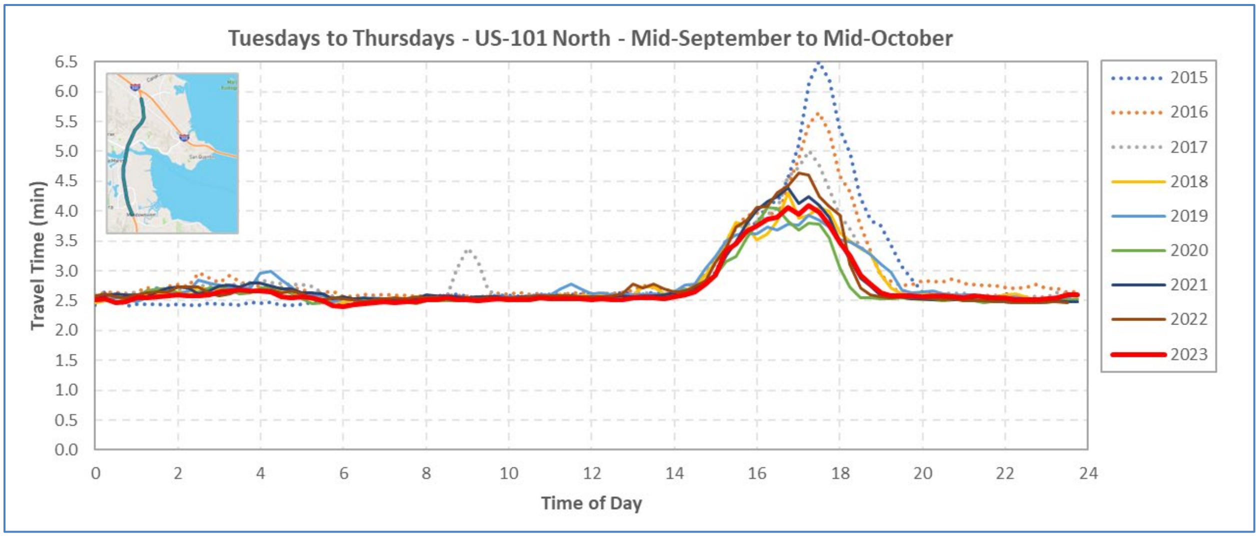

Figure 8-40: Travel Times – US-101 North – Midweek, Fall 2015-2023

No significant changes in travel time were observed for Saturday and Sunday over the same segment and evaluation period. This is explained by the fact that the bridge congestion did not affect the US-101 North traffic as much during the weekend before the modifications, as illustrated in the congestion maps of Figure 8-22.

8.2.7. TRAVEL CONDITIONS ON EASTBOUND SIR FRANCIS DRAKE BOULEVARD

Figure 8-41 to Figure 8-43 illustrate eastbound speeds along Sir Francis Drake Boulevard, from the US-101 to the I-580 interchanges, over the 2015-2023 period. Similar to I-580 East, the opening of the eastbound shoulder to traffic has positively impacted traffic conditions along the arterial. Before the opening, speeds below 20 mph were observed across the entire length of the arterial. While speeds below 20 mph are still currently observed on weekdays, their spatial and temporal extent is significantly reduced and primarily centered on the section west of the San Quentin Prison entrance.

Figure 8-44 to Figure 8-46 further illustrate changes in travel times along the arterial, from the US-101 to the I-580 interchanges, over the evaluation period. Travel times during the weekday afternoon peak have dropped from 11-12 minutes to around 5 minutes between fall 2017 and fall 2018. This is a 6–7-minute reduction that can be directly attributed to the improved traffic conditions that resulted from the bridge modifications. Saturday peak travel times similarly dropped from 8-10 minutes to about 3 minutes, while Sunday peak travel times dropped from 6-7 minutes to 3 minutes. These correspond to travel time reductions of 5-7 and 3-4 minutes, respectively.

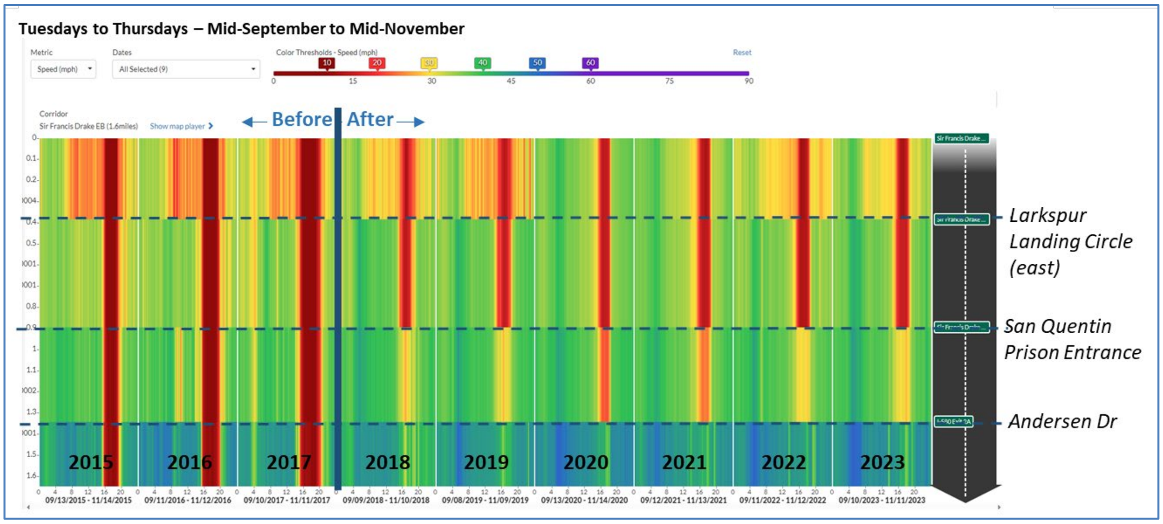

Figure 8-41: Speed Maps – Sir Francis Drake Boulevard EB – Midweek, Fall 2015-2023

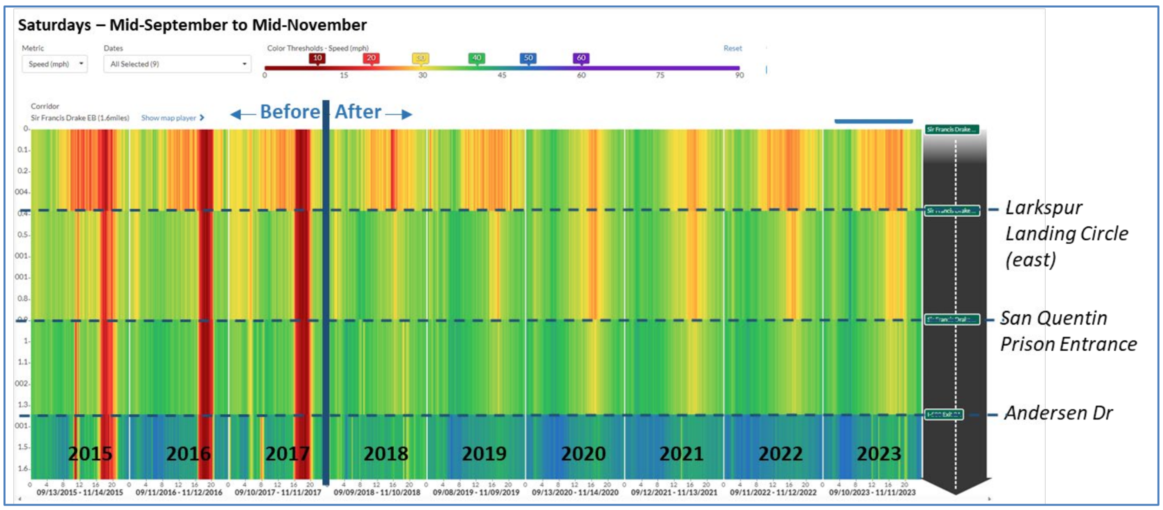

Figure 8-42: Speed Maps – Sir Francis Drake Boulevard EB – Saturdays, Fall 2015-2023

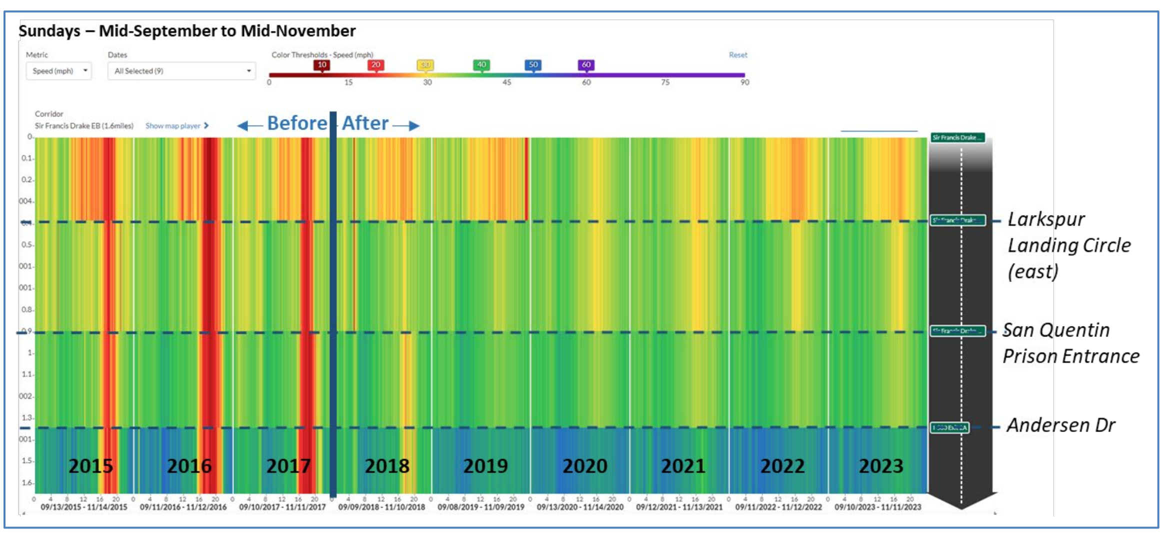

Figure 8-43: Speed Maps – Sir Francis Drake Boulevard EB – Sundays, Fall 2015-2023

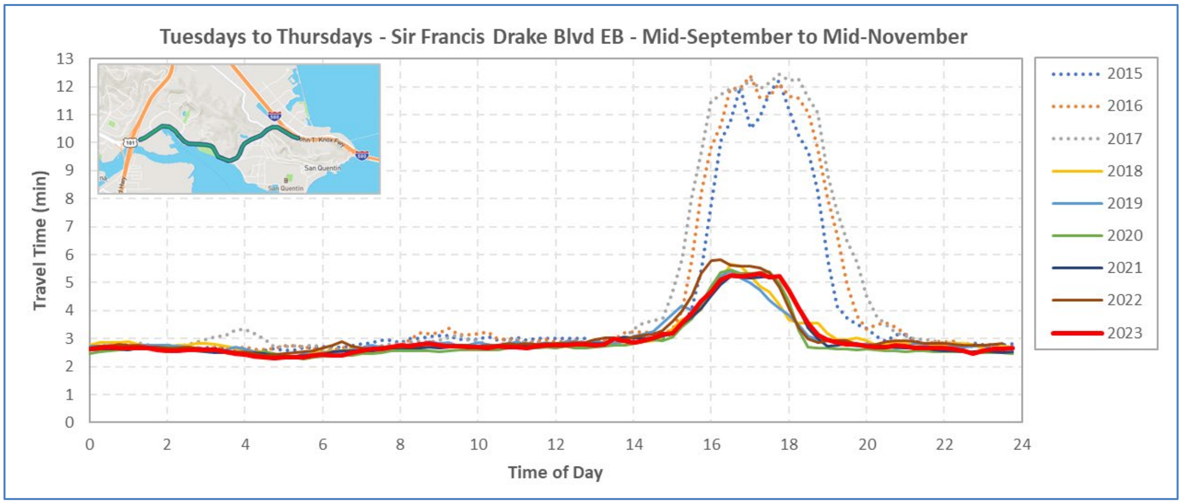

Figure 8-44: Travel Times – Sir Francis Drake Boulevard EB – Midweek, Fall 2015-2023

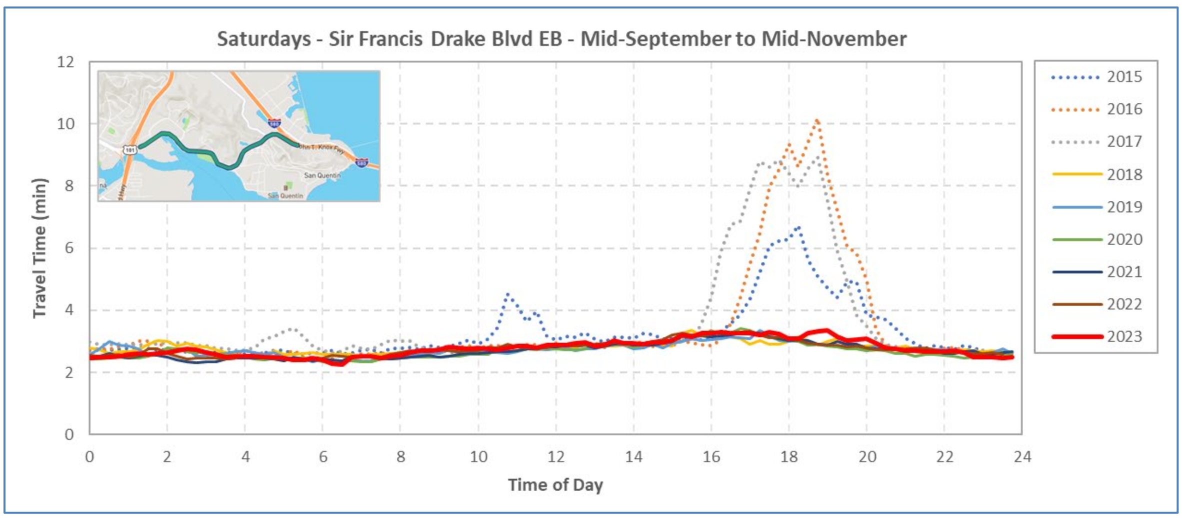

Figure 8-45: Travel Times – Sir Francis Drake Boulevard EB – Saturdays, Fall 2015-2023

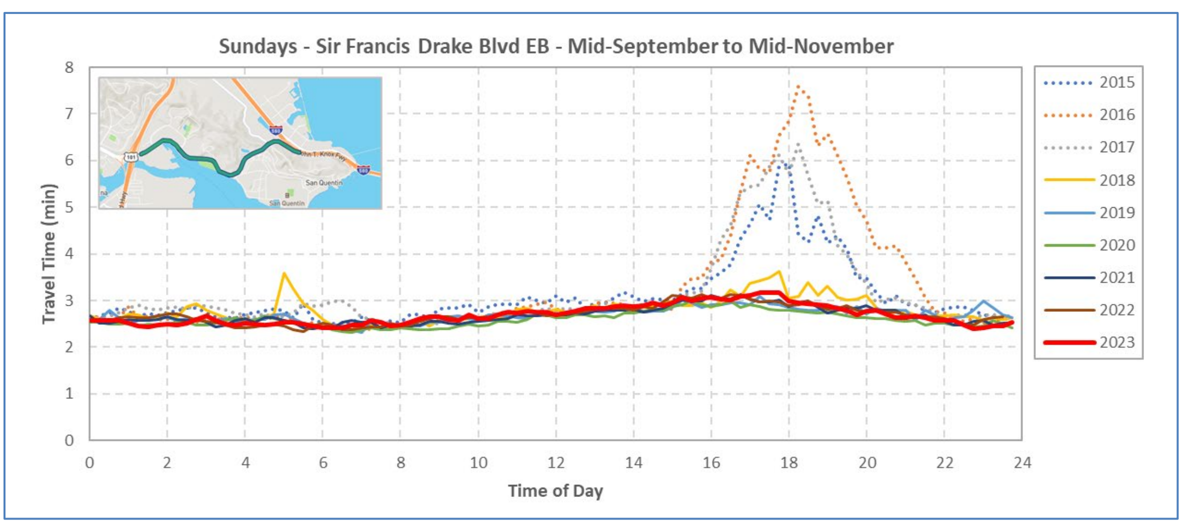

Figure 8-46: Travel Times – Sir Francis Drake Boulevard EB – Sundays, Fall 2015-2023

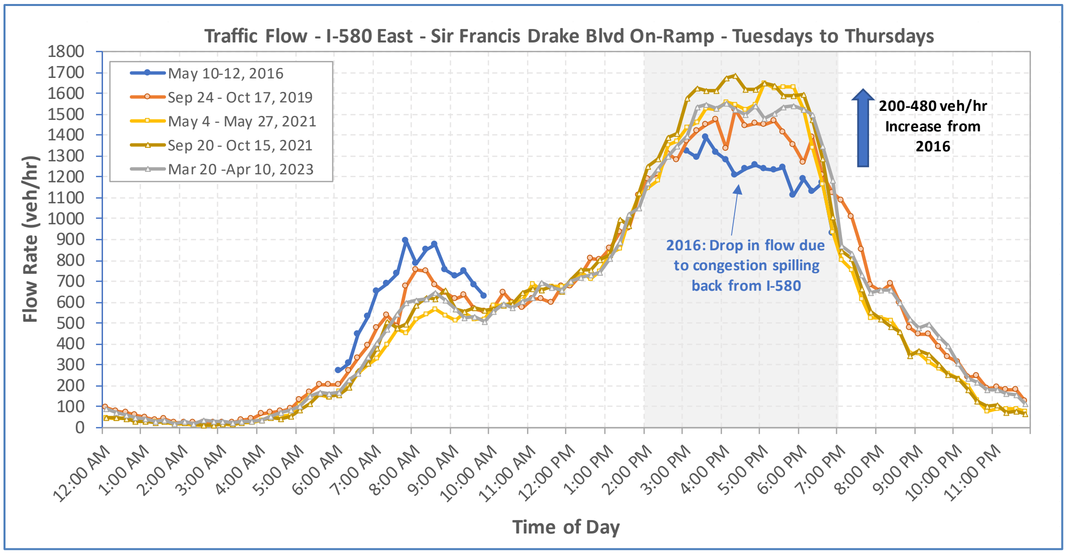

Figure 8-47: Flow on I-580 Sir Francis Drake Boulevard On-Ramp, 2016-2023

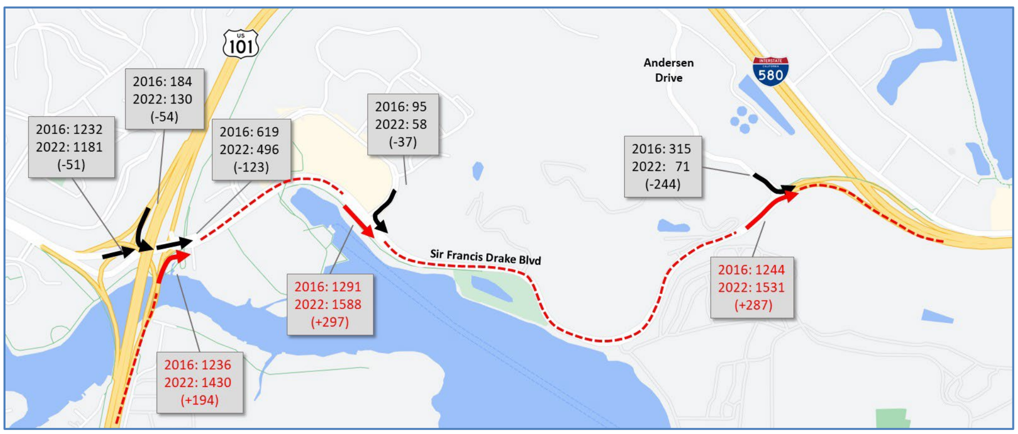

Figure 8-48: Changes in Traffic Flows along Sir Francis Drake Boulevard between 2016 and 2022

Figure 8-47 concludes by comparing weekday flows on the I-580 East on-ramp at the end of the arterial from mid-May 2016 to Fall 2019, Spring 2021, Fall 2021, and Spring 2023. Data from spring 2020 are not considered due to the impacts of the COVID-19 pandemic on traffic demand. Flows between Spring 2016 and Fall 2019 are not presented as no data were collected during this period.

Based on the illustrated data, the following three observations can be made regarding traffic using Sir Francis Drake Boulevard to access I-580 East and the Richmond-San Rafael bridge:

- Peak weekday afternoon traffic has significantly increased following the April 2020 modifications. 2021 peak flow rates are 230 to 480 vehicles/hour higher than in 2016, depending on the period considered.
- While the observed flow increases could partly be due to a background increase in traffic demand, the elimination of congestion on I-580 East that used to cause backups onto Sir Francis Drake Boulevard is seen as a major contributing factor. This assumption is further supported by a reduction in travel times along the arterial despite the increase in traffic, which may have enticed more motorists to use the arterial to reach I-580 East. This is supported by the data of Figure 8-48, which shows a nearly 300 vehicle/hour increase in flow from the US-101 North off-

ramp to the I-580 on-ramp between May 2016 and March 2022 despite reductions in flows originating from other sources.

- While AM peak on-ramp traffic has reduced since 2016, this is likely due to changes in travel demand as there was, and still is, generally no congestion affecting eastbound traffic along the arterial during the morning.

8.2.8. TRAVEL CONDITIONS ON EASTBOUND FRANCISCO BOULEVARD

Before the bridge modifications, it was hypothesized that some traffic used Francisco Boulevard to bypass congestion along I-580 East. As shown on the left side of Figure 8-49, which illustrates counts around the Main Street interchange from May 2016, this was supported by a high volume of vehicles turning right on Main Street from Francisco Boulevard and then left onto the I-580 East on-ramp during an average weekday afternoon peak hour. Recent counts from March 2022, shown on the right side, show a significant reduction in traffic accessing I-580 East at Main Street from Francisco Boulevard. Additional evidence is provided in Figure 8-50, which shows a large drop in traffic on the Main Street on-ramp in counts from 2019, 2021, and 2023 compared to May 2016. Counts between May 2016 and the fall of 2019 are not shown due to a lack of data.

While there is no direct evidence that the flow reductions described above occurred immediately after the opening of the part-time lane in April 2018, logic suggests that this is the likely contributing factor. As the modification has eliminated congestion along I-580, motorists have had since then fewer incentives to use local arterials to shave some travel time on their eastbound trips.

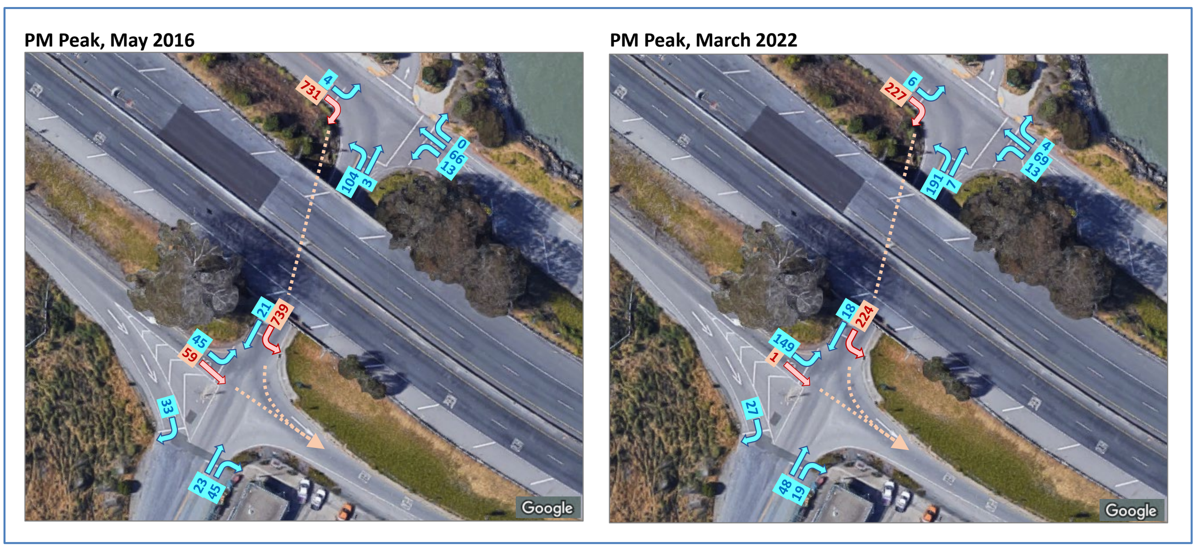

Figure 8-49: Traffic Flows at Main Street Interchange, 2016

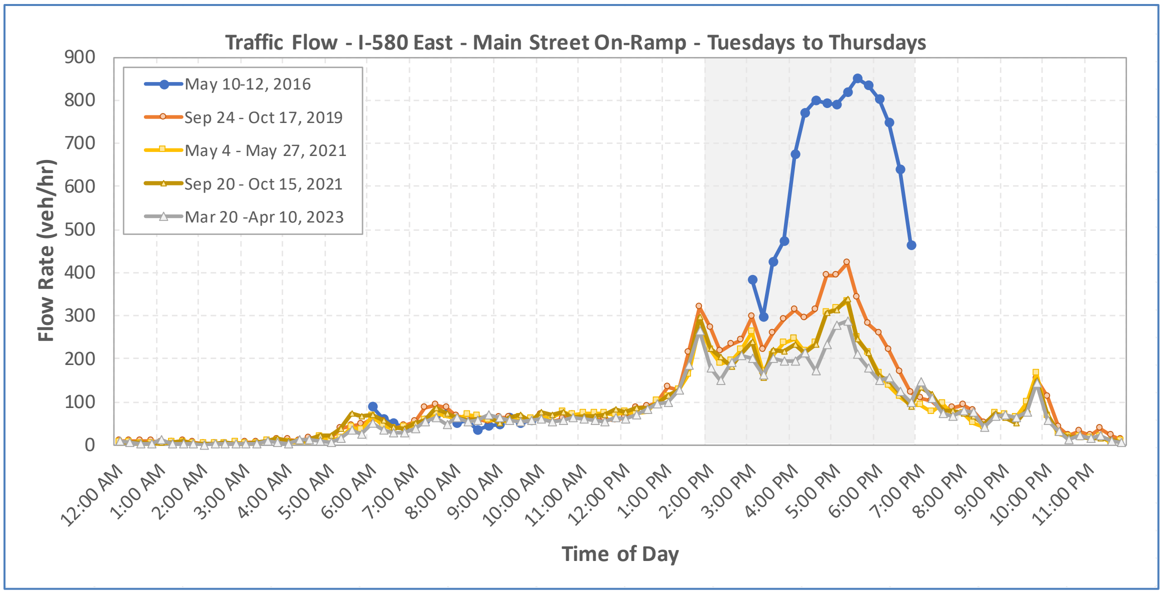

Figure 8-50: Flow on I-580 East Main Street On-Ramp, Midweek, 2016-2021

Additional evidence that fewer vehicles are utilizing Francisco Boulevard to access I-580 East is obtained by comparing counts taken at various locations along the arterial. As illustrated in Figure 8-51, most of the reduction in traffic along Francisco Boulevard appears to originate from the intersection with Bellam Boulevard. The reduction can more particularly be traced to fewer vehicles traveling north on Bellam Boulevard and turning right onto Francisco Boulevard after having bypassed the local I-580 East on-ramp.

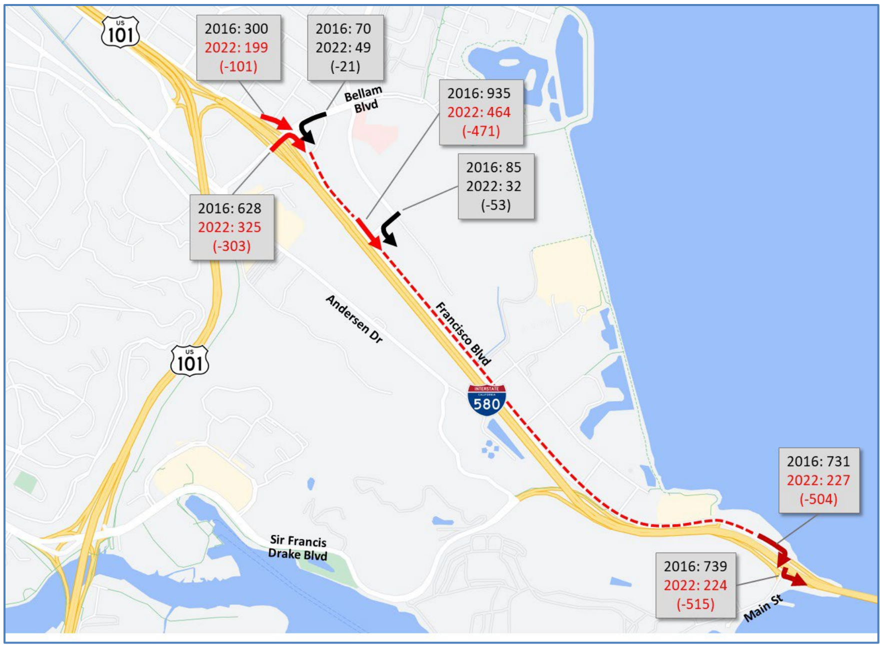

Figure 8-51: Changes in Traffic Flows along Francisco Boulevard between 2016 and 2022

While an analysis of travel times along Francisco Boulevard would help confirm the above observation, such analysis could not be made as INRIX only started collecting travel times along Francisco Boulevard in 2019, after the part-time traffic lane opening.

8.2.9. TRAVEL CONDITIONS ON ANDERSEN DRIVE

Figure 8-52 compares turning counts at the intersection between Andersen Drive and Sir Francis Drake Boulevard between May 2016 and March 2022. The illustrated data suggests that a significant reduction in traffic has occurred on Andersen Drive after the part-time lane opening. The 2016 data show an average of 315 vehicles/hour turning onto the I-580 East on-ramp from Andersen Drive while the 2022 data indicates only 71 vehicles/hour. This represents a 77% drop in traffic. This is evidenced in Figure 8-53 by the drop in congestion near the intersection between Andersen Drive and Bellam Avenue.

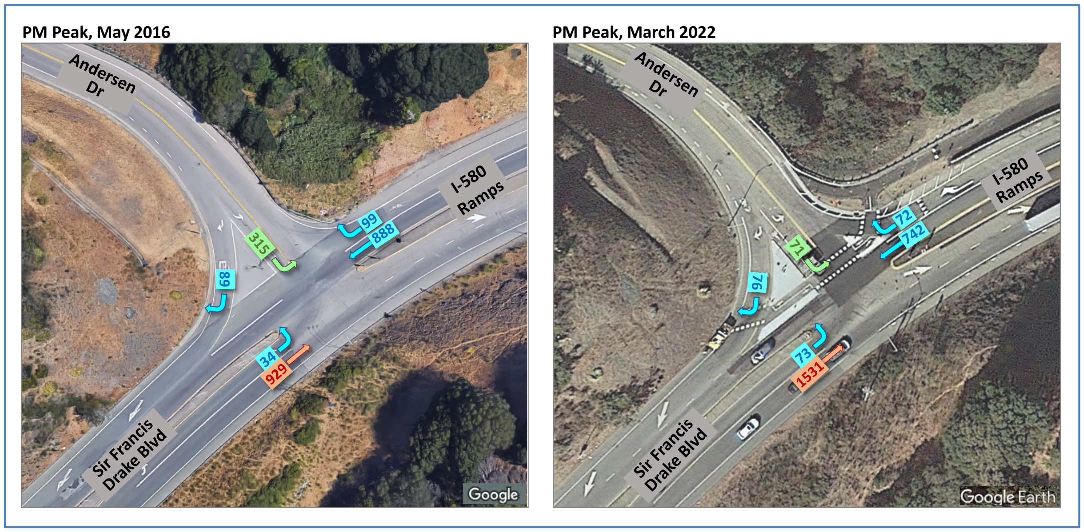

Figure 8-52: Traffic Flows at Sir Francis Drake and Andersen, 2016 and 2022

It could be hypothesized that the drop results from fewer vehicles using Andersen Drive as a bypass to I-580 East. However, a review of INRIX average speed data collected along the arterial indicates that it occurred sometime after the shoulder opening, in either late 2019 or early 2020, and likely as a result of the COVID-19 pandemic. This explanation is further supported by the resurgence of congestion at the same location in the spring of 2023, albeit at a smaller intensity than before the pandemic.

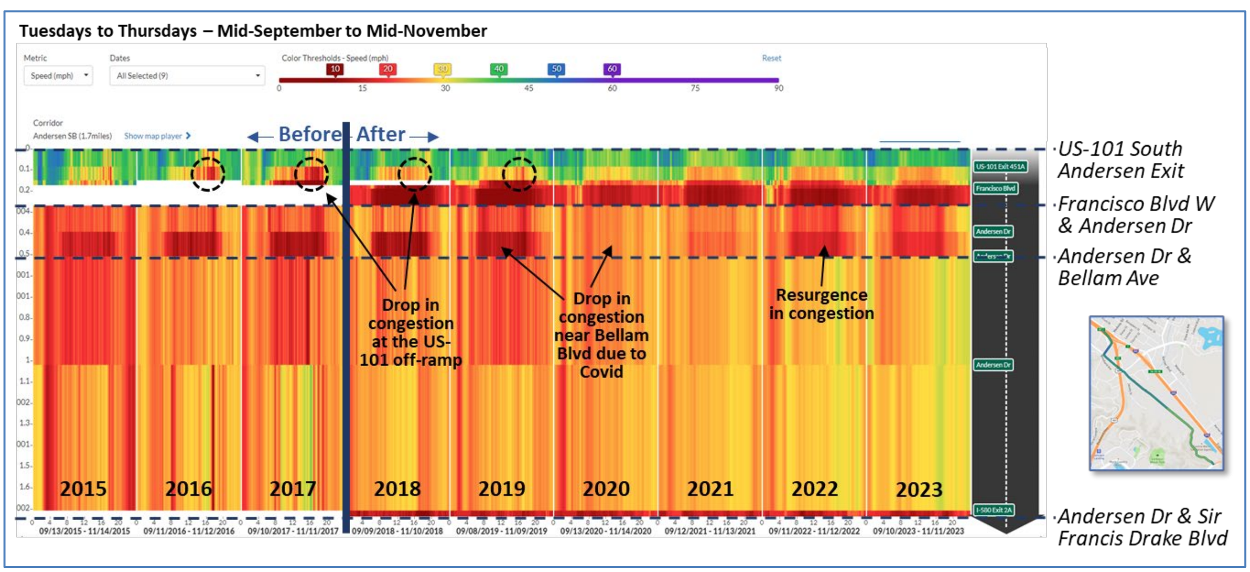

Figure 8-53: Speed Maps – Andersen Drive – Midweek, Fall 2015-2023

Another potential effect from the shoulder opening can be seen in Figure 8-53 at the Andersen Drive off-ramp along US-101 South, shown in the top part of the graph. As highlighted by the black circles, a slight reduction in congestion could be observed on the off-ramp by comparing situations before and after the April 2018 bridge modifications. This change could be the result of fewer vehicles taking the off-ramp due to less congestion on I-580 East. Unfortunately, there is no data to definitively prove this assertion since the PeMS traffic sensors on the off-ramp to Andersen Dr/Francisco Boulevard West (station 418213) did not produce reliable data before April 2020.

8.2.10. TRAVEL CONDITIONS ON I-580 EAST MAIN STREET RAMPS

As was shown in Figure 8-49, 59 vehicles/hour were observed in the May 2016 counts going straight from the Main Street off-ramp to the Main Street on-ramp during the afternoon peak. This is despite lane markings indicating the left lane as a left-turn-only lane. This behavior was likely done as a way to save some travel time by bypassing a portion of the congestion along I-580 East. In the March 2022 counts, an average of only 1 vehicle/hour was observed making the same move during the afternoon peak, indicating the existence of significantly fewer travel constraints along I-580 East.

8.2.11. TRAVEL CONDITIONS ON I-580 EAST BELLAM BOULEVARD ON-RAMP

Counts data show an increase in traffic on the I-580 East Bellam Boulevard on-ramp between May 2016 and March 2022. As shown in Figure 8-54, weekday afternoon peak ramp traffic went from 282 to 464 vehicles/hour. This represents a 64% increase that occurred at the same that traffic across the intersection decreased by around 10%. This increase can be attributed to both a change in traffic demand and fewer vehicles opting to use Francisco Boulevard as a bypass to I-580, as noted in Section 8.2.8.

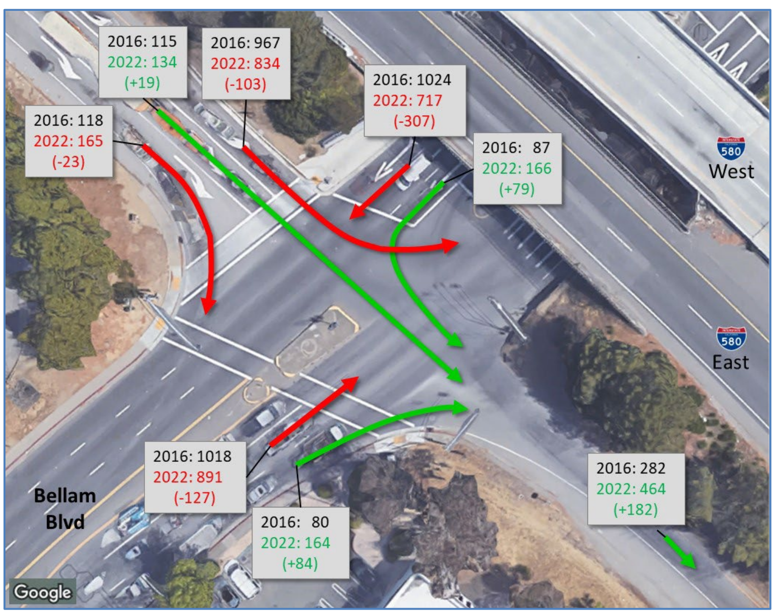

Figure 8-54: Traffic Flows at I-580 East Bellam Boulevard Ramps, 2016 and 2022

8.2.12. SUMMARY OBSERVATIONS

The following are key observations from the analysis of impacts on eastbound traffic associated with the opening to traffic of the bridge lower deck shoulder between 2 PM and 7 PM daily:

- The availability of an extra traffic lane has increased eastbound peak hourly flow across the bridge by 13-26%, from 3,300-3,570 vehicles/hour to 3,750-4500 vehicles/hour.
- The part-time lane typically only carries less than 25% of the eastbound bridge traffic during weekday peak periods, and less than 20% on weekends.
- The added peak-hour capacity has eliminated congestion on the eastbound approach to the bridge. This has caused peak travel times from the US-101 interchange to the toll plaza to drop by 14-17 minutes on midweek days, 10-14 minutes on Saturdays, and 6-8 minutes on Sundays.
- Peak-hour travel times to reach the toll plaza are significantly less variable than before.
- The absence of congestion on I-580 East has likely contributed to a 1- to 2-minute reduction in average travel times on US-101 between Sir Francis Drake Boulevard and the I-580 interchange.
- Weekday afternoon peak travel times along Sir Francis Drake Boulevard have dropped by up to 4 minutes, while traffic volumes have increased by over 300 vehicles/hour.
- Less traffic is using Francisco Boulevard to bypass congestion on I-580 East. While less traffic is also using Andersen Drive, it is unclear to which extent this is due to the bridge modifications.
- Fewer vehicles are using the Main Street off-ramp and on-ramp as a congestion bypass.
- Increased traffic is observed entering I-580 East at the Bellam Boulevard on-ramp, likely partly due to fewer vehicles attempting to use local arterials as bypasses to the freeway.

The following are additional observations regarding the compliance of motorists with the period during which the shoulder is opened to traffic:

- Motorists are generally compliant with the shoulder opening period, as relatively few vehicles are observed using the lane before 2 PM and after 7 PM.
- Non-compliant use of the shoulder is highest 20 minutes before its opening and up to 25 minutes following its closure.
- CHP officers have indicated observing some vehicles using the shoulder as a passing or traveling lane when a red or yellow X is shown above it. This suggests that some motorists may not fully understand the meaning of the current lane control signs.

8.3. IMPACTS ON WESTBOUND BRIDGE TRAFFIC

This section evaluates the impacts on traffic of the conversion of the westbound upper deck shoulder into a barrier-separated bike/pedestrian path. The primary goals of this evaluation are to assess:

- Whether the provision of a travel path visually constrained by the path barrier is causing a capacity reduction on the bridge and/or traffic to slow down.
- whether the provision of a shorter merge area at the exit of the toll plaza is causing an increase in congestion on the westbound approach to the bridge.

Based on the above goals, the following subsection successively presents the following elements:

- Typical congestion profile on the bridge approach
- Impacts on upper deck capacity.
- Impacts on traffic conditions on the approach to the bridge.
- Impacts on traffic conditions across the bridge.
- Impacts on traffic distribution across lanes on the bridge.
- Impacts on local arterials on the Richmond side of the bridge.
- Summary of observations

8.3.1. TYPICAL APPROACH CONGESTION PROFILES

To help with the analysis of traffic impacts associated with the bridge modifications, Figure 8-55 presents speed maps illustrating general traffic conditions on the westbound approach to the bridge in the fall of 2023. The heat map on the left illustrates average conditions on midweek days, the one in the middle on Saturdays, and the one on the left on Sundays.

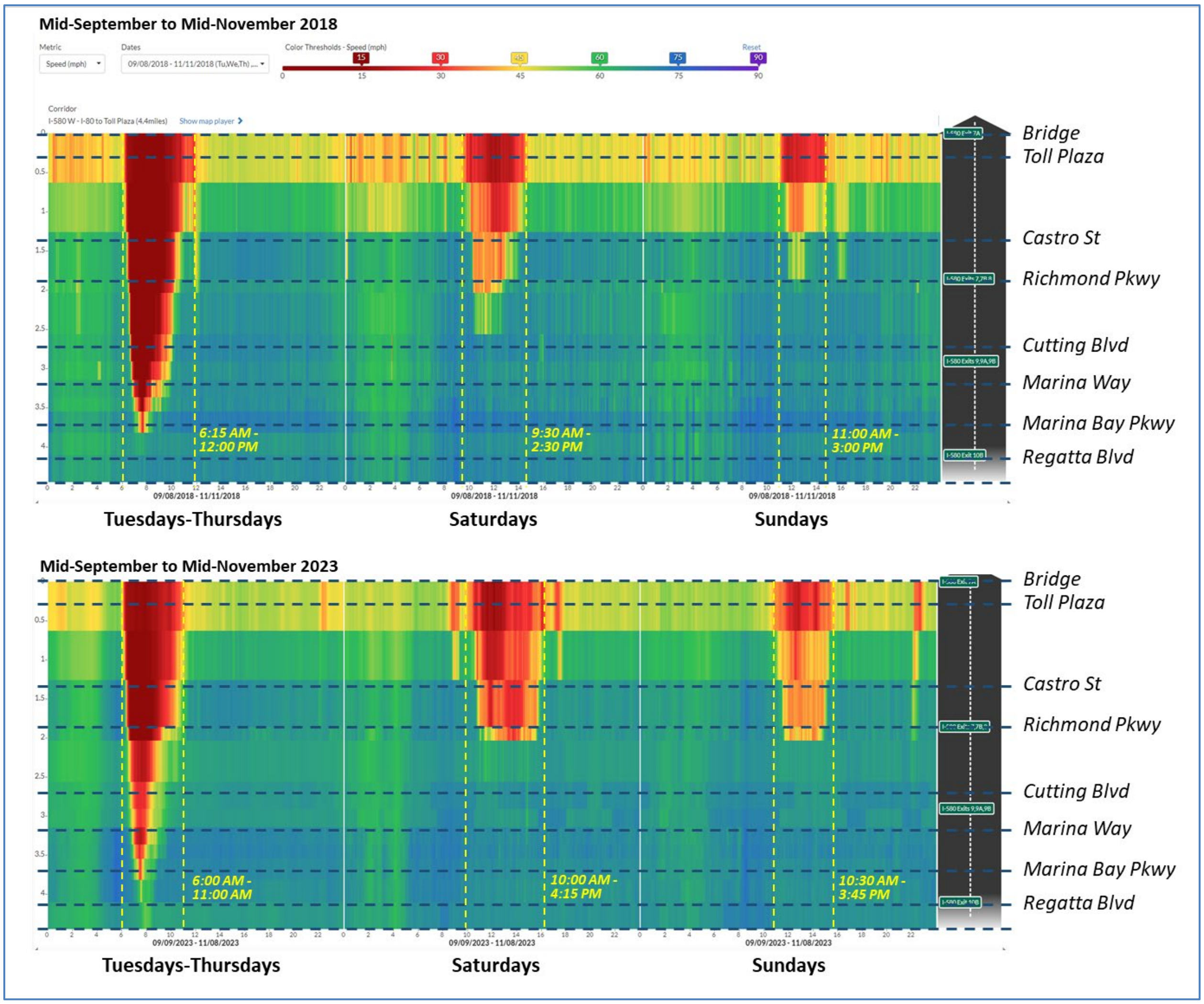

Figure 8-55: Typical Congestion Profiles on Westbound Bridge Approach, Fall 2018 and 2023

Based on the illustrated data, the following observations can be made:

- During weekdays, congestion currently exists between 6 AM and 11 AM. Traffic speeds during this period drop below 15 mph, with peak queues occurring between 7:00 and 7:30 AM and extending 3.5 miles upstream of the toll plaza, to between the Marina Bay Parkway and Regatta Boulevard interchanges. This is generally similar to the observed 2018 conditions.
- On Saturdays, congestion currently exists between 10 AM and 4:15 PM. Traffic speeds during this period drop to about 20 mph, with peak queues occurring between 12:00 PM and 3:00 PM and extending 1.75 miles from the toll plaza, to around Richmond Parkway. When compared to the 2018 conditions, the extent of the congestion is about the same but its duration is significantly longer.
- On Sundays, congestion is typically observed between 10:30 AM and 3:45 PM. Traffic speeds during this period only drop to around 20-25 mph, with peak queues occurring between 12:00 Noon and 2:00 PM and extending 1.75 miles from the toll plaza, to around Richmond Parkway. When compared to the 2018 conditions, both the extent and duration of the congestion appear longer.

8.3.2. IMPACTS ON UPPER DECK CAPACITY

Figure 8-56 and Figure 8-57 illustrate the peak weekday and weekend hourly flows observed at the Richmond toll plaza from January 2015 to March 2024. Within the figure, the dots illustrate the maximum observed flow on a given day, excluding holidays and days with abnormally low volume. Since day-to-day maximum flows are subject to significant fluctuations due to weather, incidents, variations in the proportion of trucks, and other factors, a 2-week rolling average is superimposed on the daily data to facilitate the identification of trends.

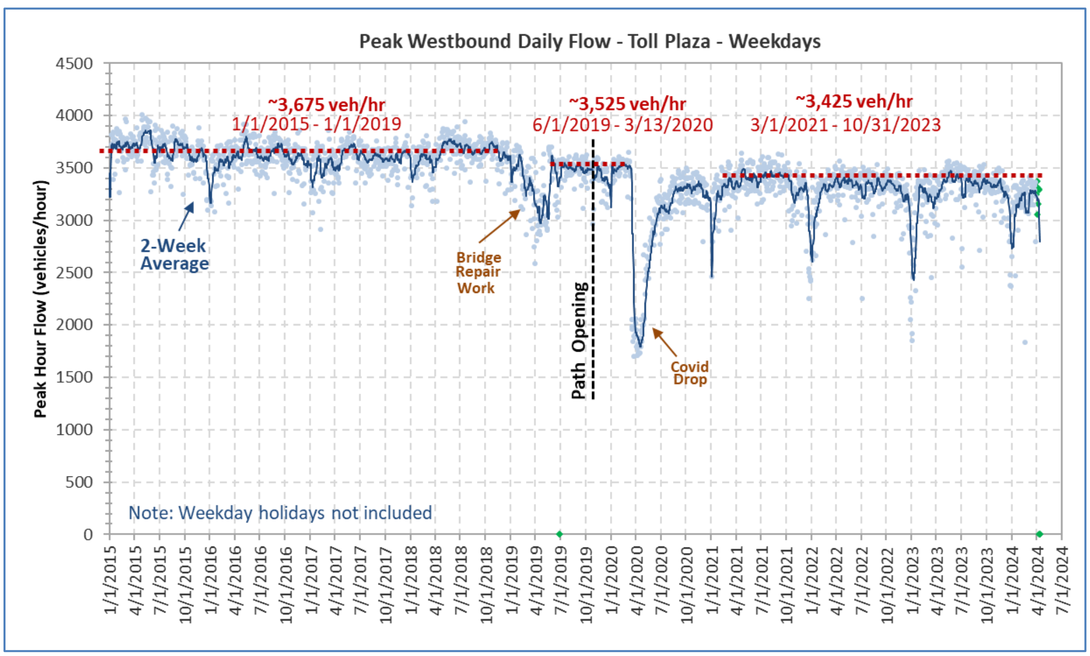

Figure 8-56: Peak Hourly Flows – I-580 West – Toll Plaza, Weekdays, 2015-2024

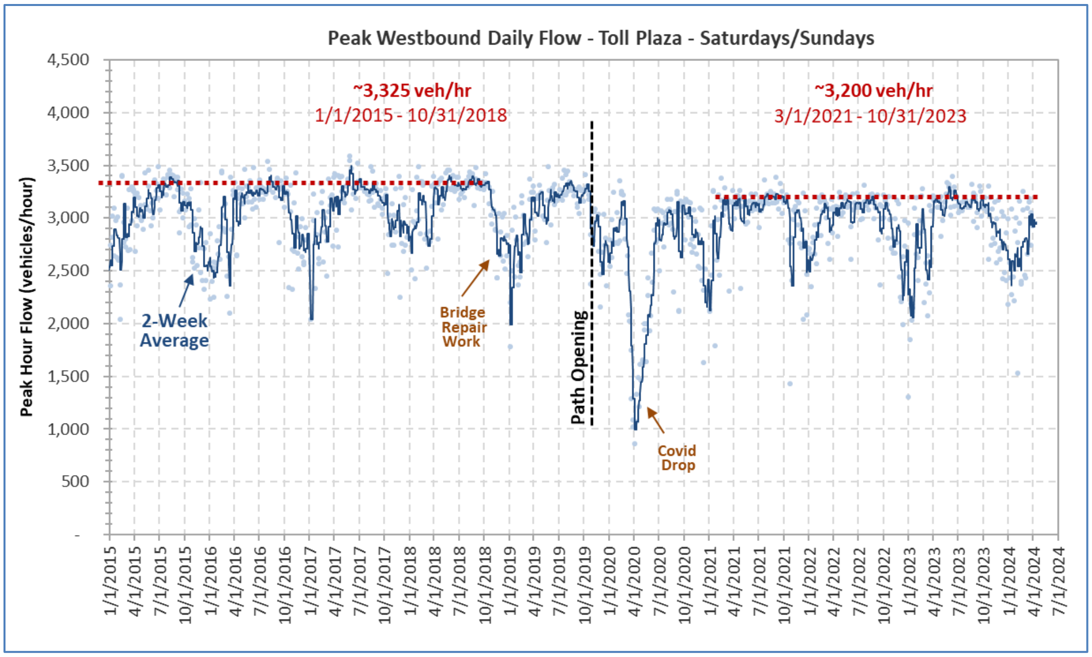

Figure 8-57: Peak Hourly Flows – I-580 West – Toll Plaza, Weekends, 2015-2024

The following observations can be made from the illustrated data:

- A weekday peak capacity of approximately 3,675 vehicles/hour existed before January 2019. On Saturdays and Sundays, average peak flows were slightly lower, at 3,325 vehicles/hour, likely due to the presence of drivers with less aggressive behavior.
- Following the failure of a bridge joint on February 7, 2019, and the subsequent emergency bridge maintenance, significantly lower maximum flows were observed from February to July 2019 on both weekdays and weekends. These are the results of occasional lane closures and reduced traffic speeds caused by steel plates covering joints.
- After the installation of the barrier separating the bike/pedestrian path, peak weekday flows averaged 3,525 vehicles/hour between November 2019 and February 2020. This represents a 150 vehicles/hour, or 4%, average drop over the before conditions. Weekend peak traffic flows remained too variable at that time to provide a representative average.
- Since June 2021, following the termination of workplace COVID-19 restrictions, average peak flows across the bridge have remained around 3,425 vehicles/hour. This represents a 250 vehicles/hour drop, or roughly a 7% reduction, from the pre-modifications historical average. On Saturdays and Sundays, a similar reduction is observed, with average peak flows dropping from 3,325 to 3,200 vehicles/hours, corresponding to a roughly 4% drop.
- Over a four-hour peak period, the observed weekday decrease in capacity could translate into up to 1,100 vehicles that could potentially not be served by the bridge. This is assuming that traffic demand would remain at or above capacity over the entire period. If it is considered that traffic demand typically only remains above capacity for the first one-third to one-half of the peak period, with the remaining period servicing the residual queue, the potential loss in traffic volume might be closer to 500-600 vehicles. On weekends, the data further suggest that 600 vehicles may potentially not be served by the bridge if demand similarly exceeds the capacity for four hours, with perhaps a more realistic 300 loss.

While daily traffic has remained lower than pre-COVID-19 levels, as shown earlier in Figure 8-1 to Figure 8-6, congestion is again observed on the approach to the toll plaza on Weekdays, Saturdays, and Sundays. This is an indication that traffic is again exceeding the bridge's capacity during peak periods. However, since daily maximum flows have not returned to pre-COVID-19 levels, it can be inferred that the observed drops in capacity are the results of the bridge modifications, as outlined below:

- The capacity chokepoint appears to be the section downstream of the toll plaza where the number of traffic lanes reduces from seven to two. Implementation of the bikeway has reduced the length of the merge area from 900 ft to 325 ft. Forcing vehicles to merge over a shorter distance causes more friction between traffic streams and reduces the maximum number of vehicles that can go through the section in an interval.
- The barrier also creates a more visually constrained environment on the bridge, enticing vehicles to slow down. This is particularly true near the entrance of the bridge, where vehicles often change lanes. While lower speeds have historically been observed on the first half-mile of the bridge due to lane-changing activities, as evidenced later in Figure 8-70, Figure 8-71, and Figure 8-72, slight additional speed reductions could further lower the maximum number of vehicles that can enter the bridge in periods of heavy traffic.

The impacts of the above factors are further compounded by the elimination of cash toll payments at the toll plaza in March 2020. By not requiring a portion of vehicles to stop, this change allows more vehicles to cross the plaza within a given interval and thus potentially increases the number of vehicles attempting to go through the merge area at the same time.

8.3.3. TRAVEL CONDITIONS ON THE WESTBOUND APPROACH

The following sets of figures are presented to illustrate traffic conditions on the westbound approach to the bridge:

- Figure 8-58 to Figure 8-60 present average speed contour maps from the I-80 interchange to the toll plaza, for midweek days, Saturdays, and Sundays, between 2015 and 2023. The speeds are the averages from mid-September to mid-November. To facilitate analyses, the thick vertical blue line indicates when the path opening occurred.
- Figure 8-61 to Figure 8-63 further present travel times over the same period and freeway section. In this case, data from the before period are indicated by a dotted line, while the after are shown by solid lines.
- Figure 8-64 to Figure 8-66 present the buffer time index for the weekday, Saturday, and Sunday conditions illustrated in the previous graphs. This is a measure of reliability. It represents the additional time that travelers must add to their planned trip to arrive on time 95 percent of the time, expressed as a percentage of the average travel time.
- Figure 8-67 to Figure 8-69 finally present observed peak hour flows at the PeMS station near Cutting Boulevard (station 400734). This data is used to assess the magnitude of the traffic demand toward the bridge as observations made closer to the bridge might be affected by the congestion that builds up upstream of the toll plaza.

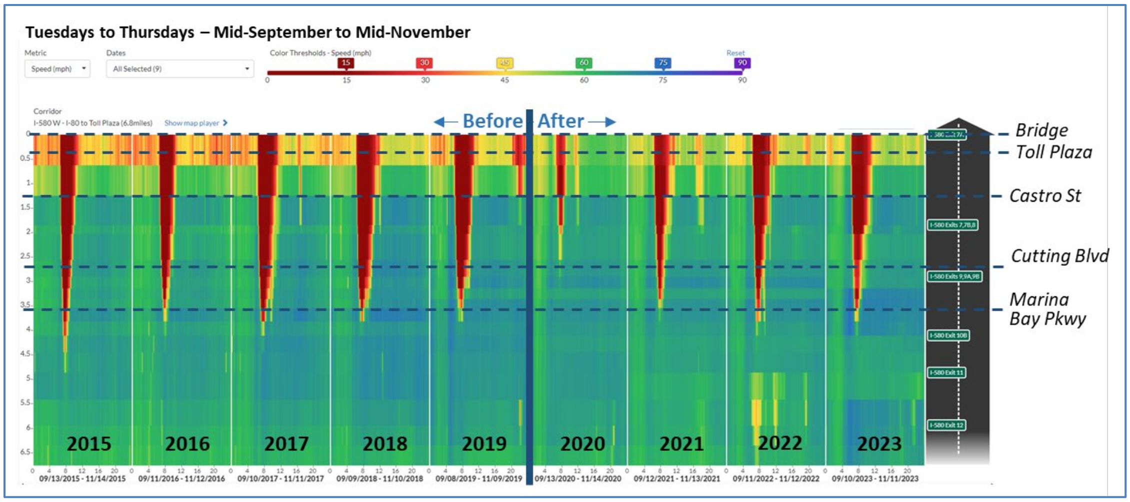

Figure 8-58: Speed Maps – I-580 West – Richmond Approach – Midweek, Fall 2015-2023

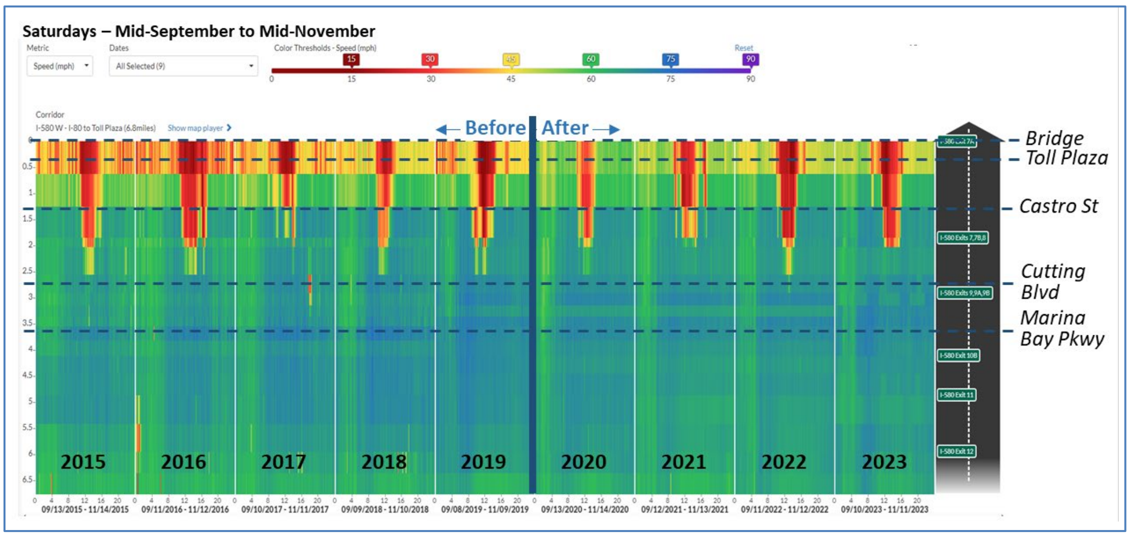

Figure 8-59: Speed Maps – I-580 West – Richmond Approach – Saturdays, Fall 2015-2023

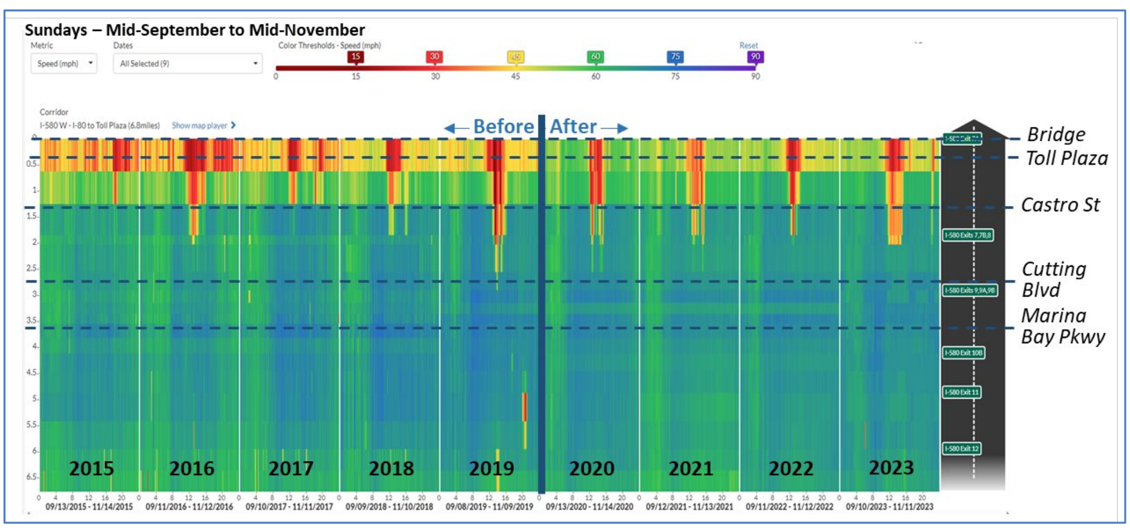

Figure 8-60: Speed Maps – I-580 West – Richmond Approach – Sundays, Fall 2015-2023

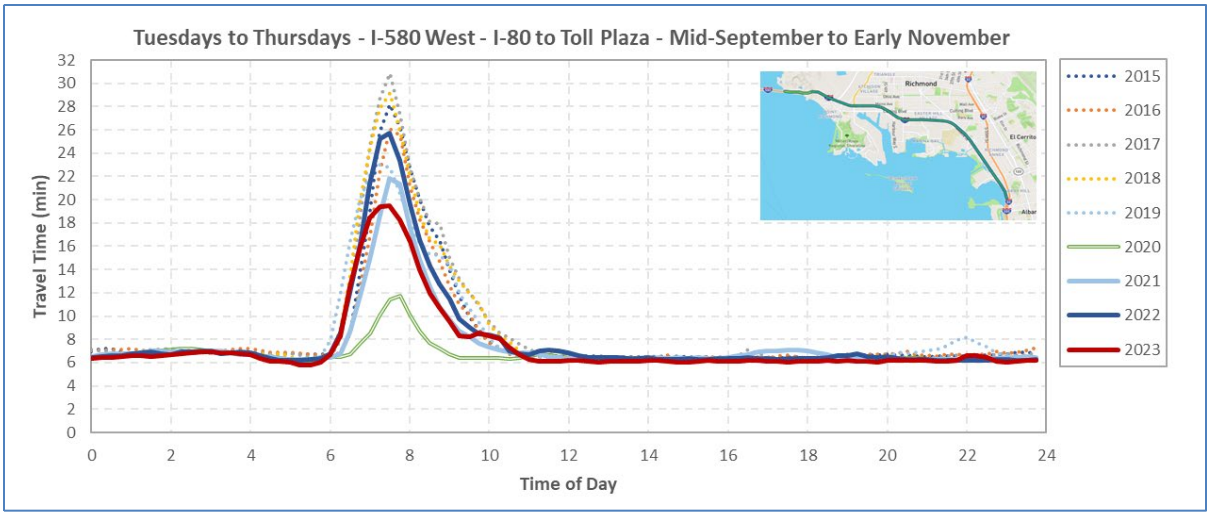

Figure 8-61: Travel Times – I-580 West – Richmond Approach – Midweek, Fall 2015-2023

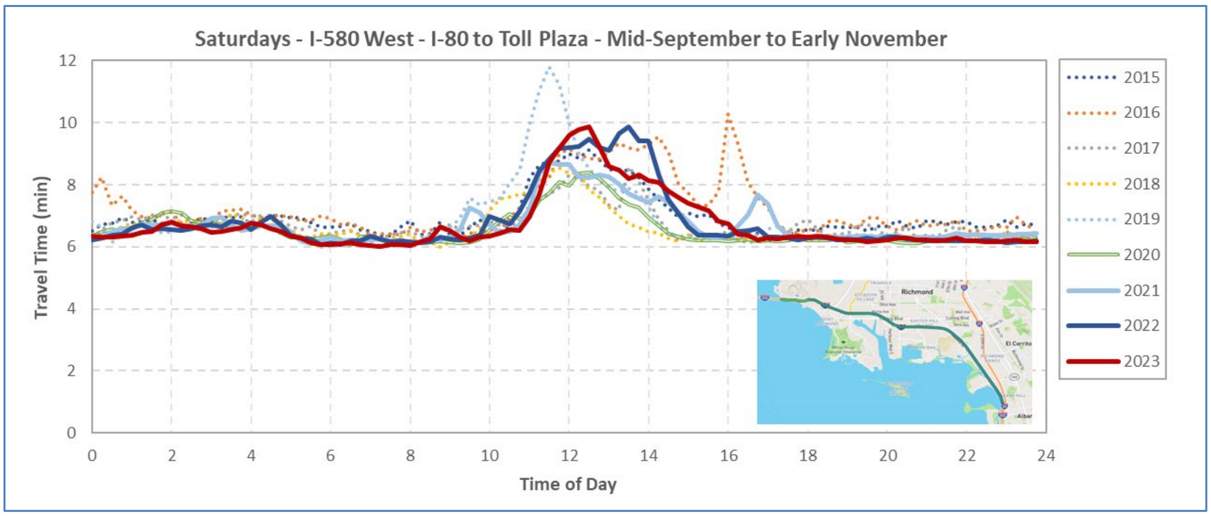

Figure 8-62: Travel Times – I-580 West – Richmond Approach – Saturdays, Fall 2015-2023

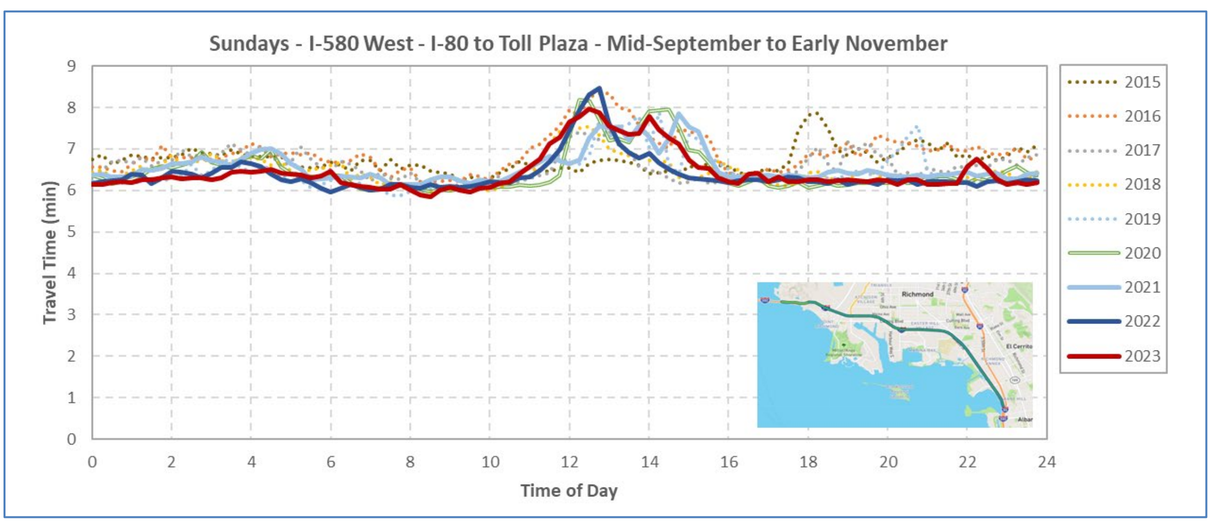

Figure 8-63: Travel Times – I-580 West – Richmond Approach – Sundays, Fall 2015-2023

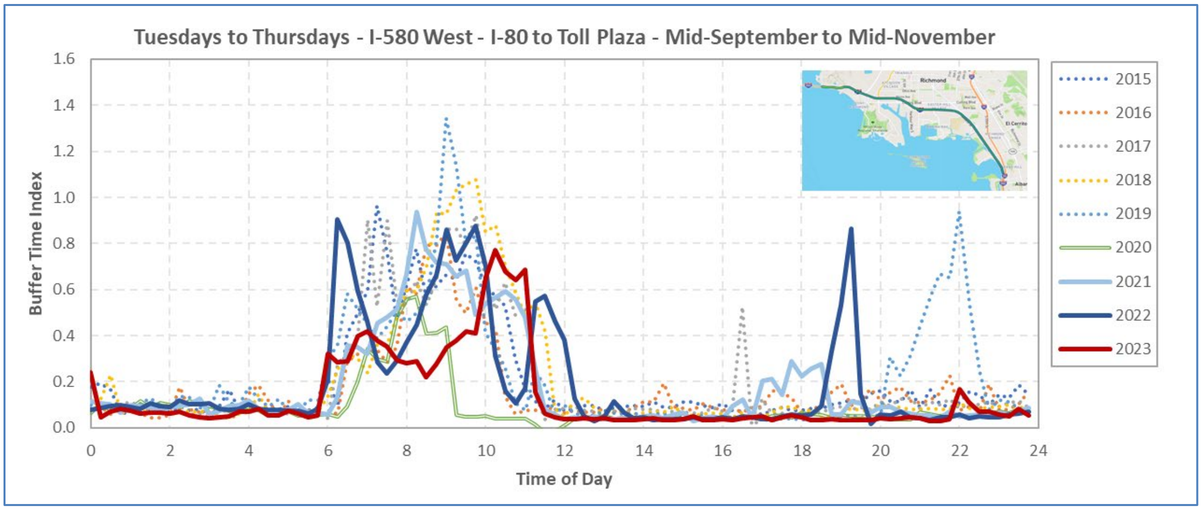

Figure 8-64: Travel Time Reliability – I-580 West – Richmond Approach – Midweek, Fall 2015-2023

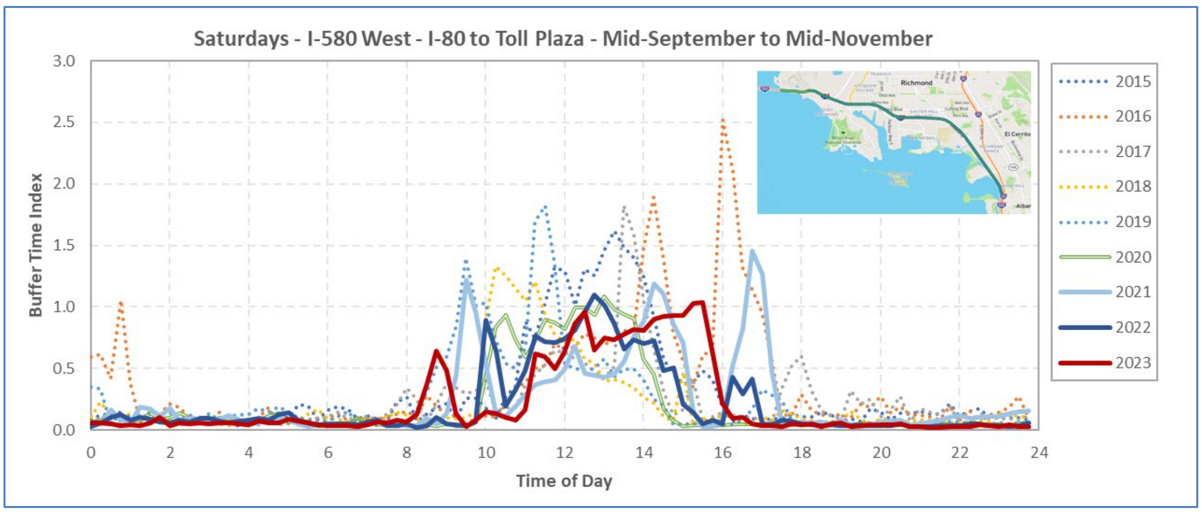

Figure 8-65: Travel Time Reliability – I-580 West – Richmond Approach – Saturdays, Fall 2015-2023

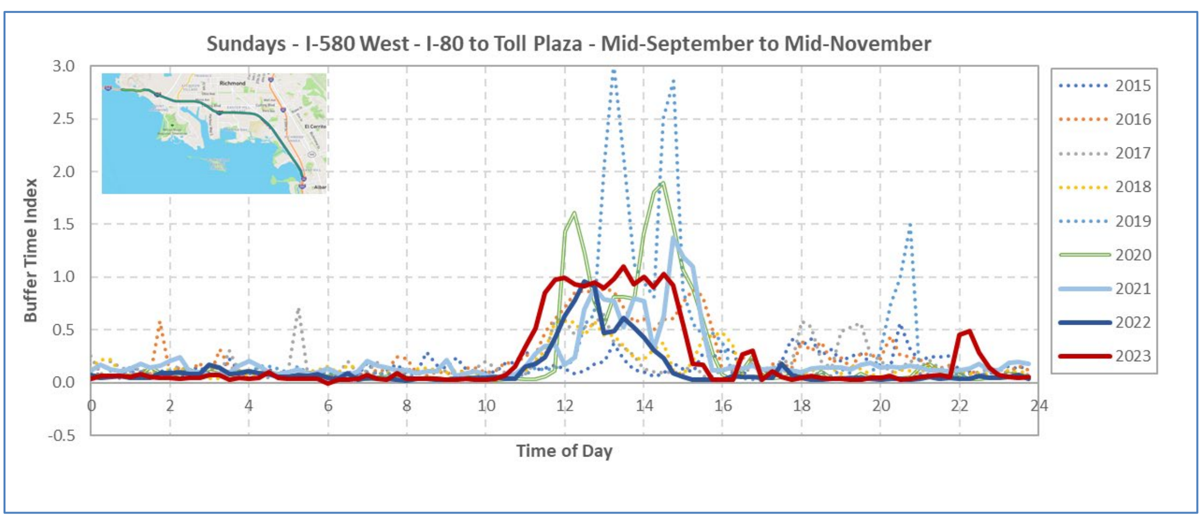

Figure 8-66: Travel Time Reliability – I-580 West – Richmond Approach – Sundays, Fall 2015-2023

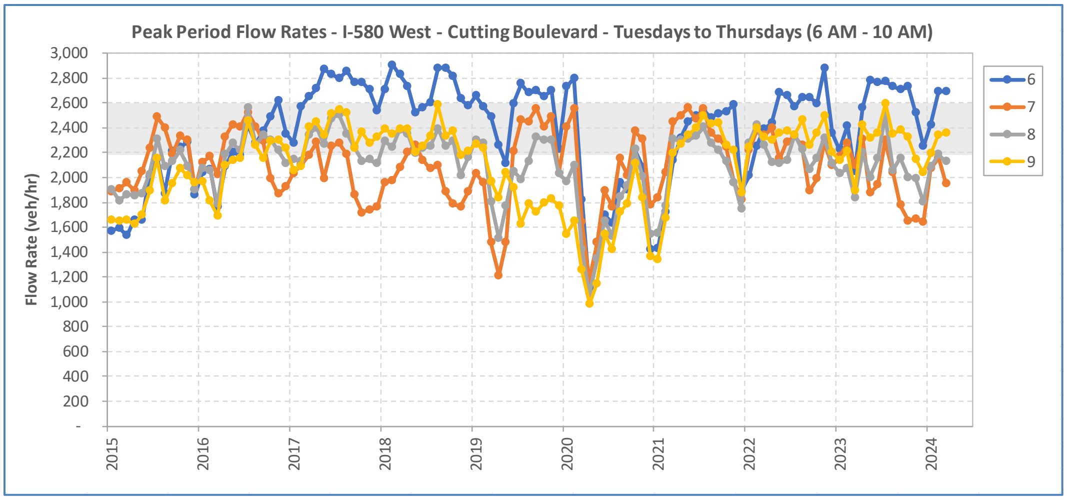

Figure 8-67: AM Peak Flows – I-580 West – Cutting Boulevard – Midweek Peak, 2015-2024

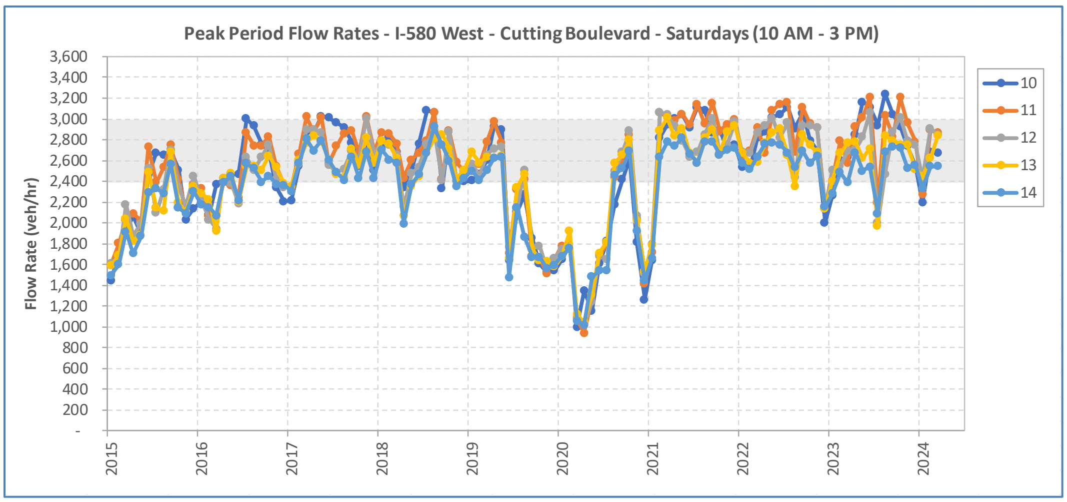

Figure 8-68: AM Peak Flows – I-580 West – Cutting Boulevard – Saturdays, 2015-2024

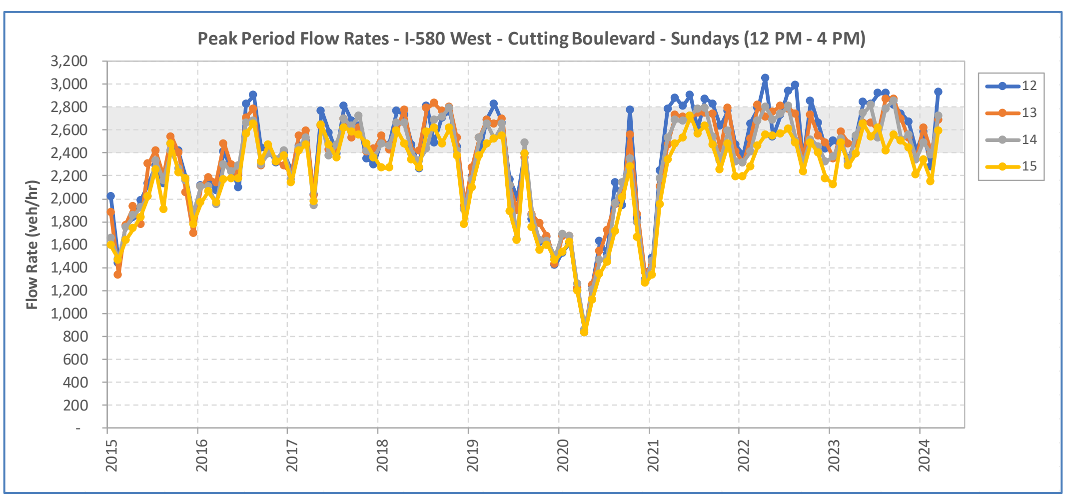

Figure 8-69: AM Peak Flows – I-580 West – Cutting Boulevard – Sundays, 2015-2024

The following observations can be made from the illustrated data regarding weekday traffic conditions on the approach to the bridge:

- Current weekday congestion is similar to pre-modifications. In Figure 8-58, the congested area upstream of the toll plaza in the falls of 2021, 2022, and 2023 typically extends to between Cutting Boulevard and Marina Bay Parkway. This is similar to what was observed before 2019.
- As shown in Figure 8-61, average peak weekday travel times from I-80 to the entrance of the bridge reached 22 minutes in the fall of 2021, 26 minutes in 2022, and nearly 20 minutes in 2023. These travel times remain below observations from 2015 to 2018, which varied between 26 and 31 minutes.
- As shown in the buffer time index diagram of Figure 8-64, weekday morning travel time reliability since 2021 is generally similar to in previous years. This is despite the lack of a shoulder preventing moving disabled vehicles out of the way. While incidents can be expected to produce more significant impacts post modifications, the graph simply indicates that their occasional impacts do not translate into significant impacts on average traffic conditions.
- As shown in the diagram of Figure 8-67, midweek traffic flow on the approach of the bridge in 2022 and 2023 appears relatively similar to the traffic observed in 2017 and 2018, before the modifications.
- Data from 2020, and to some extent 2021, must be disregarded as the observed reductions in congestion and travel times are largely due to the drop in traffic caused by the COVID-19 pandemic. This caused the congestion on the bridge approach to artificially remain subdued during incidents.

The following observations can further be made for the Saturday conditions:

- As shown in Figure 8-59, peak Saturday congestion after the modifications generally appears to match the before conditions. Midday congestion in the fall of 2022 and 2023 typically extends to Cutting Boulevard, similar to what was observed in 2016 and 2018.
- The similarity of traffic conditions between the before and after periods is further highlighted by the travel time data of Figure 8-60, which shows peak average travel times across the bridge of 9-10 minutes in 2022 and 2023 compared to 8-9 minutes between 2015 and 2019.
- As shown in Figure 8-65, peak travel time reliability appears to be similar to what was observed before the modifications.
- The diagram of Figure 8-68 indicates that Saturday midday peak traffic is generally higher in 2022 and 2023 than before the modifications, indicating that a portion of the observed changes in the congested area on Saturdays could be due to an increase in traffic.
- Similar to the weekday data, data from 2020 must be ignored as the reduced congestion is largely due to the drop in traffic caused by the COVID-19 stay-at-home restrictions. However, it is interesting to note that the reduction in congestion on Saturdays appears to be much less significant than on weekdays. This is likely because the initial Saturday traffic demand did not significantly exceed the capacity of the toll plaza.

The following observations can further be made for the Sunday conditions:

- As shown in Figure 8-60, peak Sunday congestion following the bridge modifications generally matches conditions observed before, with the extent of the congestion typically reaching around Castro Street, and occasionally beyond, both before and after the modifications.
- As shown in Figure 8-63, travel times to cross the bridge in the fall of 2022 and 2023 generally correspond to the travel times that were observed from 2015 to 2019.
- As shown in Figure 8-66, peak travel time reliability also appears to be similar to what was observed before the modifications.
- The diagram of Figure 8-69 indicates that Sunday midday peak traffic is generally higher in 2022 and 2023 than before the modifications, suggesting again that increases in the congested area on the approach may be due to an increase in traffic.
- Similar to the weekday and Saturday data, the reduction in congestion in 2020 must be ignored as it is largely due to the drop in traffic caused by the COVID-19 stay-at-home restrictions.

Based on the assessed reduction in bridge capacity outlined in Section 8.3.2, an initial expectation was that congestion on the westbound approach to the bridge should have increased following the modifications. While some increases are observed on Saturdays, no significant increases are observed on weekdays and Sundays. These diverging results can be explained by interactions with elements not related to the bridge modifications:

- **Peak weekday traffic demand remains slightly below pre-modification levels.** As shown in Figure 8-67, weekday peak hourly flows on I-580 West near Cutting Boulevard in 2021, 2022, and 2023 generally appear to remain below the levels from 2017, 2018, and 2019. In this case, less traffic approaching the plaza thus results in less potential for congestion to build up upstream of the plaza.
- **Peak weekend traffic is higher than pre-modification levels.** Data from Figure 8-68 and Figure 8-69 indicate that peak hourly flows on Saturdays and Sundays for 2021, 2022, and 2023 are generally above the peak levels from before 2020. Increases of up to 200 vehicles/hour, or 7-8%, compared to the pre-pandemic average levels are observed. Such increases in traffic would have likely resulted in increases in congestion on the approach to the bridge even in the absence of modifications.
- **Elimination of cash toll collectors.** The elimination of cash toll collectors, which was implemented in 2020, allows for more vehicles to go through the toll plaza in a given interval. By increasing throughput, this change thus reduces the potential for congestion to build up upstream of the toll plaza. The collected data suggests that it is partly responsible for reducing observed congestion at the start and end of the peak periods.
- **Congestion from the merge area at the foot of the bridge.** While the elimination of cash toll collectors allows in theory for more vehicles to go through the plaza in a given interval, this can only be so when there is no traffic backing up from the merge area at the foot of the bridge downstream of the toll plaza. As shown in Figure 8-70, Figure 8-71, and Figure 8-72, presented in the next section, congestion often exists at the entrance of the bridge during peak periods. In such situations, the congestion downstream of the plaza likely constrains the rate at which vehicles can cross the plaza, resulting in increased potential for congestion to build up upstream of the plaza. While the shortening of the merge area as part of the bridge modifications is likely to have increased friction at the foot of the bridge, it would not have entirely created the observed congestion as congestion existed with the previous layout.

8.3.4. TRAVEL TIMES ACROSS BRIDGE

Figure 8-70 to Figure 8-72 illustrate the average mid-September to mid-November speeds on the bridge upper deck for midweek days, Saturdays, and Sundays from 2016 to 2023. Figure 8-73 to Figure 8-75 further illustrate travel times across the bridge for the same period, from the toll plaza to just before the Main Street exit in Marin County. Only fall speeds are analyzed, as this is typically the season with the highest traffic.

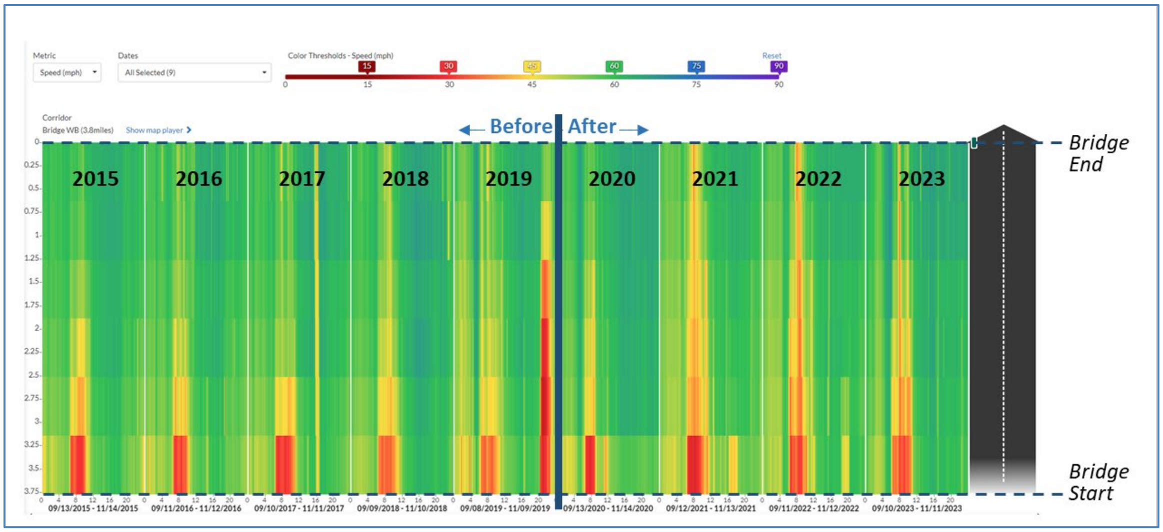

Figure 8-70: Speed Maps – I-580 West – Bridge – Midweek, Fall 2015-2023

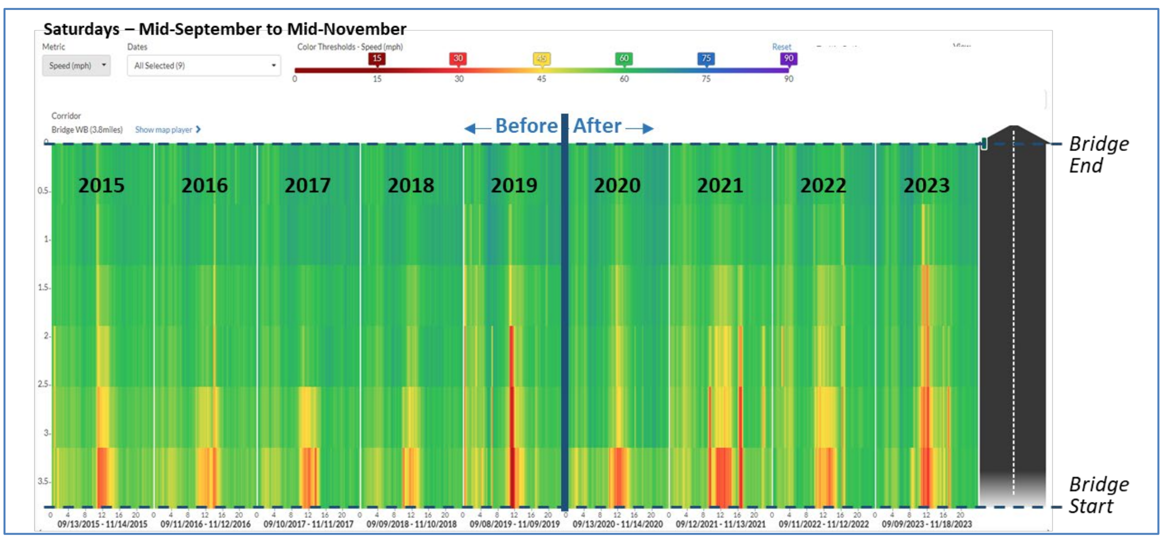

Figure 8-71: Speed Maps – I-580 West – Bridge – Saturdays, Fall 2015-2023

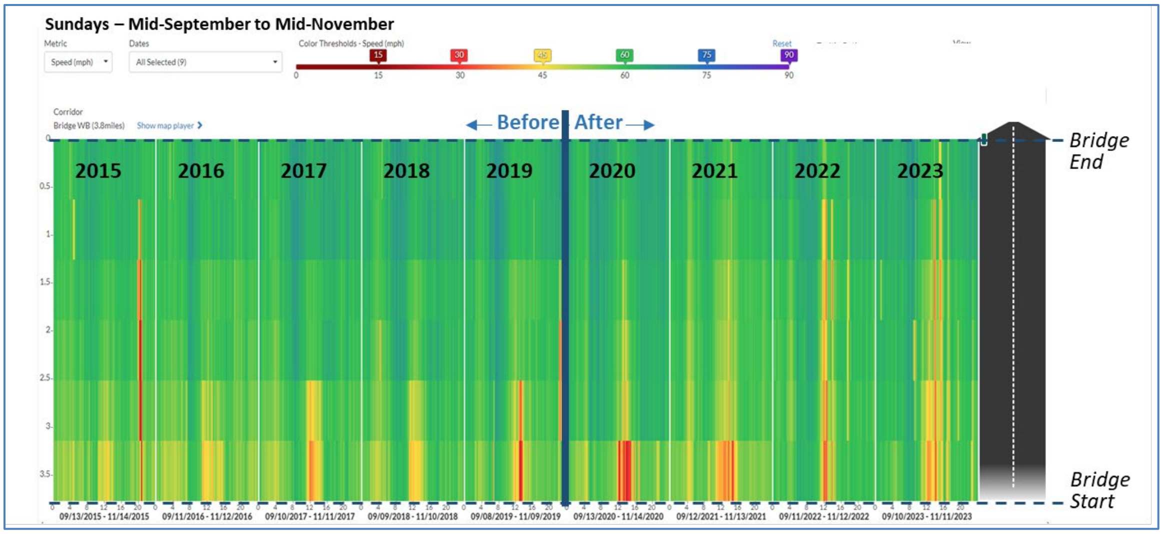

Figure 8-72: Speed Maps – I-580 West – Bridge – Sundays, Fall 2015-2023

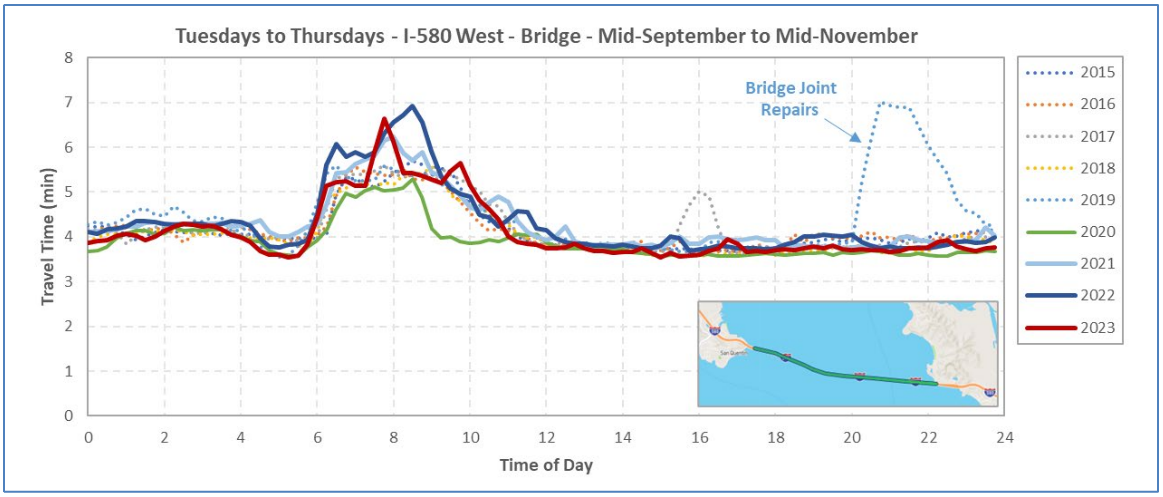

Figure 8-73: Travel Times –Bridge WB – Midweek, Fall 2015-2023

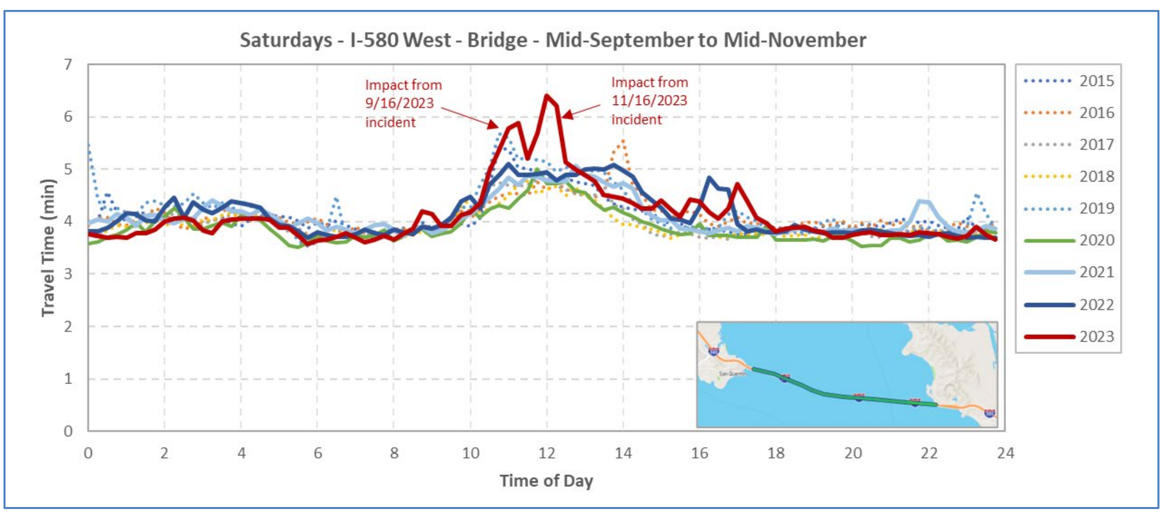

Figure 8-74: Travel Times –Bridge WB – Saturdays, Fall 2015-2023

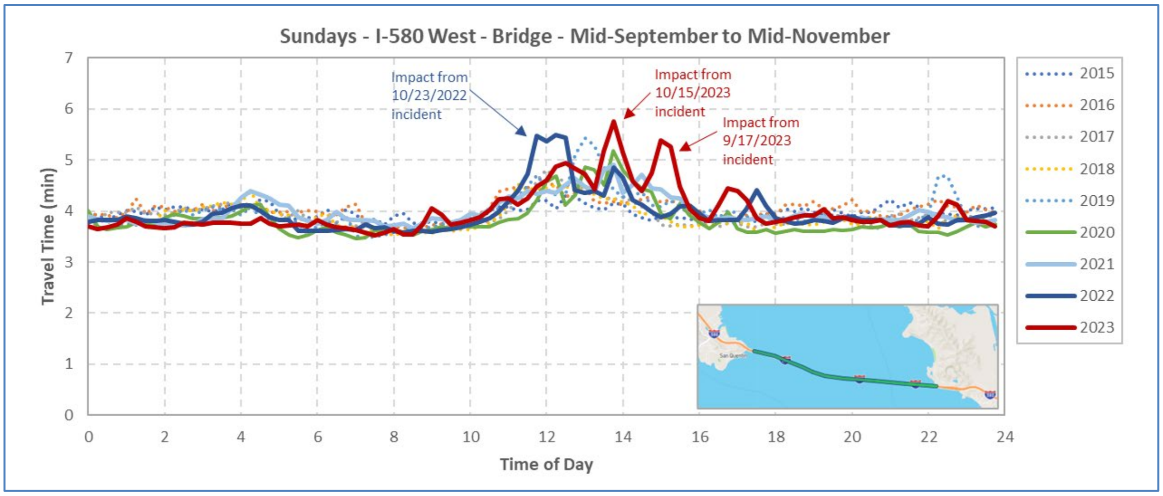

Figure 8-75: Travel Times –Bridge WB – Sundays, Fall 2015-2023

Based on the illustrated data, the following observations can be made regarding weekday traffic conditions on the upper deck of the bridge:

- The addition of the barrier-separated path appears to have caused some speed reductions during the morning peak period. Before the modifications, reduced speeds were primarily contained to the first third of the bridge, more particularly to the first half-mile. Past this initial section, traffic then generally flowed at or above 50 mph. However, in both 2022 and 2023, average speeds between 40 and 50 mph (yellow and orange areas) are observed across a sizable portion of the length of the bridge during the morning peak period.
- The observed peak-hour speed reductions across the bridge did not translate into significant increases in travel times across the bridge. As shown in Figure 8-73, while longer average midweek morning peak travel times are observed in 2021, 2022, and 2023, these generally remain within 1.5 minutes of the average travel times observed before the modifications.

The following additional observations can be made regarding traffic conditions on Saturdays and Sundays:

- Similar to weekdays, more noticeable speed reductions are observed in the first half mile of the bridge on both Saturdays and Sundays. Slight speed reductions are also observed on the remainder of the bridge on both Saturdays and Sundays.
- As shown in Figure 8-74 and Figure 8-75, peak Saturday and Sunday travel times remain similar to those observed before the modifications. In both cases, the various significant peaks in travel time observed in the 2022 and 2023 data compared to previous years are due to single-day events that have affected traffic flow across the bridge and not regular conditions.
- As evidenced by the hourly flow measurements near Cutting Boulevard shown earlier in Figure 8-68 and Figure 8-69, the observed deterioration in traffic conditions across the bridge can partly be explained by increases in traffic demand. On both Saturdays and Sundays, peak midday traffic in 2021, 2022, and 2023 exceeds the peak flows observed before the modifications, with increases reaching 200 vehicles/hour. In the absence of modifications on the bridge, these traffic increases would have likely caused longer travel time to be observed.

8.3.5. TRAFFIC DISTRIBUTION ACROSS LANES ON THE BRIDGE UPPER DECK

Figure 8-76 and Figure 8-77 present the average distribution of traffic across the two or three available traffic lanes along I-580 West during the peak weekday and Saturday travel periods in September/October 2023. Both figures indicate a noticeable shift towards the left lane on the bridge. While traffic is almost equally distributed across all three lanes upstream of the toll plaza (Stenmark Drive) and downstream of the bridge (Main Street and Francisco Boulevard), between 53% and 57% of the traffic is typically seen using the left lane on the bridge.

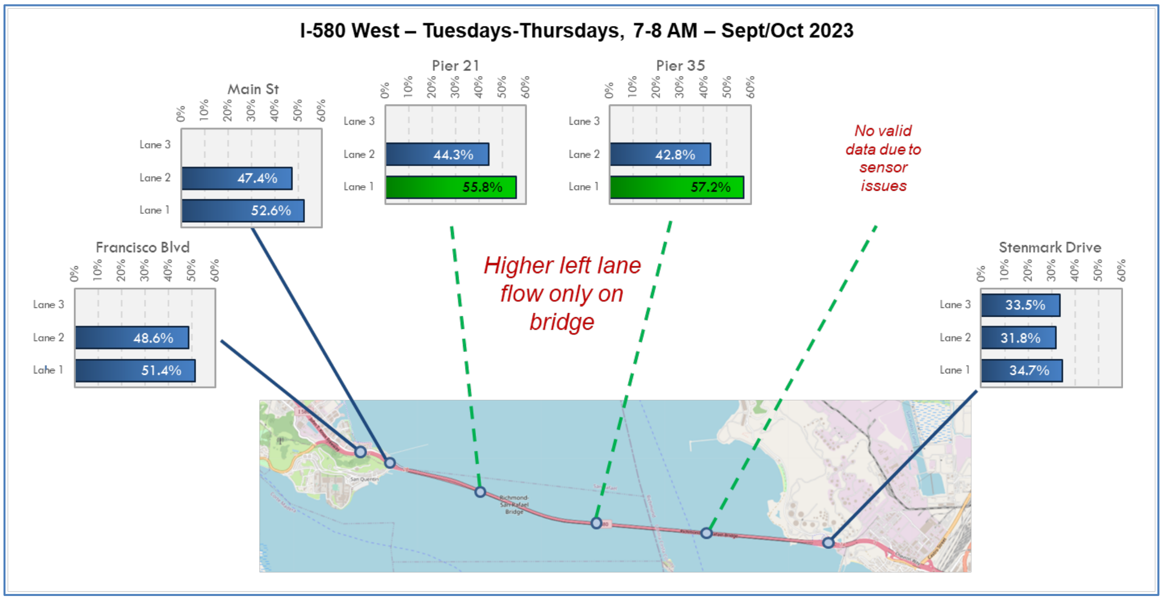

Figure 8-76: Traffic Distribution across Lanes – Upper Deck, Weekdays, 7-8 AM, Fall 2023

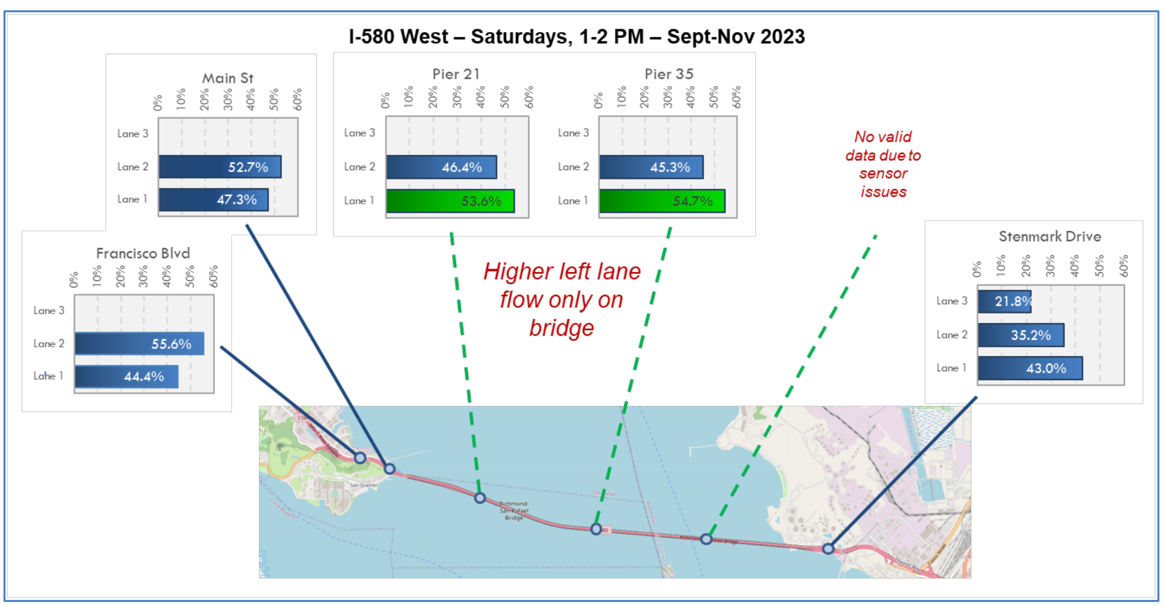

Figure 8-77: Traffic Distribution across Lanes – Upper Deck, Saturdays, 1-8 AM, Fall 2023

Figure 8-78 further analyses the proportion of traffic using the left lane in the middle of the bridge (Pier 35) across an average midweek day, Saturday, and Sunday. It compares the traffic distribution that was observed in September/October 2018, a year before the modifications, to the distribution of September/October 2023. Based on the illustrated data, the following observations can be made:

- The bridge modifications appear to have slightly altered the distribution of traffic across the two available lanes on the bridge during the day. Before the modifications, between 52% and 56% of traffic used the left lane between 7 AM and 7 PM, with higher proportions during high-traffic periods. Similar proportions are observed in the fall of 2023 but with a 1-2% higher proportion of traffic on the left lane.
- More significant increases in left lane usage are observed before 7 AM and after 7 PM across all days, with shifts of up to 20% observed.

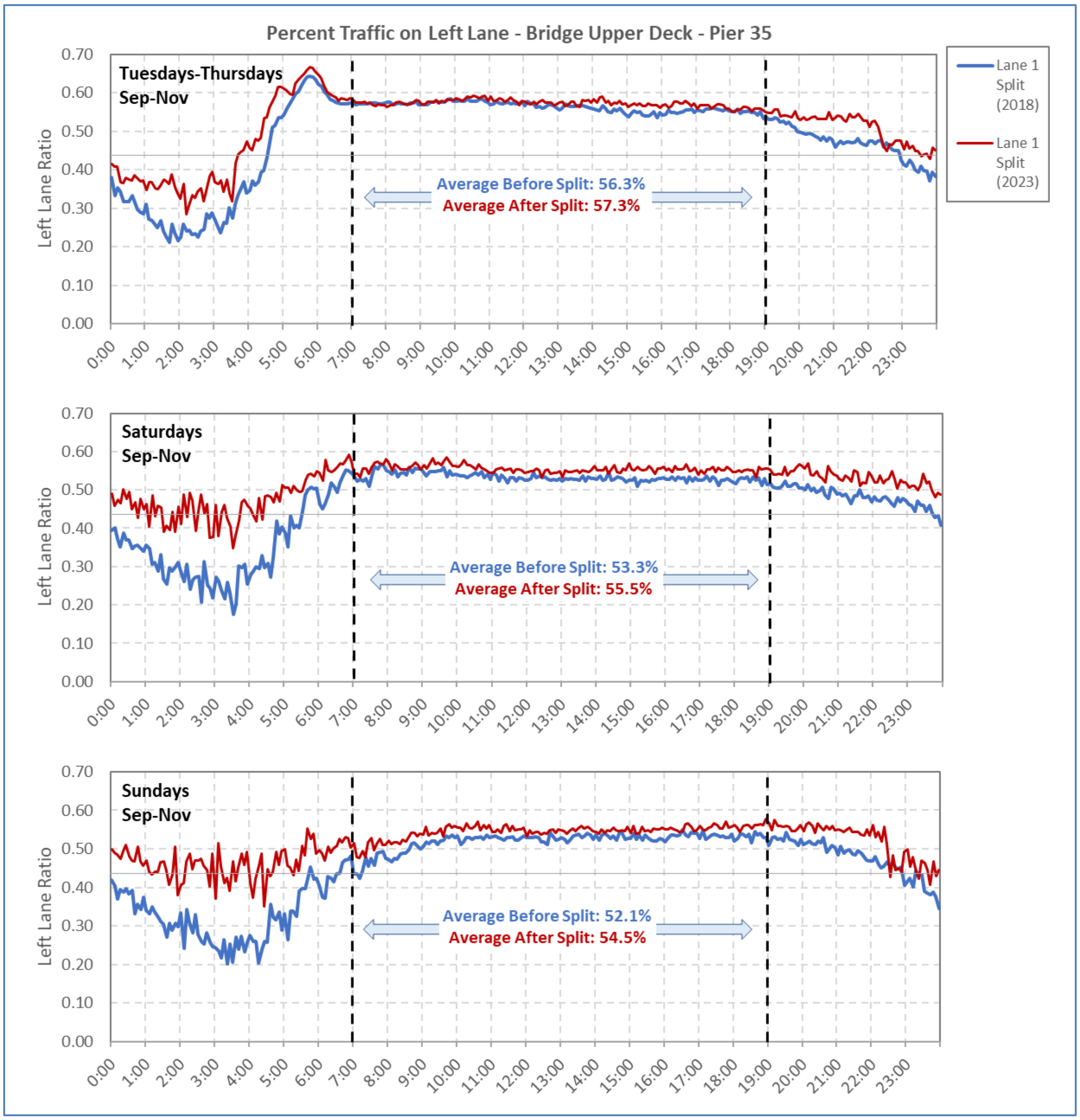

Figure 8-78: Percent of Traffic in Left Lane – Upper Deck, 2018 & 2023

The observed shifts in the evening and morning cannot be attributed to increases in traffic as demand for the fall of 2023 was generally similar to or below the demand for the fall of 2018. A potential cause is motorists being uncomfortable with the barrier being at the edge of the right traffic lane, as illustrated in Figure 8-79. Before the modifications, a 12-foot gap existed between the edge of the right traffic lane and the right bridge guardrail. This gap fully disappeared with the modifications. The uneasiness of driving close to the path's barrier might then have pushed some motorists to travel on the left lane instead, where the recess in the bridge guardrail at eye level makes its presence less intimidating.

Figure 8-79: Relative Closeness Bridge Guardrail on the left and Path Barrier on the Right

Another suggestion for the shift is that motorists might prefer to use the left lane to avoid traveling behind slow vehicles. To assess this suggestion, the average speeds on each traffic lane across a typical weekday were compiled. Figure 8-80 shows the result of the analysis for the fall of 2023. The illustrated data indicate that the suggestion may be true during off-peak periods when there is a 10-mph speed differential between the two lanes. However, with a differential of only 2 mph, this suggestion holds less truth during the AM peak period and cannot fully explain the observations of Figure 8-76. This suggests that both uneasiness and a desire to avoid slow vehicles likely explain the shift toward the left lane.

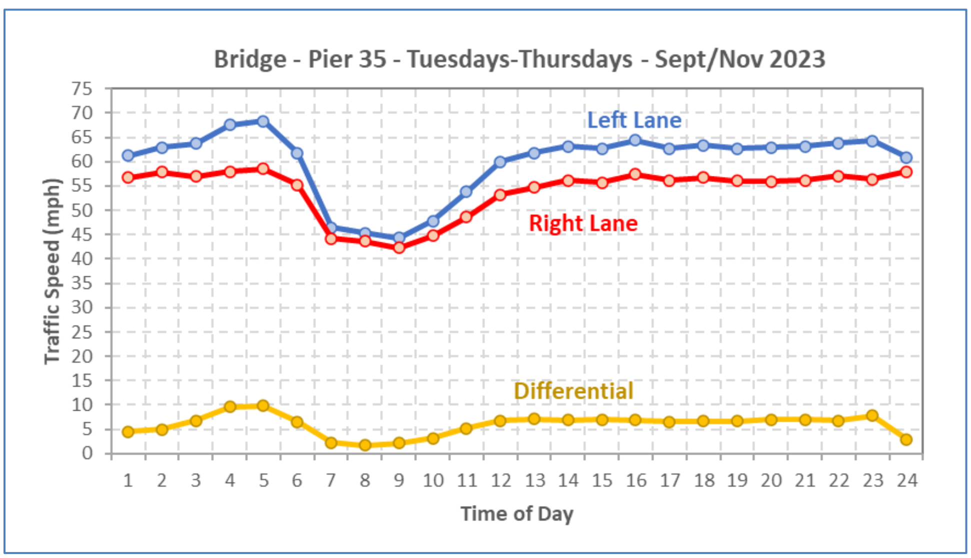

Figure 8-80: Average Speeds on Upper Deck Lanes by Time of Day – Midweek, Fall 2023

8.3.6. IMPACTS ON LOCAL ARTERIALS IN RICHMOND

Figure 8-81 to Figure 8-83 illustrates observed average February/March speeds along southbound Castro Street, southbound Richmond Parkway, and westbound Cutting Boulevard from 2015 to 2023. The following observations can be extracted from the illustrated data:

- The diagrams do not reveal negative impacts on traffic congestion following the bridge modifications. Along Castro Street and Richmond Parkway, the highest level of congestion in the morning peak, when traffic on I-580 is mainly traveling towards the bridge, was observed before 2019. Along Cutting Boulevard, no noticeable changes in AM peak congestion are observed across the before/after boundary.

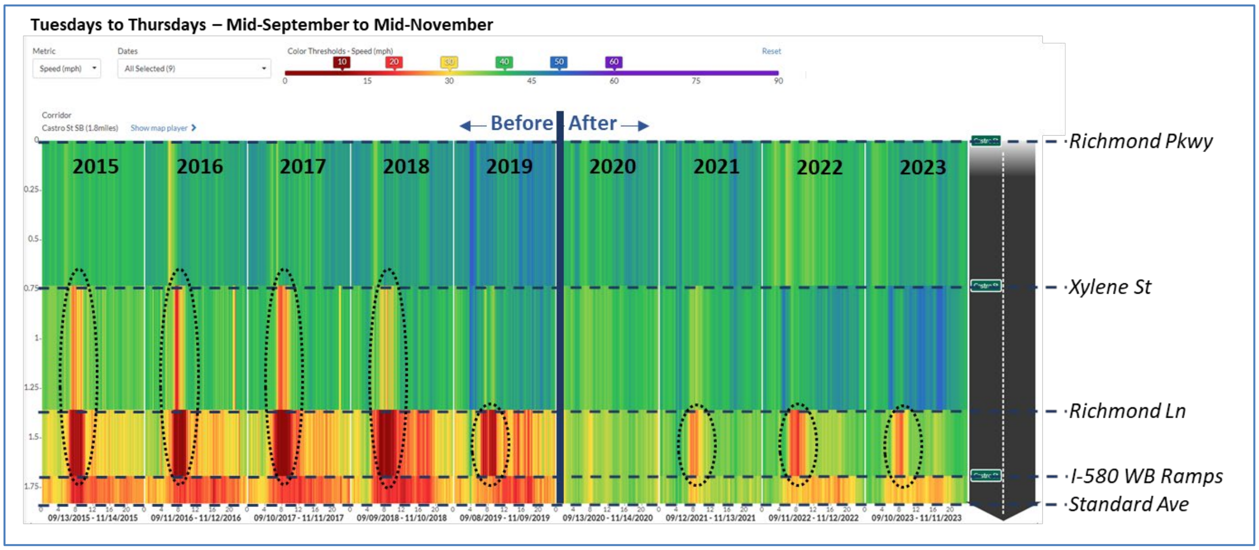

Figure 8-81: Speed Maps – Castro Street SB – Midweek, Fall 2015-2023

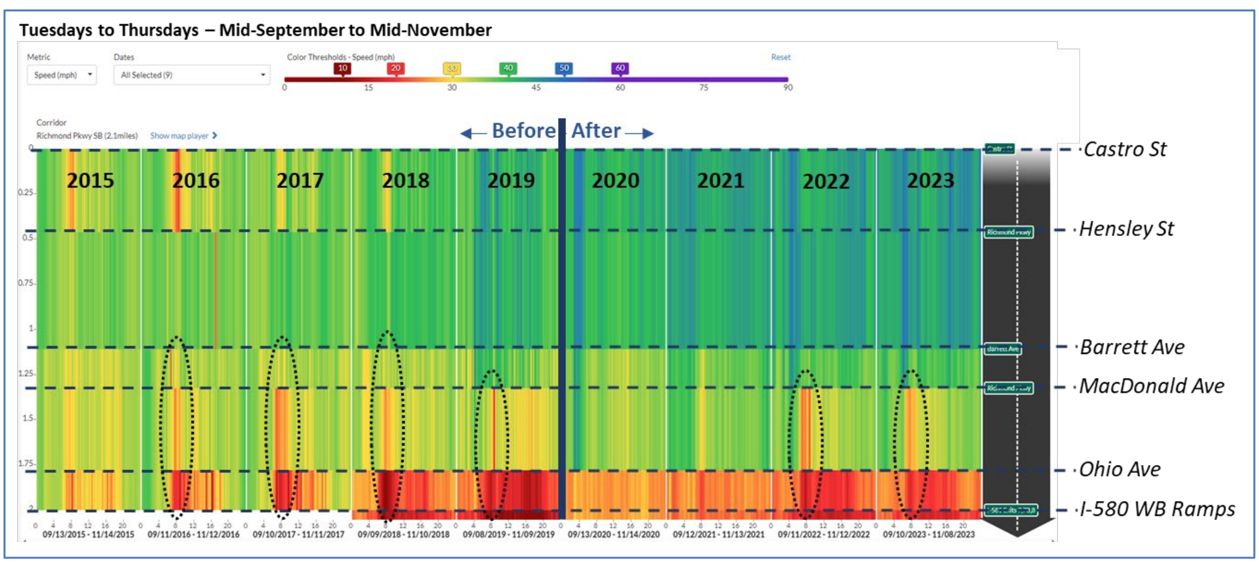

Figure 8-82: Speed Maps – Richmond Parkway SB – Midweek, Fall 2015-2023

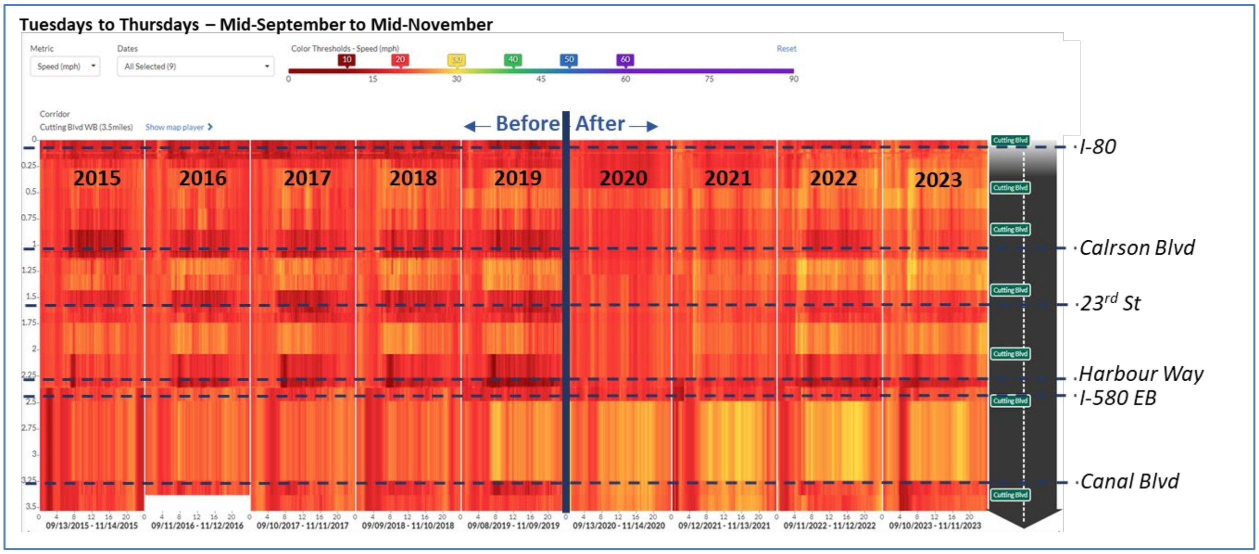

Figure 8-83: Speed Maps – Cutting Boulevard WB – Midweek, Fall 2015-2023

- Data for 2020 and 2021 are affected by the drop in traffic that accompanied the COVID-19 pandemic. The appearance of improved conditions in both years should therefore be attributed to unusual situations and ignored in the evaluations.
- While arterial traffic has somewhat rebounded since 2021, congestion levels generally appear to remain below pre-pandemic levels. A comparison of traffic counts taken along the three arterials and I-580 West on-ramps in May 2016 and March 2022 (see section 5.2.4) indicated for instance that AM peak traffic in March 2022 remained 15-20% below the May 2016 counts. While further recovery is expected to occur over time, observed speeds in the most recent analysis period still appear to be better than in early 2019.

8.3.7. IMPACTS FROM SIR FRANCIS DRAKE BOULEVARD CONGESTION

Occasionally, congestion on westbound Sir Francis Drake Boulevard affects traffic conditions on the bridge and the approach. An example is shown in Figure 8-84. The figure illustrates traffic conditions along the westbound bridge approach, the upper deck of the bridge, and along westbound Sir Francis Drake Blvd across successive Saturdays in January and February 2024. On most days, congestion along Sir Francis Drake Boulevard, largely due to the operation of traffic signals, remains contained to the arterial. On the last day, however, the congestion reaches the freeway and propagates at times across the bridge, causing additional congestion upstream of the toll plaza.

The key takeaway from the above example is that congestion observed on the bridge or upstream of the toll plaza cannot always be linked to incidents occurring on the bridge or the geometry of the bridge. Since about 40% of traffic exiting the bridge tends to use Sir Francis Drake Boulevard, what happens on this arterial can affect conditions on the bridge.

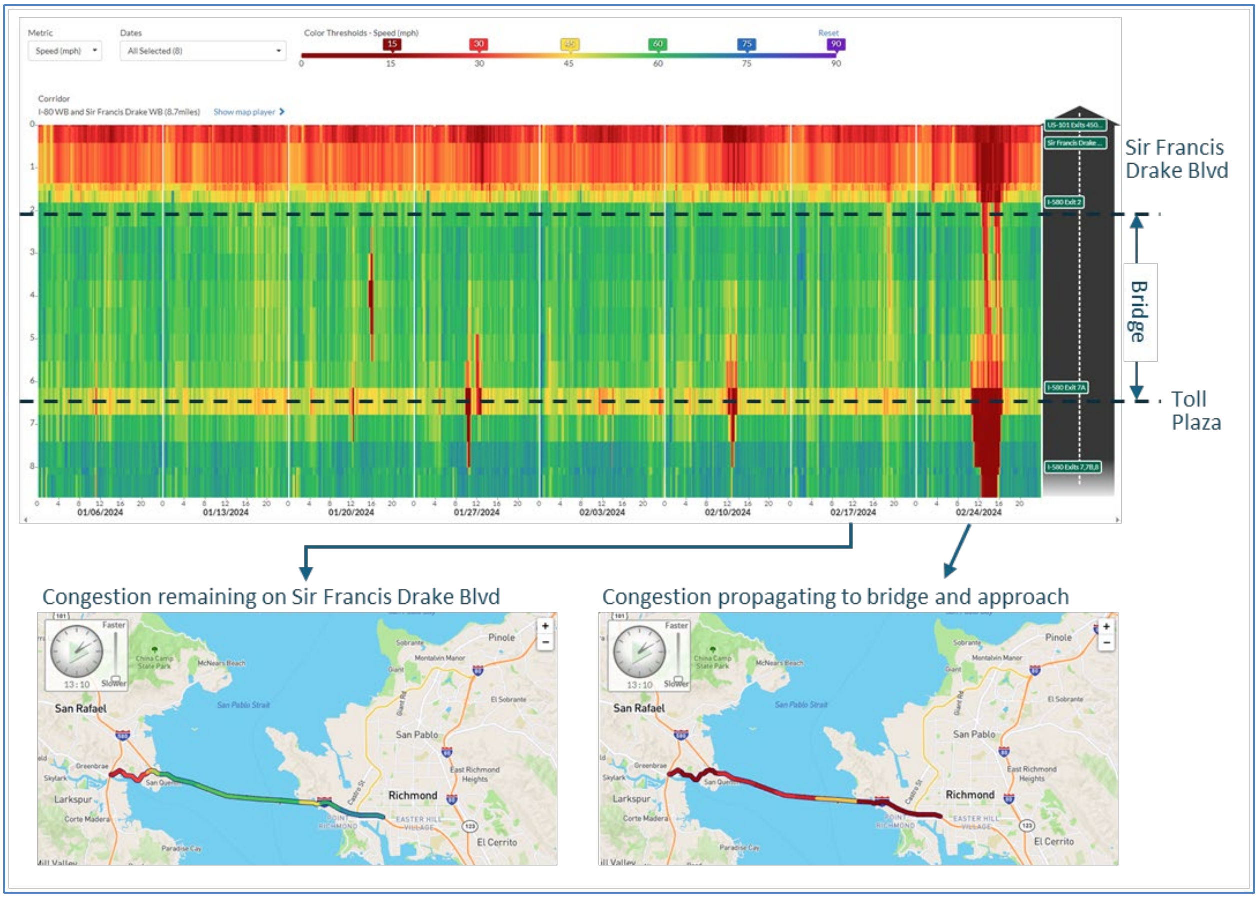

Figure 8-84: Example of Westbound Congestion Spreading from Sir Francis Drake Boulevard

8.3.8. ROADWAY CONFIGURATION CONSTRAINTS IN MARIN COUNTY

Throughout the project, the suggestion has been made that the space used by the multi-use path on the upper deck of the bridge could perhaps be best used to provide a part-time third traffic lane similar to what has been done on the lower deck. While this option would result in the removal of the path and the availability of a third traffic lane on the bridge to accommodate westbound traffic, several constraining elements also limit its viability, as detailed below and in Figure 8-85.

- Without expanding the number of traffic lanes available on I-580 West between the bridge and the US-101 interchange, providing a third traffic lane on the bridge would simply move the bottleneck currently associated with the drop in the number of traffic lanes from three to two at the entrance of the bridge. In such a situation, traffic would queue on the bridge itself instead of upstream of the toll plaza. This could potentially negate some of the travel time savings associated with providing an additional traffic lane, in addition to potentially making it harder for emergency vehicles to access incidents on the bridge during peak travel periods.
- A significant portion of the westbound bridge traffic is taking the Sir Francis Drake Boulevard off-ramp, typically between 35% and 45% during peak weekday periods, 35% and 40% on Saturdays, and 30 and 35% on Sundays. This is in great part due to a lack of a direct interchange between I-580 West and US-101 South. In this context, providing a third traffic lane on the bridge would likely increase the volume of exiting traffic. Because of the single traffic lane east of the Larkspur Ferry Terminal and the presence of signalized intersections around the terminal

and the US-101 interchange, an influx of traffic on the arterial without local modifications could result in congestion developing along it and backing up onto the freeway, potentially resulting in congestion on the bridge. As was illustrated in Figure 8-84, such backups have already been observed to occur when incidents or traffic signal malfunctions affect traffic on Sir Francis Drake.

Figure 8-85: Marin County Roadway Configuration Constraints

8.3.9. SUMMARY OBSERVATIONS

The following are the key summary observations from the analysis of the traffic impacts of the conversion of the westbound shoulder into a barrier-separated bike/pedestrian path:

- Following the modifications, average weekday peak hourly flows have dropped by 7%, and peak weekend flows by 4%. This may be due to the shorter merge area downstream of the toll plaza, as well as a roadway that appears narrower due to the barrier.
- Despite the apparent slight drop in capacity, the extent of the congestion upstream of the toll plaza during the weekday, Saturday, and Sunday peak periods remains similar to before the modifications.
- Travel times to access the bridge from I-80 remain close to historical averages on weekdays, Saturdays, and Sundays.
- Peak weekday travel times are more variable than before the modifications, likely due to the increased impacts of incidents due to the lack of a shoulder to move vehicles out of the way. Travel time reliability on weekends is like before the modifications.
- While reduced speeds are observed on more bridge sections during weekday peak periods, these reductions have only increased travel times across the bridge by less than one minute. Speed reductions observed during Saturday and Sunday midday peaks have also not caused significant changes in average travel times across the bridge.

- The installation of the path barrier appears to have caused some shift in traffic towards the left lane, particularly under low traffic volumes. Only 1-2% of traffic is observed to have shifted towards the left during high-traffic periods, but up to 15% during low-traffic periods.
- Available data do not indicate that the bridge modifications have had significant impacts on local arterials on the Richmond side of the bridge.

8.4. IMPACTS ON SIR FRANCIS DRAKE OVERCROSSING

Figure 8-86 illustrates the observed traffic flow rates on the Sir Francis Drake overcrossing in the fall of 2019, before the modification, the fall of 2021, and the fall of 2022. Data before 2019 are not shown as sensors only started producing data on the off-ramp in the summer of 2019. Data from 2020 are further ignored as the flow rates for that year are influenced by the stay-at-home orders associated with COVID-19. No data from 2021 are finally shown as sensors were down during the fall of that year. Similar to previous graphs, data from before the overcrossing modifications in the summer of 2020 are shown with a dotted line while data from after the modifications are shown with a solid line.

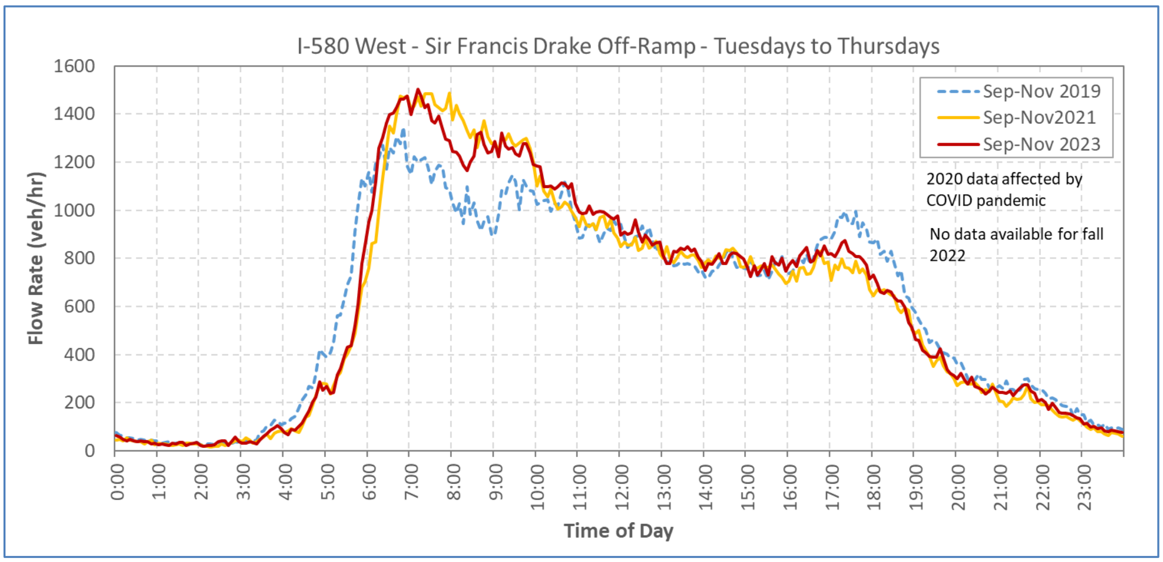

Figure 8-86: Traffic Flow on Sir Francis Drake Overcrossing – Midweek, 2019-2023

As can be observed, the conversion of the existing one-way bike path on the overcrossing into a barrier-separated two-way path does not appear to have affected traffic flows at the facility. This is evidenced by morning peak-hour flow rates from 2021 and 2022 that are significantly higher than the maximum flow rate observed in 2019. It is not suggested that the increase in flow rates is due to the modification, simply that the modification has not constrained the observed increase due to higher traffic demand.

Figure 8-87 to Figure 8-89 further illustrates the observed travel speeds along Sir Francis Drake Boulevard from the overcrossing to the US-101 interchange. In this case, it can again be observed that the modifications do not appear to have caused noticeable speed reductions on the overcrossing. While some periods with lower speeds are observed, typically during the morning peak period, the diagrams indicate that the reduced speed is primarily the result of congestion downstream of the overcrossing, typically from around Larkspur Landing Circle, propagating back to the overcrossing.

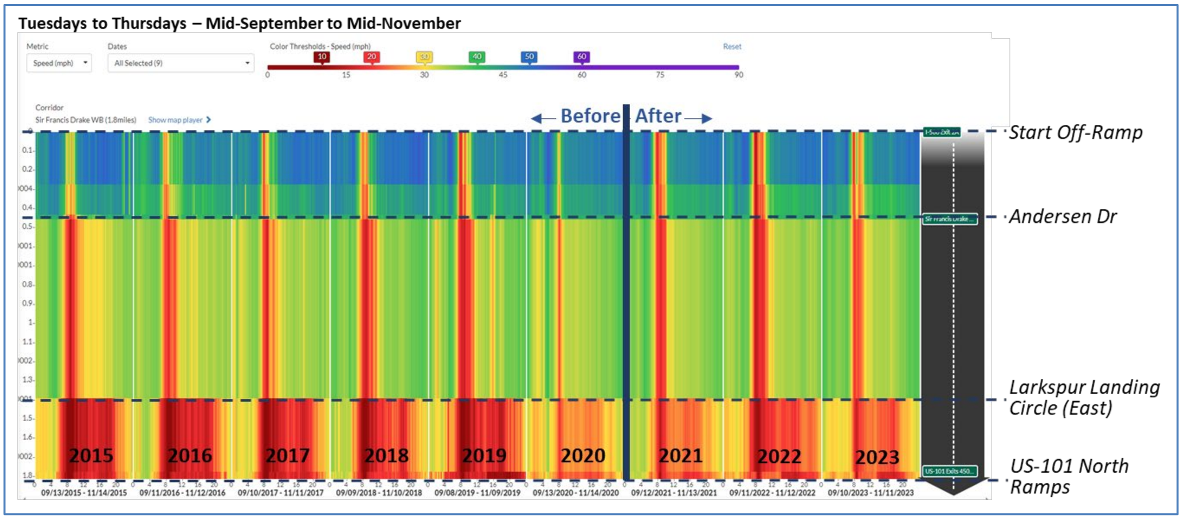

Figure 8-87: Speed Maps – Sir Francis Drake WB – Midweek, Fall 2015-2023

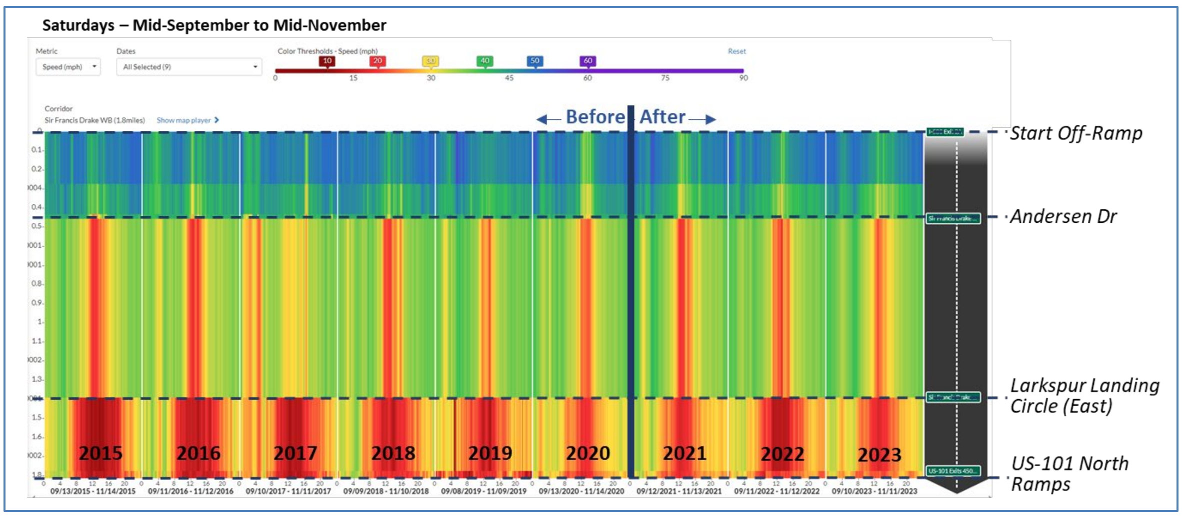

Figure 8-88: Speed Maps – Sir Francis Drake WB – Saturdays, Fall 2015-2023

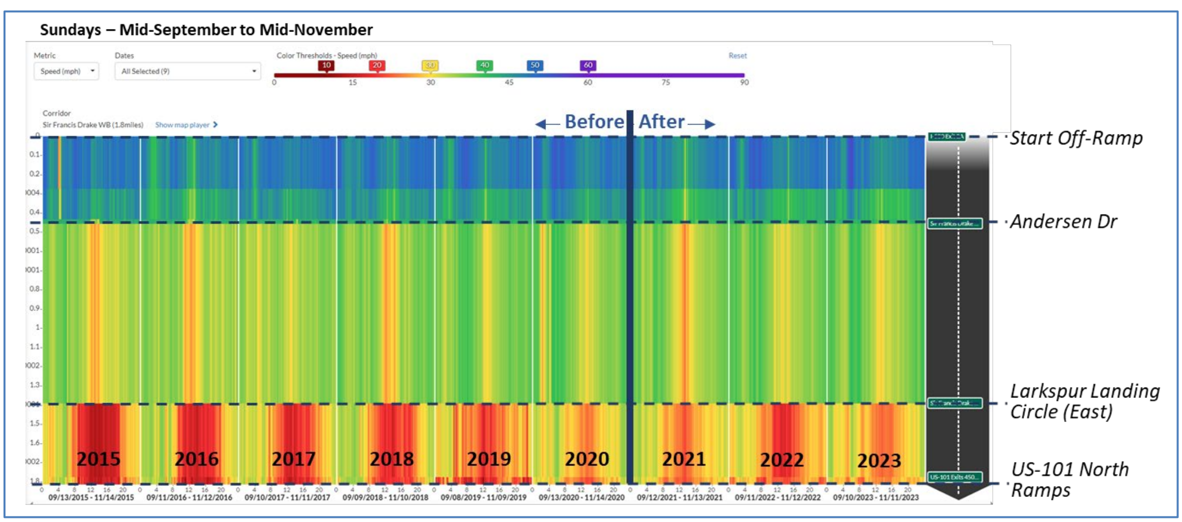

Figure 8-89: Speed Maps – Sir Francis Drake WB – Sundays, Fall 2015-2023

8.5. SUMMARY OBSERVATIONS

The following is a summary of key observations from the analysis of traffic impacts associated with the various bridge modifications:

- **Compliance with lower deck shoulder open/close periods:**
    - Motorists are generally compliant with the shoulder opening period.
    - Non-compliant use of the shoulder is highest 20 minutes before its opening and up to 25 minutes following its closure.
    - CHP officers have indicated observing some vehicles using the shoulder as a passing or traveling lane when a red or yellow X is shown above it. This suggests that some motorists may not fully understand the meaning of the current lane control signs.

- **Traffic impacts – Lower deck:**
    - The availability of an extra traffic lane has increased the eastbound peak hourly flow across the bridge by 13-26%, from 3,300-3,570 to 3,750-4500 vehicles/hour.
    - Traffic is generally not evenly split across lanes. Less than 25% of traffic is observed using the part-time lane during weekday peak periods, and less than 20% on weekends.
    - The added peak-hour capacity has eliminated congestion on the I-580 East approach to the bridge. This has caused peak travel times from the US-101 interchange to the toll plaza to drop by 14-17 minutes on midweek days, 10-14 minutes on Saturdays, and 6-8 minutes on Sundays.
    - Travel times to reach the toll plaza from the US-101 during peak periods are significantly less variable than before.
    - The absence of congestion on I-580 East has led to a 1- to 2-minute reduction in average travel time on US-101 North between the Sir Francis Drake Boulevard and I-580 exits.
    - Afternoon peak travel times along Sir Francis Drake Boulevard have dropped by up to 4 minutes while traffic volumes have increased by nearly 475 vehicles/hour.
    - Fewer vehicles are using local arterials as bypasses to I-580 East. The modifications have contributed to reducing traffic along Francisco Boulevard, and possibly Andersen Drive. More vehicles are also observed entering I-580 east at Bellam Boulevard, while fewer vehicles are using the Main Street ramps as a bypass.

- **Traffic Impacts – Upper deck:**
    - Following the modifications, average peak hourly flows have dropped by 7% on weekdays and 4% on weekends. This may be due to the shorter merge downstream of the toll plaza and a roadway that appears narrower on the bridge due to the barrier.
    - Despite the slight apparent drop in capacity, the extent of the congestion upstream of the toll plaza during the weekday, Saturday, and Sunday peak periods remains similar to before the modifications. Travel times to cross the bridge from I-80 also remain close to historical averages. This can be explained by overall traffic demands remaining slightly

below before conditions, particularly at the start and end of the traditional peak periods, due to lingering COVID-related factors.

- While reduced speeds are observed on more bridge sections during weekday peak periods, these reductions have only increased average travel times across the bridge by less than one minute. Speed reductions observed during Saturday and Sunday midday peaks have also not caused significant changes in average travel times across the bridge.
- Peak weekday travel times are more variable than before the modifications, likely due to the increased impacts of incidents due to the lack of a shoulder to move vehicles out of the way. Travel time reliability on weekends is like before the modifications.
- The path barrier appears to have caused a shift in traffic toward the left lane, particularly during low-traffic periods. Only 1-2% of traffic is observed to have shifted left during high-traffic periods, but up to 15% during low-traffic periods.
- Available data do not indicate that the bridge modifications have had significant impacts on local arterials on the Richmond side of the bridge.
- Evaluations regarding the possibility of a third traffic lane on the upper deck of the bridge must consider capacity constraints in the existing road network in Marin County.

- **Traffic Impacts – Upper deck:**
  - No constraining impacts have been observed on the overcrossing traffic.

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9. IMPACTS ON VEHICLE EMISSIONS

This section presents a rudimentary assessment of the impacts of the bridge modifications on vehicle emissions. This is done by first developing VMT distributions by speed for each direction of travel representing typical traffic conditions before and after the bridge modifications. These distributions are then used to estimate average vehicle emission rates per mile traveled before and after the modifications using version 2021 of the Emission Factor (EMFAC) model from the California Air Resource Board (CARB). To ensure that changes in the composition of average traffic are not affecting the evaluations, the before and after comparisons are done using emission rates associated with a 2023 vehicle fleet. In this context, any observed change in vehicle emission could directly be linked to changes in traffic dynamics.

Before going further, it must be emphasized that the evaluation results reported in this section are rough estimates as the limited amount of traffic data from before the modifications leads to a need to make multiple assumptions that may affect the outcomes of the evaluations.

The following sections present the following information:

- Estimated speed profiles
- Estimated truck proportions
- Estimated VMT distributions by speed
- Emission rates per mile traveled retrieved from EMFAC2021
- Estimated impact on vehicle emission rates along corridor

9.1. SPEED PROFILES

The EMFAC model provides vehicle emission rates by mile traveled based on speed. The evaluation for the Richmond-San Rafael bridge project thus requires developing average speed profiles on the approach to the bridge and the bridge itself along I-580 East and I-580 West.

Information about speeds at the various traffic monitoring stations located along the freeway could in theory be obtained from the PeMS system. However, all the reported speeds are estimates and not direct measurements, and thus subject to potential errors. In addition, the reported speeds are only estimates at the location of the sensors and do not reflect average conditions between the sensors. A more reliable approach is to use average segment speeds reported by INRIX based on vehicle tracking data. This would allow us to reflect average traffic conditions more accurately between the traffic monitoring stations.

Figure 9-1 and Figure 9-2 illustrate the various speed profiles that were estimated for each direction of travel for an average weekday and average weekend day during the summer (May to October) and winter (November to April) emission evaluation seasons. Each diagram divides the corridor into 10 sections associated with the various PeMS sensors located along the corridor. While INRIX data is used to obtain average speed estimates, sections based on PeMS sensors are used to ensure compatibility with VMT estimates conducted in other analyses. For each section, the average speed reported by INRIX for the section covering the PeMS sensor of interest is used. While this may result in some loss of details regarding true speed profiles, this slight simplification is deemed acceptable given the non-negligible degree of uncertainty associated with traffic volumes and VMT estimates.

SUMMER PROFILES

I-580 EAst - Weekdays - Before (May 2017 to October 2017)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	58.8	56.4	57.5	56.8	56.2	56.8	56.7	55.9	58.9	60.3
1:00	59.1	56.6	57.5	56.6	55.8	56.4	56.2	55.7	58.6	58.9
2:00	59.3	56.6	57.6	56.6	56.1	56.8	56.6	55.8	58.5	59.1
3:00	59.6	56.9	57.9	57.1	56.5	57.1	57.0	56.1	59.5	60.4
4:00	62.0	59.0	60.1	59.4	58.8	59.4	59.2	58.4	61.8	62.2
5:00	64.1	61.6	62.9	62.6	61.8	62.3	61.9	60.6	64.0	65.2
6:00	64.9	62.2	64.2	64.1	62.6	63.3	63.0	61.3	64.9	66.8
7:00	62.9	61.3	63.6	63.7	62.2	63.0	62.4	59.4	65.2	67.4
8:00	62.3	60.6	62.9	62.8	61.6	62.4	61.8	59.3	64.9	67.4
9:00	62.0	59.7	61.8	61.5	60.1	60.9	60.6	58.5	64.6	66.7
10:00	61.6	59.2	61.0	60.4	58.6	59.7	59.7	57.9	64.0	66.3
11:00	61.3	58.9	60.6	59.7	57.7	58.6	58.9	57.3	63.6	66.0
12:00	61.1	58.8	60.5	59.2	56.4	56.5	56.0	55.8	63.5	66.0
13:00	58.3	53.1	53.0	51.4	48.3	49.3	51.1	53.4	63.1	66.2
14:00	39.8	36.1	40.5	44.6	45.6	49.0	51.1	53.2	63.1	65.9
15:00	20.1	18.5	26.5	45.3	50.6	52.8	54.2	53.9	62.8	66.5
16:00	9.6	13.8	22.2	44.5	51.4	53.3	54.7	54.5	63.6	67.3
17:00	8.1	13.1	21.4	43.5	50.9	53.2	54.8	54.6	63.7	67.3
18:00	9.8	13.3	21.1	43.4	50.3	53.0	54.6	54.7	63.5	65.9
19:00	24.1	22.2	29.8	46.3	50.3	53.0	54.5	54.7	63.2	65.9
20:00	52.6	49.6	53.8	56.6	56.3	57.2	56.4	55.4	62.8	64.6
21:00	49.1	37.2	34.5	37.8	46.6	51.3	52.8	53.9	61.5	63.4
22:00	39.2	28.5	27.2	33.1	45.5	50.3	52.3	52.9	60.3	61.9
23:00	46.0	46.1	48.4	48.4	51.5	55.1	54.9	54.8	59.8	60.8

I-580 EAst - Weekends - Before (May 2017 to October 2017)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	53.2	52.7	54.3	55.1	54.9	55.2	55.5	53.9	59.2	60.8
1:00	60.6	57.7	58.5	58.2	56.6	57.4	56.2	55.9	58.8	59.2
2:00	59.8	56.5	57.3	57.7	56.8	57.6	57.2	56.1	59.1	59.8
3:00	59.6	56.1	57.1	57.4	56.5	57.0	57.2	56.6	59.3	60.5
4:00	60.6	57.6	58.2	58.5	57.9	58.5	57.8	57.6	59.6	61.0
5:00	61.4	58.8	59.7	59.3	57.5	59.2	58.6	57.6	60.3	61.5
6:00	63.5	60.1	61.8	62.8	61.8	61.8	61.7	58.4	63.0	64.1
7:00	56.8	52.9	61.5	64.8	64.2	64.5	63.4	58.6	63.8	65.1
8:00	57.6	57.3	62.6	64.2	63.2	63.6	63.0	60.3	65.4	66.8
9:00	63.3	60.4	62.3	63.0	61.4	62.0	61.6	59.0	65.6	67.9
10:00	63.4	59.8	61.1	61.7	59.8	60.1	60.1	57.7	65.3	68.0
11:00	63.1	59.3	60.9	61.1	59.3	59.7	59.7	56.9	65.0	67.9
12:00	62.1	59.2	60.4	60.2	58.1	58.7	58.9	56.7	65.0	67.8
13:00	61.9	58.3	59.8	59.6	57.8	58.4	58.4	56.3	64.3	67.7
14:00	59.2	52.0	54.2	57.1	55.9	56.6	57.2	55.9	64.6	67.5
15:00	39.8	34.3	40.7	50.6	52.4	54.0	55.0	54.8	64.3	67.6
16:00	24.9	23.4	31.2	47.0	49.5	52.4	54.6	54.9	64.5	68.0
17:00	15.7	17.4	24.9	41.9	46.7	51.0	53.7	54.5	64.8	68.3
18:00	13.5	16.1	23.3	40.4	46.3	50.3	53.1	53.9	64.3	67.9
19:00	18.7	19.4	26.3	39.4	41.8	45.6	48.8	50.3	63.2	67.6
20:00	26.5	28.6	36.1	47.1	49.9	52.6	54.5	53.9	62.8	66.0
21:00	43.4	44.4	49.3	53.8	53.8	55.3	55.6	54.1	62.9	65.3
22:00	60.1	54.5	53.0	54.3	54.6	56.8	57.2	55.2	62.5	65.1
23:00	61.7	58.6	59.6	58.7	57.4	57.2	55.7	55.2	61.5	63.6

I-580 EAst - Weekdays - After (May 2023 to October 2023)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	60.3	58.0	57.6	51.7	51.1	55.5	58.5	58.3	61.6	62.5
1:00	60.0	57.4	57.0	51.0	50.8	55.6	58.1	57.4	60.9	62.3
2:00	58.3	55.0	54.0	49.8	49.6	53.7	56.2	56.2	57.8	59.0
3:00	60.4	57.3	56.8	52.0	51.7	55.4	57.6	57.8	59.2	60.9
4:00	64.5	61.5	60.4	57.2	57.5	61.0	62.3	61.7	62.7	63.7
5:00	67.1	65.3	64.7	61.8	61.9	64.2	65.9	65.7	66.2	66.7
6:00	65.6	64.1	63.9	60.4	60.6	62.3	64.6	64.4	66.6	67.1
7:00	62.7	61.9	62.2	58.8	58.3	60.2	62.5	61.9	64.6	65.3
8:00	62.1	61.1	61.7	58.7	57.6	59.3	61.8	61.6	64.6	65.5
9:00	62.0	60.7	61.1	57.5	56.3	58.2	60.7	60.4	64.2	65.2
10:00	62.0	60.6	60.8	56.6	54.8	57.3	60.2	60.5	64.2	65.2
11:00	60.9	60.6	60.7	56.3	55.1	57.2	60.2	60.6	64.5	65.5
12:00	61.4	61.0	60.8	56.0	54.8	57.0	60.4	60.9	64.8	65.8
13:00	55.0	48.2	47.2	44.9	50.8	57.3	60.0	60.7	65.1	66.0
14:00	51.0	49.6	49.5	50.1	56.1	60.1	61.2	61.0	65.1	66.0
15:00	51.1	50.4	51.1	52.0	56.0	60.0	61.3	60.7	64.8	66.1
16:00	50.2	50.9	51.3	54.7	55.5	59.0	60.5	60.4	63.6	64.4
17:00	49.6	48.4	47.9	52.9	56.1	58.4	60.2	60.2	64.0	65.2
18:00	50.2	49.8	49.3	52.6	57.9	60.1	60.6	60.8	65.7	67.2
19:00	46.3	39.2	35.0	48.3	54.5	58.2	61.5	61.9	66.0	67.0
20:00	51.6	51.4	48.6	52.0	53.4	56.6	60.0	61.0	65.2	66.2
21:00	46.8	43.6	29.0	31.8	47.4	55.1	59.3	59.4	62.9	64.7
22:00	45.7	47.4	32.6	30.9	44.8	55.6	60.9	60.8	64.4	65.6
23:00	53.8	54.3	46.0	45.2	49.6	55.8	59.6	59.3	62.7	63.7

I-580 EAst - Weekends - After (May 2023 to October 2023)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	46.4	57.6	49.4	54.8	55.8	59.1	60.4	59.0	62.6	64.3
1:00	46.2	57.2	49.3	55.5	56.0	59.3	61.0	60.1	63.0	64.4
2:00	45.7	57.0	48.9	55.1	55.6	58.1	59.6	58.9	61.6	63.0
3:00	46.2	56.1	48.2	55.0	56.1	58.5	59.5	59.0	61.5	63.0
4:00	47.3	58.4	49.9	58.3	59.7	61.7	61.4	59.8	62.4	64.1
5:00	48.1	60.2	51.3	60.6	61.2	62.4	63.0	62.3	64.3	65.4
6:00	47.7	59.8	51.1	61.0	61.8	62.7	63.7	63.0	65.3	66.9
7:00	54.0	62.7	59.4	62.4	62.6	63.4	64.2	63.6	66.0	67.6
8:00	64.9	64.2	64.8	63.7	63.0	63.6	64.4	63.8	66.9	68.1
9:00	64.8	64.0	64.2	62.7	61.8	62.6	63.8	63.6	66.9	68.0
10:00	64.1	63.3	63.4	61.5	60.1	60.8	62.2	62.4	66.4	67.7
11:00	63.0	62.6	62.6	60.2	58.4	59.4	61.2	61.6	65.9	67.5
12:00	62.0	61.5	61.6	59.4	58.2	59.5	61.1	61.4	65.9	67.6
13:00	62.9	60.0	59.9	57.6	56.7	58.8	60.7	61.4	65.8	67.4
14:00	63.5	62.2	62.8	61.2	59.7	60.8	61.7	61.6	65.7	67.3
15:00	63.5	61.9	62.3	61.3	59.7	60.8	62.0	61.7	65.9	67.5
16:00	62.9	59.1	57.9	59.1	58.2	59.4	60.6	61.1	65.3	67.0
17:00	59.2	56.0	55.4	55.9	57.6	59.2	60.5	61.1	65.2	67.0
18:00	59.4	58.8	55.5	57.6	59.2	60.6	61.7	61.7	65.7	67.7
19:00	58.4	57.4	53.4	52.5	54.0	57.4	59.9	60.9	65.8	67.5
20:00	62.4	57.3	54.6	53.2	55.4	57.9	59.9	60.2	65.3	67.0
21:00	63.2	60.7	60.8	58.3	57.4	59.0	59.8	59.5	64.6	66.1
22:00	64.5	63.1	64.0	62.2	60.7	62.5	62.7	61.7	65.6	67.1
23:00	63.5	62.5	63.7	62.0	61.2	62.5	62.4	61.1	64.7	65.9

WINTER PROFILES

I-580 EAst - Weekdays - Before (November 2017 to March 2018)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	58.2	56.2	57.4	57.1	56.7	57.3	56.6	54.8	58.2	61.2
1:00	57.7	55.8	56.9	56.8	56.5	57.1	56.3	54.8	58.2	62.1
2:00	57.6	55.8	56.9	56.8	56.1	56.9	56.1	54.9	57.7	62.2
3:00	58.4	56.1	57.3	57.1	56.1	57.5	56.6	55.0	58.0	61.8
4:00	60.1	57.4	58.9	58.4	58.0	58.9	58.0	56.1	59.9	62.7
5:00	62.5	60.0	61.5	61.1	60.4	61.5	60.9	58.8	62.2	64.3
6:00	62.7	60.5	62.0	62.3	61.1	62.0	61.4	59.4	63.8	66.6
7:00	61.7	60.8	62.9	63.8	62.5	63.3	62.5	59.6	64.7	67.6
8:00	62.3	60.4	62.8	63.7	62.7	63.6	62.5	59.3	65.1	68.0
9:00	61.8	59.6	62.1	62.8	61.3	62.1	61.3	58.5	64.7	68.0
10:00	61.7	59.4	61.7	61.8	60.2	61.1	60.3	57.6	64.0	67.2
11:00	61.8	59.2	61.4	61.5	59.9	60.8	60.1	57.5	63.8	66.9
12:00	59.3	56.0	58.2	59.9	59.6	60.5	60.0	57.6	64.4	67.4
13:00	60.2	58.5	60.3	59.8	57.9	58.8	58.2	56.5	63.6	67.0
14:00	57.2	50.2	53.0	55.4	55.1	56.6	56.7	55.3	63.9	67.6
15:00	27.9	23.1	30.2	45.3	50.9	53.9	55.2	54.3	63.4	67.4
16:00	11.6	14.0	21.0	37.1	44.9	51.5	54.8	54.2	63.4	67.4
17:00	8.8	13.2	20.7	39.6	47.3	51.0	53.1	52.6	62.4	66.9
18:00	12.5	15.5	23.0	41.4	48.7	51.1	51.9	51.4	61.9	66.4
19:00	31.7	31.9	39.1	49.4	52.3	54.5	54.7	53.4	62.3	66.0
20:00	56.1	54.3	56.8	57.4	56.5	58.6	58.2	55.5	62.0	63.9
21:00	57.1	51.2	52.0	53.4	52.5	55.6	55.3	54.0	60.2	58.9
22:00	54.6	50.7	52.4	54.7	55.4	56.2	54.8	55.2	60.7	61.6
23:00	57.4	55.7	56.6	57.4	57.2	58.0	57.2	55.3	59.8	62.9

I-580 EAst - Weekends - Before (November 2017 to March 2018)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	59.7	57.0	58.6	58.7	58.7	59.3	57.8	55.5	59.6	62.4
1:00	59.4	56.6	58.1	58.2	57.7	58.5	57.2	55.3	58.2	62.4
2:00	60.2	56.7	58.5	58.8	58.5	58.9	57.5	56.1	58.2	64.0
3:00	59.4	56.7	58.3	58.7	58.3	58.7	57.3	55.8	59.4	63.6
4:00	59.2	56.7	58.0	58.0	57.7	58.1	57.1	55.4	59.5	63.4
5:00	59.8	57.9	59.4	59.7	59.4	59.3	58.4	56.2	59.8	63.6
6:00	62.5	59.5	60.7	62.5	61.5	62.2	60.9	58.6	62.9	65.8
7:00	63.0	61.1	62.9	64.5	63.7	64.3	63.4	60.6	64.7	67.3
8:00	60.6	60.2	62.2	64.0	62.8	63.6	62.5	59.6	64.5	67.7
9:00	63.2	61.2	63.1	64.4	62.9	63.3	62.5	59.6	65.5	68.4
10:00	62.6	60.3	62.2	62.8	61.2	62.3	61.9	59.0	66.1	69.3
11:00	63.9	60.3	61.8	62.6	60.8	61.5	61.0	58.3	65.9	68.9
12:00	63.1	60.0	61.8	62.6	60.4	59.9	58.3	56.8	65.9	69.1
13:00	63.4	59.4	60.8	60.7	55.6	54.1	54.1	55.0	65.4	69.0
14:00	58.8	50.6	51.8	53.2	51.1	51.6	52.7	54.6	65.6	69.3
15:00	48.6	44.1	47.7	50.5	49.4	51.3	52.5	54.9	65.4	68.6
16:00	37.9	33.8	39.6	47.0	50.2	54.5	56.2	55.5	65.4	69.0
17:00	26.0	25.5	32.6	44.6	49.0	52.5	53.9	53.7	64.3	68.0
18:00	28.8	29.6	37.0	48.6	52.2	54.2	54.6	53.5	63.7	67.7
19:00	48.6	44.1	48.4	53.7	56.1	57.5	56.9	54.4	63.8	67.1
20:00	62.7	58.4	59.9	60.0	58.3	59.5	59.1	56.4	63.8	67.0
21:00	62.8	59.0	60.2	60.6	59.1	59.0	59.2	56.5	63.4	66.3
22:00	61.9	58.9	60.3	60.4	58.7	53.4	57.5	56.4	63.0	66.3
23:00	60.4	57.6	59.0	59.0	57.9	56.8	57.6	56.1	61.4	64.8

I-580 EAst - Weekdays - After (November 2022 to May 2023)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	60.1	57.6	57.2	53.1	50.8	54.6	58.6	58.0	60.9	62.4
1:00	60.3	57.3	56.9	52.4	49.3	54.0	58.1	57.6	61.0	62.7
2:00	59.5	57.1	55.7	51.2	48.8	52.5	57.0	56.9	58.8	60.7
3:00	59.7	57.8	56.8	53.0	50.4	53.9	57.7	57.3	59.2	61.4
4:00	63.6	61.8	60.9	56.6	53.6	57.4	61.7	61.4	62.1	64.1
5:00	65.6	61.0	61.0	58.9	57.1	60.7	64.8	64.4	65.8	67.2
6:00	63.7	61.8	61.5	58.4	55.2	58.3	62.6	62.2	64.7	65.8
7:00	62.0	60.2	60.4	57.4	54.1	57.2	61.7	61.3	64.1	65.1
8:00	61.5	59.5	60.1	57.2	53.8	56.7	61.1	60.8	63.8	65.3
9:00	61.2	58.9	59.1	56.0	52.5	55.6	60.1	60.1	63.8	65.6
10:00	61.6	59.2	59.6	56.3	52.4	55.5	60.0	60.2	63.8	65.6
11:00	61.7	59.2	59.4	55.7	51.9	55.3	59.9	60.3	63.8	65.5
12:00	59.6	54.9	54.8	54.6	51.8	55.8	60.4	60.6	64.4	66.1
13:00	46.9	43.2	51.2	52.6	53.0	56.2	59.7	60.2	64.3	66.2
14:00	51.3	52.5	59.0	59.0	58.0	59.8	61.5	60.6	64.3	66.2
15:00	56.1	54.0	56.9	58.7	57.7	59.1	60.7	59.8	63.6	65.7
16:00	52.4	48.5	51.8	53.8	52.1	55.5	58.9	58.8	62.6	64.8
17:00	50.7	49.7	51.5	52.0	53.4	55.1	57.3	57.1	62.3	64.7
18:00	56.6	52.1	49.9	53.6	53.8	56.0	58.2	57.6	63.2	65.7
19:00	52.0	34.8	32.5	42.4	48.9	55.5	59.5	59.5	64.1	66.2
20:00	62.2	59.2	58.5	54.5	51.3	56.2	60.1	59.9	64.0	65.9
21:00	62.2	51.9	40.0	38.8	45.3	52.6	59.5	60.0	63.8	65.8
22:00	62.8	58.4	54.0	43.9	45.5	53.4	60.4	60.6	64.2	66.0
23:00	60.8	58.3	57.8	52.1	49.1	53.9	59.3	59.3	62.3	63.2

I-580 EAst - Weekends - After (November 2022 to May 2023)

Time	Sir Francis Drake Blvd	Main St (Upstream)	Main St (Dwnstrm)	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd
0:00	62.2	59.5	60.7	57.1	54.9	58.2	61.9	60.5	63.8	65.4
1:00	62.4	59.9	59.8	56.6	54.7	58.3	61.6	60.2	63.1	64.8
2:00	61.2	59.4	58.8	55.2	53.6	56.1	59.8	59.0	62.1	63.7
3:00	61.0	58.6	58.7	56.2	55.6	58.0	60.5	59.3	61.9	63.5
4:00	62.9	59.3	58.4	57.2	57.3	60.0	62.0	60.3	63.1	65.3
5:00	65.2	63.5	62.9	60.5	60.1	62.0	64.1	62.8	65.3	66.9
6:00	64.7	62.7	62.7	61.1	60.3	61.7	61.9	61.0	65.4	67.8
7:00	65.4	63.9	64.0	62.7	61.6	63.1	65.0	63.9	66.8	68.4
8:00	65.4	63.7	64.0	63.2	62.3	63.7	64.9	63.9	67.2	68.5
9:00	65.1	63.7	63.9	62.9	61.6	62.8	64.1	63.5	67.0	68.7
10:00	64.3	62.6	62.9	61.4	59.9	61.2	62.1	62.4	66.6	68.3
11:00	63.8	62.0	62.4	60.5	58.7	60.4	62.0	62.0	66.1	68.0
12:00	63.8	61.7	62.4	60.4	58.6	60.2	61.8	61.8	66.0	67.6
13:00	63.3	60.1	61.4	59.7	57.2	59.5	61.4	61.3	65.7	67.1
14:00	63.3	59.9	62.2	61.4	60.0	61.1	62.3	61.8	65.6	67.5
15:00	63.2	60.5	61.9	61.0	59.8	60.6	61.4	61.3	65.2	67.4
16:00	63.1	60.3	61.1	59.8	58.6	59.8	61.1	60.7	64.8	66.8
17:00	62.3	58.7	59.4	57.3	56.3	58.4	59.6	59.3	63.9	66.1
18:00	62.8	60.1	61.3	59.9	58.3	59.7	60.5	59.5	64.0	66.5
19:00	63.5	61.2	62.1	60.2	58.4	59.9	61.0	60.3	65.0	67.2
20:00	63.2	61.2	62.1	60.2	58.6	60.2	61.3	60.1	64.6	66.7
21:00	63.3	61.3	62.0	60.3	59.0	60.6	61.6	60.5	64.6	66.7
22:00	64.3	62.1	62.7	60.5	60.0	62.0	63.1	61.7	65.3	67.4
23:00	63.1	60.0	60.9	59.9	59.5	61.1	62.7	60.9	64.2	65.8

Figure 9-1: Estimated Speed Profiles – I-580 East

SUMMER PROFILES

I-580 West - Weekdays - Before (May 2018 to October 2018)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	59.7	60.4	58.9	55.2	43.2	43.2	57.2	62.3	64.1	68.0
1:00	57.8	58.3	56.7	52.7	42.4	42.4	54.3	59.8	61.8	65.3
2:00	57.5	58.2	56.5	52.4	43.2	43.2	52.8	58.9	59.9	64.8
3:00	58.5	59.4	57.6	53.0	43.6	43.6	55.6	60.5	61.3	64.9
4:00	58.7	59.8	58.4	54.4	43.6	43.6	58.2	63.9	65.2	67.8
5:00	61.1	62.1	60.5	57.1	47.9	47.9	59.4	66.3	67.8	69.8
6:00	58.2	57.4	53.9	44.8	19.5	19.5	14.4	15.0	26.8	56.4
7:00	55.0	55.5	51.3	38.9	13.1	13.1	11.3	10.4	18.8	53.4
8:00	54.7	54.5	51.2	40.2	14.4	14.4	14.6	18.7	33.5	62.1
9:00	55.4	52.8	49.1	40.3	18.7	18.7	21.7	30.4	49.1	64.4
10:00	58.9	58.2	54.9	45.4	25.6	25.6	34.4	48.1	61.5	67.4
11:00	60.2	60.3	57.8	50.7	35.7	35.7	42.4	52.4	64.2	67.8
12:00	60.3	60.2	58.9	54.5	41.6	41.6	48.8	56.2	64.3	67.8
13:00	60.0	59.1	58.1	54.5	44.2	44.2	51.8	60.4	66.8	68.4
14:00	59.8	59.4	59.6	56.7	44.5	44.5	59.6	65.9	67.2	68.4
15:00	60.5	61.1	59.3	54.8	47.0	47.0	62.3	66.7	67.6	68.2
16:00	62.3	64.5	63.8	62.1	49.7	49.7	62.2	65.8	67.4	68.1
17:00	62.2	64.8	64.2	62.7	51.0	51.0	62.5	64.9	66.9	67.8
18:00	63.1	65.4	64.4	62.6	50.5	50.5	62.2	65.7	67.2	68.0
19:00	63.6	65.4	64.4	62.3	49.7	49.7	59.8	65.1	66.6	68.5
20:00	62.8	64.4	63.5	61.3	49.2	49.2	63.9	64.8	65.9	68.4
21:00	61.6	63.6	62.3	60.1	47.7	47.7	62.0	63.4	65.4	68.2
22:00	60.8	61.8	61.6	58.7	46.8	46.8	58.4	62.8	65.7	68.4
23:00	59.2	61.3	60.6	57.3	44.8	44.8	56.9	63.5	64.9	68.1

I-580 West - Weekends - Before (May 2018 to October 2018)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Sarine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	60.4	62.4	60.8	57.5	45.6	45.6	59.5	63.8	65.1	67.9
1:00	59.2	61.1	60.1	55.8	44.7	44.7	58.2	64.3	64.5	67.7
2:00	58.9	60.0	58.4	53.8	45.4	45.4	56.1	61.4	62.8	66.4
3:00	58.3	58.6	56.7	52.5	43.8	43.8	54.8	60.7	61.6	65.2
4:00	59.9	59.0	56.8	52.8	43.7	43.7	55.7	62.7	63.8	66.9
5:00	61.9	63.3	61.6	58.4	46.8	46.8	58.8	65.7	66.0	67.9
6:00	63.7	64.7	62.3	57.1	46.1	46.1	61.8	67.9	67.9	70.0
7:00	64.1	65.4	63.9	60.6	47.5	47.5	62.7	69.0	70.0	71.0
8:00	62.7	63.6	61.8	58.5	44.8	44.8	59.2	68.0	69.7	71.0
9:00	61.1	60.6	59.0	55.6	41.1	41.1	48.0	58.4	68.5	70.3
10:00	58.8	56.0	51.8	46.5	24.7	24.7	28.3	38.9	63.6	69.6
11:00	57.6	54.5	46.1	35.8	16.1	16.1	17.3	22.0	48.3	68.5
12:00	57.1	54.1	48.1	38.5	15.6	15.6	15.7	16.9	36.3	66.2
13:00	56.7	53.4	47.4	37.4	15.8	15.8	15.9	18.8	41.5	66.9
14:00	57.1	54.4	46.3	38.4	19.7	19.7	20.4	27.5	51.3	68.0
15:00	56.7	56.3	53.4	48.0	27.5	27.5	31.0	42.7	62.3	69.1
16:00	58.4	58.5	56.9	53.4	40.0	40.0	48.0	54.0	65.1	69.1
17:00	59.2	60.2	58.4	55.3	42.5	42.5	55.3	62.8	67.5	68.5
18:00	60.6	62.0	60.6	57.9	46.0	46.0	53.8	58.2	67.2	69.1
19:00	61.3	62.6	60.7	58.5	45.2	45.2	55.1	61.0	67.3	68.8
20:00	61.5	62.5	59.4	55.4	45.0	45.0	60.9	66.4	66.8	68.3
21:00	59.4	57.5	55.0	56.0	45.2	45.2	59.7	65.8	66.1	67.9
22:00	61.7	62.0	56.7	55.5	46.0	46.0	60.7	65.8	66.6	68.5
23:00	61.9	62.4	58.0	56.6	47.9	47.9	60.8	65.9	65.3	67.7

I-580 West - Weekdays - After (May 2023 to October 2023)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	60.1	58.5	56.3	55.4	49.3	49.3	59.9	62.8	63.2	64.4
1:00	57.6	55.8	53.1	52.5	47.2	47.2	56.8	59.8	60.4	62.9
2:00	56.3	55.8	53.9	52.4	47.6	47.6	56.6	58.9	59.6	62.1
3:00	57.5	56.1	54.0	52.3	46.8	46.8	56.8	60.4	61.4	62.9
4:00	59.4	57.5	55.3	54.2	49.7	49.7	58.9	62.1	64.1	66.3
5:00	61.9	60.8	58.5	57.4	52.4	52.4	62.4	65.7	66.9	67.7
6:00	56.1	52.0	45.7	39.6	22.5	22.5	29.9	46.9	60.9	65.7
7:00	50.4	45.8	41.8	35.3	13.4	13.4	12.1	14.1	29.1	55.5
8:00	54.0	50.5	44.4	35.2	16.3	16.3	17.6	26.1	43.1	57.1
9:00	56.4	53.9	48.0	41.9	26.9	26.9	34.4	45.7	57.4	62.8
10:00	58.9	57.2	53.9	50.6	40.1	40.1	53.4	60.6	64.8	66.2
11:00	59.4	58.8	57.3	53.6	42.6	42.6	54.4	59.4	65.2	66.0
12:00	60.4	58.7	55.4	52.8	44.4	44.4	57.4	64.1	66.3	63.8
13:00	61.2	61.1	59.7	56.8	47.4	47.4	61.9	66.0	66.7	65.1
14:00	61.4	61.2	60.2	56.9	48.9	48.9	63.4	66.2	66.5	65.2
15:00	61.4	61.1	60.6	59.5	49.8	49.8	63.3	65.9	66.5	66.4
16:00	61.0	61.2	60.1	58.4	50.7	50.7	63.2	64.5	65.8	65.8
17:00	60.8	60.5	59.4	57.9	49.8	49.8	63.0	64.1	65.3	65.2
18:00	60.4	60.6	58.8	57.6	50.0	50.0	62.9	64.9	65.7	65.4
19:00	62.3	62.3	60.6	59.6	51.3	51.3	63.6	65.9	66.8	66.9
20:00	62.7	62.3	60.5	59.5	51.3	51.3	63.6	66.0	66.8	67.1
21:00	62.5	61.7	60.1	59.5	51.9	51.9	64.1	66.4	66.9	67.1
22:00	62.6	61.3	58.9	57.8	51.1	51.1	63.0	65.6	66.4	67.0
23:00	62.0	60.3	58.4	57.7	50.8	50.8	62.5	65.0	65.6	66.5

I-580 West - Weekends - After (May 2023 to October 2023)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Sarine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	63.1	62.9	60.7	58.4	48.7	48.7	61.5	65.0	65.7	66.5
1:00	60.7	59.8	58.0	56.4	49.8	49.8	59.6	62.6	62.7	64.0
2:00	60.3	60.2	58.2	55.8	50.6	50.6	59.3	62.4	62.6	64.3
3:00	60.1	59.5	57.3	54.8	49.8	49.8	59.1	61.8	62.0	63.8
4:00	60.1	60.0	58.4	55.3	49.2	49.2	58.5	62.3	63.0	63.7
5:00	61.0	61.5	60.0	57.9	51.4	51.4	60.9	64.0	64.8	65.8
6:00	61.0	63.1	61.7	60.5	54.3	54.3	63.8	66.5	67.4	68.4
7:00	64.2	64.6	63.2	61.5	53.5	53.5	64.8	67.4	67.3	69.4
8:00	64.3	64.5	62.5	61.0	52.4	52.4	65.6	68.5	69.4	70.1
9:00	62.7	61.4	56.6	53.6	42.5	42.5	58.8	67.2	69.2	69.9
10:00	60.5	57.5	50.7	38.9	24.7	24.7	34.4	48.0	64.6	68.9
11:00	59.5	55.6	49.9	36.2	15.8	15.8	16.7	22.2	39.6	64.5
12:00	58.7	55.6	49.2	35.5	14.9	14.9	14.3	16.5	30.0	61.8
13:00	57.8	52.5	45.3	35.3	15.1	15.1	15.3	16.9	30.3	63.0
14:00	56.1	54.7	47.3	37.5	17.4	17.4	18.5	21.2	34.5	65.3
15:00	57.3	54.4	47.1	37.7	21.9	21.9	25.5	28.2	43.8	67.2
16:00	59.5	58.4	53.6	44.2	30.0	30.0	35.2	40.8	57.5	68.2
17:00	60.7	60.5	57.9	52.3	39.5	39.5	49.6	56.2	66.6	68.2
18:00	61.9	62.6	61.0	59.2	49.1	49.1	62.5	67.0	68.7	68.6
19:00	63.2	63.1	62.0	61.2	51.7	51.7	65.3	68.0	69.0	69.3
20:00	63.1	63.0	61.9	60.6	51.6	51.6	64.5	67.2	68.0	68.7
21:00	62.7	62.8	60.7	59.0	51.4	51.4	60.4	65.4	67.4	68.2
22:00	63.3	63.2	60.6	57.7	51.3	51.3	53.7	65.4	67.9	68.5
23:00	62.8	62.6	59.7	58.4	51.2	51.2	59.5	65.6	66.7	67.6

WINTER PROFILES

I-580 West - Weekdays - Before (November 2018 to April 2019)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	58.5	59.0	57.7	53.9	41.0	41.0	56.1	62.3	62.0	64.8
1:00	57.0	57.9	55.3	52.3	40.3	40.3	55.1	62.9	62.3	64.2
2:00	56.7	57.3	55.8	52.2	40.9	40.9	54.7	62.3	61.6	63.5
3:00	56.6	57.4	55.8	51.8	41.3	41.3	55.3	62.0	61.4	62.7
4:00	57.6	58.3	56.8	53.3	41.7	41.7	56.1	62.2	61.8	63.3
5:00	59.8	60.5	59.0	56.1	46.3	46.3	58.8	64.5	64.4	65.4
6:00	56.7	55.6	52.4	42.5	19.2	19.2	22.8	29.6	49.0	66.6
7:00	49.7	51.0	49.3	38.3	12.5	12.5	12.4	11.3	18.7	54.0
8:00	55.1	51.0	46.3	38.1	15.0	15.0	17.0	21.2	35.1	59.7
9:00	58.1	55.5	51.3	41.7	21.3	21.3	27.8	37.4	50.0	66.7
10:00	60.2	60.2	57.6	51.4	34.9	34.9	48.3	56.2	63.3	67.8
11:00	60.9	61.7	60.2	56.4	45.6	45.6	61.2	66.5	66.9	68.2
12:00	61.7	62.7	61.5	58.4	47.8	47.8	61.7	66.8	67.2	68.4
13:00	62.0	62.9	61.9	59.1	48.3	48.3	62.1	66.7	67.0	68.2
14:00	62.2	63.6	62.7	60.0	48.3	48.3	62.5	67.0	67.4	68.4
15:00	63.3	64.6	64.1	61.2	48.6	48.6	63.8	68.3	68.1	69.2
16:00	62.9	64.3	63.9	61.9	49.3	49.3	64.2	67.9	67.9	68.7
17:00	61.5	62.7	61.7	60.0	48.3	48.3	63.1	66.4	65.9	67.5
18:00	61.0	62.1	60.6	59.2	47.2	47.2	62.6	66.0	65.5	67.1
19:00	58.9	57.8	57.4	59.0	45.9	45.9	62.4	66.2	66.2	67.6
20:00	62.1	62.9	61.3	59.0	45.7	45.7	61.9	65.5	64.3	67.6
21:00	61.4	62.0	60.3	57.2	44.3	44.3	61.0	65.2	64.0	66.9
22:00	61.5	61.6	59.7	57.2	44.2	44.2	60.4	65.1	64.0	67.2
23:00	59.2	59.9	58.8	55.9	43.6	43.6	58.8	64.6	64.0	66.3

I-580 West - Weekends - Before (November 2018 to April 2019)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Sarine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	57.7	56.0	51.0	55.2	43.8	43.8	52.4	62.1	61.6	65.6
1:00	56.8	57.0	55.6	54.0	44.0	44.0	54.5	61.9	61.6	64.4
2:00	57.0	57.0	56.1	52.5	43.5	43.5	54.2	61.1	60.9	64.0
3:00	56.4	56.2	54.8	51.2	42.9	42.9	53.4	60.7	60.8	64.3
4:00	56.4	56.2	54.6	51.2	42.7	42.7	53.9	61.4	61.1	63.8
5:00	57.0	58.0	56.2	52.4	43.1	43.1	55.2	62.3	61.7	64.0
6:00	58.3	60.0	58.3	54.4	44.8	44.8	56.3	63.7	63.0	65.6
7:00	59.8	61.7	60.3	55.9	41.4	41.4	56.3	64.9	64.4	66.8
8:00	60.1	61.6	60.6	56.4	41.9	41.9	54.4	64.8	65.4	68.0
9:00	59.9	61.5	60.1	56.9	42.5	42.5	49.8	58.5	65.7	67.9
10:00	57.6	59.1	57.6	53.8	41.2	41.2	51.4	57.9	64.8	67.8
11:00	57.5	58.3	55.3	49.9	31.0	31.0	40.0	52.5	65.5	68.4
12:00	56.9	58.1	55.6	49.8	30.5	30.5	36.2	43.5	61.0	67.4
13:00	56.6	57.5	55.6	50.7	32.4	32.4	37.4	45.7	62.3	67.3
14:00	56.6	57.3	54.1	51.0	33.3	33.3	39.8	51.5	64.5	66.8
15:00	56.9	58.3	56.3	53.7	40.4	40.4	52.7	61.3	65.3	67.3
16:00	57.6	59.0	57.2	55.4	45.8	45.8	60.2	64.8	66.1	67.7
17:00	57.1	58.3	57.1	55.3	45.1	45.1	59.5	63.2	64.8	66.9
18:00	57.7	59.5	57.7	55.2	43.3	43.3	55.7	63.2	63.7	66.0
19:00	57.3	59.3	58.0	55.5	44.7	44.7	58.8	64.8	63.2	65.9
20:00	58.6	59.6	57.3	55.1	44.9	44.9	59.4	64.7	64.6	66.6
21:00	58.0	59.2	57.3	55.0	44.2	44.2	58.1	63.4	63.3	66.1
22:00	58.1	59.3	57.5	54.4	44.6	44.6	58.6	64.5	63.8	65.2
23:00	59.2	60.2	58.4	54.8	44.7	44.7	58.4	64.7	63.4	66.7

I-580 West - Weekdays - After (November 2022 to April 2023)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Marine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	60.1	58.5	56.3	55.4	49.3	49.3	59.9	62.8	63.2	64.4
1:00	57.6	55.8	53.1	52.5	47.2	47.2	56.8	59.8	60.4	62.9
2:00	56.3	55.8	53.9	52.4	47.6	47.6	56.6	58.9	59.6	62.1
3:00	57.5	56.1	54.0	52.3	46.8	46.8	56.8	60.4	61.4	62.9
4:00	59.4	57.5	55.3	54.2	49.7	49.7	58.9	62.1	64.1	66.3
5:00	61.9	60.8	58.5	57.4	52.4	52.4	62.4	65.7	66.9	67.7
6:00	56.1	52.0	45.7	39.6	22.5	22.5	29.9	46.9	60.9	65.7
7:00	50.4	45.8	41.8	35.3	13.4	13.4	12.1	14.1	29.1	55.5
8:00	54.0	50.5	44.4	35.2	16.3	16.3	17.6	26.1	43.1	57.1
9:00	56.4	53.9	48.0	41.9	26.9	26.9	34.4	45.7	57.4	62.8
10:00	58.9	57.2	53.9	50.6	40.1	40.1	53.4	60.6	64.8	66.2
11:00	59.4	58.8	57.3	53.6	42.6	42.6	54.4	59.4	65.2	66.0
12:00	60.4	58.7	55.4	52.8	44.4	44.4	57.4	64.1	66.3	63.8
13:00	61.2	61.1	59.7	56.8	47.4	47.4	61.9	66.0	66.7	65.1
14:00	61.4	61.2	60.2	56.9	48.9	48.9	63.4	66.2	66.5	65.2
15:00	61.4	61.1	60.6	59.5	49.8	49.8	63.3	65.9	66.5	66.4
16:00	61.0	61.2	60.1	58.4	50.7	50.7	63.2	64.5	65.8	65.8
17:00	60.8	60.5	59.4	57.9	49.8	49.8	63.0	64.1	65.3	65.2
18:00	60.4	60.6	58.8	57.6	50.0	50.0	62.9	64.9	65.7	65.4
19:00	62.3	62.3	60.6	59.6	51.3	51.3	63.6	65.9	66.8	66.9
20:00	62.7	62.3	60.5	59.5	51.3	51.3	63.6	66.0	66.8	67.1
21:00	62.5	61.7	60.1	59.5	51.9	51.9	64.1	66.4	66.9	67.1
22:00	62.6	61.3	58.9	57.8	51.1	51.1	63.0	65.6	66.4	67.0
23:00	62.0	60.3	58.4	57.7	50.8	50.8	62.5	65.0	65.6	66.5

I-580 West - Weekends - After (November 2022 to April 2023)

Time	Main St	Pier 21	Pier 35	Pier 49	Toll Plaza	Stenmark Dr	Sarine St	Canal Blvd	Cutting Blvd	Marina Bay Pkwy
0:00	61.9	61.1	59.6	58.6	51.2	51.2	62.6	65.2	65.7	66.7
1:00	61.3	60.3	58.0	56.7	50.2	50.2	60.4	63.0	63.7	65.2
2:00	60.1	59.3	57.1	56.1	49.9	49.9	60.3	62.7	63.2	64.8
3:00	59.2	59.0	56.5	54.7	50.2	50.2	59.7	62.6	62.8	64.0
4:00	58.9	57.2	54.6	53.1	49.2	49.2	57.7	61.1	62.3	63.3
5:00	60.7	59.8	58.2	57.6	52.1	52.1	61.7	64.9	65.9	66.5
6:00	62.6	61.4	59.3	58.4	53.1	53.1	63.5	66.2	66.7	66.9
7:00	62.3	62.0	60.9	59.6	52.2	52.2	63.6	66.7	67.2	67.7
8:00	62.0	63.2	62.3	60.6	52.3	52.3	64.6	67.5	68.0	68.6
9:00	62.9	62.6	60.2	58.2	49.6	49.6	64.2	67.7	68.0	68.6
10:00	61.3	60.6	57.8	51.3	40.2	40.2	53.4	62.3	67.7	68.1
11:00	59.6	54.0	49.0	41.2	27.1	27.1	36.9	49.3	64.8	67.2
12:00	58.7	56.3	52.9	46.0	26.4	26.4	30.3	38.5	59.7	65.5
13:00	59.0	58.3	56.1	49.4	30.0	30.0	40.0	52.7	64.1	66.8
14:00	59.0	58.7	56.2	51.4	32.9	32.9	47.0	59.5	66.4	67.1
15:00	58.9	53.7	53.4	51.9	40.6	40.6	55.4	63.6	66.9	67.0
16:00	59.8	60.0	59.0	57.5	48.7	48.7	62.9	66.3	66.8	66.5
17:00	58.1	55.3	53.4	53.3	46.2	46.2	61.4	65.7	66.3	66.5
18:00	60.6	60.1	58.4	57.9	49.7	49.7	63.3	66.1	66.8	66.8
19:00	62.3	62.4	60.7	59.7	50.5	50.5	64.0	66.8	67.6	67.9
20:00	62.3	61.9	60.5	59.5	50.6	50.6	63.8	66.6	67.2	67.5
21:00	62.4	61.9	60.3	59.4	51.6	51.6	63.8	66.5	67.2	67.6
22:00	62.4	61.5	59.5	58.8	51.4	51.4	63.2	65.9	66.7	67.3
23:00	62.5	61.4	59.2	58.8	51.6	51.6	62.9	65.9	66.7	67.7

Figure 9-2: Estimated Speed Profiles – I-580 West

9.2. TRUCK PROPORTIONS

When estimating emissions, it is important to distinguish between passenger cars and trucks as the use of more powerful engines and diesel by trucks typically results in different emission profiles. This is accounted for in the analysis by first separately estimating emission rates per mile traveled for passenger cars and trucks and by subsequently merging the obtained vehicle-based rates based on the proportions of miles traveled by passenger cars and trucks to obtain an overall emission rate.

To develop truck percentage profiles for the portion of the I-580 freeway crossing the Richmond-San Rafael bridge the following data sources were used:

- Vehicle classification counts from the Richmond toll plaza on I-580 Wast
- Estimates of truck percentages from PeMS sensors

While the traffic counts from the toll plan provide accurate classification data at the entrance of the bridge and allow the development of relatively reliable estimates of truck percentages for the bridge and its approach along I-580 West, the data retrieved from PeMS must be used with caution. None of the PeMS sensors along I-580 are equipped with devices allowing the capture of vehicle classification through the analysis of axle spacing. In the absence of such devices, data collection algorithms within PeMS then attempt to break down the total observed flow into passengers and large trucks using a series of assumptions regarding lane usage, observed speeds, detected vehicle length, and sensor occupancy. This results in estimates of truck proportions that may or may not correctly represent the true portion. However, in the absence of other data, this is the only source of information regarding truck traffic along I-580 East.

Figure 9-3 illustrates the truck percentage daily profiles that were estimated for average weekday and weekend days for each direction of travel. Identical profiles were used to represent truck percentages before and after the bridge modifications to remove any effects from changes in the composition of the vehicle fleet. This is a reasonable assumption as an analysis of classification data from the toll plaza indicates that daytime truck percentages along the freeway have been relatively consistent between 2015 and 2023, except for 2020-2021 due to the impact of COVID-related stay-at-home orders, as shown in Figure 9-4. This assumption allows the analysis to concentrate on effects associated with changes in traffic dynamics and thus, changes directly impacted by the bridge modifications.

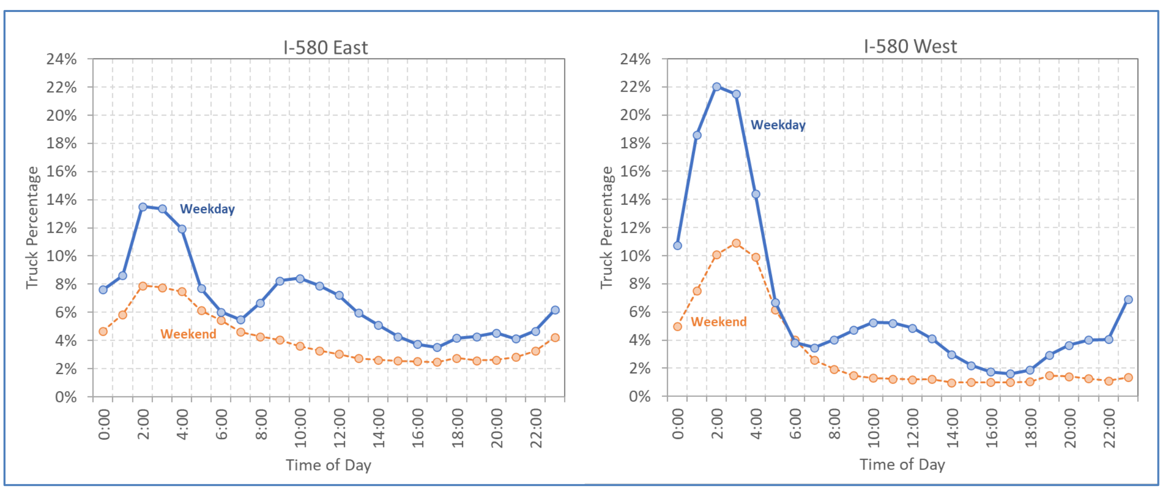

Figure 9-3: Estimated Daily Truck Percentage Profile – I-580 East

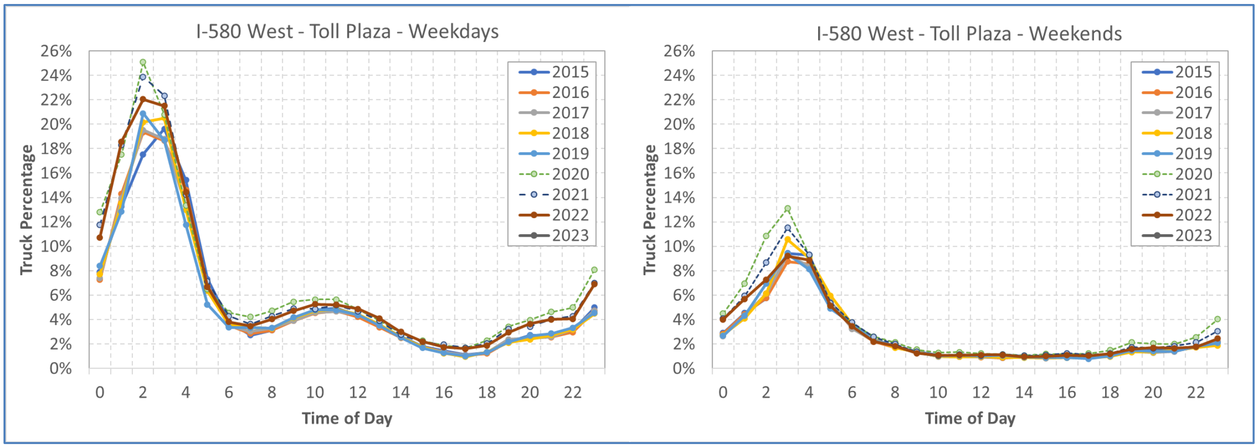

Figure 9-4: Observed Truck Percentages at I-580 West Toll Plaza, 2015-2023

9.3. VMT DISTRIBUTIONS BY SPEED

This section presents the distributions of VMT by speed that were estimated for the approach to the bridge and bridge itself along I-580 East and I-580 West based on the following elements:

- **Vehicle type** (passenger cars and trucks), to take advantage of the ability of the EMFAC model to provide aggregate emission rates for passenger cars and trucks.
- **Period of the year** (summer and winter), to take advantage of the ability of the EMFAC model to provide aggregate estimates for summer and winter periods.
- **Day of week** (weekday and weekend), to account for the fact that different weekday and weekend traffic patterns could produce different impacts on emissions.
- **Before and after bridge modification**, to be able to assess the impacts of the bridge modifications on emissions.
- **Period of interest** (all day and congested period), to allow evaluations to consider potentially different impacts based on congestion level.

9.3.1. I-580 EAST

Figure 9-5 to Figure 9-8 present the various VMT distributions that were estimated for I-580 East. These distributions were developed based on the following elements:

- In the eastbound direction, the period of interest revolves around the period during which the shoulder is open to traffic. While the shoulder is normally open from 2 PM to 7 PM, the analysis covers 1 PM to 8 PM to ensure that any impact on congestion outside the period during which the shoulder is open is considered.
- Since the shoulder opening occurred in April 2018, the summer distribution for the before conditions was developed based on traffic data from April to September 2017, while the winter distribution is based on data from October 2017 to March 2018.
- For the after conditions, the winter distribution was developed using data from October 2022 to March 2023, while the distribution was developed using data from April to September 2023.

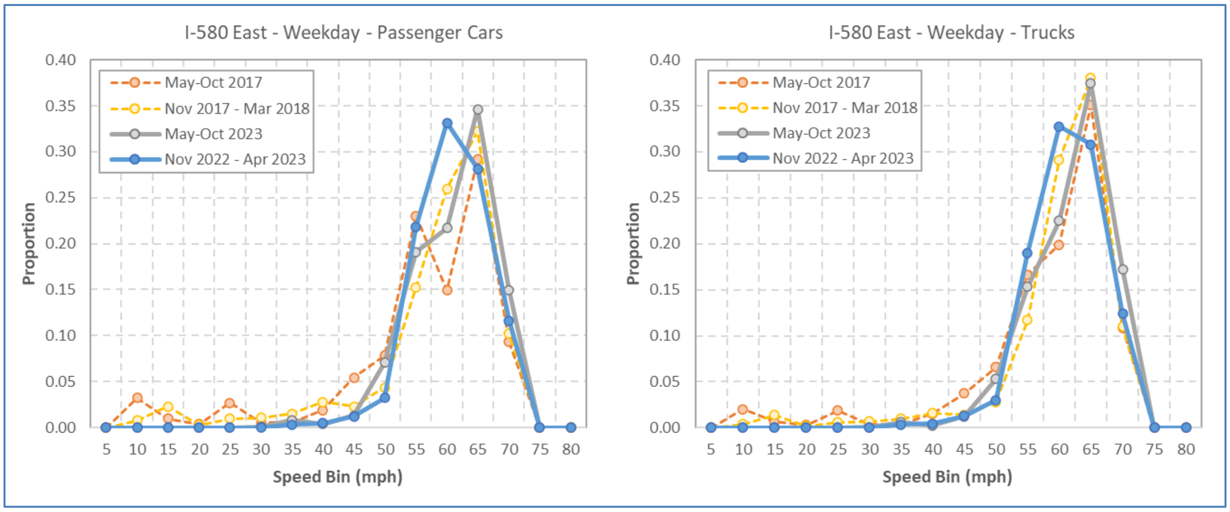

Figure 9-5: Estimated VMT Distributions by Speed – I-580 East, Weekday, All Day

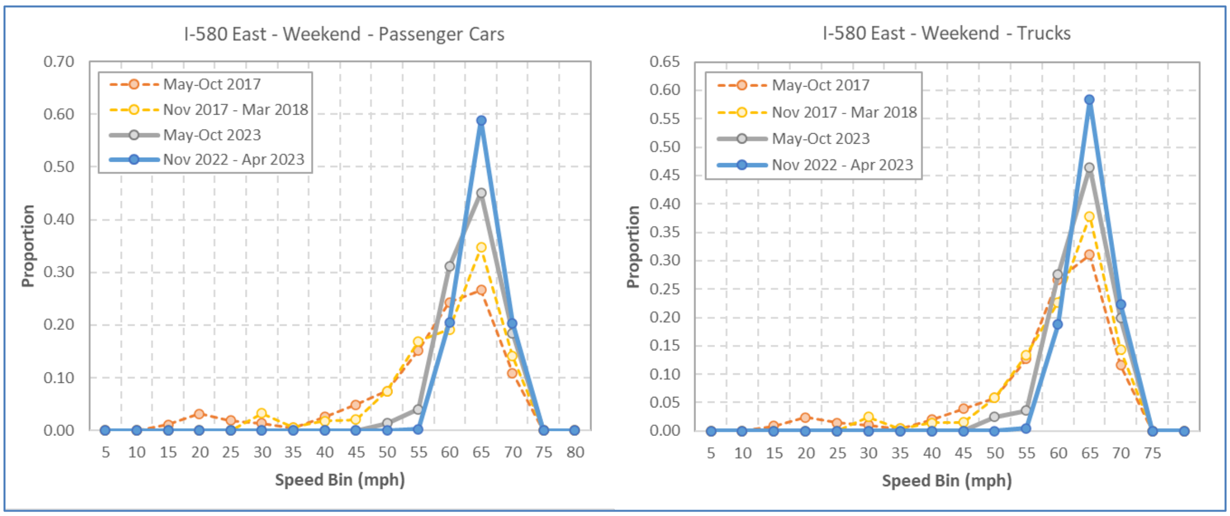

Figure 9-6: Estimated VMT Distributions by Speed – I-580 East, Weekend, All Day

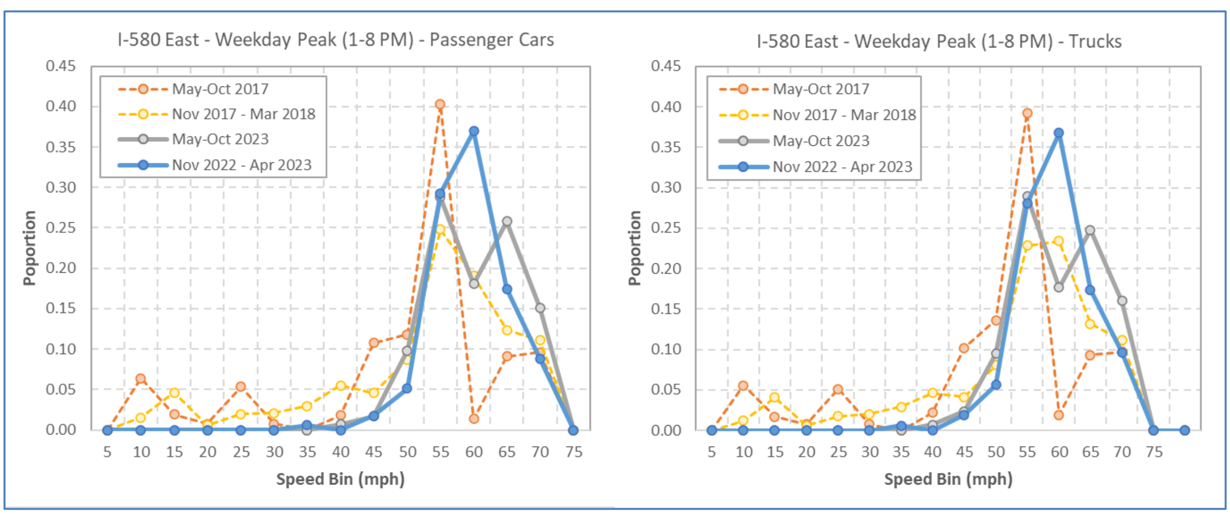

Figure 9-7: Estimated VMT Distributions by Speed – I-580 East, Weekday, Afternoon/Evening

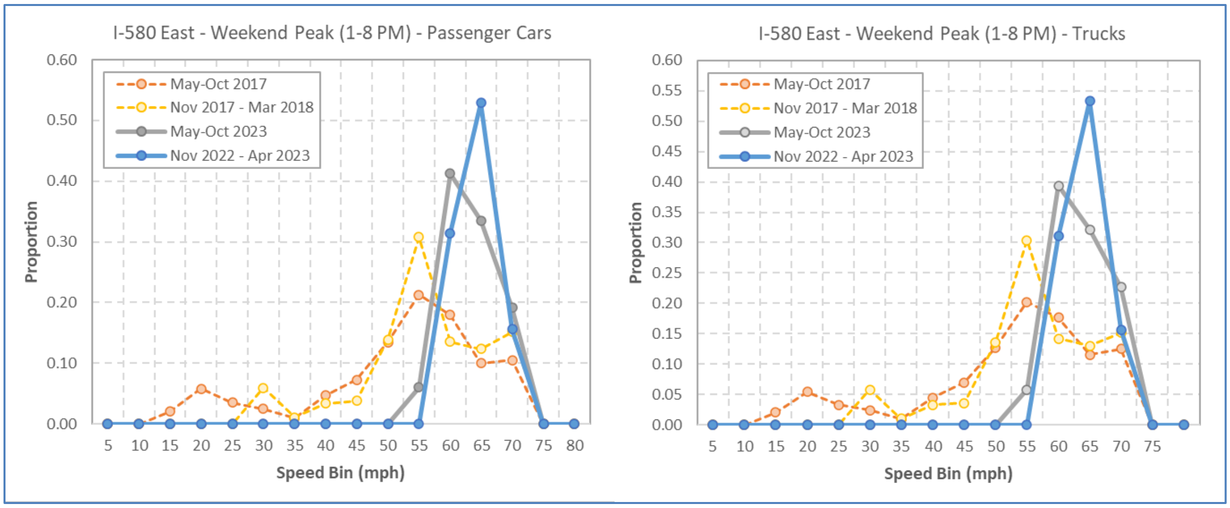

Figure 9-8: Estimated VMT Distributions by Speed – I-580 East, Weekend, Afternoon/Evening

A key particularity of the VMT distributions developed for the eastbound direction is a shift towards a higher proportion of VMT associated with higher speed bins. This is a direct consequence of the elimination of congestion on the approach to the bridge during peak travel periods following the conversion of the shoulder on the lower deck of the bridge into a part-time traffic lane.

9.3.2. I-580 WEST

Figure 9-9 to Figure 9-12 present the various VMT distributions that were estimated for I-580 West. In this case, the period of interest revolves around the AM peak travel period. For the analysis, the period extending from 5 AM to 12 Noon was considered to ensure that congestion that potential impacts on congestion that may remain late in the morning is considered.

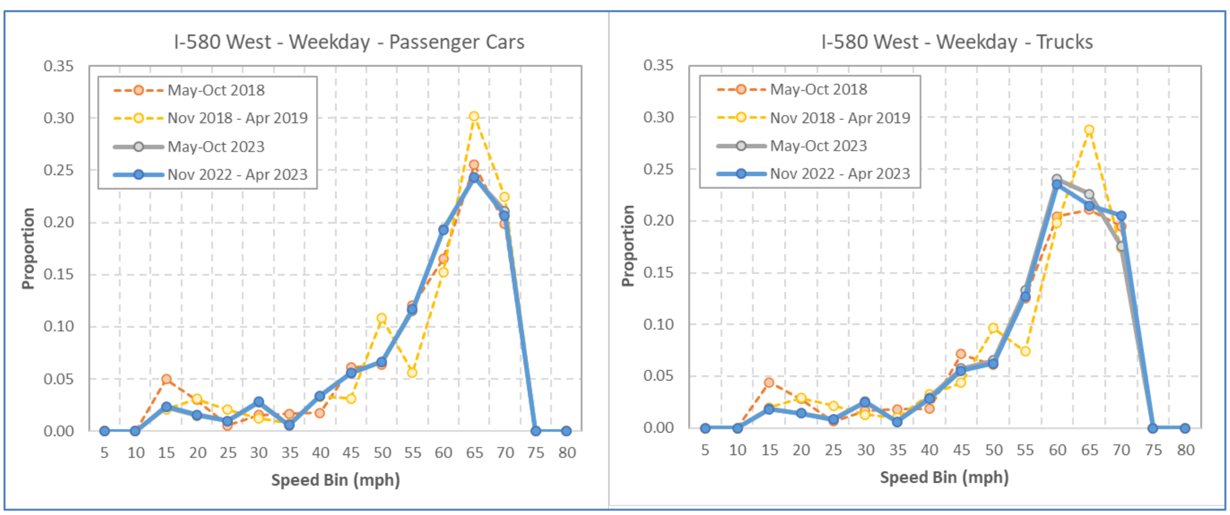

Figure 9-9: Estimated VMT Distributions by Speed – I-580 West, Weekday, All Day

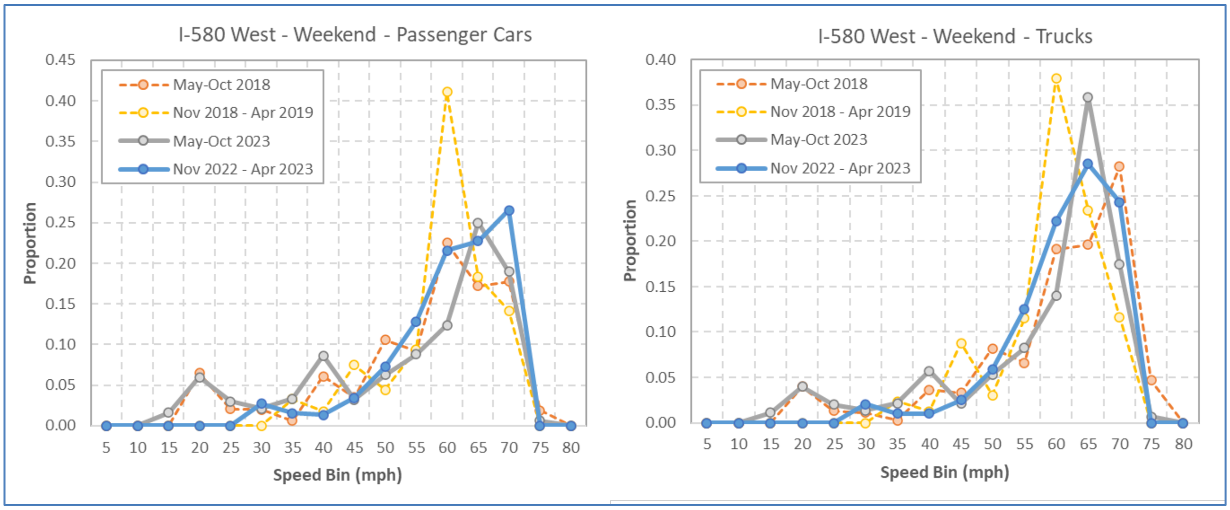

Figure 9-10: Estimated VMT Distributions by Speed – I-580 West, Weekend, All Day

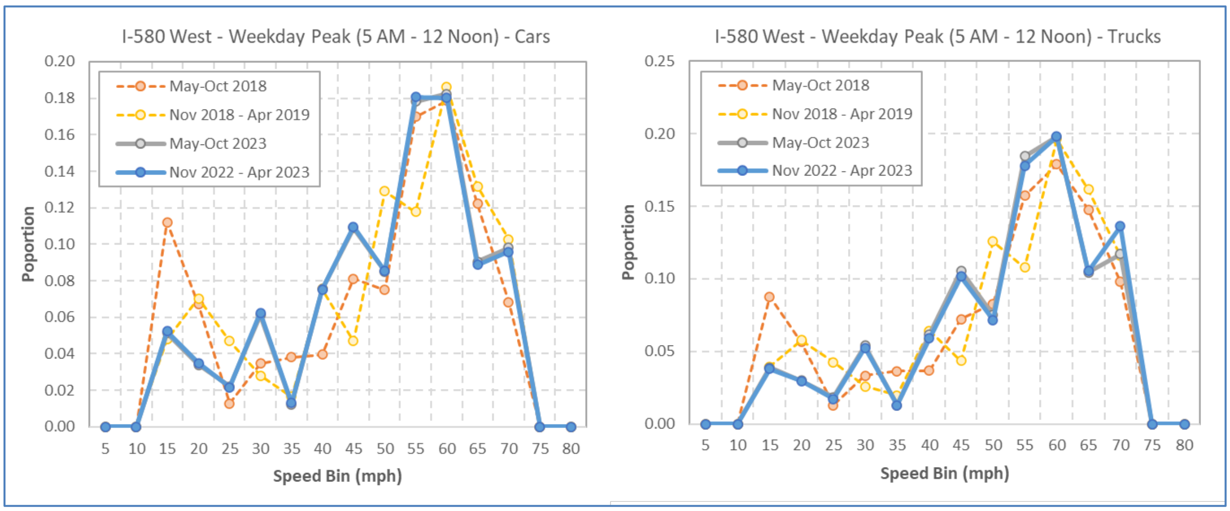

Figure 9-11: Estimated VMT Distributions by Speed – I-580 West, Weekday, AM Peak

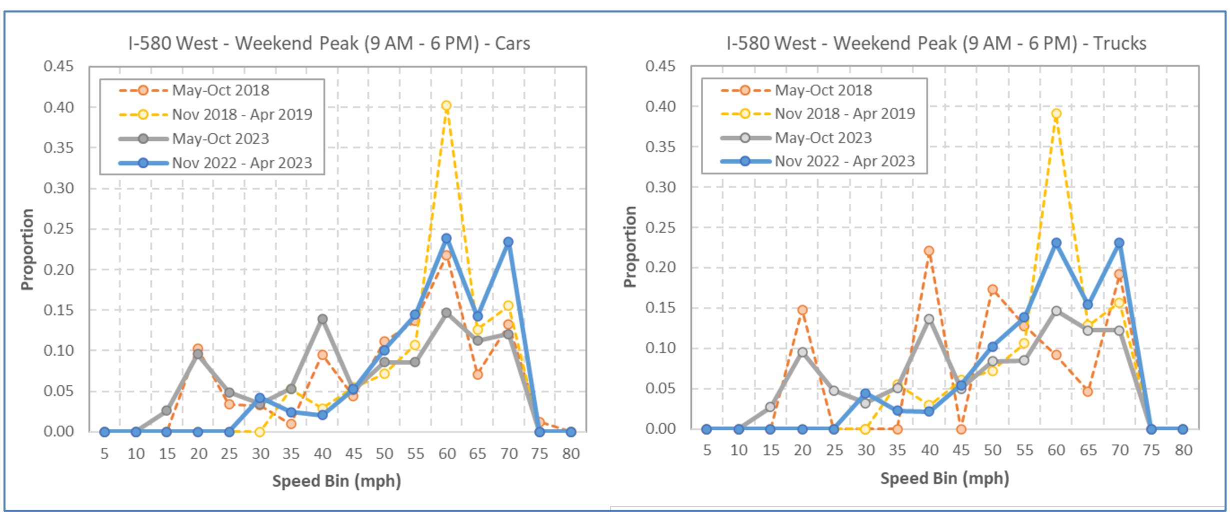

Figure 9-12: Estimated VMT Distributions by Speed – I-580 West, Weekend, Midday Peak

9.4. EMISSION RATES PER VMT

Figure 9-13 and Figure 9-14 provide the 2023 summer and winter running exhaust rates per mile traveled for passenger cars and trucks provided by EMFAC2021 for the Contra Costa and Marin counties. Since EMFAC only reports rates by county, the Contra Costa rates were used to assess emissions from the I-580 West approach and bridge, while the Marin rates were used for the I-580 East approach and bridge.

Each of the tables reports the running exhaust rates:

- CH_4: Methane
- CO: Carbon monoxide
- CO_2: Carbon dioxide
- HC: Hydrocarbons
- NOx: Nitrogen oxides
- PM: Total suspended particulate matter
- PM_{10}: Particulate matter with a diameter of 10 microns or less
- $PM_{2.5}$: Particulate matter with a diameter of 2.5 microns or less
- ROG: Relative organic gases (similar to EPA's volatile organic compound class)
- SOx: Sulfur oxides
- TOG: Total organic gases

Only running exhaust rates are reported as the focus of the evaluation is on emissions from moving vehicles traveling along I-580. In this context, there is no reason to consider start or idle exhaust emissions or evaporative emissions. Running exhaust emissions are provided for the following pollutants:

2023 Running Exhaust Rates - Contra Costa County - Passenger Cars -Summer
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.0240	1.762	744.04	0.1499	0.1440	0.01084	0.00972	0.00895	0.1169	0.0074	0.1627
10	0.0163	1.568	603.52	0.0961	0.1232	0.00689	0.00619	0.00570	0.0751	0.0060	0.1043
15	0.0115	1.406	493.51	0.0646	0.1062	0.00461	0.00414	0.00381	0.0505	0.0049	0.0701
20	0.0086	1.272	410.41	0.0458	0.0940	0.00325	0.00292	0.00269	0.0358	0.0041	0.0497
25	0.0067	1.160	351.03	0.0343	0.0852	0.00242	0.00217	0.00200	0.0268	0.0035	0.0372
30	0.0054	1.065	311.59	0.0271	0.0788	0.00190	0.00171	0.00158	0.0212	0.0031	0.0294
35	0.0046	0.981	288.80	0.0225	0.0741	0.00157	0.00142	0.00131	0.0176	0.0029	0.0244
40	0.0041	0.909	279.37	0.0197	0.0710	0.00137	0.00124	0.00114	0.0154	0.0028	0.0213
45	0.0038	0.847	280.04	0.0181	0.0692	0.00126	0.00114	0.00105	0.0142	0.0028	0.0196
50	0.0037	0.793	287.94	0.0175	0.0686	0.00123	0.00111	0.00102	0.0137	0.0029	0.0189
55	0.0038	0.747	299.51	0.0178	0.0693	0.00125	0.00113	0.00104	0.0139	0.0030	0.0192
60	0.0040	0.709	311.52	0.0190	0.0713	0.00135	0.00122	0.00112	0.0149	0.0031	0.0206
65	0.0044	0.681	321.09	0.0214	0.0747	0.00152	0.00137	0.00127	0.0169	0.0032	0.0232
70	0.0047	0.670	324.08	0.0232	0.0769	0.00165	0.00149	0.00138	0.0183	0.0032	0.0251
75	0.0047	0.670	324.08	0.0232	0.0769	0.00165	0.00149	0.00138	0.0183	0.0032	0.0251
80	0.0047	0.670	324.08	0.0232	0.0769	0.00165	0.00149	0.00138	0.0183	0.0032	0.0251
85	0.0047	0.670	324.08	0.0232	0.0769	0.00165	0.00149	0.00138	0.0183	0.0032	0.0251
90	0.0047	0.670	324.08	0.0232	0.0769	0.00165	0.00149	0.00138	0.0183	0.0032	0.0251

2023 Running Exhaust Rates - Contra Costa County - Trucks - Summer - gr/vehicle-miles
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.2211	2.584	2212.38	0.4252	4.6057	0.0402	0.0398	0.0380	0.2452	0.0208	0.4983
10	0.1507	1.877	1876.64	0.2979	3.5180	0.0327	0.0324	0.0310	0.1790	0.0177	0.3522
15	0.0928	1.324	1541.61	0.1957	2.5295	0.0253	0.0251	0.0240	0.1258	0.0146	0.2340
20	0.0666	1.028	1344.68	0.1433	2.0685	0.0200	0.0198	0.0189	0.0941	0.0127	0.1720
25	0.0524	0.833	1182.99	0.1138	1.7158	0.0165	0.0163	0.0156	0.0759	0.0112	0.1371
30	0.0432	0.692	1070.26	0.0939	1.4412	0.0142	0.0140	0.0134	0.0628	0.0101	0.1133
35	0.0368	0.587	986.28	0.0793	1.2297	0.0127	0.0125	0.0120	0.0528	0.0093	0.0956
40	0.0320	0.513	927.45	0.0685	1.0806	0.0120	0.0119	0.0113	0.0452	0.0088	0.0824
45	0.0284	0.465	892.86	0.0607	0.9936	0.0121	0.0120	0.0114	0.0398	0.0085	0.0729
50	0.0257	0.443	882.33	0.0554	0.9682	0.0129	0.0128	0.0123	0.0366	0.0084	0.0665
55	0.0236	0.447	894.23	0.0525	1.0045	0.0146	0.0145	0.0138	0.0354	0.0085	0.0632
60	0.0237	0.488	926.85	0.0535	1.1009	0.0169	0.0168	0.0160	0.0361	0.0088	0.0643
65	0.0240	0.557	978.60	0.0562	1.2556	0.0198	0.0196	0.0187	0.0388	0.0093	0.0677
70	0.0243	0.628	1001.60	0.0584	1.2785	0.0206	0.0204	0.0195	0.0410	0.0095	0.0705
75	0.0243	0.628	1001.60	0.0585	1.2785	0.0206	0.0204	0.0195	0.0410	0.0095	0.0705
80	0.0243	0.628	1001.60	0.0585	1.2785	0.0206	0.0204	0.0195	0.0411	0.0095	0.0705
85	0.0243	0.629	1001.60	0.0585	1.2785	0.0206	0.0204	0.0195	0.0411	0.0095	0.0705
90	0.0243	0.629	1001.60	0.0585	1.2785	0.0206	0.0204	0.0195	0.0411	0.0095	0.0706

2023 Running Exhaust Rates - Contra Costa County - Passenger Cars - Winter
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.0243	1.750	744.04	0.1513	0.1240	0.0108	0.0097	0.0090	0.1178	0.0074	0.1643
10	0.0165	1.560	603.52	0.0969	0.1060	0.0069	0.0062	0.0057	0.0756	0.0060	0.1053
15	0.0117	1.400	493.51	0.0652	0.0912	0.0046	0.0041	0.0038	0.0508	0.0049	0.0707
20	0.0086	1.267	410.41	0.0462	0.0806	0.0032	0.0029	0.0027	0.0360	0.0041	0.0501
25	0.0067	1.156	351.03	0.0346	0.0731	0.0024	0.0022	0.0020	0.0269	0.0035	0.0375
30	0.0055	1.061	311.59	0.0273	0.0675	0.0019	0.0017	0.0016	0.0213	0.0031	0.0295
35	0.0047	0.978	288.80	0.0226	0.0635	0.0016	0.0014	0.0013	0.0176	0.0029	0.0245
40	0.0041	0.906	279.37	0.0198	0.0608	0.0014	0.0012	0.0011	0.0154	0.0028	0.0214
45	0.0038	0.843	280.04	0.0182	0.0592	0.0013	0.0011	0.0011	0.0142	0.0028	0.0197
50	0.0037	0.789	287.94	0.0175	0.0587	0.0012	0.0011	0.0010	0.0137	0.0029	0.0190
55	0.0038	0.743	299.51	0.0178	0.0593	0.0013	0.0011	0.0010	0.0139	0.0030	0.0193
60	0.0040	0.705	311.52	0.0191	0.0610	0.0013	0.0012	0.0011	0.0149	0.0031	0.0207
65	0.0044	0.675	321.09	0.0215	0.0639	0.0015	0.0014	0.0013	0.0168	0.0032	0.0233
70	0.0047	0.664	324.08	0.0233	0.0658	0.0017	0.0015	0.0014	0.0182	0.0032	0.0252
75	0.0047	0.664	324.08	0.0233	0.0658	0.0017	0.0015	0.0014	0.0182	0.0032	0.0252
80	0.0047	0.664	324.08	0.0233	0.0658	0.0017	0.0015	0.0014	0.0182	0.0032	0.0252
85	0.0047	0.664	324.08	0.0233	0.0658	0.0017	0.0015	0.0014	0.0182	0.0032	0.0252
90	0.0047	0.664	324.08	0.0233	0.0658	0.0017	0.0015	0.0014	0.0182	0.0032	0.0252

2023 Running Exhaust Rates - Contra Costa County - Trucks - Winter
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.2213	2.606	2212.38	0.4274	4.3964	0.0402	0.0398	0.0380	0.2468	0.0208	0.5007
10	0.1509	1.895	1876.64	0.2993	3.3573	0.0327	0.0324	0.0310	0.1801	0.0177	0.3537
15	0.0929	1.339	1541.61	0.1967	2.4128	0.0253	0.0251	0.0240	0.1266	0.0146	0.2351
20	0.0667	1.040	1344.68	0.1440	1.9725	0.0200	0.0198	0.0189	0.0947	0.0127	0.1728
25	0.0524	0.843	1182.99	0.1144	1.6356	0.0165	0.0163	0.0156	0.0763	0.0112	0.1377
30	0.0433	0.701	1070.26	0.0943	1.3733	0.0142	0.0140	0.0134	0.0632	0.0101	0.1138
35	0.0368	0.595	986.28	0.0796	1.1713	0.0127	0.0125	0.0120	0.0530	0.0093	0.0960
40	0.0321	0.520	927.45	0.0688	1.0289	0.0120	0.0119	0.0113	0.0454	0.0088	0.0828
45	0.0285	0.472	892.86	0.0610	0.9457	0.0121	0.0120	0.0114	0.0400	0.0085	0.0732
50	0.0257	0.450	882.33	0.0557	0.9215	0.0129	0.0128	0.0123	0.0368	0.0084	0.0669
55	0.0236	0.455	894.23	0.0528	0.9561	0.0146	0.0145	0.0138	0.0356	0.0085	0.0635
60	0.0238	0.497	926.85	0.0538	1.0482	0.0169	0.0168	0.0160	0.0364	0.0088	0.0646
65	0.0241	0.568	978.60	0.0566	1.1959	0.0198	0.0196	0.0187	0.0391	0.0093	0.0681
70	0.0244	0.640	1001.60	0.0589	1.2176	0.0206	0.0204	0.0195	0.0414	0.0095	0.0710
75	0.0244	0.640	1001.60	0.0589	1.2176	0.0206	0.0204	0.0195	0.0414	0.0095	0.0710
80	0.0244	0.641	1001.60	0.0589	1.2176	0.0206	0.0204	0.0195	0.0414	0.0095	0.0710
85	0.0244	0.641	1001.60	0.0589	1.2176	0.0206	0.0204	0.0195	0.0414	0.0095	0.0710
90	0.0244	0.641	1001.60	0.0590	1.2176	0.0206	0.0204	0.0195	0.0414	0.0095	0.0710

Figure 9-13: 2023 Emission Rates per VMT Returned by EMFAC2021 for Contra Costa County

2023 Running Exhaust Rates - Marin County - Passenger Cars -Summer
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.02446	1.7827	732.29	0.1552	0.1413	0.0110	0.0098	0.0091	0.1220	0.0073	0.1687
10	0.01665	1.5802	594.01	0.0998	0.1207	0.0070	0.0063	0.0058	0.0786	0.0059	0.1085
15	0.01184	1.4099	485.75	0.0672	0.1038	0.0047	0.0042	0.0039	0.0528	0.0049	0.0730
20	0.00883	1.2711	403.90	0.0477	0.0917	0.0033	0.0030	0.0028	0.0374	0.0040	0.0517
25	0.00691	1.1579	345.41	0.0358	0.0832	0.0025	0.0022	0.0021	0.0280	0.0035	0.0388
30	0.00565	1.0617	306.54	0.0283	0.0769	0.0020	0.0018	0.0016	0.0222	0.0031	0.0307
35	0.00483	0.9787	284.07	0.0236	0.0723	0.0016	0.0015	0.0014	0.0184	0.0028	0.0255
40	0.00431	0.9070	274.74	0.0206	0.0693	0.0014	0.0013	0.0012	0.0161	0.0028	0.0223
45	0.00402	0.8451	275.36	0.0190	0.0676	0.0013	0.0012	0.0011	0.0149	0.0028	0.0206
50	0.00390	0.7922	283.10	0.0184	0.0671	0.0013	0.0011	0.0011	0.0144	0.0028	0.0199
55	0.00396	0.7477	294.49	0.0187	0.0679	0.0013	0.0012	0.0011	0.0147	0.0029	0.0202
60	0.00418	0.7120	306.36	0.0200	0.0699	0.0014	0.0013	0.0012	0.0157	0.0031	0.0216
65	0.00461	0.6857	315.89	0.0225	0.0734	0.0016	0.0014	0.0013	0.0177	0.0032	0.0243
70	0.00493	0.6768	318.95	0.0243	0.0756	0.0017	0.0015	0.0014	0.0192	0.0032	0.0263
75	0.00493	0.6768	318.95	0.0243	0.0756	0.0017	0.0015	0.0014	0.0192	0.0032	0.0263
80	0.00493	0.6768	318.95	0.0243	0.0756	0.0017	0.0015	0.0014	0.0192	0.0032	0.0263
85	0.00493	0.6768	318.95	0.0243	0.0756	0.0017	0.0015	0.0014	0.0192	0.0032	0.0263
90	0.00493	0.6768	318.95	0.0243	0.0756	0.0017	0.0015	0.0014	0.0192	0.0032	0.0263

2023 Running Exhaust Rates - Marin County - Trucks -Summer
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.22739	2.9269	2029.12	0.4720	3.4084	0.0444	0.0439	0.0419	0.2814	0.0192	0.5505
10	0.15639	2.1553	1717.17	0.3335	2.7019	0.0359	0.0356	0.0340	0.2075	0.0163	0.3929
15	0.09660	1.5632	1414.24	0.2228	2.0285	0.0278	0.0275	0.0263	0.1490	0.0135	0.2658
20	0.06892	1.2296	1220.02	0.1635	1.6980	0.0218	0.0216	0.0206	0.1124	0.0116	0.1960
25	0.05430	1.0063	1066.72	0.1300	1.4669	0.0179	0.0177	0.0169	0.0906	0.0102	0.1565
30	0.04490	0.8463	956.70	0.1072	1.2907	0.0151	0.0150	0.0143	0.0750	0.0091	0.1293
35	0.03826	0.7303	876.01	0.0906	1.1565	0.0131	0.0130	0.0124	0.0631	0.0083	0.1092
40	0.03336	0.6505	820.19	0.0784	1.0634	0.0119	0.0118	0.0113	0.0542	0.0078	0.0943
45	0.02968	0.6032	787.89	0.0698	1.0110	0.0114	0.0113	0.0108	0.0479	0.0075	0.0837
50	0.02690	0.5874	778.64	0.0641	0.9990	0.0116	0.0115	0.0110	0.0441	0.0074	0.0767
55	0.02485	0.6043	789.56	0.0611	1.0273	0.0126	0.0125	0.0119	0.0427	0.0075	0.0732
60	0.02505	0.6655	818.53	0.0624	1.0936	0.0141	0.0140	0.0134	0.0436	0.0078	0.0746
65	0.02551	0.7679	863.57	0.0661	1.1955	0.0161	0.0160	0.0153	0.0470	0.0083	0.0790
70	0.02590	0.8684	891.98	0.0693	1.2223	0.0171	0.0170	0.0162	0.0499	0.0085	0.0829
75	0.02590	0.8684	891.98	0.0693	1.2223	0.0171	0.0170	0.0162	0.0500	0.0085	0.0829
80	0.02590	0.8686	891.98	0.0693	1.2223	0.0171	0.0170	0.0162	0.0500	0.0085	0.0829
85	0.02590	0.8687	891.98	0.0693	1.2223	0.0171	0.0170	0.0162	0.0500	0.0085	0.0829
90	0.02590	0.8689	891.98	0.0693	1.2223	0.0171	0.0170	0.0162	0.0500	0.0085	0.0829

2023 Running Exhaust Rates - Marin County - Passenger Cars -Winter
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.02472	1.7698	732.29	0.1566	0.1217	0.0110	0.0098	0.0091	0.1227	0.0073	0.1702
10	0.01682	1.5709	594.01	0.1006	0.1039	0.0070	0.0063	0.0058	0.0790	0.0059	0.1094
15	0.01196	1.4028	485.75	0.0677	0.0891	0.0047	0.0042	0.0039	0.0530	0.0049	0.0735
20	0.00892	1.2655	403.90	0.0480	0.0786	0.0033	0.0030	0.0028	0.0375	0.0040	0.0520
25	0.00697	1.1532	345.41	0.0360	0.0712	0.0025	0.0022	0.0021	0.0281	0.0035	0.0390
30	0.00570	1.0575	306.54	0.0284	0.0658	0.0020	0.0018	0.0016	0.0222	0.0031	0.0308
35	0.00487	0.9749	284.07	0.0237	0.0619	0.0016	0.0015	0.0014	0.0185	0.0028	0.0256
40	0.00435	0.9033	274.74	0.0207	0.0593	0.0014	0.0013	0.0012	0.0161	0.0028	0.0224
45	0.00405	0.8414	275.36	0.0190	0.0579	0.0013	0.0012	0.0011	0.0149	0.0028	0.0206
50	0.00393	0.7883	283.10	0.0184	0.0575	0.0013	0.0011	0.0011	0.0144	0.0028	0.0199
55	0.00398	0.7434	294.49	0.0187	0.0581	0.0013	0.0012	0.0011	0.0146	0.0029	0.0203
60	0.00421	0.7068	306.36	0.0200	0.0599	0.0014	0.0013	0.0012	0.0157	0.0031	0.0217
65	0.00464	0.6794	315.89	0.0225	0.0628	0.0016	0.0014	0.0013	0.0177	0.0032	0.0244
70	0.00496	0.6695	318.95	0.0243	0.0647	0.0017	0.0015	0.0014	0.0191	0.0032	0.0264
75	0.00496	0.6695	318.95	0.0243	0.0647	0.0017	0.0015	0.0014	0.0191	0.0032	0.0264
80	0.00496	0.6695	318.95	0.0243	0.0647	0.0017	0.0015	0.0014	0.0191	0.0032	0.0264
85	0.00496	0.6695	318.95	0.0243	0.0647	0.0017	0.0015	0.0014	0.0191	0.0032	0.0264
90	0.00496	0.6695	318.95	0.0243	0.0647	0.0017	0.0015	0.0014	0.0191	0.0032	0.0264

2023 Running Exhaust Rates - Marin County - Trucks - Winter
Grams/Vehicle-Mile

Upper Speed	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
5	0.22782	2.9640	2029.12	0.4757	3.2480	0.0444	0.0439	0.0419	0.2842	0.0192	0.5545
10	0.15669	2.1843	1717.17	0.3360	2.5737	0.0359	0.0356	0.0340	0.2094	0.0163	0.3956
15	0.09682	1.5866	1414.24	0.2245	1.9308	0.0278	0.0275	0.0263	0.1503	0.0135	0.2677
20	0.06909	1.2489	1220.02	0.1648	1.6155	0.0218	0.0216	0.0206	0.1133	0.0116	0.1974
25	0.05443	1.0226	1066.72	0.1309	1.3950	0.0179	0.0177	0.0169	0.0913	0.0102	0.1576
30	0.04501	0.8605	956.70	0.1080	1.2270	0.0151	0.0150	0.0143	0.0756	0.0091	0.1302
35	0.03835	0.7431	876.01	0.0913	1.0989	0.0131	0.0130	0.0124	0.0636	0.0083	0.1099
40	0.03345	0.6625	820.19	0.0790	1.0101	0.0119	0.0118	0.0113	0.0546	0.0078	0.0950
45	0.02976	0.6149	787.89	0.0703	0.9600	0.0114	0.0113	0.0108	0.0483	0.0075	0.0843
50	0.02698	0.5995	778.64	0.0646	0.9485	0.0116	0.0115	0.0110	0.0445	0.0074	0.0773
55	0.02493	0.6173	789.56	0.0617	0.9754	0.0126	0.0125	0.0119	0.0431	0.0075	0.0738
60	0.02514	0.6803	818.53	0.0630	1.0386	0.0141	0.0140	0.0134	0.0441	0.0078	0.0753
65	0.02561	0.7854	863.57	0.0668	1.1358	0.0161	0.0160	0.0153	0.0475	0.0083	0.0798
70	0.02601	0.8884	891.98	0.0701	1.1612	0.0171	0.0170	0.0162	0.0505	0.0085	0.0837
75	0.02601	0.8885	891.98	0.0701	1.1612	0.0171	0.0170	0.0162	0.0505	0.0085	0.0837
80	0.02601	0.8886	891.98	0.0701	1.1612	0.0171	0.0170	0.0162	0.0506	0.0085	0.0837
85	0.02601	0.8888	891.98	0.0701	1.1612	0.0171	0.0170	0.0162	0.0506	0.0085	0.0838
90	0.02601	0.8890	891.98	0.0701	1.1612	0.0171	0.0170	0.0162	0.0506	0.0085	0.0838

Figure 9-14: 2023 Emission Rates per VMT Returned by EMFAC2021 for Marin County

In each diagram, the emission rates are color-coded using a red-to-green gradient to highlight increasing or decreasing rates as speed goes up. The area shown in green, typically between 40 to 60 mph represents the lowest emission rates per mile traveled. Depending on the pollutant, the lowest exhaust rates are either reported for the 40-45 mph (45 mph) or 45-50 mph (50 mph) speed bins.

2023 rates are further used for the emission analysis to reflect the current fleet of vehicles. Comparisons are not made across the years, using for instance 2017 or 2018 rates for the before conditions and 2023 rates for the after conditions, as this would allow changes in vehicle technology to influence the results. As emission rates have reduced over time, this would lead to include in the analyses emission reductions not related to the bridge modifications.

Finally, the rates shown in each figure were obtained using the reference average daily temperature and humidity reported in Table 9-1. These were determined based on average weather data from San Rafael and Richmond.

Table 9-1: Reference Temperature and Humidity Data

Summer Temperature/Humidity Set	Winter Temperature/Humidity Set
56 F, 70 %	47 F, 75 %
69 F, 70 %	58 F, 75 %
77 F, 70 %	64 F, 75 %
68 F, 70 %	57 F, 75 %

9.5. IMPACTS ON EMISSIONS ALONG CORRIDOR

Figure 9-15 and Figure 9-16 present changes in average emission rates per vehicle mile traveled for I-580 East and I-58- west, while Figure 9-17 and Figure 9-18 further present changes in total vehicle emissions in each direction. Within each figure, impact results are presented for an average weekday and average weekend day for both a summer and winter assessment. In each case, impacts are further presented based on an all-day analysis and an analysis focusing on a period of peak traffic of directional interest. For I-580 East, the period of interest is centered around when the lower deck shoulder is open to traffic. For I-580 West, it is the AM peak period on weekdays and the midday peak travel period on weekends.

WEEKDAYS - I-580 East

Weekday - All Day — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0063	0.777	346.7	0.0271	0.1351	0.0025	0.0023	0.0021	0.0209	0.0034	0.0298
May-Oct 2023	0.0056	0.715	337.0	0.0236	0.1315	0.0022	0.0021	0.0020	0.0183	0.0034	0.0260
	-11.1%	-7.9%	-2.8%	-12.6%	-2.7%	-9.0%	-8.7%	-8.6%	-12.4%	-2.8%	-12.6%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0061	0.749	344.1	0.0258	0.1219	0.0024	0.0022	0.0021	0.0199	0.0034	0.0284
Nov 2022 - Apr 2023	0.0056	0.709	337.0	0.0234	0.1188	0.0022	0.0021	0.0019	0.0181	0.0034	0.0258
	-7.8%	-5.2%	-2.1%	-9.2%	-2.6%	-7.1%	-6.9%	-6.8%	-9.1%	-2.1%	-9.2%

Weekday - Afternoon/Peak (1 PM - 8 PM) — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0066	0.845	346.2	0.0295	0.1231	0.0024	0.0023	0.0021	0.0228	0.0034	0.0324
May-Oct 2023	0.0052	0.721	327.0	0.0226	0.1159	0.0020	0.0019	0.0017	0.0176	0.0033	0.0248
	-21.2%	-14.7%	-5.5%	-23.3%	-5.9%	-18.1%	-17.7%	-17.5%	-23.0%	-5.5%	-23.4%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0061	0.803	338.5	0.0269	0.1085	0.0023	0.0021	0.0020	0.0208	0.0034	0.0295
Nov 2022 - Apr 2023	0.0052	0.717	326.4	0.0223	0.1030	0.0020	0.0018	0.0017	0.0172	0.0033	0.0245
	-15.3%	-10.8%	-3.6%	-17.1%	-5.1%	-13.6%	-13.3%	-13.2%	-17.0%	-3.6%	-17.2%

WEEKENDS - I-580 East

Weekend - All Day — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0054	0.763	328.0	0.0242	0.1078	0.0020	0.0019	0.0017	0.0188	0.0033	0.0264
May-Oct 2023	0.0052	0.698	330.1	0.0233	0.1085	0.0020	0.0018	0.0017	0.0182	0.0033	0.0255
	-3.7%	-8.5%	0.6%	-3.6%	0.7%	-1.2%	-1.0%	-1.0%	-3.4%	0.6%	-3.7%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0052	0.724	323.9	0.0229	0.0947	0.0019	0.0018	0.0017	0.0178	0.0032	0.0251
Nov 2022 - Apr 2023	0.0053	0.687	332.3	0.0238	0.0973	0.0020	0.0019	0.0018	0.0185	0.0033	0.0260
	2.5%	-5.1%	2.6%	3.8%	2.8%	5.3%	5.3%	5.3%	4.0%	2.6%	3.8%

Weekend - Afternoon Peak (1 PM - 8 PM)

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0055	0.814	324.8	0.0250	0.1020	0.0020	0.0018	0.0017	0.0194	0.0032	0.0273
May-Oct 2023	0.0050	0.700	325.9	0.0228	0.1015	0.0019	0.0017	0.0016	0.0178	0.0033	0.0248
	-8.6%	-14.0%	0.3%	-8.8%	-0.5%	-5.3%	-5.0%	-4.9%	-8.5%	0.3%	-8.9%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0050	0.755	314.1	0.0221	0.0865	0.0018	0.0016	0.0015	0.0172	0.0031	0.0242
Nov 2022 - Apr 2023	0.0051	0.689	327.7	0.0232	0.0899	0.0019	0.0018	0.0016	0.0180	0.0033	0.0253
	2.9%	-8.7%	4.3%	4.7%	3.9%	7.3%	7.5%	7.5%	5.1%	4.3%	4.6%

Figure 9-15: Impacts on Vehicle Emission per Mile Traveled – I-580 East

WEEKDAYS - I-580 West

Weekday - All Day — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0058	0.771	351.3	0.0253	0.1253	0.0023	0.0022	0.0020	0.0196	0.0035	0.0278
May-Oct 2023	0.0055	0.751	344.2	0.0237	0.1218	0.0022	0.0021	0.0019	0.0184	0.0034	0.0260
	-5.6%	-2.6%	-2.0%	-6.2%	-2.7%	-5.0%	-4.9%	-4.8%	-6.1%	-2.0%	-6.2%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0056	0.749	347.3	0.0245	0.1107	0.0023	0.0021	0.0020	0.0189	0.0035	0.0268
Nov 2022 - Apr 2023	0.0055	0.747	343.9	0.0239	0.1087	0.0022	0.0021	0.0019	0.0184	0.0034	0.0261
	-2.2%	-0.2%	-1.0%	-2.6%	-1.7%	-2.7%	-2.7%	-2.7%	-2.6%	-1.0%	-2.6%

Weekday - AM Peak (5 AM - 12 Noon) — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0066	0.866	364.3	0.0290	0.1345	0.0026	0.0024	0.0022	0.0223	0.0036	0.0318
May-Oct 2023	0.0059	0.824	346.7	0.0253	0.1264	0.0023	0.0022	0.0020	0.0195	0.0034	0.0278
	-11.3%	-4.9%	-4.8%	-12.7%	-6.0%	-10.8%	-10.7%	-10.6%	-12.6%	-4.8%	-12.7%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0062	0.831	353.7	0.0267	0.1169	0.0024	0.0023	0.0021	0.0205	0.0035	0.0293
Nov 2022 - Apr 2023	0.0059	0.822	346.8	0.0255	0.1135	0.0023	0.0022	0.0020	0.0196	0.0035	0.0280
	-4.0%	-1.1%	-2.0%	-4.6%	-3.0%	-4.5%	-4.5%	-4.5%	-4.6%	-1.9%	-4.6%

WEEKENDS - I-580 West

Weekend - All Day — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0049	0.780	327.4	0.0230	0.0937	0.0019	0.0017	0.0016	0.0179	0.0033	0.0250
May-Oct 2023	0.0051	0.795	330.0	0.0239	0.0946	0.0019	0.0017	0.0016	0.0186	0.0033	0.0260
	3.1%	1.9%	0.8%	3.9%	1.0%	3.3%	3.2%	3.2%	3.9%	0.8%	3.9%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0045	0.722	319.5	0.0206	0.0790	0.0017	0.0015	0.0014	0.0161	0.0032	0.0225
Nov 2022 - Apr 2023	0.0046	0.717	322.4	0.0213	0.0800	0.0017	0.0016	0.0015	0.0166	0.0032	0.0232
	2.5%	-0.7%	0.9%	3.3%	1.2%	3.4%	3.4%	3.4%	3.4%	0.9%	3.3%

Weekend - MiddayPeak (9 AM - 6 PM) — grams/vehicle mile

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.0050	0.831	324.8	0.0238	0.0885	0.0018	0.0017	0.0015	0.0186	0.0032	0.0259
May-Oct 2023	0.0052	0.857	327.2	0.0248	0.0897	0.0019	0.0017	0.0016	0.0194	0.0033	0.0270
	3.8%	3.1%	0.8%	4.4%	1.4%	3.9%	3.9%	3.8%	4.4%	0.8%	4.4%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.0044	0.732	314.9	0.0204	0.0736	0.0016	0.0014	0.0013	0.0159	0.0031	0.0222
Nov 2022 - Apr 2023	0.0045	0.736	316.3	0.0209	0.0743	0.0016	0.0015	0.0014	0.0163	0.0032	0.0227
	1.9%	0.5%	0.4%	2.3%	0.9%	2.3%	2.2%	2.2%	2.3%	0.4%	2.3%

Figure 9-16: Impacts on Vehicle Emission per Mile Traveled – I-580 West

WEEKDAYS - I-580 East

Weekday - All Day — kilograms

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	1.99	246	109,648	8.56	43	0.78	0.72	0.68	6.60	1.09	9.42
May-Oct 2023	1.64	210	99,060	6.95	39	0.66	0.61	0.58	5.38	0.99	7.65
	-17.4%	-14.4%	-9.7%	-18.8%	-9.6%	-15.4%	-15.1%	-15.0%	-18.6%	-9.7%	-18.8%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	1.65	204	93,915	7.04	33	0.65	0.61	0.57	5.43	0.93	7.75
Nov 2022 - Apr 2023	1.68	214	101,777	7.08	36	0.67	0.63	0.59	5.46	1.01	7.79
	2.0%	4.9%	8.4%	0.5%	7.8%	2.8%	3.0%	3.1%	0.6%	8.4%	0.5%

Weekday - Afternoon/Peak (1 PM - 8 PM) — kilograms

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	1.04	133	54,333	4.64	19	0.38	0.36	0.33	3.58	0.54	5.09
May-Oct 2023	0.82	112	51,004	3.53	18	0.31	0.29	0.27	2.74	0.51	3.87
	-21.7%	-15.2%	-6.1%	-23.8%	-6.4%	-18.6%	-18.2%	-18.0%	-23.5%	-6.1%	-23.9%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.82	108	45,333	3.60	15	0.31	0.28	0.26	2.78	0.45	3.96
Nov 2022 - Apr 2023	0.80	110	49,991	3.41	16	0.30	0.28	0.26	2.64	0.50	3.75
	-3.2%	2.0%	10.3%	-5.2%	8.5%	-1.2%	-0.9%	-0.7%	-5.1%	10.3%	-5.3%

WEEKENDS - I-580 East

Weekend - All Day — kilograms

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	1.75	247	106,155	7.82	35	0.65	0.60	0.56	6.08	1.06	8.56
May-Oct 2023	1.63	219	103,672	7.31	34	0.62	0.58	0.54	5.70	1.03	8.00
	-6.6%	-11.2%	-2.3%	-6.5%	-2.3%	-4.2%	-4.0%	-3.9%	-6.3%	-2.4%	-6.6%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	1.48	207	92,835	6.57	27	0.55	0.51	0.48	5.10	0.93	7.18
Nov 2022 - Apr 2023	1.54	199	96,501	6.91	28	0.59	0.55	0.51	5.37	0.96	7.55
	3.9%	-3.9%	3.9%	5.2%	4.2%	6.6%	6.7%	6.7%	5.4%	3.9%	5.1%

Weekend - Afternoon Peak (1 PM - 8 PM) — kilograms

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	0.96	142	56,841	4.37	18	0.35	0.32	0.30	3.40	0.57	4.77
May-Oct 2023	0.86	120	55,956	3.91	17	0.32	0.30	0.28	3.05	0.56	4.27
	-10.4%	-15.7%	-1.6%	-10.5%	-2.4%	-7.1%	-6.8%	-6.6%	-10.2%	-1.6%	-10.7%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.76	115	48,049	3.39	13	0.27	0.25	0.23	2.63	0.48	3.70
Nov 2022 - Apr 2023	0.79	106	50,378	3.56	14	0.29	0.27	0.25	2.77	0.50	3.89
	3.4%	-8.3%	4.8%	5.3%	4.5%	7.9%	8.0%	8.1%	5.6%	4.8%	5.1%

Figure 9-17: Impacts on Total Vehicle Emissions – I-580 East

WEEKDAYS - I-580 West

Weekday - All Day (kilograms)

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	2.00	266	121,418	8.75	43	0.81	0.75	0.70	6.76	1.21	9.59
May-Oct 2023	1.75	240	109,972	7.59	39	0.71	0.66	0.62	5.87	1.09	8.32
	-12.8%	-10.0%	-9.4%	-13.3%	-10.1%	-12.2%	-12.1%	-12.0%	-13.2%	-9.4%	-13.3%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	1.85	246	114,137	8.04	36	0.75	0.70	0.65	6.20	1.14	8.82
Nov 2022 - Apr 2023	1.60	217	99,806	6.92	32	0.65	0.60	0.56	5.34	0.99	7.59
	-13.6%	-11.9%	-12.6%	-14.0%	-13.2%	-14.0%	-14.0%	-14.0%	-14.0%	-12.6%	-14.0%

Weekday - AM Peak (5 AM - 12 Noon) (kilograms)

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	1.02	133	56,094	4.47	21	0.40	0.37	0.35	3.44	0.56	4.90
May-Oct 2023	0.86	121	50,735	3.71	18	0.34	0.31	0.29	2.85	0.50	4.07
	-15.7%	-9.6%	-9.6%	-17.0%	-10.7%	-15.3%	-15.1%	-15.0%	-16.9%	-9.5%	-17.0%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.90	120	51,225	3.87	17	0.35	0.33	0.30	2.97	0.51	4.25
Nov 2022 - Apr 2023	0.79	109	46,211	3.40	15	0.31	0.29	0.27	2.61	0.46	3.73
	-11.7%	-9.0%	-9.8%	-12.2%	-10.7%	-12.2%	-12.2%	-12.1%	-12.2%	-9.8%	-12.2%

WEEKENDS - I-580 West

Weekend - All Day (kilograms)

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	1.61	254	106,759	7.50	31	0.60	0.55	0.51	5.85	1.07	8.17
May-Oct 2023	1.63	255	105,852	7.67	30	0.61	0.56	0.52	5.98	1.06	8.34
	1.4%	0.3%	-0.8%	2.2%	-0.7%	1.6%	1.6%	1.5%	2.2%	-0.8%	2.2%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	1.36	218	96,251	6.22	24	0.50	0.46	0.43	4.84	0.96	6.77
Nov 2022 - Apr 2023	1.26	195	87,706	5.80	22	0.47	0.43	0.40	4.52	0.88	6.31
	-7.5%	-10.4%	-8.9%	-6.7%	-8.6%	-6.7%	-6.7%	-6.7%	-6.7%	-8.9%	-6.8%

Weekend - MiddayPeak (9 AM - 6 PM) (kilograms)

SUMMER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
May-Oct 2017	1.01	168	65,677	4.81	18	0.37	0.33	0.31	3.75	0.66	5.23
May-Oct 2023	1.07	176	67,083	5.09	18	0.39	0.35	0.33	3.97	0.67	5.54
	5.2%	4.5%	2.1%	5.8%	2.8%	5.4%	5.3%	5.3%	5.8%	2.1%	5.9%

WINTER	CH4	CO	CO2	HC	NOx	PM	PM10	PM2_5	ROG	SOx	TOG
Nov 2017 - Apr 2018	0.83	137	58,933	3.83	14	0.30	0.27	0.25	2.98	0.59	4.16
Nov 2022 - Apr 2023	0.79	130	55,704	3.68	13	0.29	0.26	0.24	2.87	0.56	4.00
	-4.1%	-5.5%	-5.5%	-3.7%	-5.0%	-3.8%	-3.8%	-3.8%	-3.7%	-5.5%	-3.7%

Figure 9-18: Impacts on Total Vehicle Emissions – I-580 West

The key distinction between the two sets of results is that changes in emission rates reflect more closely changes in travel behavior, such as traffic moving at higher or lower speeds or spending less time in bottlenecks, while changes in total emissions can be influenced by some degree by an increase or decrease in traffic volume.

Based on the calculated results, the following observations can be made regarding the impacts associated with the conversion of the eastbound shoulder into a part-time traffic lane:

- On weekdays, the shoulder conversion has contributed to a significant reduction in vehicle emissions. The analysis results show that the elimination of the congestion that used to affect traffic on I-580 East in Marin County has led to reductions in specific pollutant emission rates per mile varying between 2.1% and 12.6% during summer, and 3.6% and 23.4% during winter. Reductions are also observed for the total emissions, except for the winter periods. This is largely due to the estimated VMT for the winter assessment being 10.6% higher for the all-day evaluation and 14.4% for AM peak evaluation in the after period than in the before period.

- On weekends, the analysis shows mixed results, with notable reductions in emission rates for most pollutants during summer but increases in winter. In this case, some of the increases in emissions could be attributed to the higher traffic speeds resulting from the bridge modifications. While the portion of emissions due to travel at speeds lower than 40 mph has largely been eliminated, the removal of the congestion on the approach to the bridge is also allowing traffic to travel at speeds greater than the optimal speeds for emissions (50-55 mph). In this case, the tradeoff between the benefits of removing the congestion and the negative aspect associated with allowing traffic to travel at speeds greater than 55 mph leads to overall increases in emissions. In this case, total emissions appear to mirror observed changes in rate, with different magnitudes. In this case, it should be noted that the estimated after VMT for the after periods is 0.5% to 1.3% higher than the before period.

The following observations can further be made regarding the addition of the multi-use path on the upper deck of the bridge:

- The addition of the path has not contributed to increasing vehicle emissions on weekdays. Based on observed changes in traffic behavior on the approach and the bridge, the analysis indicates potential reductions in emission rates per mile traveler varying between 0.2% and 6.2% during summer and 1.1% and 12.7% during winter. These improvements come primarily from a reduction in the proportion of vehicles traveling above 60 mph.
- On weekends, the analysis shows generally negative impacts, with increases in emissions per mile traveled ranging between 0.4% and 4.4%. These increases are found to be the results of a combination of the following factors: (a) a slight increase in the proportion of vehicles estimated to traveling at speeds above 60 mph, leading to some increases in emission rates; (b) the slight reduction in bridge capacity discussed in Section 8.3.2, causing an increase in congestion and emissions; and (c) the historically high traffic demand observed in 2023 documented in Section 8.3.3, also causing an increase in congestion. The last item, in particular, is important to consider as it is the result of changes in traffic demand and not a consequence of the bridge modifications. Considering that lower emission rates are calculated during weekdays post-modifications, it is possible that observed changes in traffic demand heavily influence the weekend analysis and that a portion of calculated increases in emissions would have occurred regardless of the modifications made.
- Compared to emission rates, total emissions for the weekend evaluations show more reductions. This is in great part due to the estimated VMTs for the after periods being generally lower than for the before period, but up to slightly over 10% in some cases.

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10. CYCLIST/PEDESTRIAN SAFETY

This section reviews reports of incidents that have occurred on the new bike/pedestrian bridge path to determine its safety for cyclists and pedestrians. The following specific elements are discussed:

- Incidents logged into the SWITRS database.
- Analysis of video recordings of Sir Francis Drake's overcrossing activities
- Incidents reported on the Street Story online platform.
- Comments from a user survey
- Summary of observations.

10.1. SWITRS BICYCLE/PEDESTRIAN INCIDENT DATA

A review of bicycle and pedestrian incidents contained in the SWITRS database indicates that no incident involving cyclists or pedestrians has been logged into the database related to the new bridge path or modified Sir Francis Drake's overcrossing path between November 2019 and December 2023.

10.2. REVIEW OF SIR FRANCIS DRAKE OVERCROSSING VIDEO RECORDINGS

Summaries of key observations from the two video recordings that were executed for the Sir Francis Drake overcrossing path are provided below.

10.2.1. CALTRANS MAY 2021 MIOVISION RECORDING

As shown in Figure 10-1, the videos of the overcrossing path captured by Caltrans on May 15-18, 2021, using a Miovision camera provided a partial view of the overcrossing path. Investigations were made to see if safety-related events, such as cyclists swerving or stopping when encountering cyclists traveling in the opposite direction, could be identified. Unfortunately, this proved impossible as the low resolution did not allow for determining what was happening on the narrower portion of the path on the overcrossing.

Figure 10-1: Snapshot of May 2021 Sir Francis Drake Overcrossing Video

10.2.2. CALTRANS CCTV RECORDINGS

The videos captured by Caltrans using a high-resolution CCTV camera located east of the overcrossing on I-580 provided much clearer views of the overcrossing than the Miovision recordings, As shown in Figure 10-2. This included a view of the 90-degree turn along the path at the bottom of the overcrossing.

Figure 10-2: Snapshot of February 2022 Sir Francis Drake Overcrossing Video

Table 10-1 summarizes the safety-related observations that were made across the CCTV recordings. Over the four recordings made between February 2022 and October 2023, 1,727 individuals were observed using the path across nine weekend days and 324 across six weekdays, for a total of 2,065 individuals. Of these, 1,186 were observed going towards Andersen Drive (up) and 879 towards Francisco Drive (down).

Interactions between these two groups on the overcrossing section were the focus of the assessment. Across all observations, there were only 114 instances in which cyclists traveling up crossed others going down. Please note that interactions between a cyclist going in one direction and a group of cyclists going in the opposite direction were counted as a single event.

Table 10-1: Summary of Safety Analysis of CCTV Video Recordings

Recording	Days	Path Users	Going Up	Going Down	Crossings[1]	Issues	Remark
Weekdays							
February 19-21, 2022	0		--	--	--	--	
June 23-24, 2022	2	132	85	47	4	0	
December 19-20, 2022	2	64	38	26	1	0	
October 16-17, 2023	2	131	81	50	3	0	
Weekend/Holidays							
February 19-21, 2022	3	497	270	227	33	1	Downhill cyclists slowed significantly
June 25-26, 2022	2	403	243	160	34	0	
December 17-18, 2022	2	346	175	171	15	0	
October 14-15, 2023	2	492	294	198	24	0	
All Observations							
Weekdays	6	327	204	123	8	0	
Weekends	9	1,738	982	756	106	1	
TOTAL	15	2,065	1,186	879	114	1	

NOTE 1: Crossings between one cyclist and a group of cyclists going in opposite directions counted as one event

The following is a summary of key observations regarding observed interactions:

- No crashes were observed.
- In all encounters, cyclists going down generally traveled at much higher speeds than those going up. This results in downhill cyclists being the most likely to adjust their behavior when encountering opposite cyclists.
- Only a few cyclists going downhill were observed to reduce their speed when encountering opposite traffic. In most cases, only a small reduction is observed. Only one cyclist was observed to significantly slow down.
- Overall, cyclists do not appear to be incommoded by the slightly narrower bike lanes and proximity of the barrier on the overcrossing.
- At the bottom of the overcrossing, cyclists going downhill tend to cut across the opposing bike lane to negotiate the 90-degree curve, as shown in Figure 10-3. This is a general behavior. This may create a potential for head-on collisions if the view around the curve is obstructed or if riders are not paying full attention to opposing traffic.

Figure 10-3: Riders Cutting Across Opposing Lanes at Bottom of Overcrossing

10.2.3. NDS VIDEO RECORDINGS

While the videos recorded by NDS were primarily collected for counting purposes, they allowed observing the behavior of cyclists around the intersection between Sir Francis Drake Boulevard and Andersen Drive. Below is a summary of various observations:

- Some cyclists crossing Sir Francis Drake Boulevard toward Andersen Drive or the overcrossing path stop in the middle of the intersection to wait for a gap in the oncoming freeway traffic to complete their crossing. This is a small minority, as most cyclists correctly wait at the left-turn bay stop line for a gap in the traffic oncoming traffic.
- Many cyclists traveling from the overcrossing and continuing onto Sir Francis Drake Boulevard cross Andersen Drive upstream of the delineated path at the intersection (Figure 10-4), likely because this allows them to cross Andersen Drive at a higher speed.

- Some cyclists cross Sir Francis Drake Boulevard on the ramp side of the intersection (Figure 10-5). Often, these are individuals who appear undecided about where they want to go, such as first-time riders to the location.

Figure 10-4: Cyclists Crossing Andersen Drive Upstream of Intersection

Figure 10-5: Cyclist Crossing Sir Francis Drake Boulevard Downstream of Intersection

10.3. STREET STORY REPORTS

Figure 10-6 shows a compilation of crash/near-miss incidents and safety-related reports logged by travelers on the Street Story online platform between October 2018, when the platform came online, and November 2023. The two maps indicate the following:

- Only one incident was reported on the bridge, in October 2023. This is for an incident with a pedestrian. While no detail is provided, it can likely be assumed that this is for an interaction between a pedestrian and a cyclist.
- One hazard report was logged for the bridge path in November 2019, shortly after its opening, highlighting the need to improve access to the bridge from Marin County.
- One hazard report was logged for the Sir Francis Drake overcrossing path in December 2019, before the modifications. This report indicated the hazardous nature of the I-580 shoulder path and the need to provide a two-way path on the overcrossing.

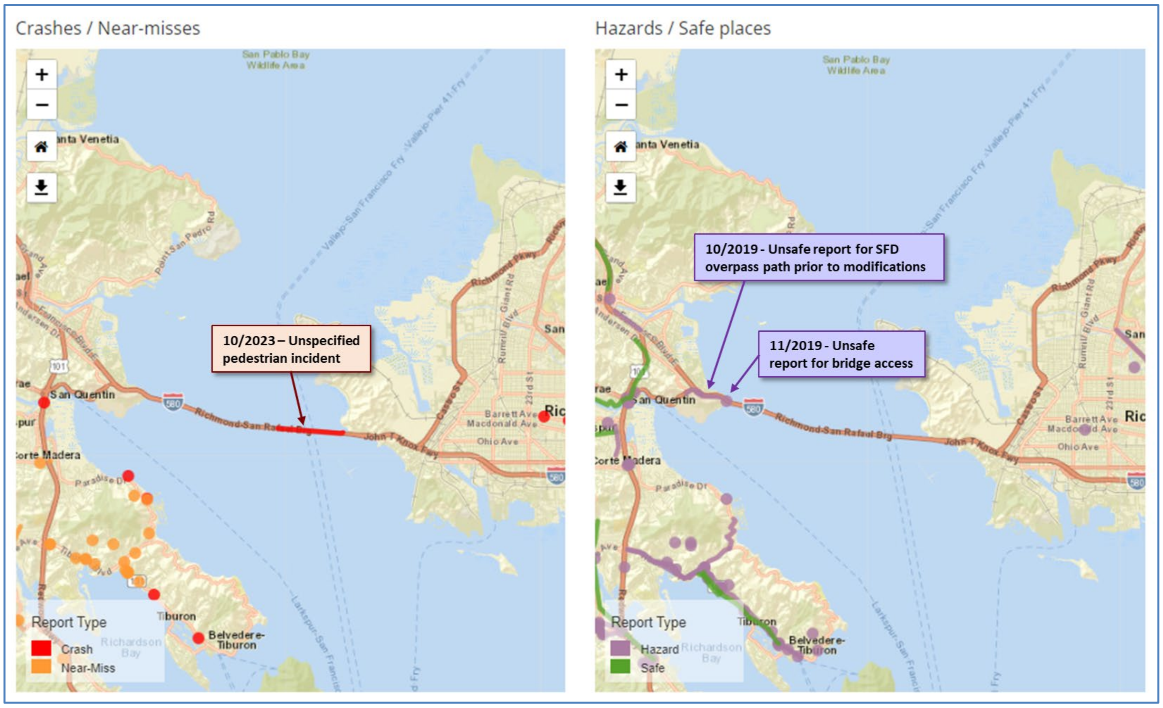

Figure 10-6: Street Story Reports for Area Surrounding Bridge

10.4. COMMENTS FROM USER SURVEY

Several respondents made safety-related comments on the bridge path during the user survey that was conducted in the summer of 2021.

Below is a summary of the key comments made regarding the bridge path:

- The bridge path needs to be swept regularly to remove glass fragments and other debris that tend to accumulate on it.
- Many were concerned about being hit by objects or incommoded by sand flung from the adjacent traffic lane and suggested that a higher barrier could help prevent such occurrences.
- A few path users commented on being blinded by lights from cars when traveling eastbound due to the low height of the barrier.
- The lane separating the two travel directions is not placed in the center of the path, resulting in a narrower eastbound lane than the westbound lane.
- Some incidents could result from cyclists traveling at high speed and sharing a narrow path with slow-moving cyclists and pedestrians.
- Noise from traffic on the adjacent lanes makes it difficult to hear other cyclists or what might be happening around.

Comments made regarding paths leading to the bridge by cyclists who respond:

- Several respondents indicated the need for improving access to the bridge, particularly on the Marin County side. Many expressed the need for fully separated bikeways going from the bridge to downtown San Rafael, as well as to Larkspur along Sir Francis Drake Boulevard.
- One rider indicated that the line of sight at the Stenmark Drive crossing might be inadequate for a safe crossing by cyclists.
- Some respondents indicated concerns that the I-580 shoulder path is only delimited by a painted line and soft bollards, as this would not stop vehicles traveling at relatively high speeds from hitting cyclists using the shoulder path.
- Several individuals also felt that allowing cyclists to travel along the freeway without a barrier presents a safety risk.

10.5. SUMMARY OBSERVATIONS

The following is a summary of key observations regarding the safety analysis of the new bridge path and modified path on the Sir Francis Drake overcrossing:

- **Bridge path:**
    - No path-related incidents were recorded by the CHP or on the Street Story platform.
    - While no incidents have been recorded in official databases, anecdotal evidence suggests that incidents have on rare occasions happened, such as cyclists injuring themselves after falling.
    - The low height of the barrier on the bridge put riders at risk of being hit by debris flung from the adjacent traffic lanes. The low height also may cause eastbound travelers to be blinded by the lights of passing cars and trucks in the adjacent traffic lane. While a desire has been expressed by many for a higher barrier, this may not be compatible with the barrier-moving system.
    - There is a need to improve paths leading to the bridge, particularly on the Marin side.
- **Sir Francis Drake overcrossing path:**
    - No path-related incidents were recorded by the CHP or on the Street Story platform after the modification.
    - Recorded videos show no inconvenience due to the slightly narrower than usual lane widths on the path as cyclists going down the overcrossing are seldom seen noticeably slowing down when encountering cyclists going up.
    - At the bottom of the overcrossing, cyclists going toward the bridge generally cut into the opposing lane to negotiate the 90-degree turn, creating a potential for collision.
    - A significant proportion of cyclists traveling east along Sir Francis Drake Boulevard cross the arterial at Andersen Drive to access the path. This requires them to do the equivalent of a permitted left turn across traffic coming off the freeway or going to it.
    - A significant proportion of cyclists traveling south along Andersen Drive cross the arterial to access the path upstream of the intersection with Sir Francis Drake Boulevard.

11. TRAFFIC SAFETY IMPACTS

This section assesses the impacts of the bridge modifications on traffic safety along the I-580. This is accomplished by comparing the number, type, and severity of incidents before and after the bridge modifications. The following subsections respectively present:

- Identification of I-580 sections used for the safety analysis.
- Impacts of the lower deck shoulder opening on traffic safety on eastbound traffic.
- Impacts of the upper deck bicycle/pedestrian path installation on westbound traffic.
- Summary of observations.

11.1. SAFETY ANALYSIS SECTIONS

Figure 11-1 illustrates the sections along the I-580 corridor considered for evaluating the safety impacts of the bridge modifications. These are the same as those used for compiling VMT statistics in Section 8.1.3. These include:

- **Bridge**: Sections of I-580 East and West between the toll plaza in Richmond and the foot of the bridge in Marin County.
- **Bridge approaches**: Section of I-580 West in Contra Costa County extending from the Harbour Way interchange to the toll plaza, and of I-580 East in Marin County from the US-101 interchange to the foot of the bridge.
- **Bridge downstream sections**: Section of I-580 West in Marin County from the Main Street off-ramp to the US-101 interchange, and of I-580 East in Contra Costa County from the toll plaza to the Harbour Way interchange in Richmond

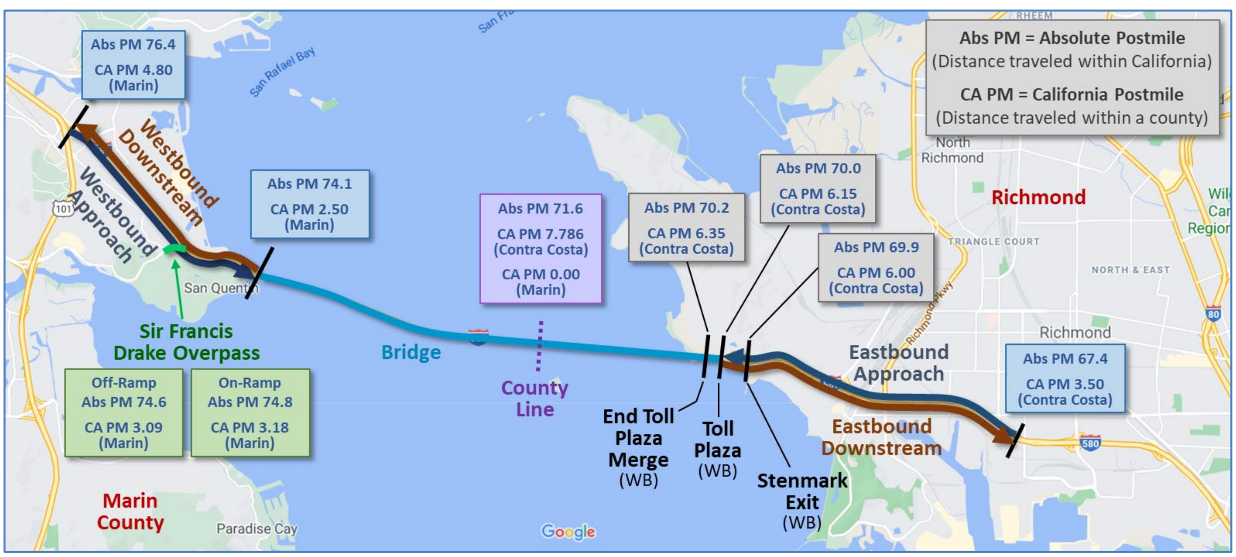

Figure 11-1: Safety Analysis Sections

The following two additional analysis areas are also identified for the westbound direction.

- **Toll Plaza area**: Section of I-580 West around the Richmond toll plaza, typically from the Stenmark off-ramp to the end of the toll plaza itself.

- **Toll Plaza merge area**: Section of I-580 West downstream of the toll plaza where the number of traffic lanes drops from 7 to 2.

Section limits are provided using California Postmile (also known as Relative Postmiles) since incidents reported by the California Highway Patrol are typically positioned along freeways using this system.

11.2. SAFETY IMPACTS ON I-580 EAST

This section presents incident statistics related to the conversion of the eastbound shoulder on the bridge's lower deck into a part-time traffic lane. The following analyses are presented based on data collected from the TASAS database from January 2016 to December 2021:

- Incident rates
- Categorization by incident types
- Categorization by incident severity
- Duration of incidents on the bridge
- Motorist recognition of overhead signs

Analyses have not been conducted using 2022 or 2023 data as data from 2018, 2019, 2020, and 2021 provided a long enough interval to assess the safety impacts of the modifications. In addition, traffic on the lower deck from late 2021 to 2023 has been significantly affected by bridge maintenance activities. These activities caused frequent closures of the two general-purpose traffic lanes and the opening of the shoulder to traffic outside its intended use period.

11.2.1. INCIDENT RATES ON BRIDGE AND APPROACH

Figure 11-2 illustrates the frequency of crashes, per million miles traveled, on I-580 East around the bridge for each quarter between January 2016 and December 2021 based on information contained in the TASAS database. Data for 2022 and subsequent years are not included as sufficient data was deemed available to conduct an impact analysis. The graph distinguishes incidents occurring on the approach to the bridge, the bridge itself, and downstream, based on the section boundaries shown earlier in Figure 11-1. The light gray area further marks the period during which the eastbound shoulder has been opened to traffic, while the dark gray area marks the period affected by COVID-19 stay-at-home orders.

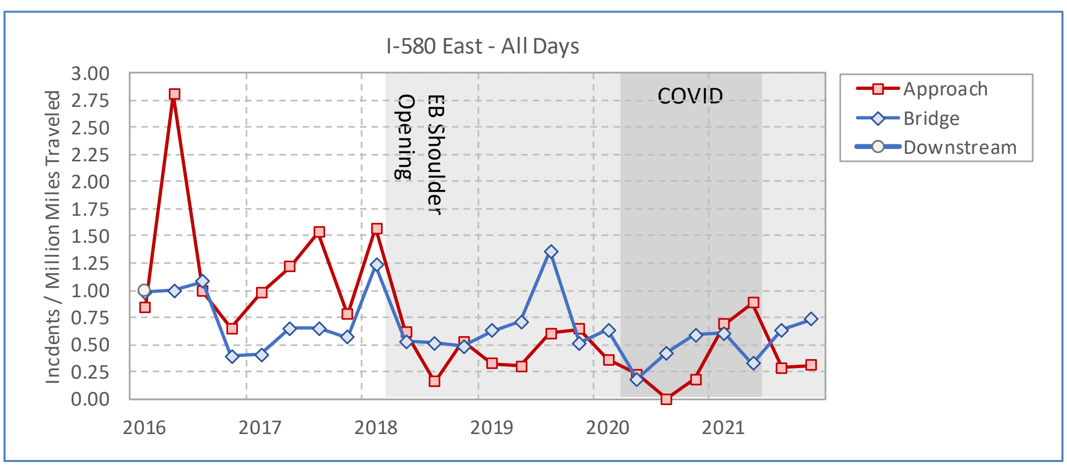

Figure 11-2: Rates of Incidents by Quarter – I-580 East, 2016-2021

Table 11-1: Before/After Overall Incident Rates per Million Miles Traveled – I-580 East

Section	Before	After	Change
Approach	1.265	0.387	-69% *
Bridge	0.769	0.699	-9%
Downstream	0.369	0.431	+17%
Approach + Bridge	**0.915**	**0.608**	**-34% ***
Overall	**0.759**	**0.557**	**-27% ***

Note 1: Before: 01/2016 to 03/2018 (9 quarters)
After: 07/2018 to 03/2020, 07/2021 to 12/2021 (9 quarters)
*Note 2: * Statistically significant change at 95% confidence level*

Table 11-1 further presents the before and after overall incident rates, on a per million vehicle miles traveled basis, for the approach to the bridge, the bridge itself, downstream of it, and a combination of sections. The after-analysis excludes data collected from the five quarters between March 2020 and June 2021 due to the impacts of COVID-related stay-at-home orders on travel demand. Based on the listed data, the following observations can be made:

- **Bridge approach:** Following the shoulder opening, the rate of incidents, on a per million miles traveled basis, drops from 1.27 to 0.39. This is a 69% reduction statistically significant at the 95% confidence level. Most of this drop coincides with the lane opening, suggesting that the modification is the primary contributing factor. This drop can largely be explained by the elimination of the congestion on the bridge approach during the weekday and weekend afternoon peak periods.
- **Bridge:** The frequency of incidents on the bridge drops by 9%, from 0.77 to 0.70 incidents per million miles traveled. However, this increase is not statistically significant at the 95% confidence level based on the observed quarter-to-quarter variations in incident rates and could therefore simply be the result of stochastic variability.
- **Downstream of bridge:** Incidents occurring downstream of the bridge increased by 17%, from 0.37 to 0.43 incidents per million miles traveled. However, this change is not statistically significant at the 95% confidence level. Significant changes were not expected here as the only modification has been an increase in the number of lanes around the toll plaza from two to three to provide continuity in the number of lanes with downstream sections of I-580.

Overall, the data suggests a significantly positive impact on incident rates, with incident rates on the bridge and approach dropping from 0.92 to 0.61 (-34%) per million miles traveled, and overall, from 0.76 to 0.56 (-27%). However, it should be pointed out that these results might be affected by the need to extrapolate data for the before conditions due to a lack of sensors on the bridge before February 2018 and on the approach before June 2019, as indicated earlier in Section 8.1.3.1.

11.2.2. INCIDENT TYPES ON BRIDGE AND APPROACH

Figure 11-3 illustrates the frequencies at which distinct types of incidents have occurred on the eastbound approach to the bridge and the bridge's lower deck for each quarter between January 2016 and December 2023. Table 11-2 further presents the total numbers of documented incidents for both sections for the before and after periods, while Table 11-3 presents the average rates, on a per million miles traveled basis, at which each type of incident occurred before and after the modifications. In both tables, data from the second quarter of 2018 are ignored as some incidents within this period fall before the change and others after. Data between April 2020 and June 2021 are also ignored due to a bias towards fewer incidents associated with the drop in traffic caused by the COVID-19 stay-at-home orders.

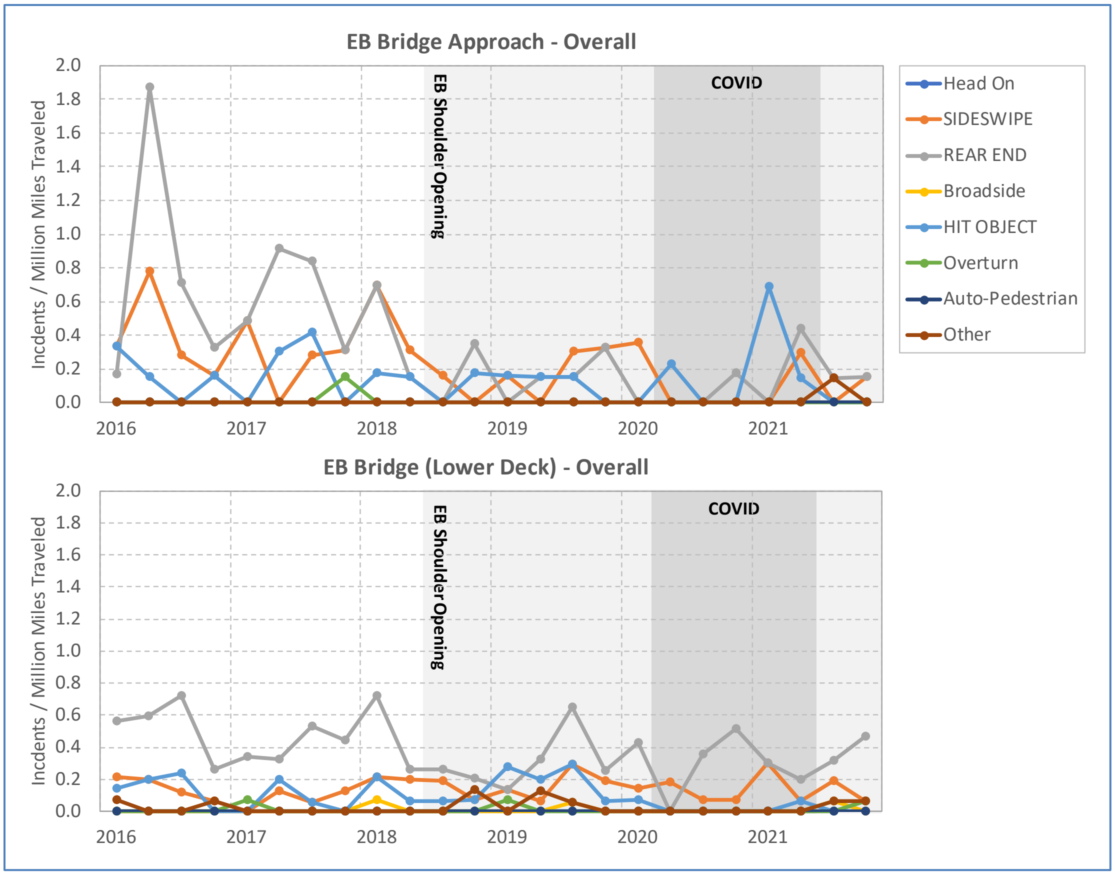

Figure 11-3: Rates of Incidents by Type – I-580 East, Overall, 2016-2021

Table 11-2: Logged Before/After Incidents by Type – I-580 East, Overall

Incident Type	Approach		Bridge Lower Deck		Approach + Bridge	
	Before	After	Before	After	Before	After
Rear-End	41 (56.2%)	8 (36.4%)	69 (65.1%)	47 (49.0%)	110 (61.5%)	55 (46.6%)
Sideswipe	21 (28.8%)	9 (40.9%)	17 (16.0%)	21 (21.9%)	38 (21.2%)	30 (25.4%)
Hit Object	10 (13.7%)	4 (18.2%)	16 (15.1%)	17 (17.7%)	26 (14.5%)	21 (17.8%)
Broadside	0 (0.0%)	0 (0.0%)	1 (0.9%)	2 (2.1%)	1 (0.6%)	2 (1.7%)
Overturn	1 (1.4%)	0 (0.0%)	1 (0.9%)	2 (2.1%)	2 (1.1%)	2 (1.7%)
Other	0 (0.0%)	1 (4.5%)	2 (1.9%)	7 (7.3%)	2 (1.1%)	8 (6.8%)
Overall	**73**	**22**	**106**	**96**	**179**	**118**

Note 1: Before: 01/2016 to 03/2018 (9 quarters)
After: 07/2018 to 03/2020, 07/2021 to 12/2021 (9 quarters, excludes COVID-impacted quarters)

Table 11-3: Incident Rates per Million Miles Traveled by Type – I-580 East, Overall

Incident Type	Approach		Bridge		Approach + Bridge	
	Before	After	Before	After	Before	After
Rear End	0.711	0.141 *	0.500	0.342 *	0.562	0.283 *
Sideswipe	0.364	0.158 *	0.123	0.153	0.194	0.154
Hit Object	0.173	0.070	0.116	0.124	0.133	0.108
Broadside	0.000	0.000	0.007	0.015	0.005	0.010
Overturn	0.017	0.000	0.007	0.015	0.010	0.010
Other	0.000	0.018	0.015	0.051	0.010	0.041
Overall	**1.265**	**0.387 ***	**0.769**	**0.699**	**0.915**	**0.608 ***

Note 1: Before: 01/2016 to 03/2018 (9 quarters)
After: 07/2018 to 03/2020, 07/2021 to 12/2021 (9 quarters, excludes COVID-impacted quarters)
*Note 2: * Statistically significant change at 95% confidence level*

The following observations can be made regarding changes in the types of incidents:

- **Proportion of incident types:** For both the before and after periods, the primary types of incidents around the bridge are rear ends, sideswipes, and vehicles hitting objects. These represent 99% of the before cases on the approach and 95% of the after cases. On the bridge, they represent 96% and 89% of the before and after incidents, respectively.
- **Rear-end collisions:** Following the shoulder opening, the rate of collisions on a per million miles traveled basis drops from 0.71 to 0.14 (-80%) on the approach, and from 0.50 to 0.34 (-32%) on the bridge. These changes reduce the overall incident rate from 0.56 to 0.28 (-50%). All observed changes are statistically significant at the 95% confidence level.
- **Sideswipes:** The rate of sideswipes on the approach drops from 0.36 to 0.16 (-57%) but increases from 0.12 to 0.15 (+24%) on the bridge, resulting in an overall drop from 0.19 to 0.15 (-20%). Only the change related to the approach is statistically significant, at the 95% level. The increase on the bridge is likely the result of more vehicles changing lanes as a result of the availability of an additional traffic lane during peak hours.
- **Vehicles hitting objects:** The rate of collisions on the approach drops from 0.17 to 0.07 (-59%) but increases from 0.11 to 0.12 (+7%) on the bridge, resulting in an overall drop from 0.13 to 0.11 (-19%) when combining both sections. None of these changes were found to be statistically significant based on the observed variability from one quarter to the next. No information was available on the types of objects being hit.
- **Other types of incidents:** No definitive observations can be made on the rates of other types of incidents due to their relatively low incidence. In these cases, the observed changes could simply be the results of stochastic variations.

The above results are a direct consequence of eliminating congestion on the bridge approach and increasing the number of traffic lanes on the bridge. The reduced congestion on the approach to the bridge has led to fewer stop-and-go situations and fewer lane changes. This has translated into fewer rear-end and sideswipe collisions. On the bridge, the addition of a traffic lane has led to lower traffic densities during peak traffic periods, and thus fewer risks for rear-end collisions. However, this change is also providing more opportunities for lane changes and leading to more frequent sideswipe collisions.

11.2.3. INCIDENT SEVERITY ON BRIDGE AND APPROACH

Figure 11-4 presents the rates, on a per million miles traveled basis, at which incidents of various severity have occurred for every quarter between January 2016 and December 2021. Table 11-4 further presents the number of incidents of each type that have been logged for the before and after periods, while Table 11-5 presents the average rates at which each type of incident occurred. In both tables, data from the second quarter of 2018 are ignored as some incidents within this period fall before the change and others after. Data from April 2020 to June 2021 are also ignored due to a bias toward fewer incidents associated with the significant drop in traffic caused by the COVID-19 stay-at-home orders.

As illustrated, the dominant types of incidents occurring around the bridge both before and after the modifications are incidents without injuries and incidents with only a complaint of pain. These represent 88% of the before and 87% of the after incidents. Of the 297 documented incidents, only 32 (11%) were incidents with other visible injuries and 5 (2%) incidents with severe injuries. No fatal crashes were reported during the analysis period (but one did occur in 2022).

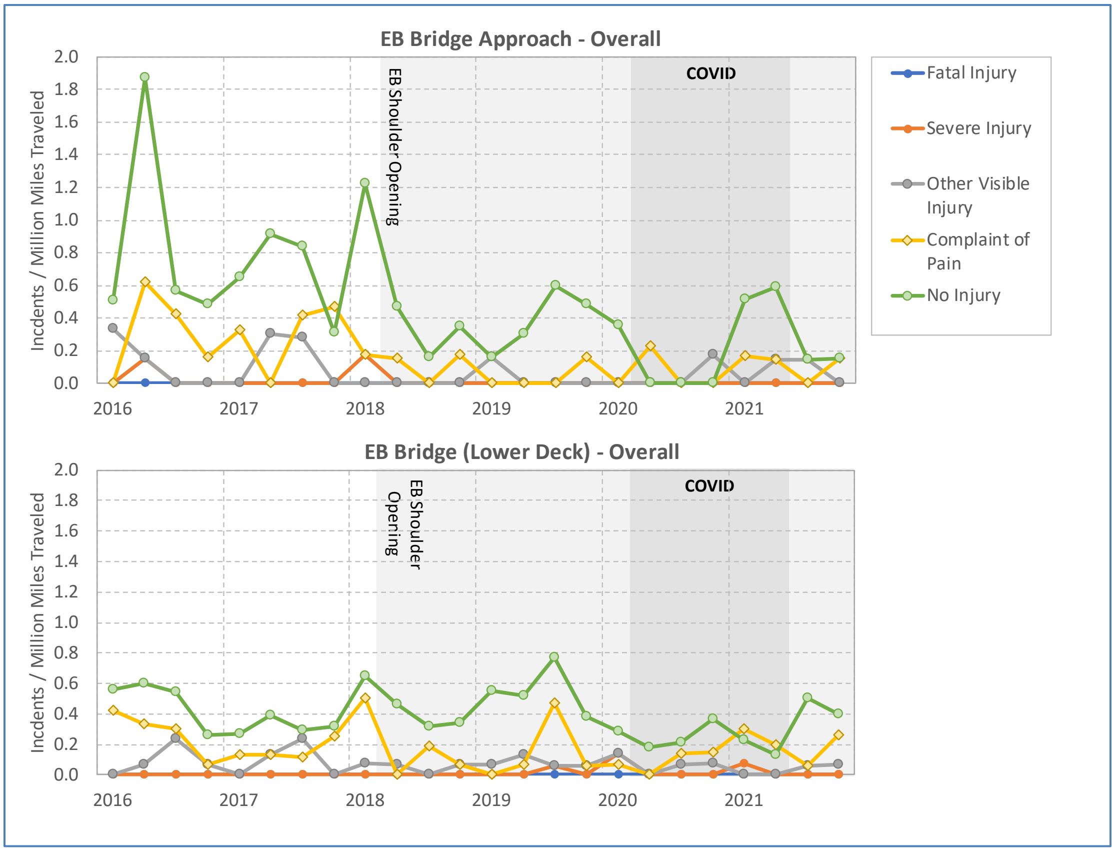

Figure 11-4: Rates of Incidents by Severity – I-580 East, Overall, 2016-2021

Table 11-4: Logged Before/After Incidents by Severity – I-580 East, Overall

Incident Type	Approach		Bridge Lower Deck		Approach + Bridge	
	Before	After	Before	After	Before	After
No Injury	47 (64%)	17 (77%)	59 (56%)	63 (66%)	106 (59%)	60 (68%)
Complaint of Pain	17 (23%)	3 (14%)	34 (32%)	20 (21%)	51 (28%)	23 (19%)
Other Visible Injury	7 (10%)	2 (9%)	13 (12%)	10 (10%)	20 (11%)	12 (10%)
Severe Injury	2 (3%)	0 (0%)	0 (0%)	3 (3%)	2 (1%)	3 (3%)
Fatal Crash	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Overall	**73**	**22**	**106**	**96**	**179**	**118**

Note: Before: 01/2016 to 03/2018 (9 quarters)
After: 07/2018 to 03/2020, 07/2021 to 12/2021 (9 quarters, excludes COVID-impacted quarters)

Table 11-5: Incident Rates per Million Miles Traveled by Severity – I-580 East, Overall

Incident Severity	Approach		Bridge		Approach + Bridge	
	Before	After	Before	After	Before	After
No Injury	0.815	0.299 *	0.428	0.459	0.542	0.412
Complaint of Pain	0.295	0.053 *	0.247	0.146	0.261	0.118 *
Other Visible Injury	0.121	0.035	0.094	0.073	0.102	0.062
Severe Injury	0.035	0.000	0.000	0.022	0.010	0.015
Fatal Crash	0.000	0.000	0.000	0.000	0.000	0.000
Overall	**1.265**	**0.387 ***	**0.769**	**0.699**	**0.915**	**0.608 ***

Note 1: Before: 01/2016 to 03/2018 (9 quarters)
After: 07/2018 to 03/2020, 07/2021 to 12/2021 (9 quarters, excludes COVID-impacted quarters)
*Note 2: * Statistically significant change at 95% confidence level*

Based on the compiled data, the following observations can be made on the potential impacts of the eastbound shoulder conversion into a part-time traffic lane on the rates of incidents of various severity:

- **Bridge Approach:** Reflecting the reducing trend of incident rates illustrated in Figure 11-2, Table 11-5 lists rate reductions for incidents of all types of severity. This is again linked to the elimination of the congestion on the approach. The data indicates a 63% reduction in the rate of incidents without injury, from 0.81 to 0.30 per million miles traveled, an 82% reduction in incidents with complaints of pain, from 0.29 to 0.05, and a 71% reduction in incidents with other visible injuries, from 0.12 to 0.04. Of these, both the reductions in incidents without injury and with complaints of pain are statistically significant at the 95% confidence level.
- **Bridge:** Mixed impacts are observed on the bridge's lower deck. The data indicate a 41% drop in incidents with a complaint of pain and a 23% drop in incidents with other visible injuries. On the other hand, the rate of incidents without injury, the dominant type, is shown to have increased by 7%, from 0.43 to 0.46 per million miles traveled. However, this change is not statistically significant. While the rate of incidents with severe injury has also increased, from 0.00 to 0.02, the frequency of this type of incident remains extremely low to represent any meaningful trend.

Overall, the data indicate a general drop in the severity of incidents occurring on the approach or the bridge. Incidents without injury, the lowest severity type, represented 59% of all incidents before the modifications and 68% of all incidents after. Conversely, the proportion of incidents with severe injury, a complaint of pain, or other visible injuries reduced from 41% to 32%.

11.2.4. INCIDENT DURATIONS ON BRIDGE

Figure 11-5 plots the estimated duration of crashes, including clean-up, that have occurred on the bridge's lower deck between 2 PM and 7 PM on any day, from July 2016 to March 2024, based on logs from the CHP CAD data feed that have been processed by the Bay Area Traffic Incident Management Dashboard. This is the only dataset from which incident duration can be estimated and the source of most statistics on incident durations reported by Bay Area transportation agencies. Only incidents that have occurred between 2 PM and 7 PM are considered as bridge operations have only changed during this period. Only incidents lasting more than 4 minutes are also considered as shorter ones often have incomplete logs.

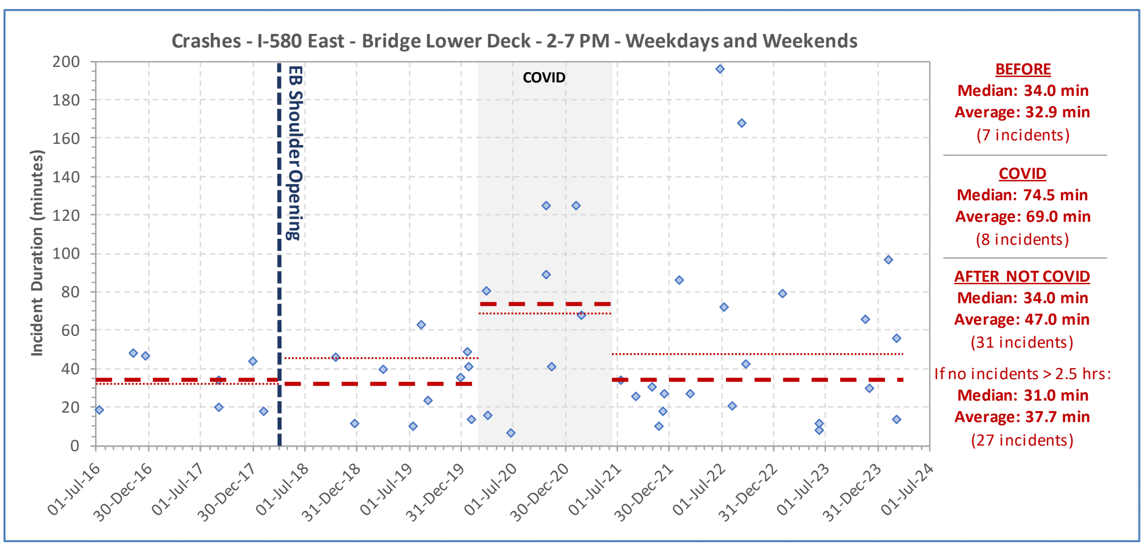

Figure 11-5: Incident Durations – Bridge Lower Deck, 2 PM to 7 PM, 2016-2024

As was indicated in Sections 5.5.4 and 5.5.5, incident durations estimated from CHP CAD logs are subject to some errors as these are simply based on when the first and last event-related messages were logged and as these messages do not always correspond to the actual start and end of an incident. While errors may exist in the reported durations, the purpose of the analysis presented here is to determine whether the bridge modifications may have had significant negative impacts on incidents. Since a single data source is used, the following analysis is thus made under the assumption that potential errors in how incident durations are estimated are consistent before and after the bridge modifications, thus allowing a rough comparative evaluation to be made of conditions before and after the changes.

The data of Figure 11-5 suggests that the average duration of incidents occurring between 2 PM and 7 PM may have increased following the opening of the eastbound shoulder as it shows an increase in average duration from 32.9 to 47.8 minutes (+14.9 minutes). However, this is contradicted by a median duration remaining constant at 34.0 minutes. If the two incidents lasting more than two-and-a-half hours that occurred in 2022 are removed, the average duration is calculated to have increased by only 5 minutes while the median duration drops from 34.0 to 31.0 minutes (-3.0 minutes).

Given the wide variability of incident durations and limited observations, particularly before the modifications, there is a high likelihood that the observed changes are simply due to randomness in the characteristics of incidents considered in the before and after datasets. This is supported by statistical tests indicating that the before and after average durations are not different at a 95% confidence level based on the low sample sizes and observed variability. As a result, no definite conclusions can be drawn from the analysis regarding the impacts of the part-time lane opening on incident duration.

11.2.5. UNDERSTANDING OF OVERHEAD LANE SIGNS

A key concern from CHP officers regarding the overhead signage on the lower deck is that some motorists do not appear to fully understand the significance of the green arrow/yellow X/red X displayed above the lanes. Officers have repeatedly seen vehicles traveling on the shoulder when a yellow or red X is displayed above, treating it as a passing or general-purpose traffic lane. Such behavior may in part be promoted by the fact that motorists now generally know that the shoulder is used at times as a traffic lane that extends across the entire bridge. As a result, there may be a reduced perceived risk of using it when it is closed.

Unauthorized use of the shoulder creates a significant safety hazard, as users run the risk of encountering stopped vehicles on the shoulder. This is particularly problematic for maintenance, tow trucks, and other emergency vehicles that may be stopped on the shoulder. Additional risks may also come from motorists in the adjacent general-purpose traffic lane not expecting to be passed by a vehicle on the right.

11.3. SAFETY IMPACTS ON I-580 WEST

This section presents incident statistics related to the conversion of the westbound shoulder on the bridge's upper deck into a barrier-separated bike/pedestrian path. The following analyses are presented based on data from the TASAS databased between January 2016 to December 2020:

- Incident rates on a per million miles traveled basis
- Categorization by incident types
- Categorization by incident severity
- Duration of incidents occurring on the bridge

11.3.1. INCIDENT RATES ON BRIDGE AND APPROACH

This section analyzes the overall rate of incidents on the bridge and its approach for the following two evaluation periods:

- Incidents at any time of the day and any day of the week.
- Incidents between 6 AM and 9 AM on weekdays.

The first evaluation is conducted based on the fact that the addition of the multi-use path on the upper deck of the bridge affects traffic on a 24/7 basis. The second evaluation is conducted based on the fact that the weekday AM peak period is a period of high interest to decision-makers as it corresponds to a period with high congestion on the approach and is a key source of motorist complaints about traffic conditions.

11.3.1.1. Overall Analysis

Figure 11-6 illustrates the rate of collisions, on a per million miles traveled basis, on I-580 West around the bridge for each quarter between January 2016 and December 2023 based on information contained in the TASAS database. The graph distinguishes incidents occurring on the approach to the bridge and the bridge itself based on the section boundaries shown earlier in Figure 11-1. Data from the downstream section are also presented, but only to December 2021 and for anecdotal purposes, as more recent data were not provided to the research team and since this section is not included in subsequent analyses. The light gray area further marks the period during which the eastbound shoulder has been used as a part-time traffic lane, while the dark gray area marks the period that has been affected by COVID-19 stay-at-home orders.

Table 11-6 further presents the before and after overall incident rates, on a per million vehicle miles basis, for the approach to the bridge, the bridge itself, and a combination of both. In this case, the after-analysis considers two scenarios: one excluding data collected from the five quarters between March 2020 and June 2021 due to the impacts of the COVID-related stay-at-home orders on travel demand (After A), and one including the COVID-impacted quarters (After B).

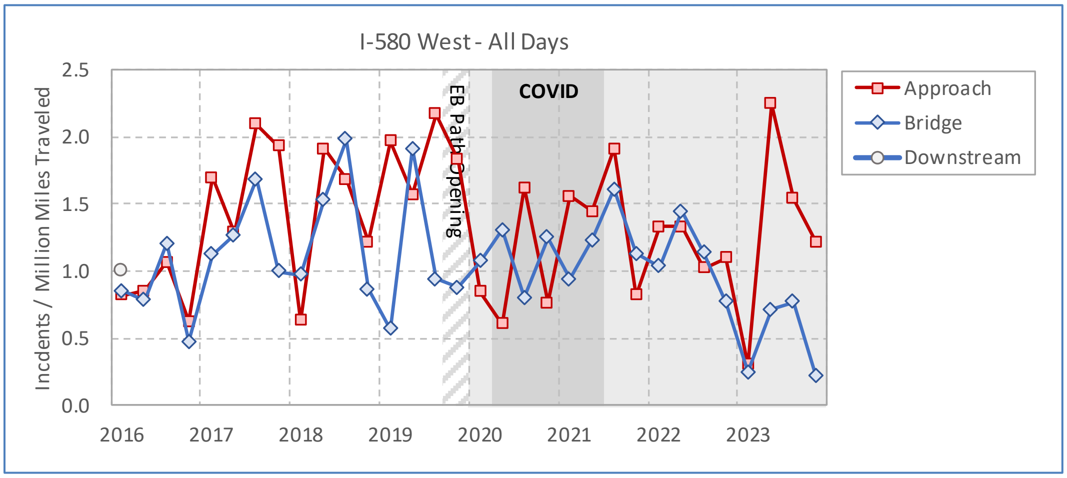

Figure 11-6: Rates of Incidents by Quarter – I-580 West, Overall, 2016-2023

Table 11-6: Before/After Incident Rates per Million Miles Traveled – I-580 West – All Days

Section	Before	After A (without COVID Period)	Change	After B (With COVID Period)	Change
Approach	1.447	1.259	-13%	1.252	-13%
Bridge	1.155	0.932	-19%	0.979	-15%
Approach + Bridge	**1.258**	**1.048**	**-17%**	**1.076**	**-14%**

Note 1: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, excludes COVID-influenced quarters)
After B: 01/2020 to 12/2023 (16 quarters)
Note 2: All observed changes are not statistically significant at the 95%, 90%, or 85% confidence levels

The following observations can be made regarding the overall rates of incidents on the approach to the bridge, the bridge itself, and the section of I-580 downstream of the bridge based on the illustrated data:

- While a large drop in incident rates is observed in the first quarter of 2020, the first full quarter after the modifications, for both the approach of the bridge and the bridge itself, the drop falls within the past observed variability of incident rates across quarters.
- Ignoring the COVID-impacted period, the rate of incidents on the approach, expressed on a per million miles traveled basis, drops from 1.45 to 1.26 (-13%) following the bridge modifications while the rate on the bridge decreases from 1.15 to 0.93 (-19%) and the combined rate decrease from 1.26 to 1.05 (-17%).
- If including the COVID-impacted period, the average rate of incidents on the approach post modifications decreases instead from 1.45 to 1.25 (-13%), while the rate on the bridge decreases from 1.16 to 0.98 (-15%), for a combined reduction of 14%.
- None of the changes reported above are statistically significant at the 95%, 90%, or 85% confidence level based on the observed variance in incidents from one quarter to the next.

Based on the assessment, there is no evidence that the bike/pedestrian path has negatively impacted traffic safety on the approach of the bridge or the bridge itself when considering all incidents. The data suggests instead a potential reduction in incident rates on both the approach to the bridge and the bridge itself. However, since the observed changes are not statistically significant, definitive statements on impacts cannot be made as the observed changes could simply be the result of randomness.

11.3.1.2. Weekday AM Peak Analysis

This section repeats the analysis of the previous section but focuses on the observed safety impacts during the weekday morning peak period, assumed to extend from 6 AM to 9 AM. Quarterly incident rates for the approach to the bridge and the bridge itself are illustrated in Figure 11-7 while Table 11-7 tabulates the overall incident rates for the before and after periods, in the latter case distinguishing between the periods without (After A) and with (After B) the COVID-influenced quarters of April 2020 to June 2021.

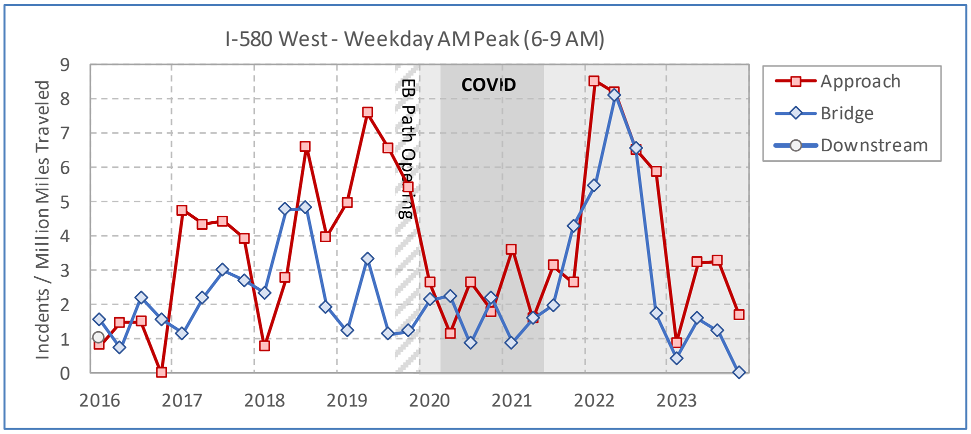

Figure 11-7: Rates of Incidents by Quarter – I-580 West, Weekday AM Peak, 2016-2023

Table 11-7: Before/After Incident Rates per Million Miles Traveled – I-580 West, Weekday AM Peak

	Before	After A (without COVID Period)	Change	After B (With COVID Period)	Change
Approach	3.611	4.261	+18%	3.654	+1%
Bridge	2.315	3.071	+33%	2.611	+13%
Approach + Bridge	**2.743**	**3.467**	**+26%**	**2.957**	**+8%**

Note 1: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 06/2023 (9 quarters, excludes COVID-influenced quarters)
After B: 01/2020 to 06/2023 (14 quarters)
Note 2: All observed changes are not statistically significant at the 95%, 90%, or 85% confidence levels

The following observations can be made regarding the overall rates of incidents during the weekday AM peak period:

- Overall incident rates appear to have increased following the addition of the path. When ignoring the COVID-impacted period, the rate of incidents on a per million miles traveled basis is found to increase from 3.61 to 4.26 (+18%) on the approach, from 2.31 to 3.07 (+33%) on the bridge, and from 2.74 to 3.47 (+26%) overall.
- If the COVID-impacted period is included, lower rate increases are observed due to the significantly reduced traffic levels that occurred between March 2020 and June 2021. In this case, the rate of incidents only increases from 3.61 to 3.65 (+1%) on the approach, from 2.31 to 2.61 (+13%) on the bridge, and from 2.74 to 2.96 (+8%) overall.
- None of the changes reported above are statistically significant at the 95%, 90%, or 85% confidence level based on the observed variance in incidents from one quarter to the next. This means that all differences could simply be the results of stochastic elements.

While the all-day analysis points to an absence of negative safety impact, an analysis focusing only on the peak travel period indicates a potential negative impact as both the incident rates on the bridge and its approach are calculated to have increased. However, statistical analysis indicates again that the before and after rates are not statistically different based on the observed quarterly variability in incident rates.

11.3.2. INCIDENT TYPES ON BRIDGE AND APPROACH

Similar to the previous section, this section analyzes the rates of incidents by type on the bridge and its approach for the following two evaluation periods:

- Incidents at any time of the day and any day of the week.
- Incidents between 6 AM and 9 AM on weekdays.

11.3.2.1. Overall Analysis

Figure 11-8 presents the quarterly rates, on a per million miles traveled basis, at which various types of incidents have occurred on the bridge and its approach between January 2016 and December 2023. Table 11-8 further documents the logged incidents for both sections, while Table 11-9 presents the average rates at which each type is calculated to have occurred. In both tables, data from the last quarter of 2019 are ignored as some incidents within this period fall before the change and others after. Data from April 2020 to June 2021 are also ignored in the first set of after statistics (After A) due to the potential effects of the COVID-19 pandemic but are included for reference in the second set of after data (After B).

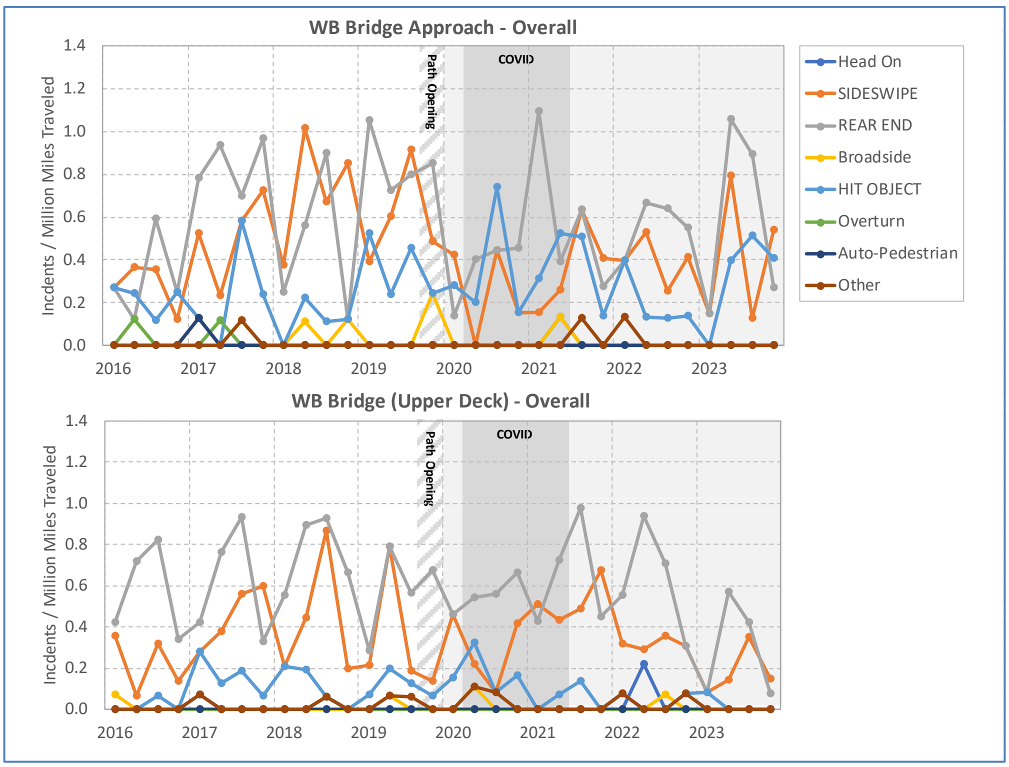

Figure 11-8: Rates of Incident Type – I-580 West, Overall, 2016-2023

Table 11-8: Logged Before/After Incident by Types – I-580 West, Overall

Incident Type	Approach			Bridge Upper Deck			Approach + Bridge		
	Before	**After A**	**After B**	**Before**	**After A**	**After B**	**Before**	**After A**	**After B**
Rear End	75 (41.9%)	43 (41.7%)	*61 (42.7%)*	145 (55.1%)	76 (55.1%)	*111 (54.7%)*	220 (49.8%)	119 (49.4%)	*172 (49.7%)*
Sideswipe	67 (37.4%)	35 (34.0%)	*42 (29.4%)*	86 (32.7%)	49 (35.5%)	*69 (34.0%)*	153 (34.6%)	84 (34.9%)	*111 (32.1%)*
Hit Object	29 (16.2%)	29 (22.3%)	*36 (25.2%)*	24 (9.1%)	7 (5.1%)	*14 (6.9%)*	53 (12.0%)	30 (12.4%)	*50 (14.5%)*
Broadside	4 (2.2%)	4 (0.0%)	*1 (0.7%)*	2 (0.8%)	1 (0.7%)	*2 (1.0%)*	6 (1.4%)	1 (0.4%)	*3 (0.9%)*
Overturn	2 (1.1%)	2 (0.0%)	*0 (0.0%)*	1 (0.4%)	0 (0.0%)	*0 (0.0%)*	3 (0.7%)	0 (0.0%)	*0 (0.0%)*
Other	2 (1.1%)	2 (1.9%)	*3 (2.1%)*	5 (1.9%)	5 (3.6%)	*7 (3.4%)*	7 (1.6%)	7 (2.9%)	*10 (2.9%)*
Overall	**179**	**103**	***143***	**263**	**138**	***203***	**442**	**241**	***346***

Note: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, excludes COVID-influenced quarters)
After B: 01/2020 to 12/2023 (16 quarters)

Table 11-9: Incident Rates per Million Miles Traveled by Type – I-580 West, Overall

Incident Type	Approach			Bridge			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
Rear End	0.606	0.525	*0.534*	0.637	0.513	*0.535*	0.626	0.518	*0.535*
Sideswipe	0.542	0.428	*0.368 **	0.378	0.331	*0.333*	0.435	0.365	*0.345*
Hit Object	0.234	0.281	*0.315*	0.105	0.047 +	*0.068*	0.151	0.130	*0.156*
Broadside	0.032	0.000 *	*0.009*	0.009	0.007	*0.010*	0.017	0.004 +	*0.009*
Overturn	0.016	0.000	*0.000*	0.004	0.000	*0.000*	0.009	0.000 +	*0.000 +*
Auto-Pedestrian	0.008	0.000	*0.000*	0.00	0.000	*0.000*	0.003	0.000	*0.000*
Other	0.008	0.024	*0.026*	0.022	0.034	*0.034*	0.017	0.030	*0.031*
Overall	**1.447**	**1.259**	**1.252**	**1.155**	**0.932**	**0.979**	**1.258**	**1.048**	**1.076**

Note 1: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, excludes COVID-influenced quarters)
After B: 01/2020 to 12/2023 (16 quarters)
*Note 2: * Change statistically significant at the 95% level.*
+ Change statistically significant at the 90% level.

The following specific observations can be made regarding changes in the types of incidents occurring in the westbound traffic direction following the bridge modifications:

- **Proportion of incident types:** For both before and after the modifications, rear-ends, sideswipes, and vehicles hitting objects represent about 96% of all reported incidents on the bridge or its approach. Rear-end incidents account for about 42% of approach incidents and 55% of bridge incidents, while sideswipes represent 34-37% of approach and 33-36% of bridge incidents, and vehicles hitting objects 16-22% of approach incidents and 5-9% of bridge incidents.
- **Rear-end collisions:** When ignoring the COVID-influenced interval (*After A*), the rate of collisions on the approach, per million miles traveled, drops from 0.61 to 0.53 (-13%) following the path's installation. On the bridge, the rate decreases from 0.64 to 0.51 (-19%). These changes reduce the overall rate from 0.63 to 0.52 (-17%). When including the COVID-affected quarters (*After B*), a 12% rate reduction is calculated for the approach, a 16% decrease for the bridge, for an overall 15% reduction.
- **Sideswipes:** When ignoring the COVID-influenced interval (*After A*), the rate of sideswipes drops from 0.54 to 0.43 (-21%) on the approach and from 0.38 to 0.33 (-12%) on the bridge, for an overall decrease from 0.43 to 0.37 (-16%). When including the COVID quarters (*After B*), the approach, bridge, and overall rates on the three reference sections drop to 0.37 (-32%), 0.33 (-12%), and 0.35 (-21%) respectively.
- **Vehicles hitting objects:** When ignoring the COVID-influenced interval (*After A*), the collision rate on the approach increases from 0.23 to 0.28 (+20%) but decreases from 0.11 to 0.05 (-55%) on the bridge, for an overall decrease from 0.15 to 0.13 (-13%). When including the COVID-affected quarters (*After B*), the approach rate further increases to 0.31 (+34%) while the bridge rate decreases to 0.07 (-36%), for an overall marginal increase to 0.16 (+3%).
- **Other types of collisions:** No definitive observations can be made on the rates of other types of incidents due to their relatively low incidence. In these cases, the observed increases and decreases could simply be the results of stochastic variations.

A key takeaway from the above analysis is that the installation of the bike/pedestrian path on the upper deck of the bridge does not appear to have negatively affected traffic safety. Following its installation, overall incident rates have dropped both on the bridge and its approach, whether the COVID-impacted interval is considered. The rates have also decreased for all types of incidents when ignoring the COVID period, and only marginally increased for some types of incidents when considering the COVID period. However, none of the observed changes is statistically significant at the 95%, 90%, or 85% levels.

11.3.2.2. Weekday AM Peak Analysis

This section repeats the analysis of the previous one but focuses on the observed safety impacts during the weekday morning peak period, assumed to extend from 6 AM to 9 AM. Quarterly incident rates by type for the bridge and its approach are illustrated in Figure 11-9 while Table 11-10 tabulates the incidents logged for the before and after periods, in the latter case distinguishing between the periods without (After A) and with (After B) the COVID-influenced quarters of April 2020 to June 2021, and Table 11-11 provides the overall incident rates.

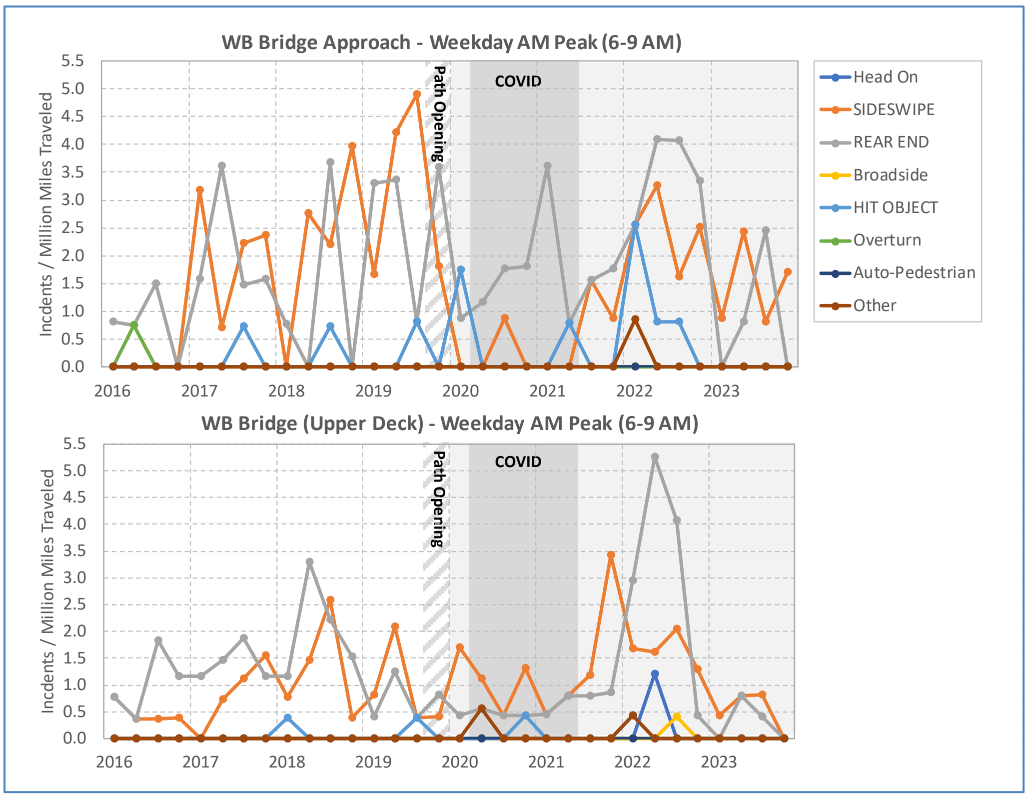

Figure 11-9: Rates of Incident Type – I-580 West, Weekday AM Peak, 2016-2022

Table 11-10: Logged Before/After Incident by Type – I-580 West, Weekday AM Peak

Incident Type	Approach			Bridge Upper Deck			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
Rear End	30 (42.9%)	26 (46.4%)	*36 (52.9%)*	53 (58.2%)	39 (48.1%)	*45 (46.3%)*	83 (51.6%)	65 (47.4%)	*81 (48.8%)*
Sideswipe	36 (45.8%)	22 (39.3%)	*23 (39.3%)*	36 (39.6%)	36 (44.4%)	*45 (45.3%)*	72 (44.7%)	58 (42.3%)	*68 (41.0%)*
Hit Object	3 (8.3%)	7 (12.5%)	*8 (12.5%)*	2 (2.2%)	1 (1.2%)	*2 (2.1%)*	5 (3.1%)	8 (5.8%)	*10 (6.0%)*
Broadside	0 (0.0%)	0 (0.0%)	*0 (0.0%)*	0 (0.0%)	1 (1.2%)	*1 (1.1%)*	0 (0.0%)	1 (0.7%)	*1 (0.6%)*
Overturn	1 (0.8%)	0 (0.0%)	*0 (0.0%)*	0 (0.0%)	0 (0.0%)	*0 (0.0%)*	1 (0.6%)	0 (0.0%)	*0 (0.0%)*
Other	0 (0.0%)	1 (1.8%)	*1 (1.8%)*	0 (0.0%)	4 (4.9%)	*5 (5.3%)*	0 (0.0%)	5 (3.6%)	*6 (3.6%)*
Overall	**70**	**56**	***68***	**91**	**81**	***98***	**161**	**137**	***166***

Note: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, no COVID-influenced interval)
After B: 01/2020 to 12/2023 (16 quarters)

Table 11-11: Incident Rates per Million Miles Traveled by Type – I-580 West, Weekday AM Peak

Incident Type	Approach			Bridge			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
Rear End	1.547	1.978	1.934	1.348	1.479	1.199	1.414	1.645	1.443
Sideswipe	1.857	1.674	1.236	0.916	1.365	1.199	1.227	1.468	1.211
Hit Object	0.155	0.533	0.430	0.051	0.038	0.053	0.085	0.202	0.178
Broadside	0.000	0.000	0.000	0.000	0.038	0.027	0.000	0.025	0.018
Overturn	0.052	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000
Auto-Pedestrian	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other	0.000	0.076	0.054	0.000	0.152	0.133	0.000	0.127	0.107
Overall	**3.611**	**4.261**	**3.654**	**2.315**	**3.071**	**2.611**	**2.743**	**3.467**	**2.957**

Note 1: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, no COVID period)
After B: 01/2020 to 12/2023 (16 quarters)
Note 2: All observed changes are not statistically significant at the 95%, 90%, or 85% confidence levels

The following observations can be made regarding the impacts of the new bridge path on the rates of incidents occurring on the bridge or its approach between 6 AM and 9 AM on weekdays during the morning peak period when ignoring the COVID-impacted quarters:

- **Overall incident rate:** As reported in Section 11.3.1.2, overall incident rates have increased on the approach from 3.61 to 4.26 (+18%), from 2.31 to 3.07 (+33%) on the bridge, and from 2.74 to 3.45 (+26%) overall.
- **Read-end incidents:** Incident rates have increased from 1.54 to 1.98 (+28%) on the approach, from 1.34 to 1.48 (+10%) on the bridge, and from 1.41 to 1.65 (+16%) overall.
- **Sideswipe incidents:** Incident rates have reduced from 1.86 to 1.68 (-10%) on the approach, increased on the bridge from 0.92 to 1.36 (+49%), and increased overall from 1.23 to 1.47 (+20%). On the bridge, in particular, the increase could be explained by more vehicles attempting to switch to the left lane, as explained in Section 8.3.5.
- **Vehicles hitting objects:** Incident rates have significantly increased on the approach from 0.16 to 0.53 (+244%), reduced from 0.05 to 0.04 on the bridge (-25%), and increased from 0.09 to 0.20 (+138%) overall.
- **Statistical significance of changes:** None of the reported changes are statistically significant at the 95%, 90%, or 85% confidence levels, indicating that they can all be the results of randomness in incident occurrence.

While the AM peak period analysis generally points to negative impacts on traffic safety, the statistical analysis indicates that the observed impacts might just be the results of some randomness effects in the types of incidents included in the before and after datasets based on the observed variance across quarters.

11.3.3. INCIDENT SEVERITY ON BRIDGE AND APPROACH

Similar to the previous sections, this section analyzes the rates of incidents by severity for the following two evaluation periods:

- Incidents at any time of the day and any day of the week.
- Incidents between 6 AM and 9 AM on weekdays.

11.3.3.1. Overall Analysis

Figure 11-10 presents the rates, on a per million miles traveled basis, at which incidents of various severity have occurred before on the bridge's westbound approach and upper deck for every quarter between January 2016 and December 2023. Table 11-12 further presents the number of incidents of each type that have been documented for the before and after periods, while Table 11-13 presents the average rates at which each type of incident occurred. In both tables, data from the last quarter of 2019 are ignored as some incidents within this period fall before the change and others after. Data from April 2020 to June 2021 are also ignored in the first set of after statistics (After A) due to the potential effects of the COVID-19 pandemic but are included for reference in the second set of after data (After B).

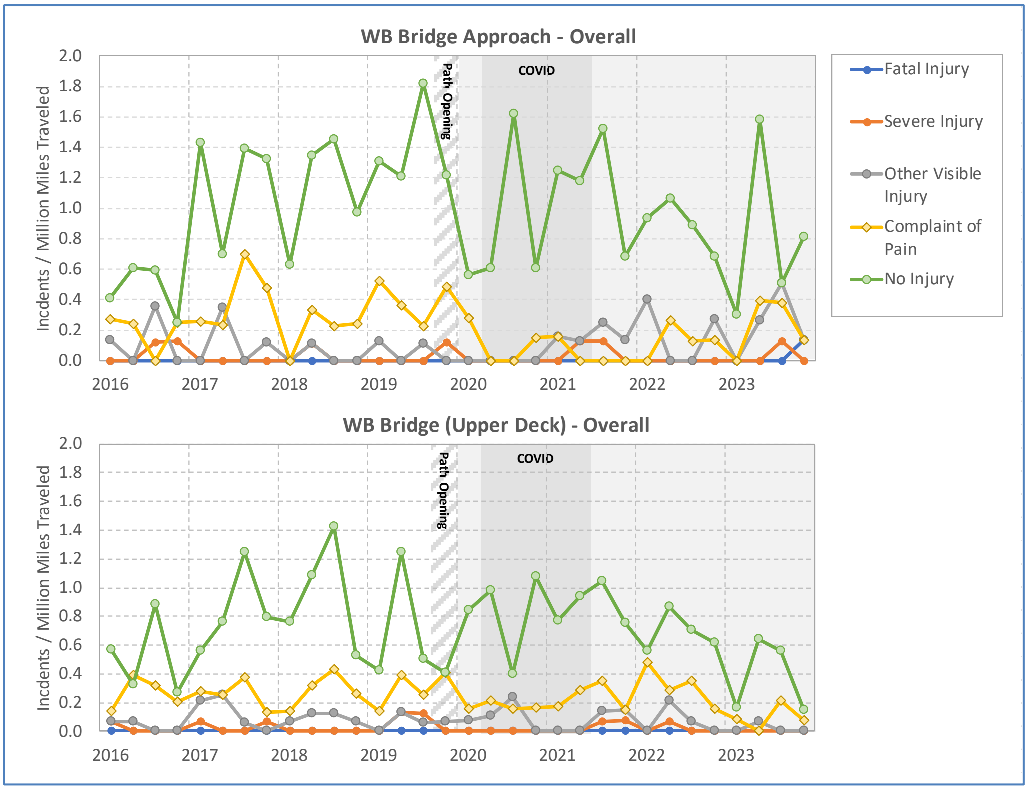

Figure 11-10: Rates of Incidents by Severity – I-580 West, 2016-2021

Table 11-12: Logged Before/After Incidents by Severity – I-580 West, Overall

Incident Type	Approach			Bridge Upper Deck			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
No Injury	129 (72%)	72 (70%)	*107 (75%)*	175 (67%)	94 (68%)	*143 (70%)*	304 (69%)	166 (69%)	*250 (72%)*
Complaint of Pain	36 (20%)	13 (13%)	*15 (10%)*	62 (24%)	31 (22%)	*43 (21%)*	98 (22%)	44 (18%)	*58 (17%)*
Other Visible Injury	11 (6%)	15 (15%)	*17 (12%)*	19 (7%)	10 (7%)	*14 (7%)*	30 (7%)	25 (10%)	*31 (9%)*
Severe Injury	3 (2%)	2 (2%)	*3 (2%)*	7 (3%)	3 (2%)	*3 (2%)*	10 (2%)	5 (2%)	*6 (2%)*
Fatal	0 (0%)	1 (1%)	*1 (1%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*1 (0%)*	*1 (0%)*
Overall	**179**	**103**	***143***	**263**	**138**	***203***	**442**	**241**	***346***

Note: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, no COVID period)
After B: 01/2020 to 12/2023 (16 quarters)

Table 11-13: Incident Rates per Million Miles Traveled by Severity – I-580 West, Overall

Incident Severity	Approach			Bridge			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
No Injury	1.043	0.880	*0.937*	0.769	0.635	0.690	0.865	0.722	0.778
Complaint of Pain	0.291	0.159 +	*0.131 **	0.272	0.209	0.207	0.279	0.191 *	0.180 *
Other Visible Injury	0.089	0.183	*0.147*	0.083	0.068	0.068	0.085	0.109	0.096
Severe Injury	0.024	0.024	*0.026*	0.031	0.020	0.014	0.028	0.022	0.019
Fatal	0.000	0.012	*0.009*	0.000	0.000	0.000	0.000	0.004	0.003
Overall	**1.447**	**1.259**	***1.252***	**1.155**	**0.932**	**0.979**	**1.258**	**1.048**	**1.076**

Note 1: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, no COVID period)
After B: 01/2020 to 12/2023 (16 quarters)
*Note 2: * Change statistically significant at the 95% level.*
+ Change statistically significant at the 90% level.

Based on the compiled data, the dominant incidents on the bridge or its approach, both before and after the modifications, are those with no injury and with a complaint of pain. These represent 91% of the before incidents and 87-89% of the after incidents depending on whether the COVID-impacted period is considered. 7% of the before and 9-10% of the after collisions were with other visible injuries, while incidents with severe injuries typically comprised only 2% of all incidents. Only one fatal incident is reported in the documented incidents over the analysis section and periods.

Based on the 11 quarters of post-modification data available without COVID influence (first quarter of 2020 to the fourth quarter of 2021), the following observations can be made from the data of Table 11-12 and Table 11-13:

- **Incidents with no injury:** The proportion slightly decreases from 72% to 70% on the approach and slightly increases from 67% to 68% on the bridge, with the overall proportion remaining at 69%. On a per million miles traveled basis, the rate of incidents on the approach drops from 1.04 to 0.88 (-16%) and from 0.77 to 0.63 (-17%) on the bridge, for an overall decrease from 0.86 to 0.72 (-17%).
- **Incidents with a complaint of pain:** The proportion decreases from 20% to 13% on the approach and from 24% to 22% on the bridge, for an overall decrease from 22% to 18%. The rate of incidents decreases from 0.29 to 0.16 (-45%) on the approach and from 0.27 to 0.21 (-23%) on the bridge, for an overall reduction from 0.28 to 0.19 (-31%). This is the only incident type for which there appears to be some statistical significance in the change, but only on the approach.
- **Incidents with other visible injuries:** The proportion on the approach increases from 6% to 15% and remains at 7% on the bridge, for an overall increase from 7% to 10%. The rate of incidents increases from 0.09 to 0.18 (+106%) on the approach but decreases from 0.08 to 0.07 (-19%) on the bridge, for an overall increase from 0.09 to 0.11 (+27%).

The following observations can further be made if data from the COVID-impacted interval are considered:

- **Incidents with no injury:** The proportion of incidents further increases to 75% on the approach and 70% on the bridge, for an overall proportion increase from 69% to 72%. The rate of incidents drops from 1.04 to 0.94 (-10%) on the approach and from 0.77 to 0.69 (-10%) on the bridge, for an overall decrease to 0.78 (-10%).

- **Incidents with a complaint of pain:** The proportion of incidents decreases from 20% to 10% on the approach and from 24% to 21% on the bridge, for an overall decrease from 22% to 17%. The rate of incidents on the approach decreases from 0.29 to 0.13 (-55%) and on the bridge from 0.27 to 0.21 (-24%), for an overall reduction to 0.18 (-35%).
- **Incidents with other visible injuries:** The proportion of incidents increases from 6% to 12% on the approach and remains at 7% on the bridge, for an overall increase from 7% to 9%. The rate of incidents on the approach increases from 0.09 to 0.15 (+67%) but decreases from 0.08 to 0.07 (-19%), for an overall increase from 0.09 to 0.10 (+13%).

The key takeaway from the above analysis is that the addition of the multi-use path on the upper deck of the bridge does not appear to have had significant negative impacts on the severity of incidents occurring on the bridge or its approach. Rates of most incident types are observed to have decreased. However, since most of the observed changes are not statistically significant at the 95% confidence level, they could be simply the result of the stochasticity of events included in the before and after analysis periods.

11.3.3.2. Weekday AM Peak Analysis

This section repeats the analysis of the previous one but focuses on the observed safety impacts during the weekday morning peak period, assumed to extend from 6 AM to 9 AM. Quarterly incident rates by severity for the bridge and its approach are illustrated in Figure 11-11 while Table 11-14 tabulates the incidents logged for the before period and after period, in the latter case distinguishing between the periods without (After A) and with (After B) the COVID-influenced quarters of April 2020 to June 2021, and Table 11-15 provides the overall incident rates.

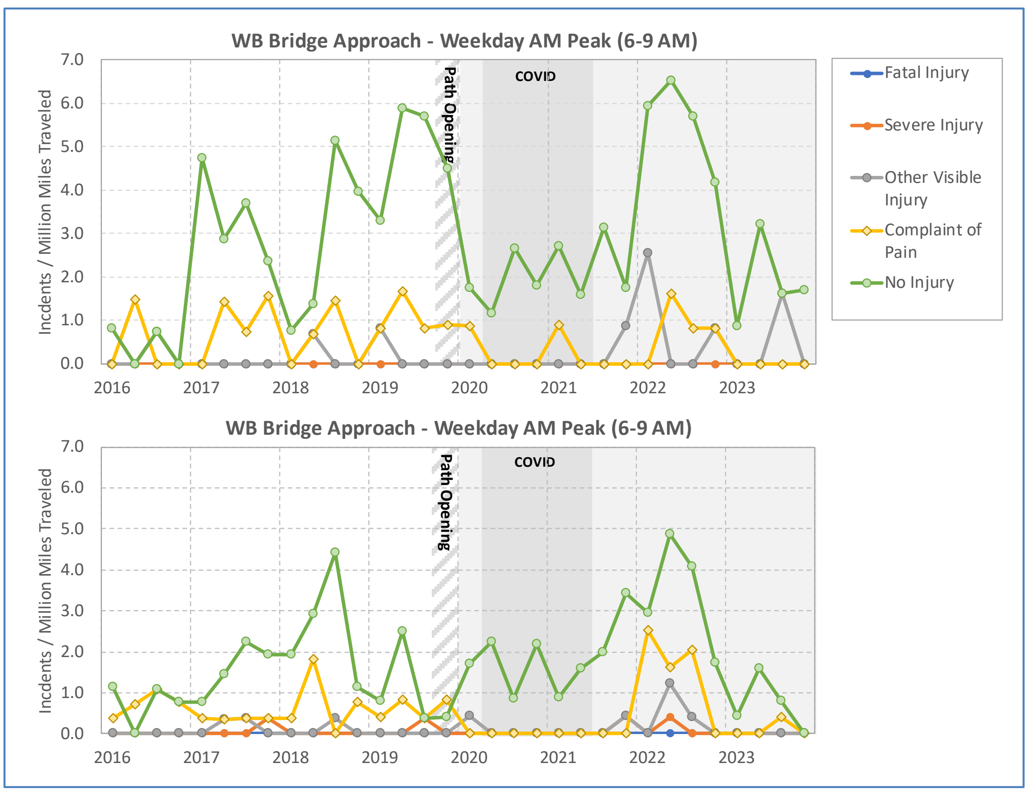

Figure 11-11: Rates of Incidents by Severity – I-580 West, Weekday AM Peak, 2016-2021

Table 11-14: Logged Before/After Incidents by Severity – I-580 West, Weekday AM Peak

Incident Type	Approach			Bridge Upper Deck			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
No Injury	53 (76%)	44 (79%)	*55 (81%)*	62 (68%)	57 (70%)	*74 (76%)*	115 (68%)	95 (74%)	*123 (78%)*
Complaint of Pain	14 (20%)	5 (9%)	*6 (9%)*	24 (26%)	16 (20%)	*16 (16%)*	38 (25%)	20 (16%)	*21 (13%)*
Other Visible Injury	3 (4%)	7 (13%)	*7 (10%)*	3 (3%)	6 (7%)	*6 (6%)*	6 (6%)	11 (9%)	*11 (7%)*
Severe Injury	0 (0%)	0 (0%)	*0 (0%)*	2 (2%)	2 (2%)	*2 (2%)*	2 (1%)	2 (2%)	*2 (1%)*
Fatal	0 (0%)	0 (0%)	*0 (0%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*
Overall	**70**	**56**	***68***	**91**	**81**	***98***	**161**	**128**	***157***

Note: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, no COVID period)
After B: 01/2020 to 12/2023 (16 quarters)

Table 11-15: Incident Rates per Million Miles Traveled by Severity – I-580 West, Weekday AM Peak

Incident Severity	Approach			Bridge			Approach + Bridge		
	Before	After A	After B	Before	After A	After B	Before	After A	After B
No Injury	2.734	3.348	2.955	1.577	2.167	1.972	1.959	2.556	2.298
Complaint of Pain	0.722	0.380	0.322 +	0.611	0.607	0.426	0.647	0.531	0.392
Other Visible Injury	0.155	0.533	0.376	0.076	0.227	0.160	0.102	0.329 *	0.232
Severe Injury	0.000	0.000	0.000	0.051	0.076	0.053	0.034	0.051	0.036
Fatal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Overall	**3.611**	**4.261**	**3.645**	**2.315**	**3.071**	**2.611**	**2.743**	**3.467**	**2.982**

Note 1: Before: 01/2016 to 09/2019 (15 quarters)
After A: 01/2020 to 03/2020, 07/2021 to 12/2023 (11 quarters, no COVID period)
After B: 01/2020 to 12/2023 (16 quarters)
*Note 2: * Change statistically significant at the 95% level.*
+ Change statistically significant at the 90% level.

The following observations can be made regarding the impacts of the new bridge path on the rates of incidents occurring on the bridge or its approach during the weekday AM peak period (6 AM – 9 PM) when ignoring the COVID-impacted quarters:

- **Overall rate:** As reported in Section 11.3.1.2, overall incident rates have increased from 3.61 to 4.26 (+18%) on the approach, from 2.31 to 3.07 (+33%) on the bridge, and from 2.74 to 3.45 (+26%) overall.
- **Incidents without injury:** Incident rates have increased from 2.73 to 3.35 (+22%) on the approach, from 1.58 to 2.16 on the bridge (+37%), and from 1.96 to 2.56 (+30%) overall.
- **Incidents with complaints of pain:** Incident rates have decreased from 0.72 +0.38 (-47%) on the approach, remained around 0.61 (+1%) on the bridge, and decreased from 0.65 to 0.53 (-18%) overall.
- **Incident with other visible injuries:** Incident rates have significantly increased, from 0.15 to 0.53 (+244%) on the approach, from 0.08 to 0.23 (+198%) on the bridge, and from 0.10 to 0.32 (+222%) overall.
- **Statistical significance of changes:** Only two observed changes, incidents with other visible injury when excluding the COVID-impacted period and incidents with complaints of pain when including the COVID period, carry some statistical significance. None of the other reported changes are statistically significant at the 95%, 90%, or 85% confidence level.

Contrary to the overall analysis of the previous section, the weekday AM peak data indicates noticeable increases in the rates of various types of incident severity, suggesting potential negative impacts from the addition of the multi-use path. However, given the observed level of variability in incident rates from one quarter to the next, the changes were not found to be statistically significant. This means that the observed negative impacts might just be the results of randomness effects in the types of incidents included in the before and after datasets based on the observed variance across quarters.

11.3.4. INCIDENT DURATIONS ON BRIDGE

Similar to the previous sections, this section analyzes the estimated duration of incidents that have occurred on the bridge for the following two periods:

- Incidents at any time of the day and any day of the week.
- Incidents between 6 AM and 9 AM on weekdays.

11.3.4.1. Overall Analysis

Figure 11-12 plots the estimated duration of all crashes that have occurred on the upper deck of the bridge between July 2016 and March 2024 based on logs from the CHP CAD data feed that have been processed by the Bay Area Traffic Incident Management Dashboard. For this analysis, all incidents that have occurred on the upper deck and lasting longer than 4 minutes are considered. Incidents that have occurred at any time of the day are included based on the fact that the multi-use path affects traffic throughout the day. Incidents shorter than 4 minutes are further excluded as these often have incomplete logs in the CHP CAD database. For the after-period, the graph finally distinguishes incidents occurring while COVID-stay-at-home orders were in effect (March 15, 2020, to June 11, 2021) and those occurring after. The latter incidents are the main focus of the analysis.

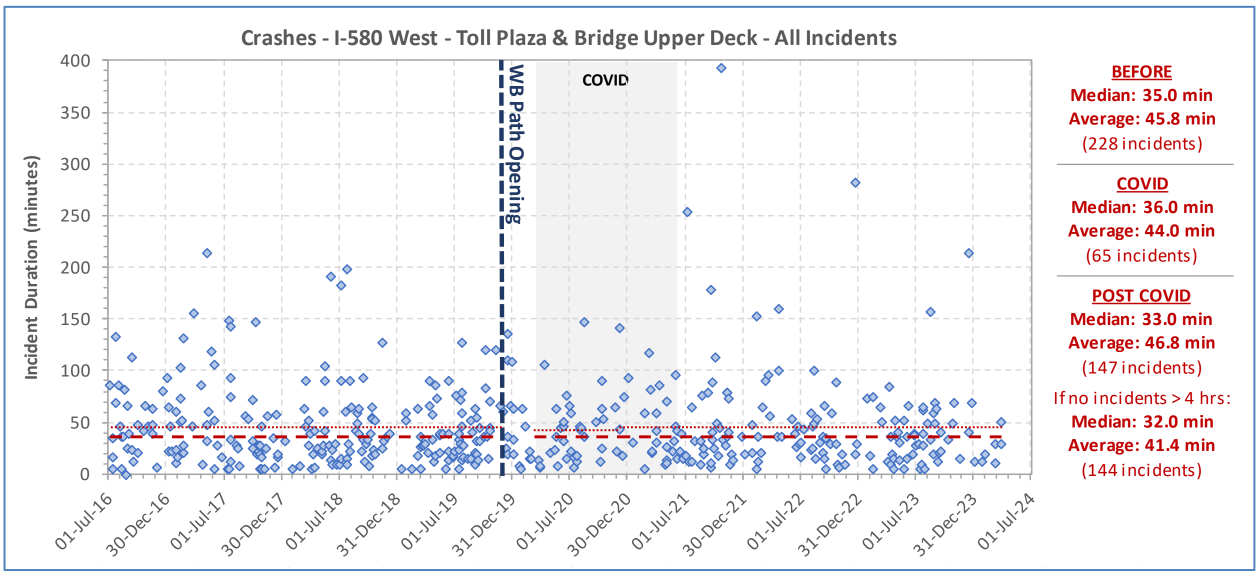

Figure 11-12: Estimated Incident Durations – Bridge Upper Deck, All Incidents, 2016-2024

As was indicated in Sections 5.5.4 and 5.5.5, logs from the CHP CAD database are the only dataset from which incident durations can be estimated, in addition to being the source of most statistics on incidents. The durations estimated from CHP CAD logs are further subject to some errors as these are simply based on when the first and last event-related messages were logged and as these messages do not always correspond to the actual start or end of an incident. While errors may exist, the purpose of the analysis is to determine whether the bridge modifications may have had significant negative impacts on incident durations. Since a single data source is used, the analysis is made under the assumption that potential biases in how incident durations are estimated are consistent before and after the bridge modifications, thus allowing a rough comparative evaluation to be made.

The data in Figure 11-12 suggests that the average duration of incidents on the bridge's upper deck has not significantly increased following the addition of the multi-use path. The data shows a slight increase in average incident duration, from 45.8 to 46.8 minutes (+1.0 minutes), and a slight reduction in median duration, from 35.0 minutes to 33.0 minutes (-2.0 minutes). However, if the three incidents lasting more than four hours (240 minutes) that have occurred between July 2021 and December 2022 are removed, the average duration then drops to 41.4 minutes post-modifications while the median further drops to 32.0 minutes, representing respective reductions of 4.4 and 3.0 minutes in average and median duration compared to the before period.

Statistical tests conducted to assess the significance of the observed changes indicate that no definitive conclusions can be made on either positive or negative impacts. Statistics tests indicate that a similar variance is observed in the before and after samples and that the estimated average duration for the post-COVID period is not statistically different from the before-period average at the 95%, 90%, 85%, or 80% confidence levels. This analysis thus indicates that converting the westbound shoulder into a barrier-separated bike/pedestrian path does not appear to have had significant impacts on the duration of incidents on the bridge.

11.3.4.2. Weekday AM Peak Analysis

Figure 11-13 reprises the analysis of the previous section by focusing attention on the incidents that have occurred on weekdays between 6 AM and 9 AM as this is a period of high interest to decision-makers. This period typically has the highest congestion on the approach to the bridge and is a key source of motorist complaints about traffic conditions.

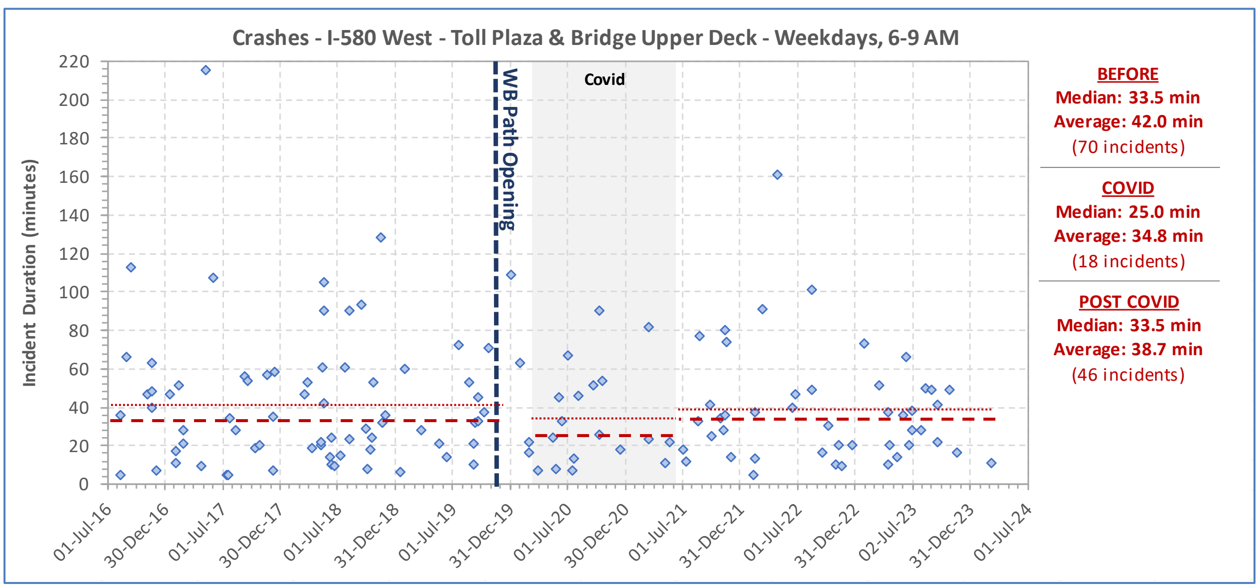

Figure 11-13: Estimated Incident Durations – Bridge Upper Deck, Weekday AM Peak, 2016-2024

For this analysis, the data indicate again that the addition of the multi-use path has not increased incident durations on the upper deck. The average duration is found to have decreased from 42.0 to 38.7 minutes

(-3.3 minutes) while the median duration remained unchanged at 33.5 minutes. However, similar to the analysis considering all incidents, these observed changes are not statistically significant at the 95%, 90%, 85%, or 80% confidence level, meaning that they could just be the result of the normal variability of incident durations on the bridge. Uncertainty in the accuracy of duration estimates also potentially reduces the validity of the observation.

11.4. IMPACTS ON SIR FRANCIS DRAKE OVERCROSSING SAFETY

The TASAS data indicates that very few vehicle collisions typically occur on the Sir Francis Drake overcrossing off-ramp. Table 11-16 shows a compilation of all logged incidents between January 2016 and December 2022. Before April 2020, incidents occurred at a rate of 1 or 2 per year. The only two incidents that have been reported since the modifications, both in 2021, suggest a similar very low rate of occurrence.

Table 11-16: Incidents on Sir Francis Drake Overcrossing Off-Ramp, 2016-2020

Year	Number of Incidents	Description
Before April 20, 2020 (Before Period)		
2016	1	• 2/22/2016 - Vehicle hitting sand barrels on the ramp
2017	2	• 2/22/2017 – 4 vehicles rear-ending • 10/06/2017 – Vehicle hitting the guardrail
2018	2	• 9/5/2018 - 3 vehicles rear-ending near Andersen Drive • 12/15/2018 - Vehicle hitting the concrete side of the overcrossing
2019	2	• 1/6/2019 - Vehicle hitting an object on the ramp • 5/11/2019 - 3 vehicles rear-ending near Andersen Dr
2020	0	• No reported incident
After April 20, 2020 (After Period)		
2020	0	• No reported incident
2021	2	• 1/3/2021 – Rear-end incident • 11/7/2021 – Vehicle hitting a fixed object on the ramp
2022	1	• 4/10/2022 – Head-on collision (wrong-way driving)
2023	0	• No reported incident

11.5. SUMMARY OBSERVATIONS

Key observations from the traffic safety impacts associated with the upper and lower deck bridge modifications are as follows:

- **Lower deck modifications:**
  - The conversion of the eastbound shoulder into a part-time traffic lane has reduced by 69% the rate of incidents on the approach to the bridge, on a per million miles traveled basis. This is mainly due to the elimination of the congestion that affected traffic along I-580 East from the US-101 interchange to the entrance of the bridge.
  - While the data also show a 9% rate reduction on the bridge, this change could simply be the result of stochastic variability.

- On the approach, the rate of incidents on the approach to the bridge, on a per million miles traveled basis, has reduced by 69% since the opening of the eastbound shoulder. This can be linked to the elimination of the heavy congestion that used to affect I-580 East traffic from the US-101 interchange to the entrance of the bridge. This was largely associated with the three-to-two-lane drop at the Main Street off-ramp just before the bridge. Similar to this drop, the rate of rear-end collisions has reduced by 80%, sideswipes by 57%, and vehicles hitting fixed objects by 59%.
- In terms of severity, the data indicate a reduction from 41% to 32% in the proportion of incidents with severe injury, complaint of pain, or other visible injuries occurring on the bridge following the opening of the path. While this may be related to the lower traffic densities, it mainly indicates a lack of negative impacts as other contributing factors could be involved.

- Based on an analysis of CHP CAD logs, there is no evidence that the bridge modifications are producing longer crash-related incidents or changing the location where crashes tend to occur on the bridge.
- Based on estimated incident duration data derived from the CHP CAD logs, there is no statistical evidence that the modification increased the time needed to clear crashes. In this case, data measuring more precisely the period during which an incident affects traffic would be required to provide a more definitive answer.
- Motorists traveling on the lower deck may not fully understand the meaning of the green arrow/yellow X/red X signage above the lower deck traffic lanes, resulting in some opting to use the shoulder as a traffic or passing lane when it is formally closed.

- **Upper deck modifications:**
    - Most of the observed changes in incident rates, types, and severity were not statistically significant at the 95%, 90%, or 85% levels. This means that the changes could all be the result of random effects in the incident associated with the before and after periods.
    - When considering all incidents that have occurred since 2016 outside the COVID-impacted quarters of April 2020 to June 2021, there is no evidence of a negative impact on traffic safety. The overall incident rate upstream of the toll plaza is calculated to have decreased from 1.45 to 1.26 per million miles traveled (-13%) following the path's opening, and from 1.16 to 0.93 (-19%) on the bridge.
    - When focusing on the weekday AM peak, 6 AM to 9 AM, the data suggests instead potential increases in overall incident rates. Ignoring again the COVID-impacted period, the rate of incidents across all weekdays is calculated to have increased from 3.61 to 4.26 (+18%) on the approach, from 2.31 to 3.07 (+33%) on the bridge, and from 2.74 to 3.47 (+26%) overall.
    - No clear impacts are observed on incident types. Rear-ends, sideswipes, and vehicles hitting objects typically represent around 95% of all incidents. When considering all reported incidents, relatively similar proportions of each incident type are observed for the before and after periods. When considering only the weekday AM peak, the proportion of sideswipes on the approach has reduced (from 51% to 40%), while the

proportions of rear ends have increased from 43% to 46%, and vehicles hitting objects from 4% to 12%. On the bridge, the proportion of sideswipes has instead increased from 40% to 44% while rear-ends have conversely decreased from 58% to 48%.

  - No clear impacts are observed on the severity of incidents. Before the modification, incidents without injury represented 72%-76% of all incidents on the approach, depending on whether all logged incidents or only those occurring during the weekday AM peak were considered, and 67%-68% of incidents on the bridge. After the modification, these accounted for 70%-79% of all approach incidents and 68-70% of the bridge incidents.
  - There is no evidence that the bridge modifications are producing longer crash-related incidents or changing the location where crashes tend to occur on the bridge.
  - There is no evidence that the bridge modifications are increasing the time needed to clear crash events. In this case, data measuring more precisely the period during which an incident affects traffic would be required to provide a more definitive answer.

- **Overcrossing modifications:**
  - The very low number of incidents occurring on the Sir Francis Drake overcrossing does not lead to clear conclusions on the impacts on incident occurrence, type, or severity.

12. IMPACTS ON INCIDENT RESPONSES

This section assesses whether significant inconveniences to incident response crews have been introduced by the conversion of the lower deck shoulder into a part-time traffic lane and the conversion of the upper deck shoulder into a barrier-separated multi-use path. This is done by:

- Assessing whether there have been significant changes in the location of bridge incidents
- Reviewing current incident response practice by CHP officers
- Analyzing tow truck logs documenting response times to bridge incidents
- Comparing approximating incident response times estimated from CHP-CAD logs before and after the modifications
- Summarizing key observed impacts

A key initial assumption was that the changes made to the bridge could increase response times due to the constraints they may impose on the movements of vehicles responding to incidents. A lack of noticeable change would therefore be viewed as a lack of significant negative impact.

12.1. LOCATION OF INCIDENTS ON BRIDGE

Figure 12-1 maps the locations of all reported upper and lower deck incidents on the bridge since January 2016. This includes 137 incidents on the upper deck, with 56 before the modification and 81 after, and 53 incidents on the lower deck, with 9 before the modification and 44 after.

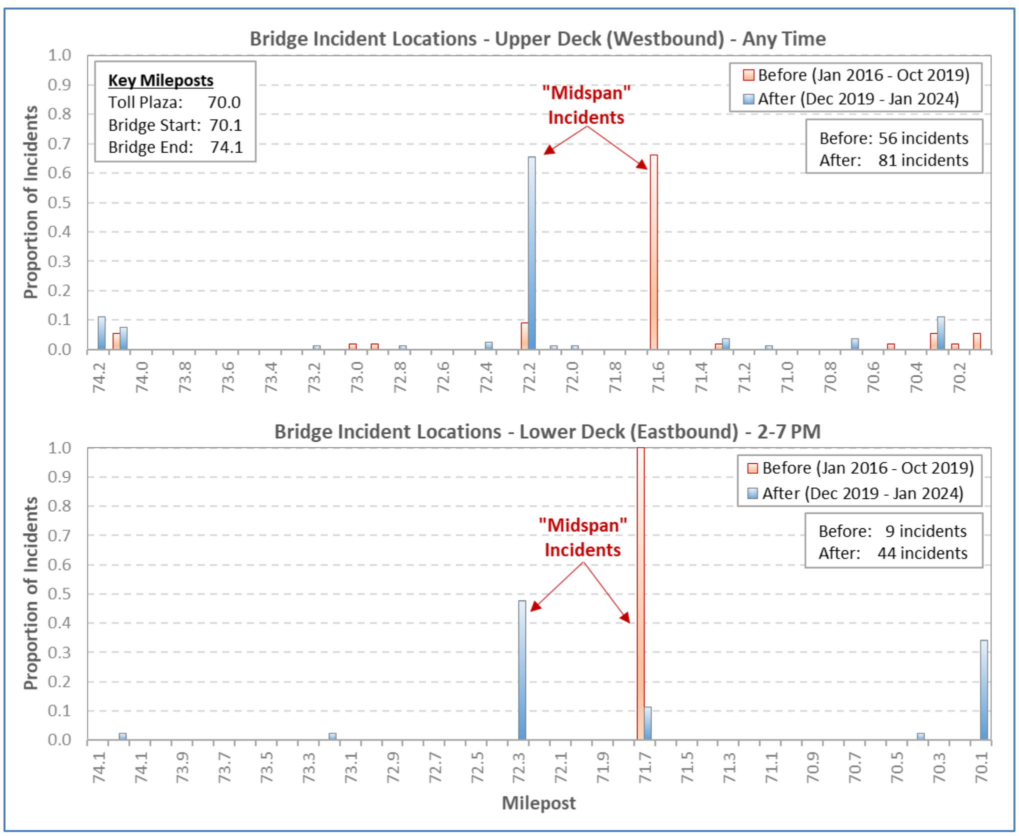

Figure 12-1: Location of Bridge Incidents – Before/After

As can be seen, most incidents are reported as having either occurred near the midspan of the bridge or the toll plaza. While there appears to be a shift in midspan location between the before and after conditions on each deck, this shift is likely the result of changes in how incident locations are reported as it would be unlikely that a similar shift happens to both decks. Milepost 71.7 appears to have generically been used to report midspan incidents up to about mid-2019, and milepost 72.3 after that.

Based on the illustrated data and the above assessment, a notable change in incident locations cannot be assumed to have occurred. This means that it can be assumed that response vehicles are roughly responding to similar incidents similarly located before and after the modifications on each deck.

12.2. CHP INCIDENT RESPONSE PRACTICE

The following summarizes current incident response practice by CHP officers for incidents occurring in traffic lanes on the Richmond-San Rafael bridge or the multi-use path.

- Response to incidents on bridge traffic lanes
  - Most incidents on the bridge are responded to by the Marin Division of the California Highway Patrol as it is often easier for them to access the bridge.
  - For incidents blocking all lanes on either deck, CHP vehicles generally reach the incident by driving counterflow on the bridge. Vehicles do not attempt to reach a site by traveling in the normal traffic direction as it could result in units being stuck in traffic. The CHP officers that were interviewed reported that some vehicles had been stuck in the past for nearly an hour. Vehicles generally wait for all the traffic downstream of an incident to have exited the bridge before attempting to travel in a counterflow direction. Some vehicles may also travel around the bay to access the bridge from its other end. This practice is similar to what was done before the modifications.
  - For incidents that do not block all lanes, responding units generally access the location of an incident by traveling within the traffic stream. This is again similar to what was done before the modifications.
- Response to incidents on the upper deck bike/pedestrian path:
  - Responding units usually travel toward the site of an incident using the lane next to the barrier. Once the incident location is reached, officers then stop their vehicle in the lane and jump over the barrier to assist.
  - While CHP officers could try to reach incidents using alternate transportation modes, this is not encouraged as it would cause officers to lose access to the computer/communication terminals located in their vehicles.
  - A new constraint is a need to stop in the right traffic lane when a response vehicle is needed.

12.3. TOW TRUCK RESPONSE TIMES ON THE BRIDGE

Tow truck response times obtained from Caltrans for incidents occurring on the bridge provided a limited view of the potential impacts of the bridge modifications on response times.

As shown in Table 12-1, the collected tow truck activity logs yielded relatively small amounts of data for both the before and after periods. The table compiles the number of logs retrieved for responses to bridge incidents and incidents around the toll plaza with a recorded dispatch time different than the arrival time at the incident site, i.e., with a response time greater than 0 minutes. For the eastbound direction, the number of logs is compiled for all incidents and for when the shoulder is open to traffic (2 PM to 7 PM). For the west direction, the logs are compiled for all incidents and incidents occurring during the weekday AM peak period (5 AM to 10 AM).

Table 12-1: Bridge Tow Truck Response Time Sample Sizes

Incident Logs with Dispatch Time	Eastbound (Lower Deck)				Westbound (Upper Deck)			
	Any Time		2 PM – 7 PM Any Day		Any Time		5 AM – 10 AM Weekdays	
	Before	After	Before	After	Before	After	Before	After
Bridge	9	79	2	36	9	98	3	23
Toll Plaza area	1	30	1	16	14	60	7	23

Notes: Before Data coverage: January-June 2016; March 21-31, 2019 (WB)
After Data coverage: March 21-31, 2019 (EB); February-March 2022, January-October 2023

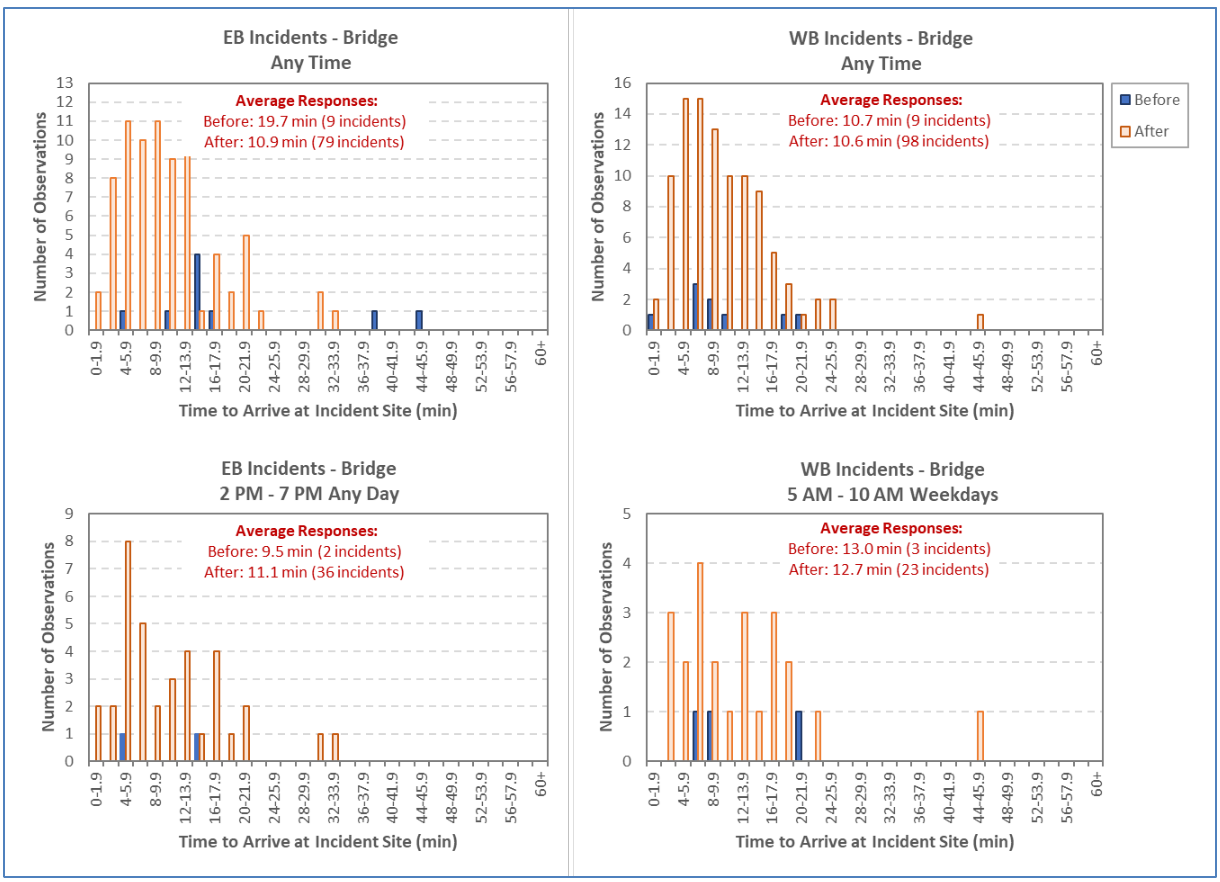

Figure 12-2: Before/After Caltrans Tow Truck Response Times

For both travel directions, the small sizes of the before and after data samples do not allow for performing robust analyses of the impacts of bridge modifications on tow truck response times. As an example, Figure 12-2 illustrates the distribution of response times for incidents on the lower and upper decks of the bridge for all four periods considered. As can be observed, no clear trend can be established as the few recorded response times from before the bridge modifications generally fall within the range of response times observed in the after period. Due to the low number of before observations, no clear differences can also be highlighted in the distribution of response times. In this case, statistical tests notably indicate that there are no significant differences at the 95 or 90 percent confidence level between the before and after averages, meaning that any observed differences could simply be due to randomness.

The following are additional elements that potentially make it difficult to ensure that the evaluated before and after conditions are for responding to similar incidents, particularly with limited samples:

- Incident locations are not usually referenced precisely. While some logs mention a specific pier or call box, most simply indicate that a response is to an incident midspan on the bridge, just east or west of it, or on the bridge incline or decline. These loose references make it difficult to ensure that the before and after samples only include responses to similar incident locations.
- Response times are subject to whether a tow truck is departing from its normal waiting location or another location. Caltrans usually has tow trucks waiting for potential responses on each side of the bridge. In some cases, a service dispatch may have been issued when a truck is already on the bridge, such as while performing a routine patrol across the bridge, resulting in shorter response times. An extreme opposite example might be for a dispatch to be issued when both trucks happen to be on the same side of the bridge, thus forcing one vehicle to first go back across the bridge before being able to access the deck on which a response is needed.
- For incidents blocking all traffic lanes, a response time may be for a tow truck traveling in a counterflow on the bridge. Unfortunately, the logs do not provide information if this may have been the case.

12.4. RESPONSE TIMES ON THE LOWER DECK BASED ON CHP-CAD LOGS

Figure 12-3 illustrates estimated response times for crashes that have occurred on the lower deck of the bridge between 2 PM and 7 PM, on any day, from July 2016 to March 2024, based on CHP dispatch messages captured by PeMS and later processed by the Bay Area Traffic Incident Management Dashboard web application. Only incidents that occurred between 2 PM and 7 PM are considered as this is the only period when bridge operations have changed for this direction of travel. In addition, only incidents for which an estimated response time could be calculated are considered.

The reported response times are the time that elapsed between when a response vehicle has been reported in the CHP CAD system as being assigned or on the way (en route) and the moment it has been logged as having arrived at the scene of an incident. These are estimates, as the dispatch logs do not always clearly indicate when a specific vehicle has been assigned, has departed, or has arrived. For instance, dispatch logs often record multiple vehicle assignments in succession but only specify one incident scene arrival. Many logs do not even indicate when, or whether, an assigned vehicle has arrived following an initial dispatch. In addition, no information is provided on the origin of the assigned vehicle, making it impossible to determine whether longer arrivals are due to congestion or simply a longer travel distance. Based on the above situations, the collected data is thus highly subject to interpretation.

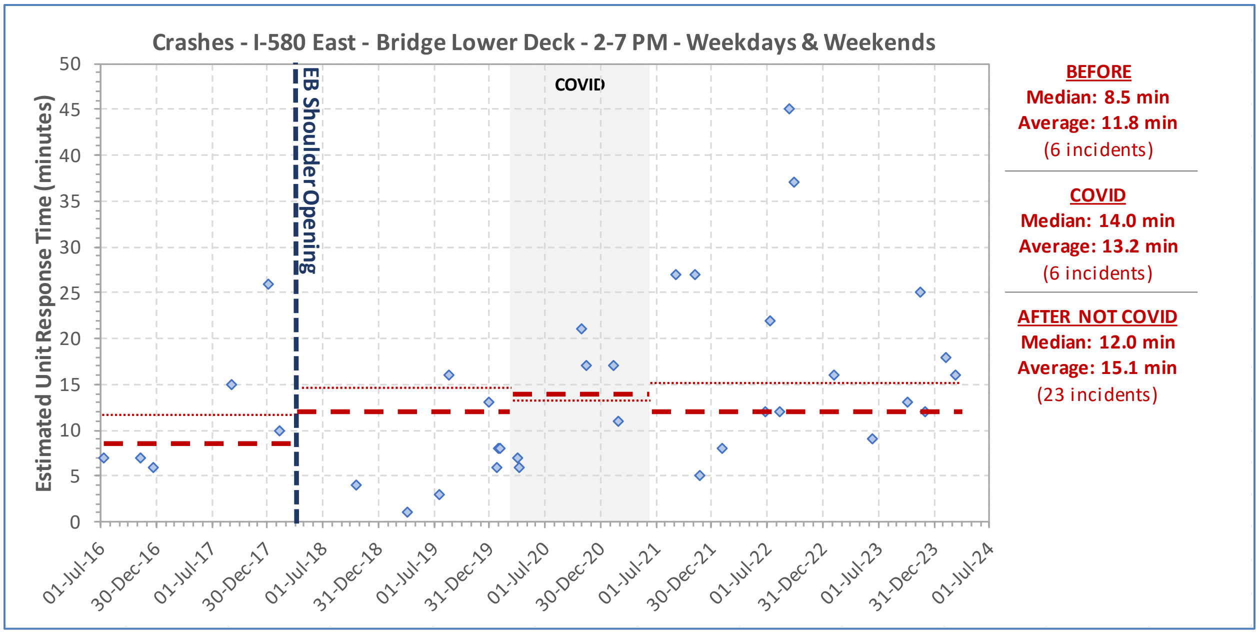

Figure 12-3: Estimated Incident Response Time – Bridge Lower Deck – 2016-2024

The collected data indicate a potential increase in response times following the conversion of the eastbound shoulder into a part-time traffic lane. For the six logged afternoon peak incidents before April 2018, the estimated median response time was 8.5 minutes, with an 11.8-minute average. For the 23 incidents logged after the bridge modifications and outside the COVID-impacted interval, the estimated median response time is 12.0 minutes (+3.5 minutes), with a 15.1-minute average (+3.3 minutes).

While the illustrated data point to an increase in response times, the observed changes are not statistically significant based on the variability of estimated response times across incidents. This assessment is based on standard statistical tests at 95%, 90%, 85%, or 80% confidence levels. This means that the observed changes could simply be due to randomness in the characteristics of the incidents considered in the before and after conditions. It must also be kept in mind that the analyzed response times are estimates based on what could be ascertained from the logs and may be inaccurate. The low number of incidents analyzed also significantly reduces the ability to identify clear trends.

12.5. RESPONSE TIMES ON THE UPPER DECK BASED ON CHP-CAD LOGS

Figure 12-4 plots the estimated incident response time for crashes that occurred on the upper deck of the bridge between July 2016 and March 2024 based on information contained in the CHP dispatch logs captured by PeMS and later processed by the Bay Area Traffic Incident Management Dashboard web application. All incidents that have occurred on a given day are included in the analysis since the shoulder is no longer available continuously. Like Figure 12-3, the reported response times are only estimates based on information captured in the CHP CAD logs and may not necessarily reflect actual response times. It should be noted that many incidents captured in the logs could not have their duration estimated due to incomplete or unclear records, potentially creating some biases.

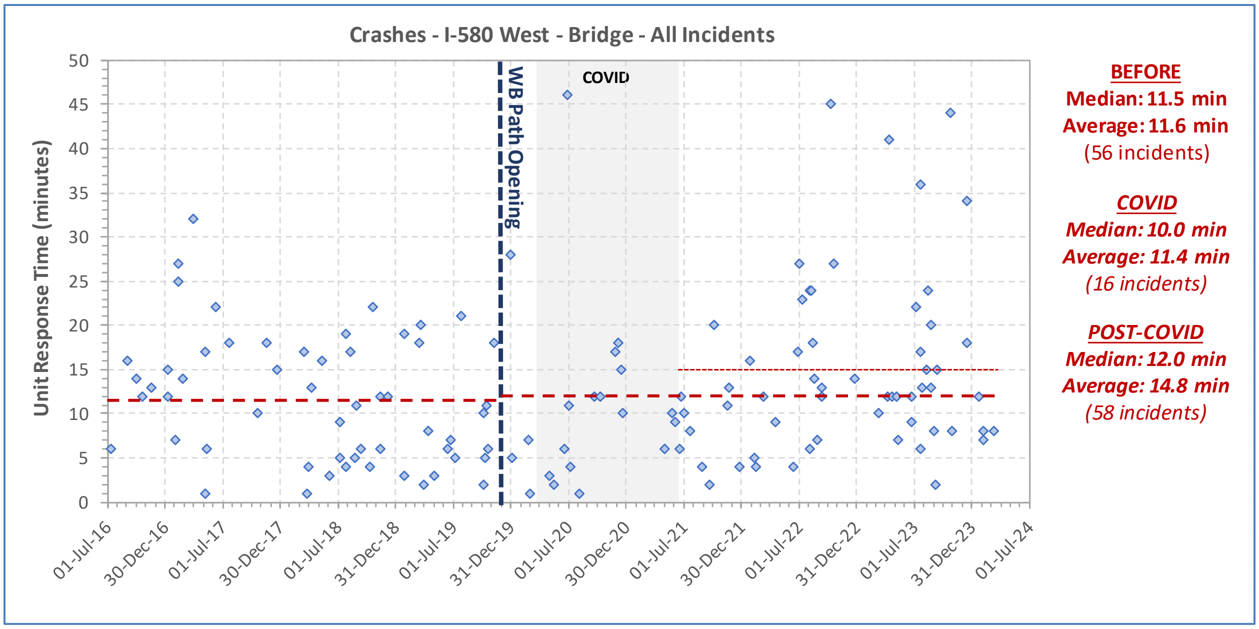

Figure 12-4: Estimated Incident Response Time – Bridge Upper Deck – All Incidents, 2016-2024

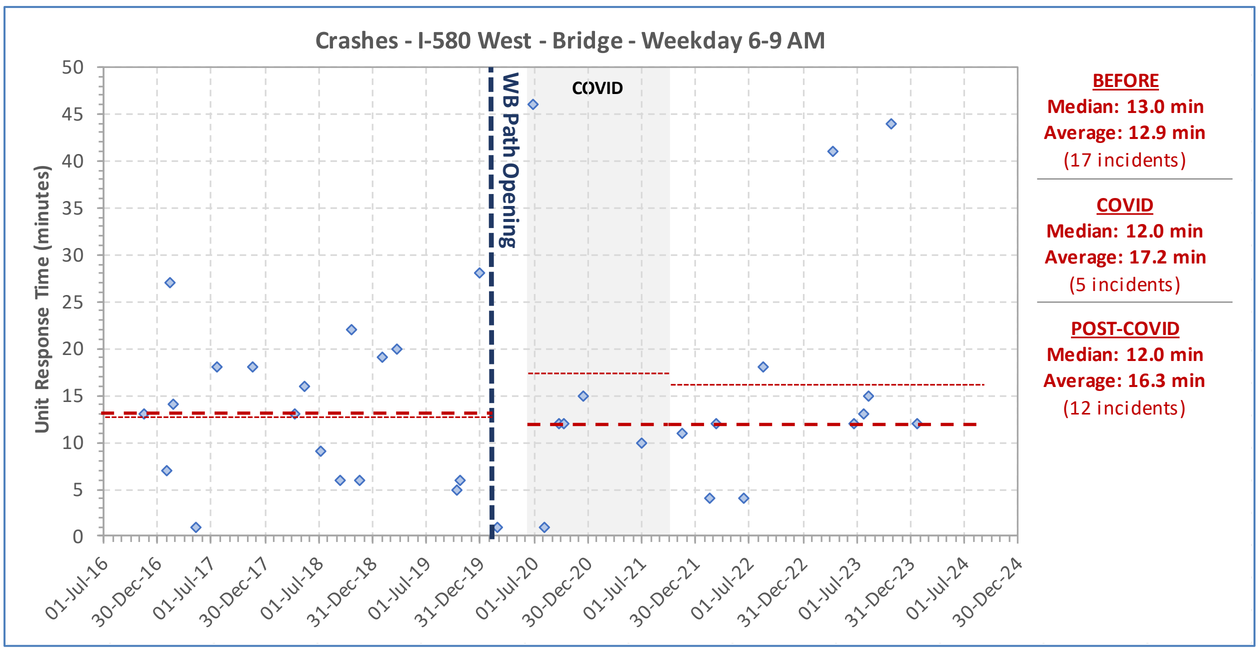

Figure 12-5: Estimated Incident Response Time – Bridge Upper Deck – Weekday AM Peak, 2016-2024

The starting hypothesis was that the introduction of a barrier to delimit the bike/pedestrian path would create a significant constraint for response vehicles attempting to reach incident locations. With the elimination of the shoulder, it was thought that response vehicles might have to travel more frequently through heavy congestion to reach an incident, thus leading to an increase in response times.

The estimated response times suggest instead that only a moderate increase might have occurred. The 56 incidents logged before the modifications have a median response time of 11.5 minutes while the 58 post-modification incidents outside the COVID-impacted period have a median of 12.0 minutes (+0.5 minutes). The average response time further slightly increased from 11.6 to 14.8 minutes (+3.2 minutes).

When focusing only on incidents that occurred during the AM peak, between 6 AM and 9 AM, the median response time decreases from 13.0 minutes to 12.0 minutes (-1.0 minutes) while the average response increases from 12.9 minutes to 16.3 minutes (+3.4 minutes).

Similar to the lower deck analysis, statistical tests indicate that the observed differences in response times are not statistically significant at the 95% confidence level. The differences may therefore simply be the result of randomness in the characteristics of the incidents included in the before and after samples. It could be the result of differences in the average location from where the response vehicle starts its trip (close or far from the bridge) or ease of travel towards the incident (through traffic still flowing at decent speed or significant congestion). The inclusion of incidents with response times greater than 35 minutes in the after samples while none is included in the before sample could also be the result of chance.

Considering all the potential influencing factors, the relatively small number of incidents that have occurred on the upper deck of the bridge since 2016 makes it difficult to provide any clear conclusion on whether the modifications have significantly affected incident response times. Current data suggests only a small potential impact.

12.6. SUMMARY OBSERVATIONS

Key observations from the analysis of impacts on incident responses are as follows:

- There is no evidence that bridge modifications changed where incidents typically occur on the upper deck or lower deck.
- Retrieved tow truck dispatch logs do not provide enough observations to determine whether the bridge modifications have resulted in longer response times.
- Estimated incident response times from CHP-CAD logs also do not provide evidence that bridge modifications have caused significant increases in incident response times.

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13. IMPACTS ON MAINTENANCE ACTIVITIES

This section assesses whether significant inconveniences to maintenance activities have been introduced by the conversion of the lower deck shoulder into a part-time traffic lane and the installation of the upper deck barrier-separated multi-use path. The assessment was primarily conducted through conversations with Caltrans maintenance staff.

Summaries of key maintenance-related elements that were mentioned by Caltrans staff are presented below for the bridge's upper and lower decks. An overall summary concludes this section.

13.1. LOWER DECK ACTIVITIES

Key impacts on lower deck maintenance activities include the following:

- Since the lower deck shoulder is only open to traffic during the afternoon and maintenance activities tend to occur in the evening and at night, there has been a relatively minimal impact on operations.
- Because vehicles might be traveling on the shoulder when it is closed, the lane must now always treat the lane as an active lane. This means taking additional precautions to ensure that motorists are aware that stopped vehicles may be on the shoulder.

13.2. UPPER DECK ACTIVITIES

Key impacts on upper deck maintenance activities include the following:

- The installation of the multi-use path has eliminated the ability of maintenance crews to park vehicles on the upper deck without impeding traffic. Vehicles must now block a traffic lane when conducting routine or emergency maintenance work on the upper deck traffic lanes, which carries additional safety setup implications, in addition to potentially resulting in some traffic disturbances if conducted during periods of significant traffic.
- Closing of a traffic lane for path maintenance mainly occurs for routine monthly cleanings when the barrier must be moved. To minimize traffic impacts, this is typically done, with bulletins published by MTC/511 well ahead of time.
- Daytime path closures are periodically needed to conduct structure inspections as this requires moving a bucket truck along the bicycle/pedestrian path. These closures typically have no effects on vehicular traffic.
- Caltrans maintenance has a motorized cart to use on the bridge path for routine maintenance. For major maintenance of the path, the path would be closed to traffic.
- The path barrier is typically realigned once a month as part of normal bridge operations. The scheduling of these activities can be observed in logs from the Caltrans Lane Closure System.
- Vehicle impacts can result in the barrier being moved inwards on the path. When this occurs, emergency repairs are only made if an incident causes the width of the path to be reduced to less than 10 feet. If more than 10 feet remain available, the maintenance crew generally either uses tools to manually realign the barrier or waits for the monthly machine re-alignment.

- Damages to the toppers sitting on top of the barrier elements, illustrated in Figure 13-1, are usually repaired as soon as possible as this is a crucial safety element of the barrier. The toppers are added to allow the barrier to reach a legal height of 42 inches and to minimize the risk of cyclists falling over the barrier into the adjacent traffic lane. Bridge maintenance indicated that 75 toppers had to be replaced between November 2019 and March 2022, representing an average replacement rate of 2.6 toppers per month.

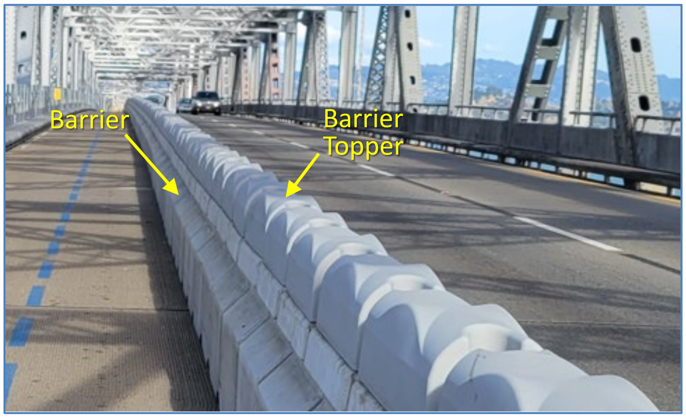

Figure 13-1: Bridge Path Barrier Toppers

13.3. ACTIVITIES REGARDING THE SIR FRANCIS DRAKE OVERCROSSING PATH

Key maintenance issues mentioned by Caltrans employees regarding the modified bike path on the Sir Francis Drake overcrossing include the following:

- Similar to the bridge, vehicle impacts can result in the barrier moving inward. However, this occurs very seldomly, likely due to the low frequency of incidents on the overcrossing and the buffer provided by the 6-ft shoulder.
- If there is a need to realign the barrier, the maintenance crew will try to manually reposition it using pry bars and digging bars as it is not possible to bring the realignment machine used on the bridge to the overcrossing.
- The small length of the overcrossing allows maintenance crews to park vehicles in relative proximity to where work is needed, either at the bottom or top of the overcrossing.
- Similar to the bridge path, damages to the toppers would be immediately replaced as these are crucial safety elements.

13.4. SUMMARY OBSERVATIONS

The following is a summary of key observations from the analysis of impacts on maintenance activities:

- **Upper deck:**
    - The path's barrier now forces the maintenance crew to close the right traffic lane when maintenance work is needed on the bridge as there is no other place to park vehicles.

    - Emergency realignment to the barrier is only conducted if an incident causes the barrier to leave less than 10 feet of width on the path. This has only occurred twice between November 2019 and April 2022. In other cases, the barrier is realigned during the monthly alignment check.

- **Lower deck:**
    - The primary impact of opening the eastbound shoulder to traffic during the afternoon peak is the need to always treat the shoulder as an active lane as vehicles are now more likely to be seen traveling on the shoulder when it is formally closed.

- **Overcrossing path:**
    - All barrier repairs are done manually due to the inability to bring the barrier-moving machine from the bridge. This can easily be done with the proper tools and not viewed as an issue due to the low frequency of incidents.
    - The relatively small length of the overcrossing path does not create significant issues for maintenance crews to access the site.

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14. QUALITY OF LIFE ASSESSMENT

This section presents the results of the following two surveys that were conducted to assess impacts on quality of life:

- Before/After interviews with managers from 8 businesses located on local Marin County streets potentially used as alternate routes to the bridge, first visited in 2016 and revisited in May 2022, to obtain information about how traffic conditions around the bridge might affect their operations (see details in Section 5.9).
- An online survey of bridge path users, in the summer of 2021, to collect information on how individuals are using the path and perceiving its safety and benefits (see details in Section 5.8).

14.1. MARIN COUNTY BUSINESS SURVEY RESULTS

The results of the business survey that was conducted between April and December 2016, before the bridge modifications, were as expected. The collected sentiments primarily reflected the inconveniences associated with the congestion on the eastbound bridge approach. It should however be noted that the comments collected only represent the views of managers from a relatively small number of businesses and may not, therefore, represent the sentiments of all businesses.

A summary of the key sentiments expressed by the few managers interviewed is provided below:

- Most of the interviewees indicated that congestion during the afternoon commute period typically spilled over to the local streets as commuters attempted to use alternative routes to reach the bridge. All the major alternate routes appeared to be affected, including Bellam, Francisco, Andersen, and Sir Francis Drake. The time intervals most cited for which this problem was observed were 3:00 PM to 7:00 PM or 4:00 PM to 7:00 PM, i.e., during the afternoon peak.
- Interviewees expressed that they believed that their businesses were adversely affected by the daily afternoon traffic congestion spillover.
- Due to high housing costs in Marin County, which were approaching or exceeding one million dollars in 2015, many employees of the surveyed 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, primarily due to congestion at the toll plaza merge, had resulted in an increasing proportion of 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 Francisco Boulevard or Andersen Avenue.
- Businesses that rely on trucks or delivery services (e.g., UPS) padded their schedules to accommodate the anticipated delays.
- Commute travel times in the afternoon/evening could be double those observed in the morning. Traffic has affected employee commute times.
- Only one business commented that their employees might use the new bicycle lane. Otherwise, the consensus was that their employees would not use it.

Below are the results of a similar business survey that was conducted in May 2022 to assess the potential impacts of the bridge modifications on business activities:

- Many interviewees indicated that congestion on the Richmond approach to the bridge during the morning peak period or midday Saturdays and Sundays remains a significant inconvenience. Many indicated perceiving that the congestion has never been worse, even though traffic data suggests this is not the case. A few further indicated that the lack of a shoulder now amplifies the impacts of simple incidents, causing significant swings in travel times.
- For some businesses, the morning congestion on the Richmond side creates a difficulty in hiring or retaining employees living on the Richmond side of the bridge. While some businesses would like to hire individuals from Marin County, it was pointed out that the high cost of housing in the counter often forces them to try to look for employees living across the bridge.
- One business indicated that while there appear to be more delays to access the bridge from Richmond in the morning this is partly compensated by shorter travel times back to Richmond in the afternoon.
- No business indicated that the congestion caused employees to frequently arrive late. Most employees appear to have built some buffer time in their morning commute to arrive on time.
- No interviewee was aware of any significant impact of the Richmond approach congestion on their business activities.
- Most of the interviewees indicated that they currently do not see any issues with traveling toward Richmond at any time of the day. Afternoon traffic conditions are much better than they were. The only few negative comments were about temporary inconveniences caused by lane closures on the lower deck for bridge repairs.
- No interviewee was aware of any significant traffic currently using local arterials as a bypass to I-580.
- Several businesses along Francisco Boulevard acknowledged that fewer vehicles now use the arterial as a bypass to I-580 East.
- One business that indicated the difficulty for corporate vehicles to reach the company office from Larkspur using Sir Francis Drake Boulevard and/or Andersen Drive that existed in 2016 has completely disappeared following the lower deck modifications and the elimination of traffic backup onto Sir Francis Drake Boulevard and Andersen Drive.
- Employees from two businesses indicated that the remaining key eastbound bottleneck is the US-101 North exit to Bellam/I-580 East. Because of the traffic light at the end of the ramp, ramp queues often back up onto US-101 North, causing occasional slowdowns on the right mainline lane upstream of the exit. A second bottleneck is the signals metering traffic at the Sir Francis Drake Boulevard exit.
- No one indicated being aware of employees using the bridge path to commute to work. Some have indicated using it on occasion for recreational purposes.

14.2. USER SURVEY RESPONSES

This section provides a summary of responses to the user survey that was conducted in the summer of 2021. Specific elements discussed below include:

- Characterization of survey respondents
- Starting and ending points of trips made on the bridge path
- Typical use of bridge path
- Perceived safety of bridge path
- Perceived benefit of the bridge path

14.2.1. CHARACTERIZATION OF SURVEY RESPONDENTS

2,166 individuals responded to the online survey between June 16 and August 13, 2021. As indicated in Table 14-1, 1,543 of these respondents, or 73.9%, are cyclists or pedestrians who reported having used the bridge path. 623 individuals, or 28.8% of respondents, further reported having never used the bridge path. Based on the comments provided by these individuals, this group is assumed to be primarily comprised of motorists traveling across the bridge.

Table 14-1: Survey Respondents – Bridge Path Users

Bridge Path User Type	Number of Respondents	Percent
Cyclist	1,402	64.7%
Cyclist/Pedestrian	78	3.6%
Pedestrian	63	2.9%
Non-User	623	28.8%
TOTAL	2,166	100.0%

14.2.2. STARTING AND END POINTS OF TRIPS MADE ON THE BRIDGE PATH

As part of the survey, respondents were asked to indicate what were their trip starting and ending points. In this case, ending destinations were defined as locations individuals were heading to before returning home, such as a place of work, a local restaurant, or a recreational location.

Table 14-2 compiles the reported trip starting and ending points from individuals who reported using the bridge path as a cyclist or a pedestrian. These respondents were primarily individuals traveling from Richmond to Marin County. These trips represented 787, or 51.7%, of the 1522 reported trips. Only 16.8% of trips were from Marin County to the Richmond side of the bridge. 22% of trips were further reported as starting and ending on the Richmond side, while 9.5% were reported as starting and ending on the Marin side.

Table 14-2: Origin/Destination of Trips by Bridge Path Users

Trip Origin	Trip Destination		Total Origin
	Richmond Side	Marin Side	
Richmond Side	335 (22.0%)	787 (51.7%)	1,122 (73.7%)
Marin County Side	255 (16.8%)	145 (9.5%)	400 (26.3%)
Total Destination Trips	590 (38.8%)	932 (61.2%)	1,522 (100.0%)

Table 14-3 further compiles the reported trips starting and ending points from individuals who did not use the bridge path. Like the path users, most of the respondents in this category were individuals traveling westward, with 361 of the 603 reported trips (59.9%) starting on the Richmond side and ending in Marin County. Only 26% of the reported trips were in the opposite direction. Only 5.8% further started and ended on the Richmond side, while 8.3% of trips started and ended in Marin County.

Table 14-3: Origin/Destination of Trips by Respondents Who Did Not Use Bridge Path

Trip Origin	Trip Destination		Total Origin
	Richmond Side	Marin Side	
Richmond Side	35 (5.8%)	361 (59.9%)	396 (65.7%)
Marin County Side	157 (26.0%)	50 (8.3%)	207 (34.3%)
Total Destination Trips	192 (31.8%)	411 (68.2%)	603 (100.0%)

14.2.3. USE OF BRIDGE PATH

The following characterizes the use of the bridge path by individuals, either as a cyclist or a pedestrian:

- 1.9% of survey responses indicated using the path more than four times per week, 10.7% up to four times per week, 29.8% up to four times a month, 31.8% less than once a month, and 25.8% less than four times since its opening.
- 68.3% of respondents indicated using the path on Saturdays, 55.4% on Sundays, and 50.7% on weekdays. This is consistent with bicycle and pedestrian count data, which show significantly higher traffic on the path on weekends than on weekdays.
- 85.1% have indicated using the path for recreation (63.1%) or exercise (22.0%). Only 14.0% have used it for commuting, either to work (4.9%) or other locations (9.1%). The remaining 0.9% used it for other, non-specified, reasons.
- 83.9% indicated having completed one or more round trips on the path while cycling or walking. Of these, 90.6% reported fully crossing the bridge both ways, 6.9% turning back mid-way, and 2.5% having both fully crossed the bridge or turned back mid-way depending on the occasion.
- 3.7% reported having used a car or a bus to come back across the bridge.
- 19.2% reported having used a different route to come back to their origin point.
- Of the 63 individuals who reported having solely used the path as a pedestrian, only 23.8% completed a full round trip on the bridge. 57.1% turned around partway, 7.9% used a vehicle to cross the bridge back, and 11.1% returned to their origin using a different route.

14.2.4. SAFETY OF BRIDGE PATH

Bridge path users generally view it as safe. As shown in Table 14-4, the path received an average safety rating of 8.19 for its cyclists and pedestrians who used it, with 75.1% of them providing a rating of 8 or above. Only 4.9% of respondents gave the path a safety rating of less than 5.

Table 14-4: Bridge Path Safety Rating by User Type

User Type	Count	Rating Distribution										Average Rating
		1	2	3	4	5	6	7	8	9	10	
Cyclists	1,399	10	6	18	20	42	63	173	353	351	363	8.27
Cyclists/Pedestrians	78	4	1	1	4	1	4	10	19	14	20	7.72
Pedestrians	61	2	4	2	3	7	3	4	14	11	11	7.05
All Users	1,538	16	11	21	27	50	70	187	386	376	394	8.19

Survey respondents generally considered the ability to separate cyclists and pedestrians from the adjacent fast-moving traffic as the primary safety benefit of the path. However, the following concerns were cited more than once by various respondents:

- 46 respondents, or 3%, noted the narrow width of the path, particularly the fact that this creates problems when encountering cyclists traveling in the opposite direction or slow-moving pedestrians or cyclists. Some individuals also cited problems for tricycle riders.
- While the barrier helps separate the path from the nearby fast-moving traffic, some concerns remain about the ability of the barrier to prevent trucks and cars from breaching the path during an incident.
- Debris on the path flying from passing cars and trucks creates riding hazards.
- Debris flying from passing cars/trucks also creates some safety hazards.

14.2.5. BENEFITS OF BRIDGE PATH

Most path users have a positive view of the new bridge path. Path users collectively assigned a rating of 8.35 to the path, with 81.5% of users giving the path a benefit rating of 8 or above. The lower ratings primarily stem from environmental factors associated with the path, such as wind, noise, pollution from traffic, interactions with cyclists, etc.

Table 14-5: Bridge Path Benefit Rating by User Type

User Type	Count	Rating Distribution										Average Rating
		1	2	3	4	5	6	7	8	9	10	
Cyclists	1,393	40	15	20	15	39	22	83	208	193	758	8.67
Cyclists/Pedestrians	78	7	3	0	0	2	0	5	7	11	43	8.24
Pedestrians	60	14	3	6	1	3	2	4	5	4	18	5.88
Non-Users	616	392	47	25	19	20	9	13	18	8	65	2.84

Most non-path users view the new path negatively. The 616 non-users who provided a benefit rating collectively assigned a rating of 2.84 to the path, with 63.6% of them assigning a rating of 1 to it, the lowest possible. Based on the written comments provided, 156 (25%) of these respondents appear to be motorists who explicitly state that they would like the path removed for one or more of the following reasons:

- The removal of the westbound shoulder now prevents vehicles from pulling out of traffic in an emergency. This results in more severe congestion when incidents occur on the bridge.
- The shoulder should best be used to relieve traffic congestion, as is done in the eastbound direction.
- The bike lane appears to be significantly underused.

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15. SUMMARY

This section presents a summary of the key findings from the study related to the modifications performed on the lower and upper decks of the bridge. This includes:

- Impacts of shoulder modification on the lower deck of the bridge.
- Impacts of the new multi-use path on the upper deck of the bridge.
- Impacts of modified bike path on the Sir Francis Drake I-580 West off-ramp overcrossing.

15.1. IMPACTS OF SHOULDER MODIFICATIONS ON BRIDGE LOWER DECK

- **Compliance of traffic with shoulder open/close periods**
    - On average, 99.6% of traffic observed on the bridge before 2 PM and after 7 PM is compliant with the shoulder closure.
    - Non-compliant lane use is highest 20 minutes before opening and 30 minutes following closure. Non-compliance before opening varies between 0.3% and 0.6% of traffic while post-closing non-compliance varies between 0.5% and 1.1%.
    - Motorists traveling on the lower deck may not fully understand the meaning of the green arrow/yellow X/red X signage above the lower deck traffic lanes, resulting in some opting to use the shoulder as a traffic or passing lane when it is formally closed.
- **Traffic impacts on I-580 East and US-101 North**
    - The availability of an extra traffic lane during peak hours has increased hourly flows across the bridge by 13-25%, from 3,300-3,600 vehicles/hour before the modification to 3,750-4,500 vehicles/hour after. This is not due to an increase in traffic demand but simply to the removal of the bottleneck at the entrance of the bridge.
    - Less than 25% of traffic is observed at any given time using the part-time lane during weekday peak periods, and less than 20% on weekends.
    - The added peak-hour capacity has eliminated congestion on the approach to the bridge, resulting in a drop in peak travel times from the US-101 to the toll plaza by 14-17 minutes on midweek days, 10-14 minutes on Saturdays, and 6-8 minutes on Sundays.
    - Peak-hour travel times from the US-101 to the toll plaza are significantly less variable.
    - Traffic improvements along I-580 East may have partly contributed to the observed 1-2 minutes reduction in average peak weekday travel times on US-101 North between the Sir Francis Drake Boulevard and I-580 interchanges since 2017.
    - Fewer vehicles are using the Main Street off-ramp and on-ramp as a congestion bypass. Such use of the ramps during the afternoon peak has dropped from an average of 56 vehicles/hour in May 2016 to 1 vehicle/hour in March 2022.

- **Traffic impacts on local arterials in Marin County**
    - Compared to 2016, weekday afternoon peak travel times along Sir Francis Drake Boulevard have dropped by up to 4 minutes, while traffic volumes have increased by over 300 vehicles/hour.
    - Fewer vehicles are using local arterials as a bypass to I-580 to save time while traveling towards the bridge in the afternoon. Peak traffic on Francisco Boulevard has for instance dropped from 730 to 227 vehicles/hour between May 2016 and March 2022.
- **Vehicle emissions along I-580 East**
    - The elimination of the congestion on the bridge approach has led to reductions in pollutant emission rates per mile traveled varying between 3.6% and 23.4% depending on the pollutant considered and season (summer/winter).
    - Mixed results were obtained on weekends due to conflicting effects from the elimination of the congestion on the approach (reduction of emissions due to low speeds) and enabling a higher proportion of vehicles to travel above 60 mph (increase in emissions due to higher engine output).
- **Traffic safety along I-580 East:**
    - On the approach, the rate of incidents on the approach to the bridge, on a per million miles traveled basis, has reduced by 69% since the opening of the eastbound shoulder. This can be linked to the This can be linked to the elimination of the heavy congestion that used to affect I-580 East traffic from the US-101 interchange to the entrance of the bridge and which was largely associated with the three-to-two-lane drop at the Main Street off-ramp just before the bridge. In terms of incident types, this has further translated into an 80% reduction in the rate of rear-end collisions, a 57% reduction in sideswipes, and a 59% reduction in vehicles hitting fixed objects.
    - On the bridge, the addition of a traffic lane has led to lower peak traffic densities and a 32% reduction in the rate of rear-end collisions. However, this change is also providing more opportunities for lane changes. This has translated into a 24% increase in the rate of sideswipes and a 7% increase in vehicles hitting objects.
    - In terms of severity, the data indicate a reduction from 41% to 32% in the proportion of incidents with severe injury, complaint of pain, or other visible injuries occurring on the bridge following the opening of the path. While this may be related to the lower traffic densities, it mainly indicates a lack of negative impacts as other contributing factors could be involved.
    - Based on CHP CAD logs, there is no evidence that the bridge modifications are producing longer incidents or altering the locations where crashes tend to occur.
    - Based on estimated incident duration data derived from the CHP CAD logs, there is no statistical evidence that the bridge modifications are increasing the time needed to clear crash events. In this case, data measuring more precisely the period during which an incident affects traffic would be required to provide a more definitive answer.

- **Incident response times:**
    - Retrieved tow truck dispatch logs do not provide enough observations to determine whether the bridge modifications have resulted in longer response times.
    - Estimated incident response times from CHP-CAD logs also do not provide evidence that bridge modifications have caused an increase in incident response times.
- **Maintenance activities on the lower deck:**
    - Because vehicles are occasionally seen using the lower deck shoulder when closed, maintenance crews must always treat it as an active lane to ensure their safety.

15.2. IMPACTS OF NEW MULTI-USE PATH ON UPPER DECK

- **Use by cyclists:**
    - In the most recent peak season, bicycle traffic on the bridge was the highest of all State-owned toll bridge paths, including the San Francisco-Oakland Bay Bridge multi-use path.
    - Bicycle traffic typically follows an annual cyclical pattern, with the highest volumes occurring in the summer (June-September) and the lowest in winter (November-March), when it is colder and rainier. Traffic also follows a weekly pattern, with the highest traffic typically observed on Saturday, the second highest on Sundays, and relatively constant lower volumes on weekdays.
        - Since January 2022, Saturday summer traffic has averaged 264 cyclists/day westbound and 219 eastbound, with peaks up to 435, while Sunday summer traffic has averaged 188 westbound and 167 eastbound, with peaks up to 285.
        - Winter Saturday traffic has averaged 177 cyclists/day westbound and 135 eastbound, with peaks near 300, while Sunday traffic has averaged 145 cyclists/day westbound and 120 eastbound, with again with peaks near 300.
        - Summer weekday has averaged 75 cyclists/day westbound and 66 eastbound, with peaks near 100, and winter traffic 50 westbound and 41 eastbound, with peaks near 60.
    - Westbound traffic is usually greater than the eastbound traffic, with a 55%/45% split.
    - Cyclists mainly travel westbound in the morning and eastbound in the afternoon. Peak westbound traffic is between 10 and 11 AM on both weekends and weekdays, while peak eastbound traffic is between 1 and 2 PM on weekends and between 3 PM and 4 PM on weekdays, with notable traffic between 12 Noon and 3 PM.
    - 1.9% of surveyed path users in 2021 indicated using it more than four times per week, 10.7% up to four times per week, 29.8% up to four times a month, 31.8% less than once a month, and 25.8% less than four times since its opening.
    - 85.1% of path users indicated using it for recreation (63.1%) or exercise (22.0%). Only 14.0% have used it for commuting, either to work (4.9%) or other locations (9.1%). The remaining 0.9% used it for other, non-specified, reasons.

- 83.9% of path users indicated having completed one or more round trips on the path while cycling or walking. Of these, 90.6% reported fully crossing the bridge both ways, 6.9% turning back mid-way, and 2.5% having both fully crossed the bridge or turned back mid-way depending on the occasion.
- While there has been a significant drop in the number of bicycles carried across the bridge by Golden Gate Transit buses, with monthly counts remaining at 51%-63% of the 2015-2019 average, it is unclear what part might be a byproduct of the COVID-19 pandemic and what part, if any, could be linked to the path opening, as the overall ridership for Golden Gate Transit remains at around 45%-48% of the 2019 level.
- Overall, trips with bicycles across the bridge, either being carried on a bus or ridden, are higher than before the path opening. Summer traffic went from 700-900 trips/month when Golden Gate Transit buses were the only option, to 6,000-8,000 trips/month during the summer of 2023.

- **Use by pedestrians:**
  - Pedestrian traffic on the bridge is relatively low. Average weekday eastbound traffic is only 11 pedestrians/day while westbound traffic is around 8 pedestrians/day. Weekend eastbound and westbound traffic reach 24 and 14 pedestrians/day, respectively.
  - The estimated pedestrian use is likely underestimated as the counts are based on a single sensor located on the Richmond side of the bridge. This sensor would not have captured individuals accessing the path from the vista point in Marin County and turning back before having fully crossed the bridge.
  - The 4-mile length of the bridge likely explains the low pedestrian demand, and why less than 24% of pedestrians indicated completing a full round trip on the bridge and 57% turned around partway.
  - Fishers have been observed using the path to access locations from where to cast fishing lines, either on the shore or the path itself. Such individuals are more often seen on the Marin County side, where they use the parking lot at the vista as a staging area.

- **I-580 West traffic conditions:**
  - Average weekday peak-hour flows across the bridge have dropped by 7% following the addition of the path, from a range of 3,500-3,850 vehicles/hour to a range of 3,250-3,600 vehicles/hour depending on the day considered. Weekend peak-hour flows have similarly dropped by 4%, from a range of 3,200-3,500 vehicles/hour to a range of 3,100-3,300 vehicles/hour.
  - The significantly shorter merge downstream of the toll plaza (325 ft instead of 850 ft) and the perceived narrowness of the roadway on the bridge causing some vehicles to slow down and others to move to the left lane may explain the maximum flow reductions across the bridge. These negative impacts may have partly been compensated by the elimination of the toll cash collection.
  - Despite the slight capacity reduction, the extent of the congestion upstream of the toll plaza and average peak travel times from I-80 to the end of the bridge on weekdays, Saturdays, and Sundays have remained similar to the before conditions. This can be

explained by traffic demands remaining slightly below before conditions, particularly at the start and end of the peak periods, due to lingering COVID-related factors.

- Before the modifications, upper deck traffic generally flowed on weekday mornings at or above 50 mph past the first mile of the bridge. In the fall of 2021, speeds between 40 and 50 mph were typically observed across the bridge, increasing travel time by less than one minute. Some slight speed reductions were also observed on Saturdays and Sundays but with negligible impacts on travel times.
- Peak weekday travel times on the bridge's approach are now more variable, i.e., less reliable, than before the path installation, mainly due to the barrier now preventing disabled vehicles from pulling out of a traffic lane. The reliability of peak weekend travel times remains similar to before.
- The closeness of the path's barrier to the right traffic lane appears to have caused 1-2% of peak-hour traffic to shift to the left lane, and up to 20% of the evening and night traffic to do the same. This has resulted in an average 57%/43% split across the left and right lanes during weekday peaks and a 55%/45% split during weekend peaks.
- Many of the traffic impacts described above may still be affected by lingering reductions in traffic caused by an increase in the proportion of individuals working from home following the COVID-19 pandemic.
- Evaluations regarding the possibility of a third traffic lane on the upper deck of the bridge must consider capacity constraints in the existing road network in Marin County.

- **Traffic conditions on local arterials in Richmond:**
  - Available data do not indicate that the bridge modifications have had significant impacts on local arterials on the Richmond side of the bridge.
- **Vehicle emissions along I-580 West**
  - Depending on the pollutant and season, reductions in emissions varying between 0.2% and 12.7% are estimated to have resulted from the bridge modification, primarily due to a reduction in the share of vehicles traveling above 60 mph.
  - On weekends, increases in emissions varying between 0.4% and 4.4% are contrarily estimated. This is due to pushes for higher emissions from (a) a higher proportion of vehicles traveling above 60 mph; (b) the documented slight reduction in bridge capacity; and (c) the historically high traffic demand observed in 2023. The last item is important to consider as it is the result of changes in traffic demand and indicates that some emission increases could have occurred in the absence of the bridge modification.
- **Safety of new bridge paths for cyclists and pedestrians:**
  - No incidents involving bicyclists or pedestrians were recorded by the CHP or reported on the Street Story platform during the evaluation period. However, anecdotal evidence suggests that some incidents have occurred.
  - Users generally have a positive view of the safety offered by the paths. The 1538 individuals who assessed the bridge path during the survey of summer 2021 gave an overall rating of 8.19 out of 10.

- Several path users indicated that the low height of the barrier put them at risk of being hit by debris flung from the adjacent traffic lanes. Several also indicated that they could be blinded at night by vehicle lights when traveling toward Richmond. However, while a desire may exist to have a higher barrier, fulfilling such a request would be incompatible with the current barrier-moving system.
- A need exists to improve paths leading to the bridge, particularly in Marin County, notably, the crossings at the intersection between Sir Francis Drake Boulevard and Andersen Drive, providing better separation for the I-580 shoulder path, and providing additional separated paths along Sir Francis Drake Boulevard and Francisco Boulevard.
- Only 3.0% of bridge path users commented on its narrowness in the user survey.

- **Traffic safety on I-580 West:**
  - There is no compelling evidence that the modifications have negatively impacted traffic safety despite the creation of a constrained roadway and a shorter merge downstream of the toll plaza. The analyses produced estimates of change that were generally not statistically significant at the 95%, 90%, or 85% level, meaning that the observed changes could simply be the result of normal variability in the quarterly data.
  - Depending on the case, overall collision rates either increased or decreased. When considering all incidents, the data points to a 13% decrease in the overall collision rate east of the toll plaza and a 19% drop on the bridge. When focusing only on the weekday AM peak, increases of 16% and 40% respectively are instead observed.
  - No clear impacts are observed on incident types. Rear-ends, sideswipes, and vehicles hitting objects typically represent around 95% of all incidents. When considering all reported incidents, relatively similar proportions of incident types are observed for the before and after periods. When considering only the weekday AM peak, the proportion of sideswipes on the approach has reduced (from 51% to 40%), while the proportions of rear ends and vehicles hitting objects have increased (43% to 46% and 4% to 12% respectively). On the bridge, sideswipes have further increased slightly (40% to 44%) while rear-ends have decreased (58% to 48%).
  - No clear impacts are observed on the severity of incidents. Before the modification, incidents without injury typically represented 72%-76% of all incidents on the approach, depending on whether all logged incidents are considered or only those occurring during the weekday AM peak, and 67%-68% of incidents on the bridge. After the modification, these incidents accounted for 70%-79% of all incidents on the approach and 68-70% on the bridge.
  - There is no statistical evidence that the bridge modifications are producing longer crash-related incidents or changing the location where crashes tend to occur on the bridge.
  - There is no statistical evidence that the modifications are increasing the time needed to clear crashes. In this case, data measuring more precisely the period during which an incident affects traffic would be required to provide a more definitive answer.

- **Incident response times:**
  - Retrieved tow truck dispatch logs do not provide enough observations to determine whether the bridge modifications have resulted in longer response times.

- Estimated incident response times from CHP-CAD logs also do not provide evidence that bridge modifications have caused an increase in incident response times.

- **Maintenance activities on the upper deck:**
  - On the upper deck, the barrier now forces the maintenance crew to close the right traffic lanes when they need to do maintenance on the bridge.
  - Emergency realignment to the barrier is only conducted if an incident causes the barrier to leave less than 10 feet of width on the path. This has only occurred twice between November 2019 and April 2022. In other cases, the maintenance crew either tries to use tools to manually realign the barrier or waits for the monthly machine re-alignment of the barrier to fix the issue.

15.3. IMPACTS OF MODIFIED BICYCLE PATH ON SIR FRANCIS DRAKE OVERCROSSING

- **Use by cyclists:**
  - Bicycle traffic is seasonal, with the highest typically observed between June and September and the lowest between November and March when it is colder and rainier.
    - Since January 2022, Saturday traffic during summer months (June-September) has averaged 189 cyclists/day westbound and 126 eastbound, while Sunday traffic has averaged 125 and 88 cyclists/day respectively.
    - Winter weekend traffic (November-March) has expectedly ranged lower, with Saturday westbound and eastbound averages of 119 and 77 cyclists/day, and Sunday averages of 92 and 60.
    - Weekday traffic is much lower than on weekends, with peak summer averages of 56 and 37 cyclists/day westbound and eastbound, and winter averages of only 37 and 24.
  - Peak travel periods are similar to the bridge, with westbound traffic peaking in the morning and eastbound in the early afternoon.
  - Eastbound traffic (going toward the bridge) is generally significantly less than westbound traffic (going away from the bridge). This is explained by the presence of an alternate eastward path on the I-580 East on-ramp and along the freeway mainline up to the Main Street exit.
  - The conversion of the overcrossing path into a two-way path has enticed some eastbound travelers to switch from using the I-580 East shoulder path to using the overcrossing path, resulting in more crossings of Sir Francis Drake Boulevard at Andersen Drive.
  - Eastbound traffic is split between the overcrossing path and the I-580 East shoulder path. With a 68% weekday and 74% weekend split, a strong preference is for using the overcrossing path, likely due to its perceived higher safety compared to traveling on the shoulder of a busy freeway.
  - The conversion of the overcrossing path from a one-way into a two-way path has likely enticed some eastbound travelers to switch from using the I-580 East shoulder, likely

associated with the uneasiness of traveling along freeway traffic on a path only delimited by painted lines, resulting in more crossings of Sir Francis Drake Boulevard at Andersen Drive.

  - The counts suggest that a majority of overcrossing users are also bridge path users, as westbound overcrossing traffic typically corresponds to 75-90% of westbound bridge traffic while eastbound traffic corresponds to 50-60% of the bridge traffic.

- **Use by pedestrians:**
  - While the overcrossing path is restricted to bicycle use, pedestrians are on occasion seen walking on the path.

- **Traffic conditions on the overcrossing:**
  - No constraining impacts have been observed on the overcrossing traffic.

- **Safety for cyclists:**
  - No path-related incidents were recorded by the CHP or on the Street Story platform after the path's modification.
  - The narrower lane width does not appear to affect behavior, as cyclists going down the overcrossing are seldom seen noticeably slowing down when crossing cyclists going up.
  - At the bottom of the overcrossing, cyclists going toward the bridge generally cut into the opposing lane to negotiate the 90-degree turn, creating a potential for collision.
  - A significant proportion of cyclists traveling east along Sir Francis Drake Boulevard cross at Andersen Drive to access the path. This requires them to do the equivalent of a permitted left turn across traffic coming off the freeway or going to it.
  - A significant proportion of cyclists traveling south along Andersen Drive cross it upstream of the intersection with Sir Francis Drake Boulevard to access the path.

- **Traffic safety:**
  - The very low number of incidents occurring on the Sir Francis Drake overcrossing does not lead to conclusions on the impacts on incident occurrence, type, or severity.

- **Maintenance activities:**
  - All barrier repairs are done manually due to the inability to bring the barrier-moving machine from the bridge. This can easily be done and not viewed as an issue due to the low frequency of incidents.
  - The relatively small length of the overcrossing path does not create significant issues for maintenance crews to access the site.

15.4. OTHER IMPACT ASSESSMENTS

- **Anecdotal impacts on businesses in Marin County**
    - According to 8 surveyed businesses in March 2022, morning congestion on the Richmond side of the bridge continues to affect the ability of businesses in Marin County to hire and retain staff from the East Bay. This is a problem that pre-existed the upper bridge modifications. However, travel time reductions to access Richmond from the Marin side during the afternoon peak following the lower deck improvements may have helped reduce the impacts of the morning commute.
    - For one business, less traffic using local streets to bypass I-580 East in the afternoon is significantly easing fleet movements around San Rafael and Larkspur.
    - None of the small number of surveyed business managers were aware of employees using the new bridge path for commute purposes.

15.5. ITEMS FOR FUTURE CONSIDERATION

While the final determination of the future of each element of the pilot project is to be made by Caltrans based on the findings documented in this report, the following are items for future considerations that have been brought to the research team during the project:

- While the objective of the project was to look at operational issues associated with the various modifications evaluated, there may be a need to conduct a more formal analysis of the equity issues associated with them, particularly with the impacts associated with the multi-use path that was installed on the upper deck of the bridge.
- Given that the use of the multi-use path varies significantly between weekdays and weekends, a possible option might be to have the path open on weekends only, when its use is the highest, and have the barrier move to the side on weekdays to re-establish the shoulder. A potential benefit of such a configuration could be the recovery of a portion, if not all, of the capacity drop that was estimated to be caused by the path.

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APPENDIX A. USER SURVEY RESPONSES

Below is a summary of the responses that were provided to the online user survey that ran over 8 weeks from June 16 to August 13, 2021. Summaries are provided for the four following categories of questions:

- Richmond-San Rafael bridge path
- Trip origin and destination
- Source of survey awareness

A.1 – RICHMOND-SAN RAFAEL BRIDGE PATH QUESTIONS

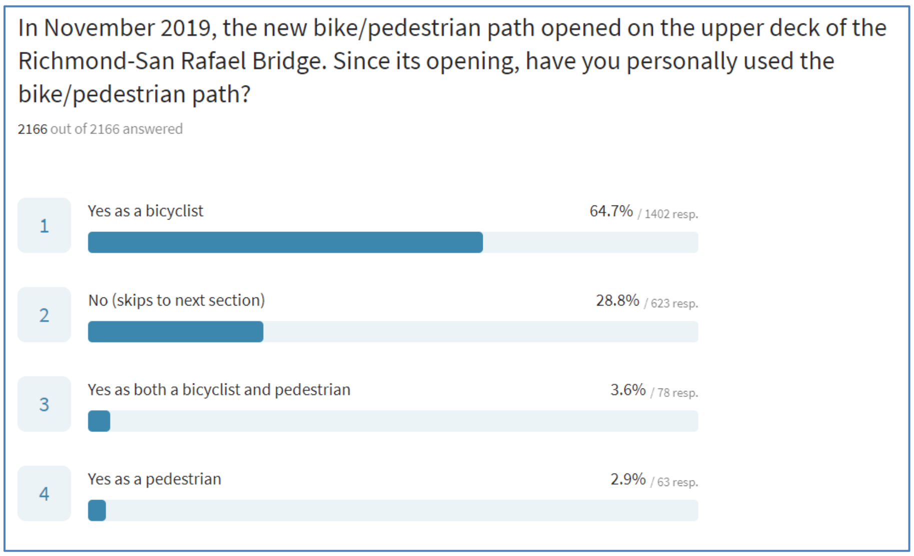

Figure A-1: User Survey – User Type

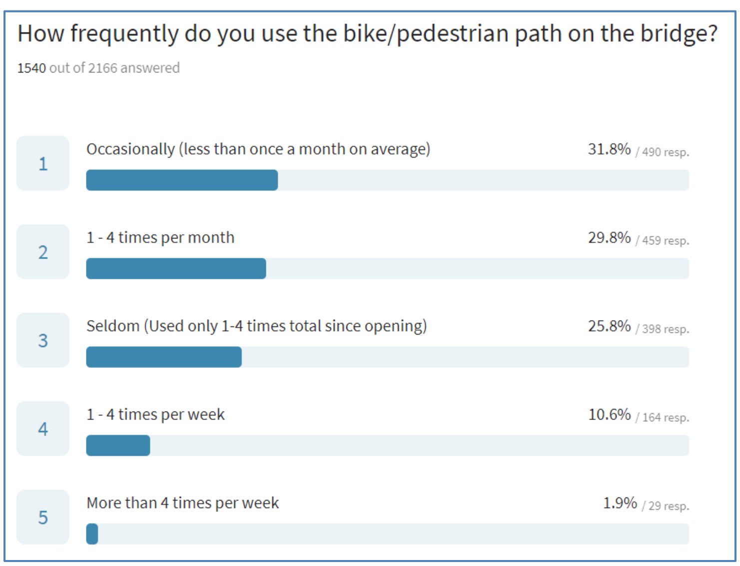

Figure A-2: User Survey – Frequency of Use

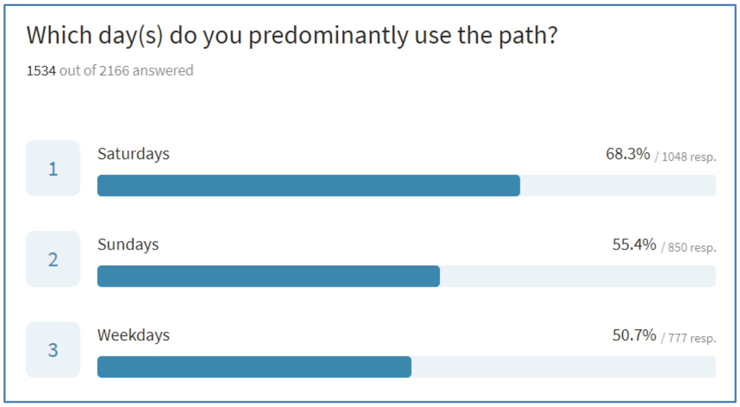

Figure A-3: User Survey – Day of Use

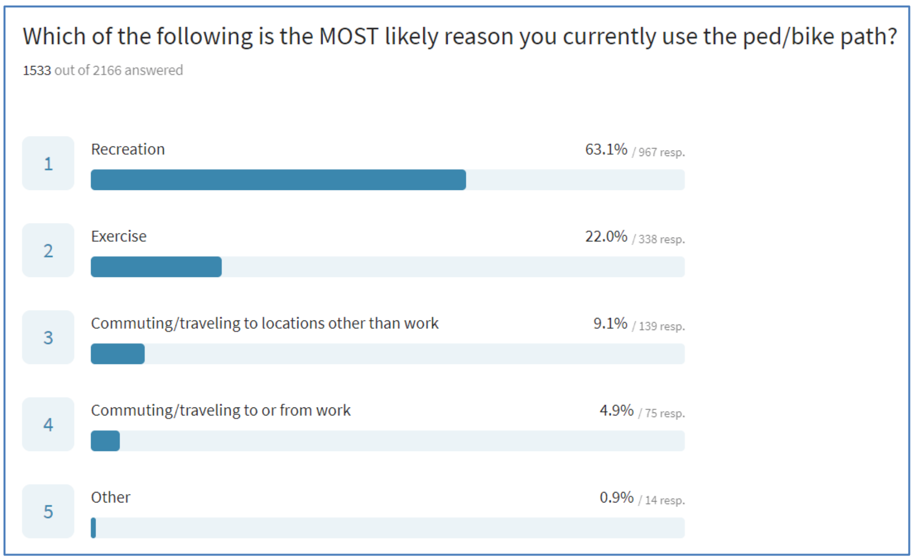

Figure A-4: User Survey – Reason for Use

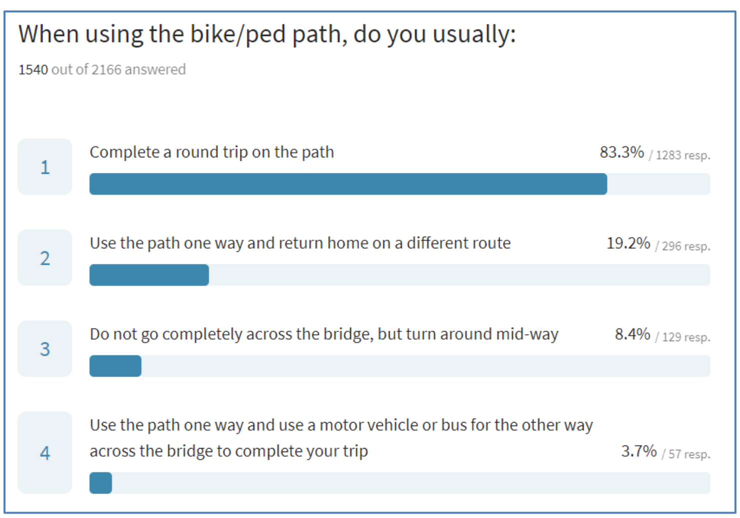

Figure A-5: User Survey – One-Way or Round Trips

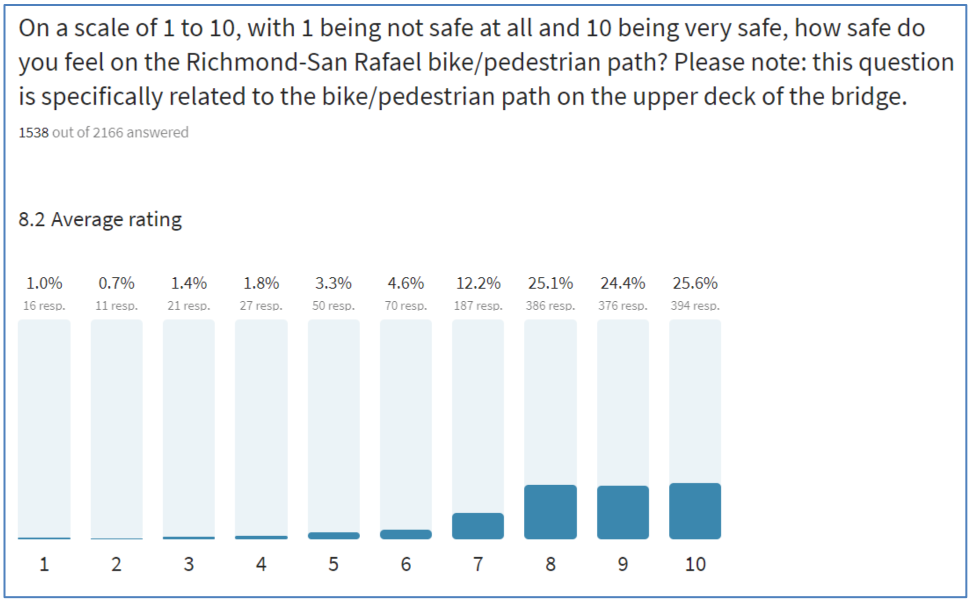

Figure A-6: User Survey – Perceived Safety

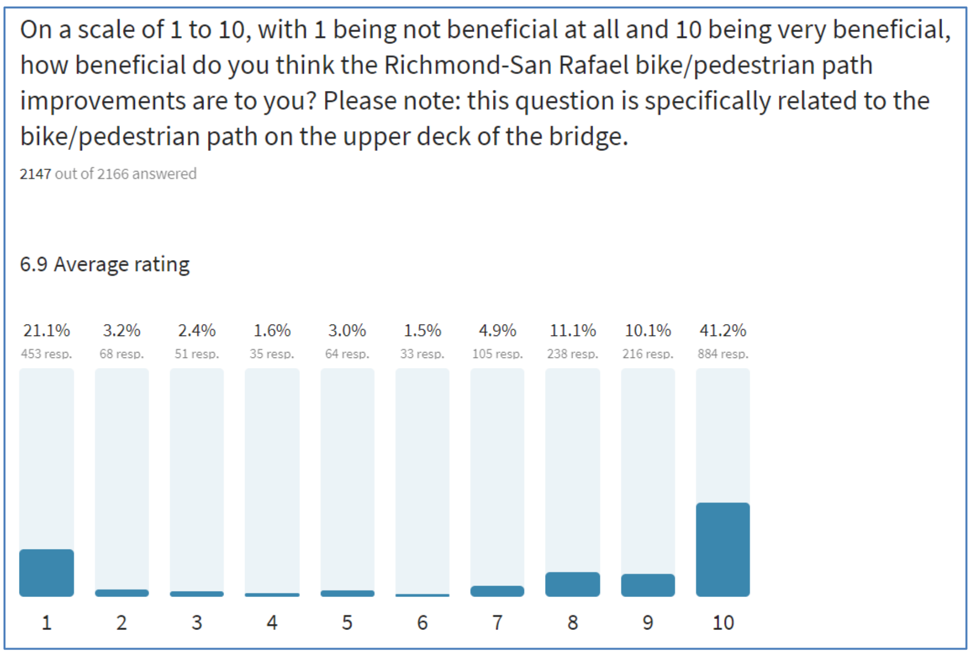

Figure A-7: User Survey – Perceived Benefits

A.2 – TRIP ORIGIN-DESTINATION QUESTIONS

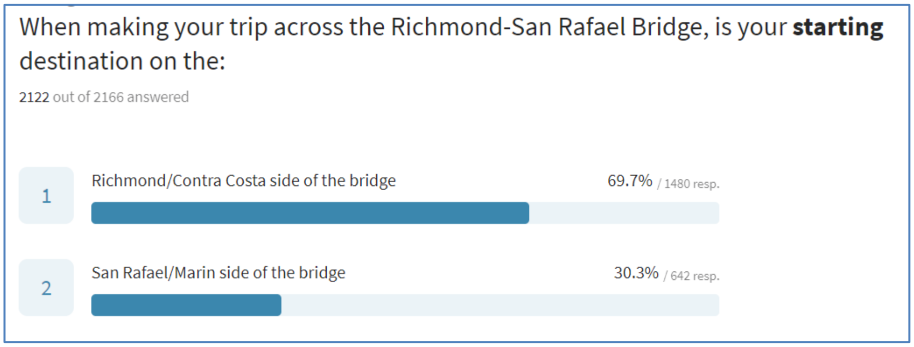

Figure A-8: User Survey – Trip Origin

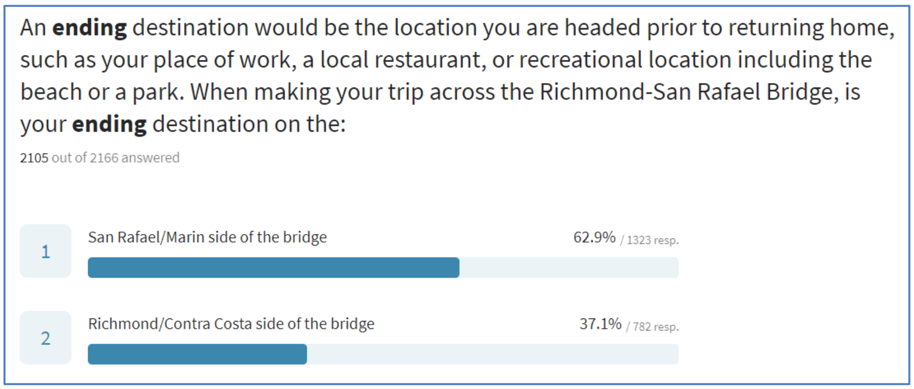

Figure A-9: User Survey – Trip Destination

A.3 – SOURCE OF SURVEY AWARENESS

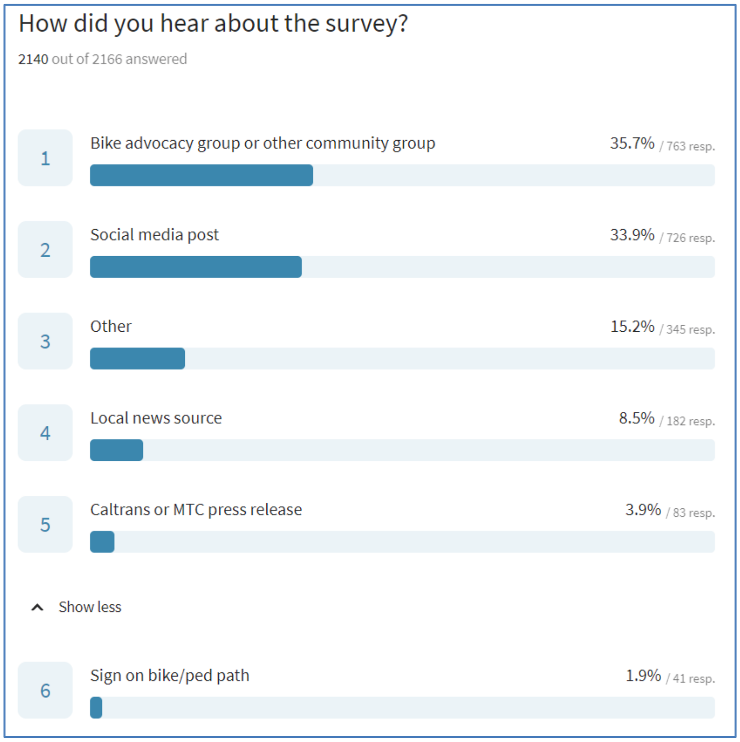

Figure A-10: User Survey – Survey Awareness