Red Transit Lanes
Final Evaluation Report

CTCDC Experiment 12-18
FHWA Experiment 9(03)-18 (E)

Submitted to:
California Traffic Control Devices Committee
Federal Highway Administration, Office of Traffic Operations

Submitted by:
San Francisco Municipal Transportation Agency

February 10, 2017

Executive Summary

The San Francisco Municipal Transportation Agency (SFMTA) conducted an experiment with red transit-only lanes (TOLs), sponsored by the California Traffic Control Devices Committee and the Federal Highway Administration. The primary purpose was to reduce TOL violations. The SFMTA installed red treatments along approximately 10 miles of TOLs between spring 2013 and fall 2016. A detailed evaluation was completed along three study corridors in downtown San Francisco where red treatments were applied in spring 2014: 3rd Street between Townsend and Stevenson streets; Geary Street between Powell and Polk streets and O'Farrell Street between Gough and Powell streets. In addition to TOL violations, the evaluation considered transit travel time, collisions, vehicle turning behavior, and on-street parking occupancy.

Along 3rd Street, red treatment reduced the number of TOL violations by 48%-55% depending on the time of day, even as total traffic volumes increased. There was a decrease in the number of TOL violations at all four study intersections along 3rd Street during each of the three time periods studied (AM peak, midday and PM peak).
A linear regression analysis suggests that several factors influence compliance, but red treatment had the strongest influence.

A ratio of transit travel times to traffic travel times was used to measure the comparative changes in travel time as traffic congestion worsened citywide. Along all three study corridors, the ratio of transit travel time to traffic travel time decreased, indicating the red treatments helped reduce the negative impacts of increasing traffic congestion on transit travel time.

The total number of collisions along the three study corridors, including police-reported collisions and minor collisions involving Muni vehicles not reported to the police, decreased 16% from 120 during calendar year 2013 to 101 during calendar year 2015. Police-reported injury collisions decreased 24% while citywide injury collision trends were unchanged. Police-reported non-injury collisions also decreased. Minor collisions involving Muni vehicles (not reported to police) decreased along the 3rd Street and Geary Street corridors, but increased along the O'Farrell Street corridor, while citywide there was 23% increase in Muni-involved collisions.

The addition of red treatments to existing TOLs has generally been well-received by the public. The addition of new TOLs with red treatments has generated significant public feedback, both positive and negative, with concerns generally focused on parking and traffic circulation changes associated with the creation of new TOLs or other street design changes implemented in addition to red treatments.

Background

The SFMTA oversees the surface transportation system in San Francisco, including operation of the San Francisco Municipal Railway (Muni). Muni carries more than 700,000 daily riders on approximately 80 routes throughout San Francisco. As part of ongoing initiatives to improve Muni service, the SFMTA conducted an experiment with the use of red colored pavement treatments along TOLs to enhance their visibility and improve motorist compliance and transit performance.

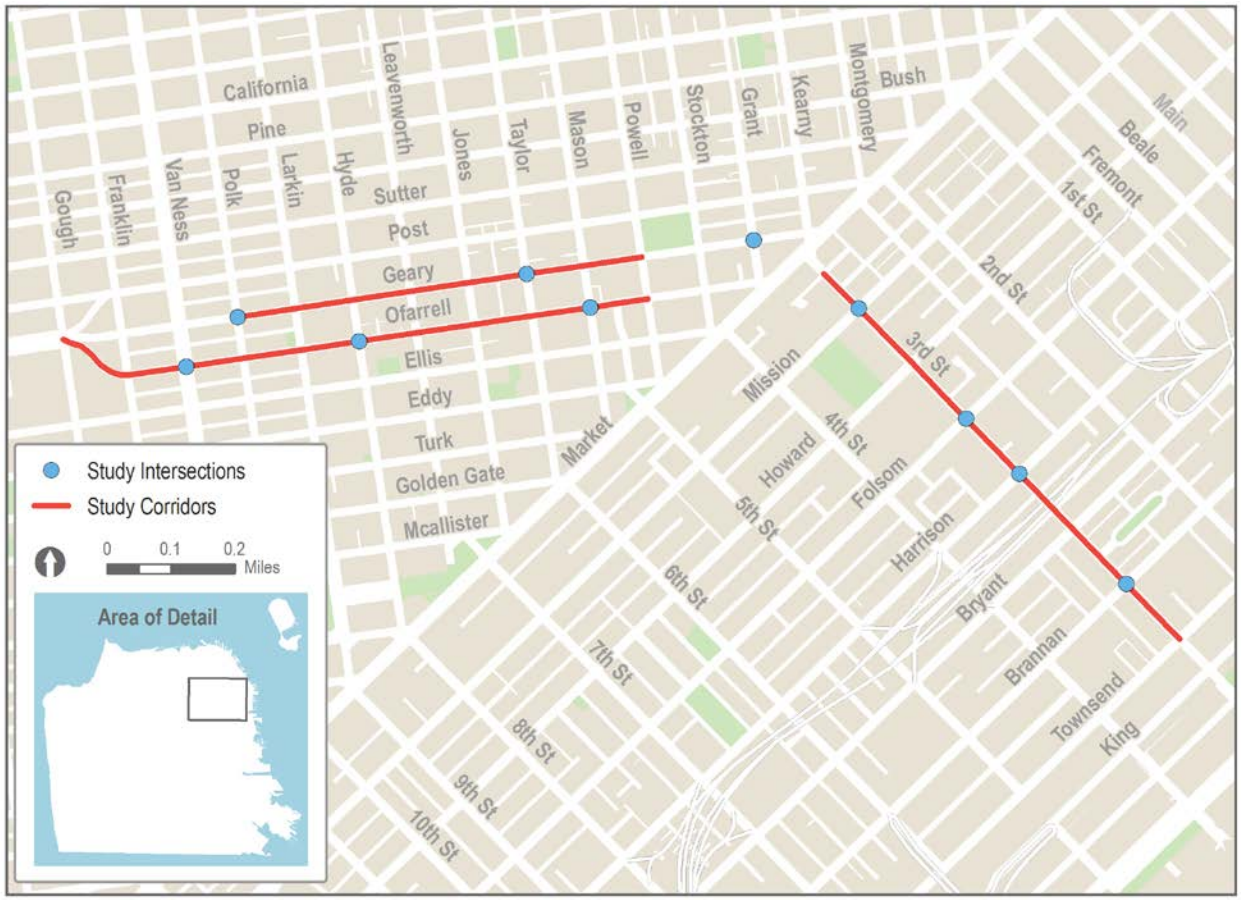
TOLs can reduce transit travel times and improve transit service reliability by allowing transit vehicles to bypass traffic congestion and avoid conflicts with other vehicles in shared travel lanes. Non-transit vehicles are generally prohibited from traveling within TOLs except to access curbside parking, driveways, or to complete turns. Non-transit vehicles that violate TOL restrictions can cause transit vehicles to slow to merge into adjacent lanes or stop and wait, contributing to longer transit travel times, reduced service reliability and reduced passenger safety and comfort. These delays reduce the effectiveness of other transit priority treatments such as transit signal priority. Given limited enforcement resources, the primary goal of the experiment was to reduce violations of TOLs by making them more visible.

Prior to experimentation with red treatments, TOLs in San Francisco included pavement messages and signs consistent with the California Manual on Uniform Traffic Control Devices, 2012 Edition (CA MUTCD). Pavement messages indicate the class of vehicles permitted to use the lanes (examples include “BUS ONLY” and “BUS TAXI ONLY”) and signs indicate when the regulations apply. Given a high density of pavement markings and signs competing for motorists’ attention on congested urban streets, red colored pavement treatments were proposed to enhance standard traffic control devices.

3rd Street TOL Before and After Red Treatment

Study Corridor Locations

Red treatments were installed in spring 2014 to existing TOLs along three major transit corridors in downtown San Francisco that are the focus of this evaluation and shown in the map below: 3rd Street between Townsend and Stevenson streets; Geary Street between Powell and Polk streets and O'Farrell Street between Gough and Powell streets. These corridors were selected for detailed evaluation because they TOLs existed prior to the installation of red treatments and due to their relatively long length, high frequency of transit service and congested traffic conditions during peak periods. Additional analysis was conducted for SFMTA's first red TOL installed in spring 2013 on Church Street between Duboce Avenue and 16th Street, where red treatment was installed in conjunction with the creation of new TOLs[1].



[1] Church Street Transit Lanes Pilot Project: https://www.sfmta.com/sites/default/files/projects/2015/Church%20Street%20Pilot%20Report%20v5.pdf.

3rd Street between Townsend and Stevenson Streets

This 0.8 mile, seven-block segment of 3rd Street is a one-way northbound arterial roadway in San Francisco's South of Market neighbourhood. 3rd Street has three northbound travel lanes and one northbound bus/taxi-only lane, with metered parallel parking generally along both sides of the street. During peak hours, on-street parking is prohibited to reduce parking friction with buses and to provide peak-hour turn pockets at intersection approaches. Between Folsom and Howard streets and between Mission and Market Streets, there is no on-street parking on the east side of the roadway and the bus/taxi-only lane is located adjacent to the curb.

Geary Street between Powell and Polk Streets

This 0.7 mile, seven-block segment of Geary Street is a one-way westbound arterial roadway that forms a one-way couplet with O'Farrell Street through San Francisco's Downtown. Geary Street has one westbound travel lane and a bus/taxi-only lane, with metered parallel parking along both sides of the street. During the PM peak, on-street parking is prohibited on both sides of the street to provide a second travel lane and to reduce parking friction with buses. Full-time right-turn pockets exist at three of five intersections where right-turns are permitted.

O'Farrell Street and Starr King Way[2] between Gough and Powell Streets

This 0.9 mile, 10-block segment of O'Farrell Street is a one-way eastbound arterial roadway that forms a one-way couplet with Geary Street through San Francisco's Downtown. For three blocks between Gough and Polk streets, two eastbound travel lanes and a bus/taxi-only lane exist at all times. For six blocks between Polk and Mason streets, O'Farrell Street has one eastbound travel lanes and a bus/taxi-only lane, with metered parallel parking along both sides of the street that is prohibited during the AM and PM peak to provide a second travel lane and to reduce parking friction with buses. For two blocks between Mason and Powell streets, there is no on-street parking on the south side of the roadway and the bus/taxi-only lane is located adjacent to the curb – this segment has two full-time travel lanes and the parking on the north side of the street is prohibited during the AM and PM peak to provide a third travel lane.

[2] O'Farrell Street becomes Starr King Way for one block between Gough and Franklin streets

Study Corridors Transit Service Overview

Muni operates the 30 Stockton, 45 Union-Stockton and 81X Caltrain Express along this entire segment of 3rd Street and operates the 8 Bayshore and 8AX/8BX Bayshore Express bus routes along 3rd Street north of Bryant Street. There are over 5,400 daily Muni boardings at the five bus stops within the 3rd Street study segment. Muni operates the 38 Geary and 38R Geary Rapid bus routes along the entire study segments of Geary and O'Farrell streets with over 8,300 daily Muni boardings at 13 bus stops. **Table 1** below summarizes the transit service along the study corridors.

Table 1: Transit Service Summary

Muni Route	Average Daily Boardings* (Full Route)	Average Daily Boardings* (Study Area)	Peak Period Headway (minutes)
3rd Street Corridor			
8 Bayshore	23,840	610	7
8AX Bayshore A Express	5,600	220	7
8AX Bayshore B Express	6,470	250	7
30 Stockton	22,350	2,910	4
45 Union-Stockton	10,960	1,430	10
Geary/O'Farrell Streets Corridor			
38 Geary	20,190	4,350	6
38R Geary Rapid	28,210	3,970	4

*Boarding data gathered weekdays 10/5/15-11/20/15, rounded to nearest 10

Results and Analysis

Motorist Compliance

Vehicle turning movement counts were collected as shown in **Table 2** below. Counts were collected at four intersections along 3rd Street in spring 2014 prior to installation of red treatments and in summer 2015 approximately one year after installation of red treatments allowing a direct before/after comparison. Additional counts were collected in summer 2015 at six intersections along Geary and O'Farrell streets approximately one year after installation of red treatments, including one intersection at Geary Street and Grant Avenue where no red treatment was applied to serve as a control location. Counts were conducted at each intersection on two weekdays from 7-9 AM, 11 AM – 1 PM and 4-6 PM and a peak hour was calculated for each of the three time periods.

Table 2: Count Locations

3rd Street Corridor (before/after counts)	Brannan Street Harrison Street Folsom Street Mission Street
Geary Street Corridor (after counts only)	Grant Avenue* Taylor Street Polk Street
O'Farrell Street Corridor (after counts only)	Van Ness Avenue Hyde Street Mason Street

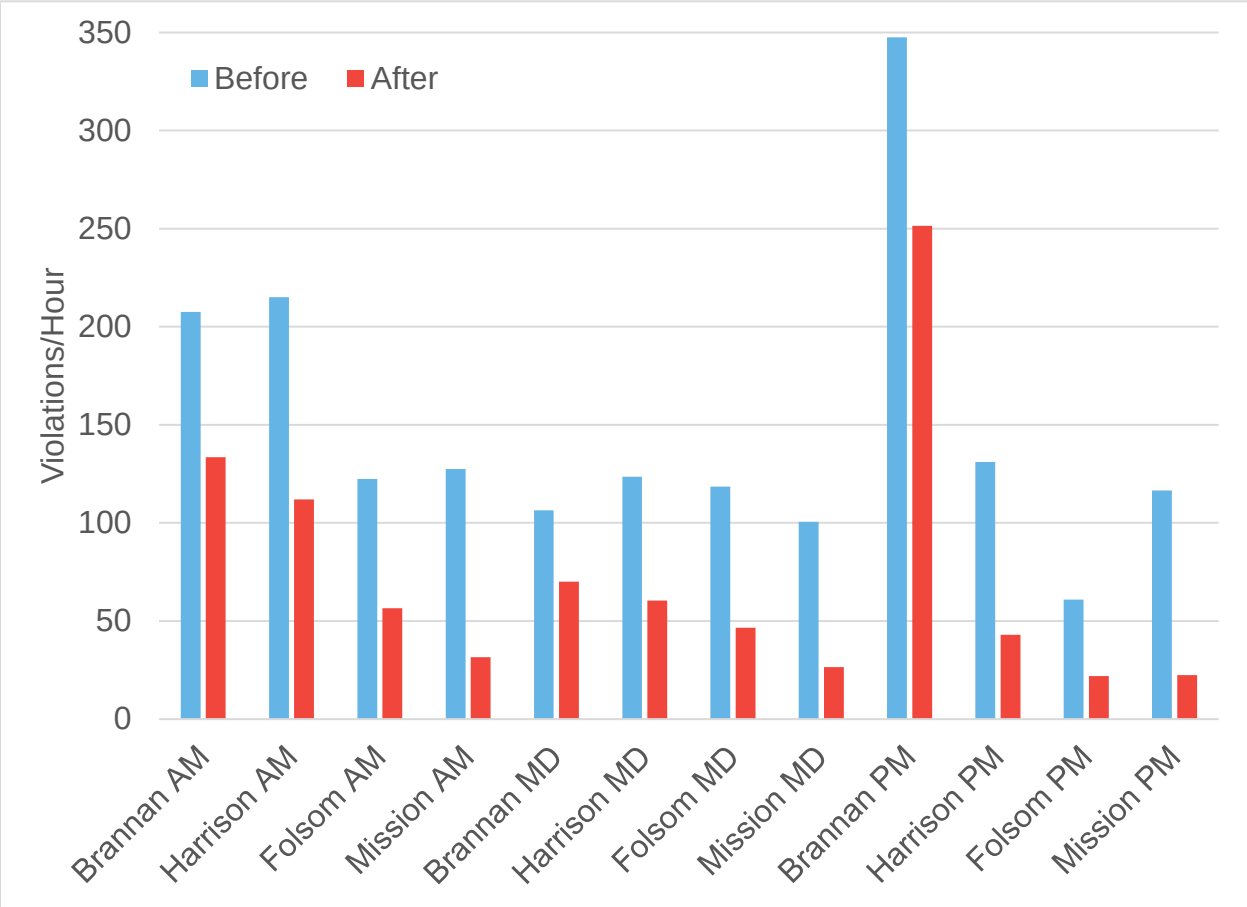
*Control location – no red treatments applied

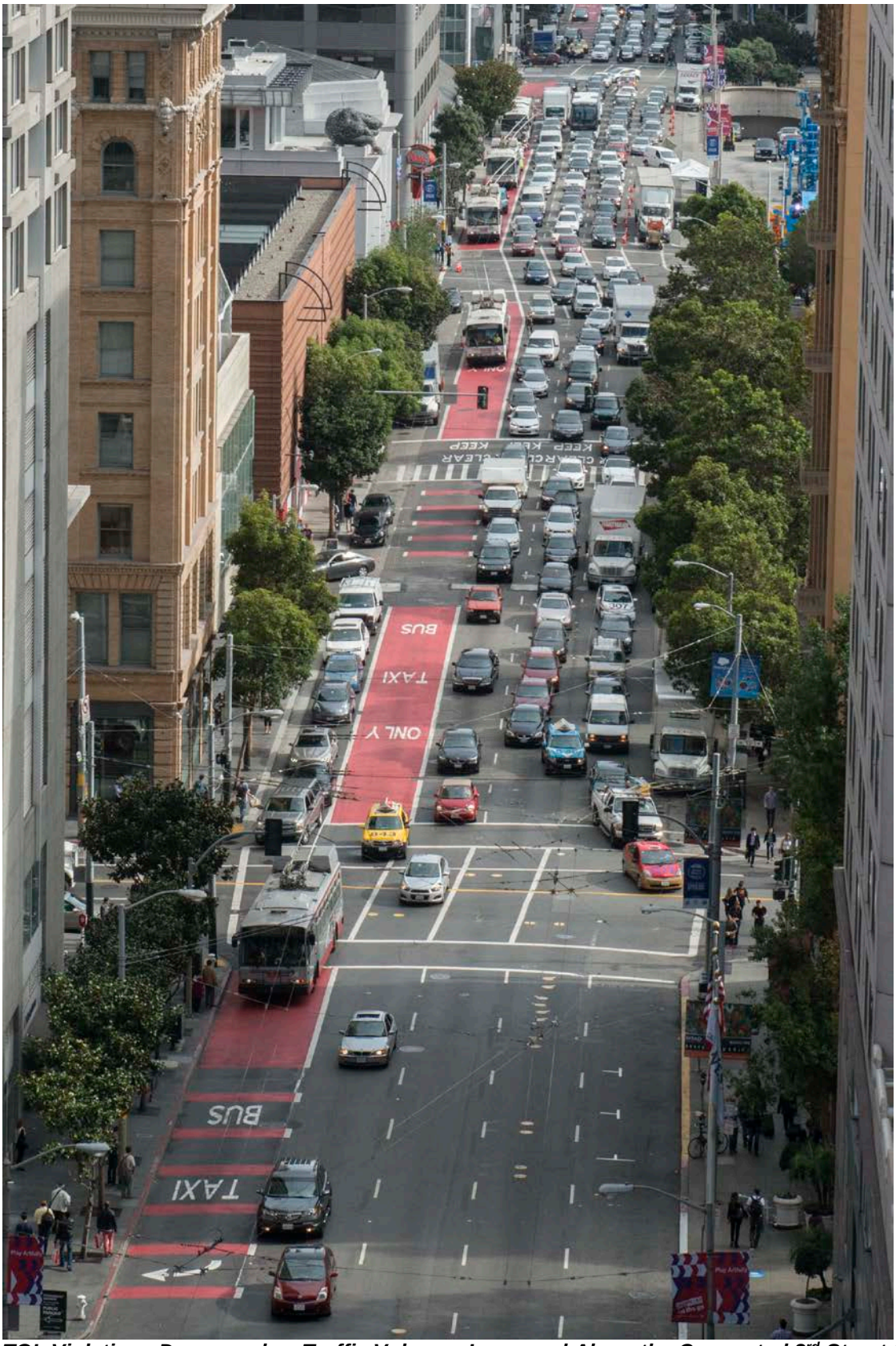
Vehicles traveling in the transit-only lane were classified as compliant (buses, taxis and right-turning private motor vehicles where permitted) or as violations (through moving private motor vehicles). Overall compliance is reported as the percentage of all traffic using an authorized lane. Although overall compliance was relatively high before the installation of red treatments (ranging from 80%-96% as shown in **Table 3**), even a small percentage of vehicles violating a TOL can negatively impact transit operations. In order to better understand impacts on transit operations, a more focused examination of the vehicles using the TOL is also reported – compliance within the TOL is reported as the number of authorized vehicles in the TOL (including buses, taxis, and all vehicles making right turns) divided by the total number of vehicles in the TOL.

Violations

Figure 1 below shows the total number of TOL violations decreased at every study intersection during every time period where before and after data were collected on 3rd Street. Averaged across all study intersections and time periods, the number of TOL violations decreased 51%. Improved compliance occurred despite increasing volumes of through traffic – through volumes increased at 10 of 12 intersection time periods and through volumes averaged across all study intersection time periods increased 8%.

Figure 1: 3rd Street TOL Violations





TOL Violations Decreased as Traffic Volumes Increased Along the Congested 3rd Street Corridor

Overall Compliance

Overall compliance measured as the percentage of all through traffic using an authorized lane are reported in **Tables 3-5** below[3]. Compliance improved at every study intersection during every time period where before and after data were collected on 3rd Street. Compliance was higher at every study intersection during every time period after red treatments were applied compared to the control intersection where no red treatments were applied (Geary Street and Grant Avenue), with the exception of the intersection of 3rd and Brannan streets during the PM peak period. The traffic conditions that contribute to lower compliance at this intersection are discussed on page 12.

Table 3: Overall Compliance - 3rd Street Corridor (Before/After)

	Brannan Street		Harrison Street		Folsom Street		Mission Street	
	Before	After	Before	After	Before	After	Before	After
AM	86%	91%	89%	95%	93%	97%	93%	98%
Midday	88%	94%	91%	97%	92%	97%	93%	98%
PM	80%	86%	92%	97%	96%	98%	93%	99%

Table 4: Overall Compliance - Geary Street Corridor (After)

	Grant Avenue*	Taylor Street	Polk Street
AM	89%	96%	95%
Midday	88%	94%	96%
PM	89%	96%	94%

*Control location – no red treatments applied

Table 5: Overall Compliance – O'Farrell Street Corridor (After)

	Van Ness Ave.	Hyde Street	Mason Street
AM	98%	98%	95%
Midday	99%	97%	96%
PM	99%	98%	94%

Compliance of Vehicles Using TOL

Given the relatively high rate of overall compliance both before and after implementation, a more focused analysis of vehicles traveling in the TOLs provides greater understanding of how red treatments influence behavior. Compliance measured as the percentage of vehicles in the TOL that are authorized users (buses, taxis and right-turning private motor vehicles where permitted) are reported in **Tables 6-8** below.

Table 6: Compliance of Vehicles Using TOL - 3rd Street Corridor (Before/After)

	Brannan Street		Harrison Street		Folsom Street		Mission Street	
	Before	After	Before	After	Before	After	Before	After
AM	28%	56%	33%	66%	36%	84%	38%	87%
Midday	34%	65%	41%	75%	38%	85%	39%	89%
PM	18%	42%	46%	81%	51%	88%	44%	89%

[3] Each value in Tables 3-5 is an average from two weekday counts. For a given location and time period, results from the two counts did not vary more than 2%.

Table 7: Compliance of Vehicles Using TOL - Geary Street Corridor (After)

	Grant Avenue*	Taylor Street	Polk Street
AM	72%	91%	78%
Midday	75%	84%	82%
PM	65%	88%	70%

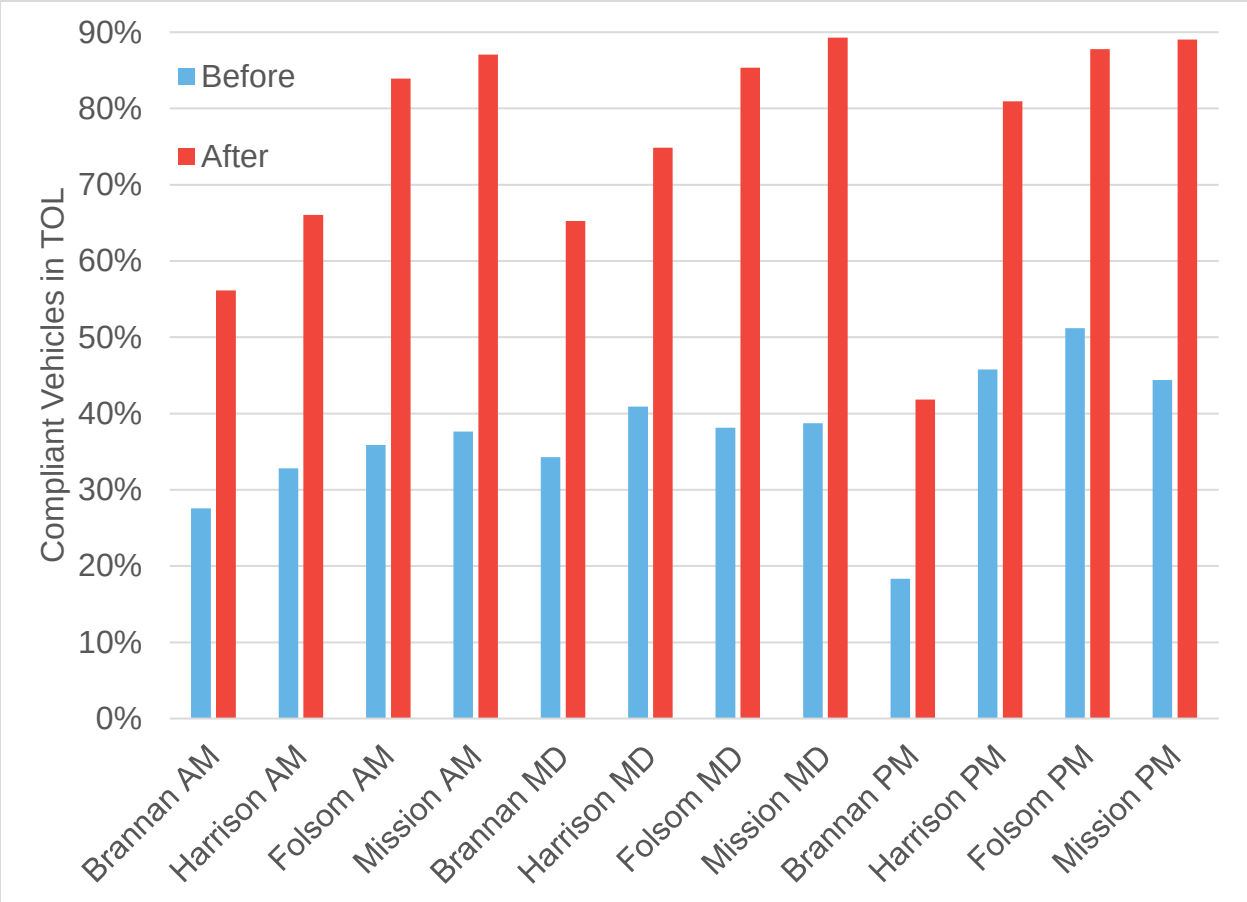
*Control location – no red treatments applied

Table 8: Compliance of Vehicles Using TOL – O'Farrell Street Corridor (After)

	Van Ness Ave.	Hyde Street	Mason Street
AM	88%	94%	96%
Midday	98%	92%	89%
PM	95%	95%	96%

The rate of unauthorized vehicles using the TOL decreased at every study intersection during every time period where before and after data were collected on 3rd Street as shown in **Figure 2** below. As noted earlier, improved compliance following implementation of red treatments occurred despite increased total traffic volumes. Prior to implementation of red treatments, a majority of vehicles using the 3rd Street TOL were unauthorized; after implementation, a strong majority of vehicles using the TOL were authorized users.

Figure 2: 3rd Street Compliance of Vehicles Using TOL



Compliance varied substantially at different intersections; for example in **Table 6** and **Figure 2** above the southern intersections of 3rd Street at Brannan and Harrison streets exhibit lower compliance than the northern intersections of 3rd Street at Folsom and Mission streets during all time periods both before and after implementation. Lower compliance at the intersections of 3rd Street at Brannan and Harrison streets are intuitive given the location of these intersections along congested access routes to the San Francisco-Oakland Bay Bridge, where on-ramp queues frequently extend onto the surface street network, causing severe queuing along 3rd Street south of Folsom Street. Vehicles are observed to violate the TOL along this portion of 3rd Street as they queue to make right-turns, sometimes turning illegally from the TOL adjacent to a right-turn pocket and even from the through lane located to the left of the TOL, as shown in the photo below.

Bay Bridge Queues Encourage TOL Violations, 3rd Street at Harrison Street

Compliance Regression Analysis

A linear regression analysis provides additional insight into how compliance is influenced by the red treatments and other variables including time period, traffic speed, congestion, presence of on-street parking, right turn lane configurations, and proximity to freeway on-ramps. Traffic speed data was collected using INRIX[4] for peak hours for the same dates that counts were collected along segments near each study intersection as shown in **Table 9** below, as well for an average weekday spanning between April and August 2015. Congestion was calculated as the volume-to-capacity ratio (V/C) for each intersection using Synchro[5] traffic analysis software and the 2010 Highway Capacity Manual (HCM 2010) methodology.

[4] INRIX compiles GPS-based data including vehicle speeds from smartphones, vehicle navigation systems, and fleet management systems: http://inrix.com/.
[5] http://www.trafficware.com/synchro-studio.html

Table 9: Count Locations and Traffic Speed Segments

Count Location	INRIX Speed Segment
Geary Street and Grant Avenue	Geary Street, from Kearny to Stockton streets (2 blocks)
Geary and Taylor streets	Geary Street, from Stockton to Leavenworth streets (5 blocks)
Geary and Polk streets	Geary Street, from Leavenworth Street to Van Ness Ave. (4 blocks)
O'Farrell Street and Van Ness Ave.	O'Farrell Street, from Franklin Street to Van Ness Ave. (1 block)
O'Farrell and Hyde streets	O'Farrell Street, from Larkin to Hyde streets (1 block)
O'Farrell and Mason streets	O'Farrell Street, from Leavenworth to Stockton streets (5 blocks)
3rd St and Brannan streets	3rd Street, from Townsend to Bryant streets (2 blocks)
3rd St and Harrison streets	3rd Street, from Bryant to Harrison streets (1 block)
3rd St and Folsom streets	3rd Street, from Harrison to Folsom streets (1 block)
3rd St and Mission streets	3rd Street, from Howard to Mission streets (1 block)

The compliance rate of vehicles using the TOL were used as the dependent variable and were analyzed alongside volume-to-capacity ratios (V/C) and average traffic speed. Dummy variables were used to classify observations by the following categories:

- Time period (AM, midday, PM)
- Corridor location (3rd Street northern intersections not influenced by freeway on-ramp queues, 3rd Street southern intersections influenced by freeway on-ramp queues, Geary Street, O'Farrell Street)
- Presence of on-street parking adjacent to the TOL
- Presence of right turn pocket adjacent to the TOL or whether vehicles are permitted to make right turns from within the TOL.

The results of the regression analysis are shown in **Table 10** below, with seven variables describing 84% of compliance behavior, as indicated by the R^2 value. Implementation of red treatments had the strongest effect, improving compliance rates by 32%. In addition to red treatments, the corridor location and traffic congestion had strong influences on compliance rates. Time of day variables were not significant influences. Traffic speeds, presence of on-street parking and presence of right turn pockets did not have significant impacts and these variables were excluded from the final regression.

Table 10: Regression Results

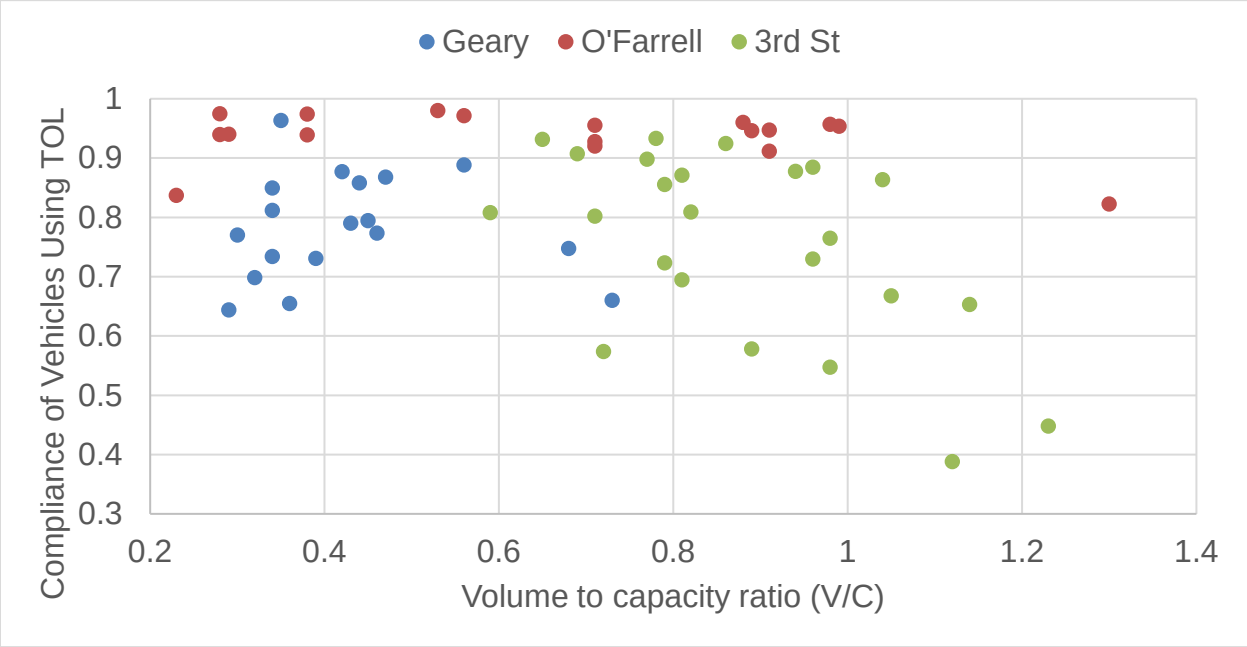
	Coefficients	Standard Error	t Stat	P-value
Intercept	0.678782	0.047147	14.39707	2.06E-23
$(V/C)^2$	-0.044	0.029331	-1.50026	0.137689
ON GEARY	-0.06596	0.036516	-1.8064	0.074814
ON 3RD	-0.12432	0.034504	-3.60302	0.000559
ON FWY	-0.26354	0.038397	-6.86356	1.59E-09
AM	-0.01637	0.028383	-0.57672	0.565834
PM	-0.00143	0.028244	-0.05074	0.959669
RED LANE	0.321942	0.025315	12.7174	1.66E-20

Regression Statistics	
Multiple R	0.915482
R^2	0.838107
Adjusted R^2	0.823196
Standard Error	0.099891
Observations	84

Compliance rates along O'Farrell Street were very high and this corridor used as the control for the two other corridors: compliance rates were 12% lower on the two northern study intersections on 3rd Street (not influenced by freeway queuing) and 7% lower on Geary Street, while the two southern study intersections on 3rd Street (influenced by freeway queues) were 26% lower. This suggests that the unique operating environment of each corridor has a strong influence on compliance behavior.

Graphs of compliance rates against V/C indicate an inverse relationship between compliance and $(V/C)^2$; at low V/C values, compliance is as low as at high V/C values[6]. In **Figure 3**, an inflection point appears near V/C of 0.6, where compliance rates are highest; as congestion increases beyond this point, compliance decreases.

Figure 3: TOL Compliance versus V/C



[6] This result reflects the limitations of using traffic counts to calculate V/C in congested urban areas – V/C calculations assume traffic counts represent travel demand under unsaturated flow, but under congested conditions, traffic counts reflect limited flow beyond a given point due to queuing from downstream bottlenecks or metering from upstream bottlenecks. The study intersections generally operate under congested conditions; therefore intersections with low V/C values may be highly congested. For this analysis, the square of V/C is used as a proxy for congestion.

Transit Travel Time

Transit travel times were analyzed along the three study corridors between May 2013[7] and December 2015. Data was selected from Mondays-Thursdays from 7-9AM and 4-7PM. INRIX data was used to compare transit travel time with general traffic for the same time periods. Red treatments were implemented along the three study corridors incrementally over a period of several months in 2014 and the construction impacts may have influenced transit and traffic travel times during these months; therefore the before/after travel time analysis focuses on the months of May-August 2013 and 2015, in order to normalize seasonal variations.

Transit travel times were calculated using data collected from GPS-enabled sensors on Muni buses that provide timestamps associated with door opening and closing events at transit stops, allowing for large samples of data to be gathered for bus travel times between transit stops. Transit travel times between subsequent transit stops were added together and compared to the sum of travel times for INRIX segments that most closely matched.

The San Francisco County Transportation Authority's 2015 Congestion Management Program Report indicates that vehicle miles traveled are increasing in San Francisco and resulting in increased congestion, with a 20.6% drop in traffic speeds on major arterial streets from 2013 to 2015[8]. This report also notes that transit speeds declined during the same period, though not as drastically. Median transit and traffic travel times during the AM and PM peak periods are compared in **Table 11** and **Figure 4** below[9]. Travel times for general traffic increased approximately 100-200 seconds along each of the corridors during both peak periods. Transit travel times decreased during both the AM and PM peak periods along the Geary Street corridor, stayed about the same during the AM peak period along the 3rd Street and O'Farrell Street corridors, and increased during the PM peak period along the 3rd Street and O'Farrell Street corridors.

To better understand the effects of the red treatments, the ratio of transit travel time to traffic travel time (tt ratio) is compared in **Table 11** below. A ratio of 2 indicates transit travel times are twice as long as travel times for the corresponding traffic; a tt ratio of 1 indicates the travel times are equal and a tt ratio less than 1 indicates that transit travel times are faster than traffic. In all three study corridors during both the AM and PM peak periods, the tt ratio decreased following implementation of red treatments, indicating that the treatments have been effective at insulating transit travel times from the effects of increased traffic congestion.

[7] Because of the large size of transit travel time datasets, historical data was only readily available going back to May 2013.

[8] http://www.sfcta.org/sites/default/files/content/Planning/CongestionManagementPlan/2015/CMP_2015_Executive_Summary_FINAL.pdf

[9] For the Geary Street and O'Farrell Street corridors, transit travel times are reported for the 38 Geary local bus service only.

Table 11: Median AM and PM Peak Travel Times Before/After Red Treatment

	AM Peak			PM Peak		
Corridor	**Before**	**After**	**Change**	**Before**	**After**	**Change**
Geary Street (transit)	6:09	5:44	-25 sec	6:23	6:04	-19 sec
Geary Street (traffic)	4:08	6:22	+134 sec	4:36	7:59	+203 sec
Geary Street (tt ratio)	**1.49**	**0.90**	**-0.59**	**1.39**	**0.76**	**-0.63**
O'Farrell Street (transit)	6:21	6:21	0 sec	7:30	8:18	+48 sec
O'Farrell Street (traffic)	3:31	5:17	+106 sec	3:51	6:28	+157 sec
O'Farrell Street (tt ratio)	**1.81**	**1.20**	**-0.61**	**1.95**	**1.28**	**-0.67**
3rd Street (transit)	5:10	5:18	+8 sec	5:36	6:03	+27 sec
3rd Street (traffic)	3:32	5:17	+105 sec	2:57	4:57	+120 sec
3rd Street (tt ratio)	**1.46**	**1.00**	**-0.46**	**1.90**	**1.22**	**-0.68**
tt ratio (All Corridors)	**1.58**	**1.03**	**-0.55**	**1.71**	**1.05**	**-0.66**

Figure 4: Traffic and Transit Travel Time Changes

Collisions

Collision data were reviewed along the study corridors for one full year before and after implementation of red treatments. Red treatments were implemented along the three study corridors incrementally over a period of several months in 2014 – the collision analysis focused on the full calendar years 2013 and 2015 in order to normalize seasonal variations. Two sources of collision data were analysed - San Francisco Police Department (SFPD) collision reports and SFMTA reports of Muni-involved collisions.

SFPD collision reports generally include diagrams and narratives from officers, witnesses and involved parties. Due to limited police staff resources, property damage only (non-injury) collisions are underreported in San Francisco. However, all collision reports were reviewed, including property-damage only collisions, in order to determine if the TOLs and red treatments had any influence on behaviour that could impact safety. Most minor collisions involving Muni vehicles are also not reported to the police, but the SFMTA maintains records of Muni-involved collisions, which generally include narratives from Muni vehicle operators and SFMTA staff who interview operators or review video evidence from on-board cameras. A review of these records provides additional insight into behaviours that lead to Muni collisions.

The total number of collisions along the three study corridors, including police-reported collisions and minor collisions involving Muni vehicles not reported to the police, decreased 16% from 120 during calendar year 2013 to 101 during calendar year 2015. Minor collisions involving Muni vehicles (not reported to police) decreased along the 3rd Street and Geary Street corridors, but increased along the O'Farrell Street corridor - the total number of these incidents along the three study corridors increased from 26 to 32, mirroring a systemwide increase in Muni-involved collisions of 23% during the same analysis periods. This systemwide trend may be attributable to increased levels of Muni service and increased traffic congestion. SFPD-reported collisions along the three study corridors are summarized in **Figure 5** below. The total number of injury collisions along the three study corridors decreased 24%, while citywide collision trends were nearly unchanged during the same analysis periods (3,082 injury collisions in 2013 versus 3,071 in 2015).

A detailed review of narratives and diagrams from SFPD collision reports found no discernible collision patterns associated with the TOLs or red treatments. During the before period, there were three reported collisions along the Geary Street corridor involving a movement within or across the TOL and during the after period there were five such reported collisions on Geary Street, two on O'Farrell Street and one on 3rd Street. A brief description of each of these collisions is provided below:

Geary Street – Before

- A bicyclist riding in the TOL was struck by a parked vehicle's opened door.
- A motorist driving in the TOL merged left and rear-ended a motorcycle in the adjacent lane.
- A motorist making a left turn from the TOL on the right side of the street broadsided a vehicle in an adjacent lane.

Geary Street – After

- A motorist merged into the TOL and sideswiped a motorcycle splitting lanes.
- Two instances of motorists reversing in the TOL hit pedestrians crossing midblock.
- A motorist in the TOL merged left and hit a vehicle in the adjacent lane.
- A bicyclist riding wrong-way in the TOL broadsided a vehicle crossing at an intersection.

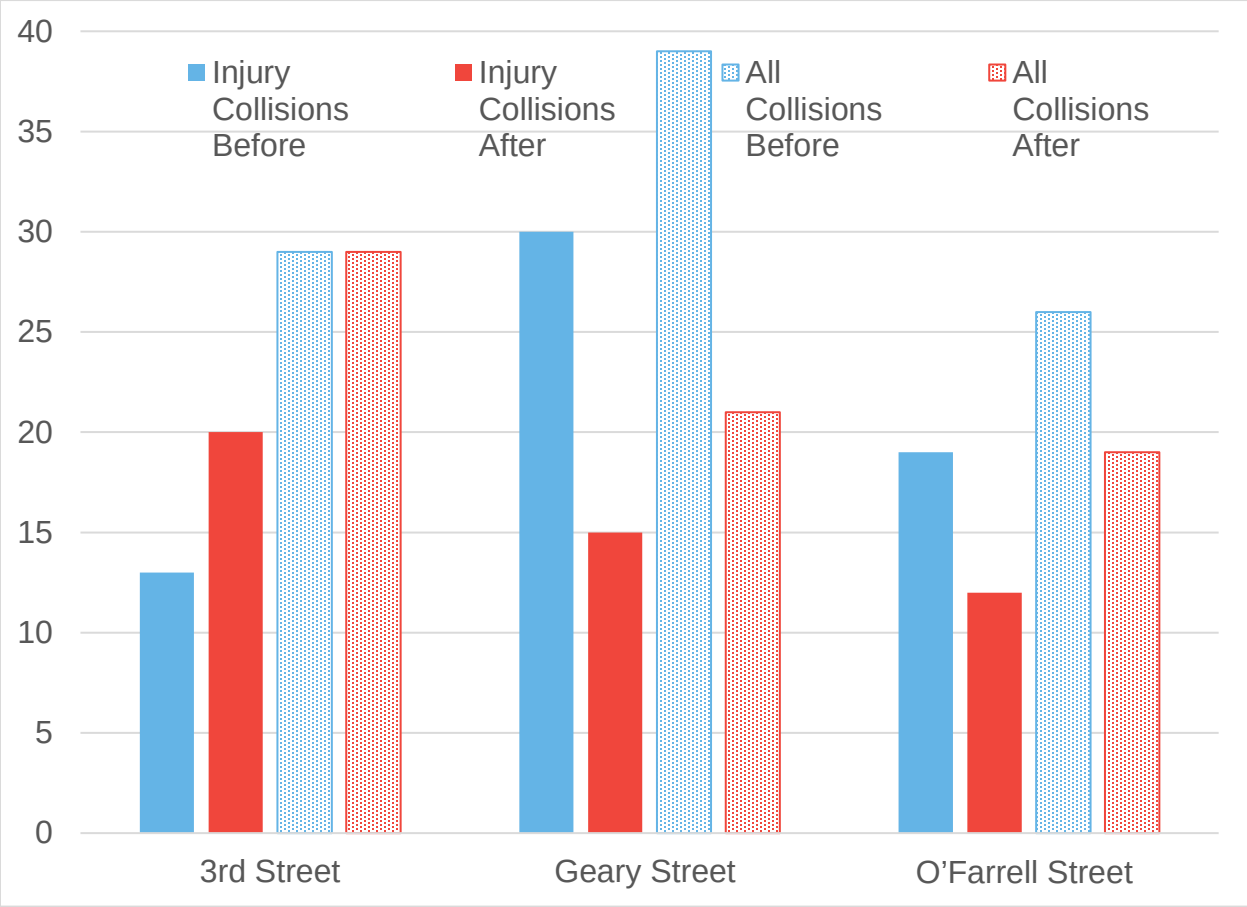
O'Farrell Street – After

- A taxi passenger opened the door of a parked taxi and struck a passing bus in the TOL.

3rd Street – After:

- A motorist turning right from the lane to left of the TOL sideswiped a vehicle in the TOL.

Figure 5 – Police-Reported Collisions



Motorist Turns

The SFMTA developed design guidelines for dashing red TOL treatments approaching intersections or major driveways where turns are permitted from a TOL or where vehicles must cross a TOL to access a turn pocket. This design follows similar markings specified by FHWA for green bike lanes in their memorandum *Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14).*

Observations of turning vehicles indicate that most roadway users understand and use the dashed red TOLs as intended.

During a 30-minute count at the intersection of O'Farrell and Cyril Magnin streets, where the curbside red TOL is dashed for approximately 100 feet approaching the intersection, 115 of 125 vehicles (93%) made right turns from the dashed red TOL. Observations indicate that the few drivers who turn from the through lane incorrectly are making last-second route change decisions or are frustrated by queues of right-turning vehicles within the dashed TOL waiting for conflicting pedestrians to clear the intersection.

Right Turns From Dashed Red TOL, O'Farrell Street at Cyril Magnin Street

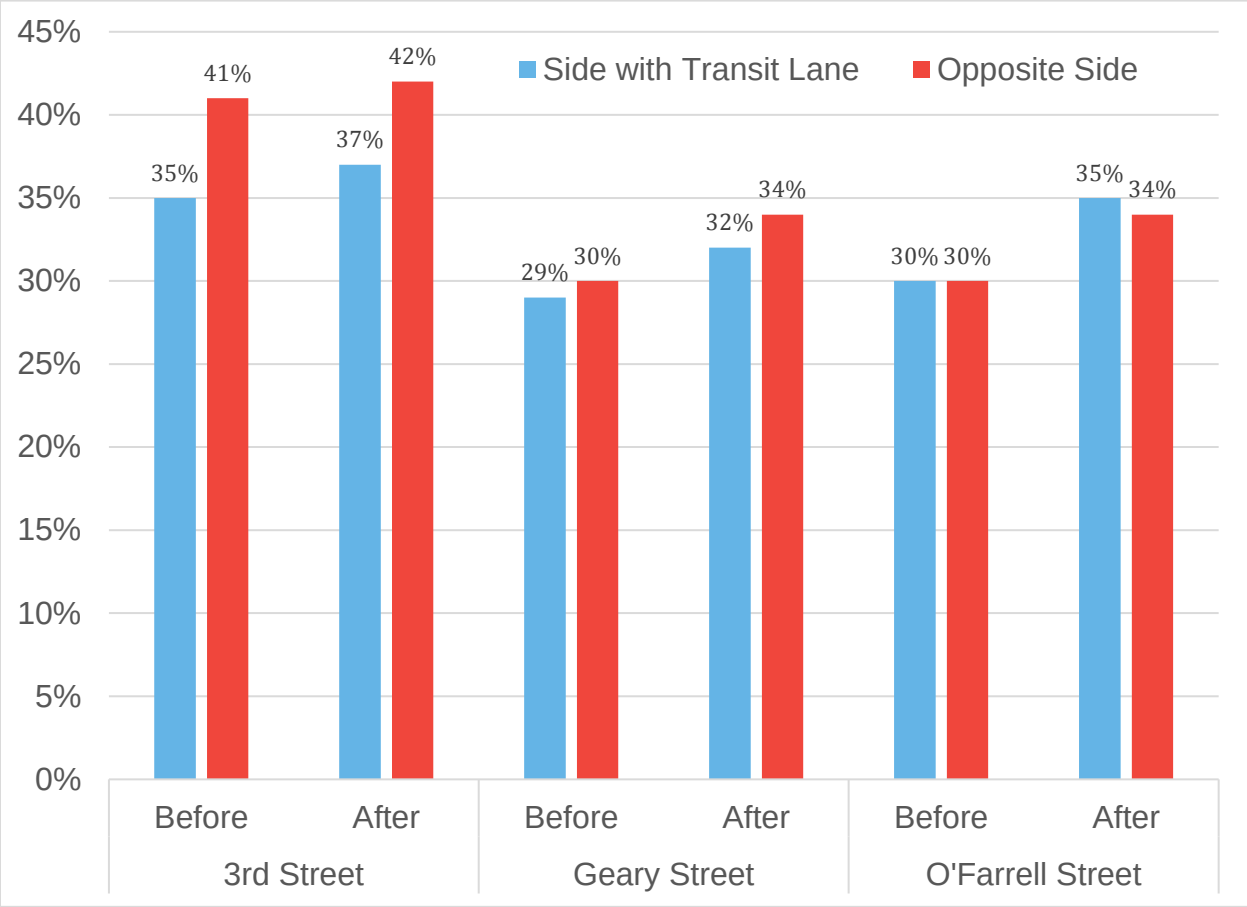
During a 30-minute count at the intersection of Geary and Leavenworth streets, where the offset red TOL is dashed for approximately 100 feet approaching a curbside right-turn pocket, 30 of 35 vehicles (86%) made right turns from the turn bay.

Vehicle Merging Across Dashed Red TOL, Geary Street at Leavenworth Street

On-Street Parking

Parking meter occupancy was analysed for the full calendar years of 2013 and 2015, and as shown in **Figure 6** below, increased along each of the study corridors, both on the side of the street with the TOLs and on the opposite side. These results indicate that the use of red treatments does not impact access to on-street parking.

Figure 6 – Parking Meter Occupancy



Material Details

The SFMTA has primarily used preformed thermoplastic for red TOLs. Tiles are cut to size and applied to the street surface using epoxy and heat. The SFMTA has also used epoxy-modified acrylic spray coatings on a limited number of corridors. Both materials have exhibited good friction characteristics and are projected to maintain visibility and adherence to the pavement for at least five years. SFMTA has favoured the use of preformed thermoplastic because lanes can be reopened more quickly than when applying sprayed coatings, which require multiple coats and curing time.

Application of Preformed Thermoplastic

Application of Spray Coating

Latex paint, typically used to mark colored curbs, was applied as a temporary red lane treatment for a one-block segment on Mission Street, where the cost to use standard materials was not justified due to a planned street resurfacing project. The SFMTA received negative feedback from bus operators and the public about the poor friction of the latex paint, and does not recommend use of this material, even for temporary installations.

Public Outreach and Feedback

Along corridors where red treatments were applied in conjunction with implementation of new TOLs and other design changes impacting parking and traffic circulation, there has been extensive public outreach and feedback. Prior to implementation of the first red TOL on Church Street, the SFMTA held a public meeting to share information before the project was reviewed at a formal public hearing. The SFMTA conducted door-to-door outreach to fronting businesses, issued a press release, posted flyers in the neighborhood and shared information with community organizations as well as with the general public via email, a project website and social media posts.

Public feedback specific to red treatments has been generally positive, highlighting improved transit experiences and improved compliance. There have been some concerns raised about the visual impact of the red treatments, but negative feedback has generally been specific to traffic circulation changes associated with the creation of new TOLs. The SFMTA has received a few clarifying questions asking if private commuter shuttle buses are permitted to use TOLs, and whether private vehicles are permitted to make turns from center-running TOLs, but the limited number of these inquiries suggests the red treatments are well understood by the public. The SFMTA has received limited public feedback directly related to the study corridors along 3rd, Geary and O'Farrell streets where red treatments were applied to existing transit-only lanes. Of the 10 miles of red TOLs implemented, much of the public feedback has been received in the context of broader street redesign projects, both planned and recently implemented, in particular the Mission Street Rapid Project and the Geary Bus Rapid Transit Project, which are discussed further below.

Mission Street Rapid Project

Following an extensive public outreach process that included several public open house meetings, door-to-door outreach to business and meetings with over 30 neighborhood groups, the SFMTA Board of directors approved the Mission Street Rapid Project in December 2015. Major elements of the Project were implemented during the spring and summer of 2016. The project spans approximately 2.5 miles of Mission Street, one of San Francisco's most-heavily utilized transit corridors. In addition to implementation of a new TOL in the southbound direction, the project increased bus stop spacing from one block to two blocks and made substantial changes to parking and vehicular circulation. Right-turn requirements for private vehicles were added at six intersections in the northbound direction to reduce vehicular though traffic conflicts with transit vehicles where a TOL was not added.

There has been a significant amount of positive feedback regarding the Mission Street Rapid Project from transit users and neighborhood residents focused on the resulting improvements to Muni travel time and reliability and a sense that Mission Street is a safer place to walk. An pedestrian intercept survey of 1,400 people on Mission Street conducted in summer 2016 supported this feedback – 58% of respondents supported the project (26% neutral, 16% opposed), while 61% of transit riders agreed that their trips had been made quicker and more reliable (21% neutral, 18% disagree). However, there has also been negative feedback from drivers who find it more difficult to access Mission

Street and to find parking on or near Mission Street. As a result, merchants have shared feedback that this difficulty is causing a decrease in sales. Most of the concerns expressed by drivers are the result of parking and circulation changes (including the conversion of one of two southbound travel lanes to a TOL and the addition of forced right turns at six intersections in the northbound direction) rather than the red lane treatment. Because the red treatment is the most visible element of the project, some negative sentiments are aimed toward the red treatment. In response to feedback, the SFMTA has made numerous modifications to the project, including removal of two of the six required right-turn restrictions.

Geary Bus Rapid Project

Members of the public have raised concerns about components of the Geary Bus Rapid Transit Project, which proposes to create new segments of TOLs connecting to existing TOLs located Downtown on Geary and O'Farrell streets. Some business owners have expressed concerns that red transit lanes will make it more difficult for motorists to access their business driveways. Based on the analysis of motorist turns and parking occupancy discussed earlier, the SFMTA believes that the use of red treatments will not change the ability of motorists to access curbside parking or driveways. Staff observations indicate that drivers routinely enter red TOLs to access driveways as intended. SFMTA staff contacted other cities that have implemented red TOLs, and have not learned of any negative impacts to businesses. New York City developed educational brochures to clarify how drivers should use TOLs – as the SFMTA continues to develop design details for the Geary BRT Project, educational campaign materials to help drivers navigate transit-only lanes will be considered.

Recommendations

Based on the results documented in this report and the positive results reported by other jurisdictions that have experimented with red transit lanes, the SFMTA recommends FHWA work toward amending Chapter 3G – Colored Pavements, to provide guidance for the use of red pavement treatments as an optional supplement to existing standard transit lane signs and markings.

Cities throughout the nation are prioritizing public transit to serve growing populations. Changes to the design and management of streets that improve transit performance allow more people to travel safely and efficiently while reducing the transportation system's carbon footprint and improving its equity. Dedicated transit lanes are increasingly being used to prioritize transit within constrained urban street networks. Transit lanes can move more people in the same amount of space than general traffic lanes – red pavement treatments can improve the performance of transit lanes and are one of several tools cities should consider to make public transit a preferred mode of travel.

In September 2011, FHWA requested the National Committee on Uniform Traffic Control Devices (NCUTCD) make recommendations for amending the MUTCD to permit the use of red transit lanes. The NCUTCD has drafted language proposing changes to the MUTCD regarding colored pavements, including red color for transit lanes.[10] The NCUTCD draft recommended language includes the following standard: "If used, red colored pavement shall be applied only in lanes, areas, or locations where general-purpose traffic is generally prohibited to use, queue, wait, idle, or otherwise occupy the lane area or location where red colored pavement is used." The SFMTA suggests that any interim approval or changes to the MUTCD use this language as a starting point, but clarify that how it applies to vehicles crossing transit lanes to access on-street parking or entering a red transit lane to make a turn into a driveway or at an intersection.

[10] http://www.ncutcd.org/Documents/Meetings/June_2016/Attach%20No.23%20Markings%20Interim%20No.%202.pdf