SFMTA
Municipal
Transportation
Agency

Church Street *Transit Lanes*

Final Report

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EXECUTIVE SUMMARY

SFMTA launched the Church Street Transit Lanes Pilot on March 23, 2013 to evaluate the effectiveness of various service improvement strategies that will be introduced as part of the Agency's larger Transit Effectiveness Project (TEP). The pilot establishes center-running, dedicated transit-and-taxi-only lanes along three blocks of Church Street, in both directions, between 16th Street and Duboce Avenue. To protect the integrity of these lanes, the pilot also includes left turn restrictions, parking changes, and a red paint treatment that has proven effective at reducing transit lane violation rates in New York City and abroad.

A comprehensive data collection and analysis effort was undertaken to understand the Pilot's impact on transit service, local circulation, driver compliance, and finally, to assess the durability of the red paint treatment. The findings from this analysis suggest that:

1. **The dedicated lanes have reduced transit travel times and improved reliability:**
    a. The lanes have largely eliminated congestion-related delay through the corridor, resulting in average travel time savings of up to 14% (1 minute).
    b. The lanes have largely reduced congestion-related reliability issues through the corridor, resulting in average reductions in travel time variability of up to 27%. This helps keep trains running on schedule, and reduces the bunching and gapping that can lead to overcrowding.
2. **These benefits come at minimal additional cost to people in personal vehicles:**
    a. The pilot has not significantly increased delay for drivers through the corridor (~800 drivers per peak hour), except at the northbound approach to Duboce Avenue, where multiple factors have combined to add up to a minute of additional delay.
    b. The pilot has not reduced parking supply, and has in fact expanded it by truncating commercial loading hours to better meet local merchants' needs.
3. **These benefits were achieved cost effectively:**
    a. Implementation costs—material and labor required to restripe and repaint the lanes—were relatively minor (~$140k total or ~$280k per mile)
    b. The red paint treatment has been an effective passive enforcement strategy
    c. The red paint treatment has held up well, with the majority of the painted lanes retaining over 90% coverage after 18 months.

These findings highlight how SFMTA brings together technical expertise, industry best practices, and deep community insight to deliver effective transportation solutions that make the best use of finite public resources, and strike an acceptable balance between competing needs and interests.

To maximize benefits and minimize costs, this study recommends: (1) moving the overhead wires serving the 22 Fillmore so that it can safely operate in the dedicated lane north of Market Street; (2) signalizing the intersection of Duboce Avenue / Church Street to improve transit reliability and minimize modal conflicts; (3) legislating a "Keep Clear" zone on Church Street adjacent to Reservoir Street (Safeway entrance); (4) targeting saturation enforcement efforts periodically at Market Street; and (5) paying special attention to transit stop and intersection approach locations when applying red paint.

INTRODUCTION

SFMTA launched the Church Street Transit Lanes Pilot on March 23, 2013 to evaluate the effectiveness of various service improvement strategies that will be introduced as part of the Agency's larger Transit Effectiveness Project (TEP). As **Figure 1A and 1B** illustrate, the pilot establishes center-running, dedicated transit-and-taxi-only lanes along three blocks of Church Street, in both directions, between 16th Street and Duboce Avenue (Corridor). The study corridor currently serves roughly 700 largely single occupied personal vehicles per hour, during the height of the AM and PM commute period, which extend from 7:45 - 8:45 AM, and 5:00 - 6:00 PM, respectively; roughly 150 of these vehicles are making a left turn at either 15th- or 16th Street. By comparison, the J Church and 22 Fillmore combined send 24 vehicles per hour through the corridor, but carry more than twice as many passengers (1500 riders per hour during the AM and PM peaks). **Figure 2** summarizes the allocation of capacity on Church Street before and after the pilot.

Except for a small segment of the northbound 22 Fillmore, both the 22 Fillmore (trolley bus) and the J Church (LRV) operate in the transit lane under the Pilot, using the existing boarding islands for passenger loading; due to constraints in the overhead wiring infrastructure, the 22 Fillmore must merge into the curbside mixed-flow lane north of Market Street. To protect the integrity of the dedicated lanes, the pilot also includes left turn restrictions, parking changes, and a red paint treatment that has proven effective at reducing transit lane violation rates in New York City and abroad. Finally, in order to increase effective capacity in the remaining mixed-flow lane, the pilot also introduces signal timing changes at 16th- and 15th Street that generally prioritize north/south movements along Church Street by transferring green times from the corresponding east/west movements.

The impact of the pilot on transit service, local circulation, and driver compliance rates, as well as an assessment of red paint durability, is discussed in the sections that follow.

TRANSIT SERVICE

This study used Automatic Vehicle Locator (AVL) data to compare travel time and travel time reliability on each line before and after the Pilot. Weekday travel times through the study corridor for the month of September 2013 (six months after the pilot went into effect) were calculated and summarized using a variety of statistical measures to estimate travel times and travel time reliability, and compared to results for September 2012. The change in the interquartile range (the difference between the 75th percentile and the 25th percentile of travel times) was used to gauge the pilot's effect on reliability, where smaller interquartile ranges translate into greater schedule adherence, and vice versa.[1]

Expected travel time savings were calculated based on how much longer it took to traverse the corridor at a given time relative to the late evening (7-10 PM), which is assumed to be free of congestion-related delay. Similarly, expected reliability improvements were estimated based on the interquartile range observed during the late evening (7-10 PM). As the pilot is designed to

[1] The pilot's effect on OTP through the corridor is difficult to isolate from actual OTP reports generated by the NextBus system, given (1) that schedules have not been adjusted to reflect potential travel time savings as a result of the pilot, (2) vehicle breakdowns that affect the percent of scheduled service actually delivered, and (3) the headway-based scheduling being piloted concurrently with the Church Street Rapid Pilot.

address only congestion-related delay and unreliability, these estimates serve as a meaningful reference for evaluating the findings.

Key findings are discussed below:

The pilot has largely eliminated congestion-related delay on the J Church.

As **Figure 3A** illustrates, the pilot has reduced average peak period travel times up to 12% (40 seconds) in the outbound direction, and up to 13% (60 seconds) in the inbound direction. The travel time savings generally match or exceed estimates of travel time delay, which generally ranged from 20-30 seconds during the AM peak and 60 seconds during the PM peak. All results were statistically significant (See **Figure 4A**).

The pilot has eliminated congestion-related delay on the 22 Fillmore inside the pilot corridor, although this delay has been offset by new pilot-related congestion outside the corridor.

As **Figure 3A** illustrates, the pilot has reduced average peak period travel times up to 12% (50 seconds) in the outbound direction, which generally match or exceed estimates of travel time delay through the corridor. These travel time savings, however, exclude the eastbound Hermann St "jog" from Fillmore Street to Church Street, which appears to have increased significantly during the AM and mid-day periods, as illustrated in **Figure 5A**. When we include these segments, the total corridor travel time savings during the AM peak is reduced by about half, from 45 seconds to 20 seconds, and the mid-day travel time savings disappears entirely.

While no statistically significant change in travel times was observed for the inbound 22 Fillmore through the corridor, a block-by-block analysis reveals a different picture. As **Figure 5A** illustrates, there are consistent decreases in inbound travel times south of Market St, especially during the PM peak when delay appears to be most problematic. However, these decreases appear to be offset by significant increases in travel times north of Market St, where the 22 Fillmore is forced to merge out of the dedicated lanes and back into heavily congested mixed-flow traffic.

The pilot has improved travel time reliability through the corridor

As **Figure 3A** illustrates, the reduction in travel time interquartile ranges met or exceeded expectations, except for the inbound 22 Fillmore during the AM peak, and the outbound J Church during the PM Peak. The inbound 22 Fillmore exception is probably due to the bus contending with additional congestion merging back into the mixed flow lane north of Market Street. A block-by-block analysis of the outbound J Church (**Figure 5A**) suggests the problem is localized to the single block between Duboce Ave and 14th Street / Market. This could be the result of (1) queuing at the left-turn pocket onto Reservoir St that the outbound 22 Fillmore can bypass, but that the J Church (fixed-guideway) cannot; or (2) modal conflicts at the intersection of Duboce Ave / Church St that interfere with the left-turn movement.

The travel time and reliability improvements have remained consistent through the 18-month pilot.

The analysis was repeated again 12-months (**Figures 3B, 4B, 5B**) and 18-months (**Figures 3C, 4C, 5C**) into the pilot. Results from both were generally consistent with the 6-month findings, within a statistical margin of error (95% confidence interval).

The inconsistencies between the 12-month and 6-month evaluation can be explained by differences in congestion-levels between September and March: higher levels of congestion in September generally allow for greater travel time savings, whereas the relatively lower levels of congestion observed in March generally lead to smaller travel time savings. Inconsistencies in the inbound J Church results, where year-over-year travel time savings observed in March 2014 were generally lower than those observed in September 2013, can be explained by changes to the transit signal priority sensors. A comparison of the distribution of travel times at the Church Street / 15th Street suggest that the sensors were non-functional in September 2012, but were repaired and functioning by September 2013, which inflated the six month results.

The 18-month evaluation is largely consistent with the 12-month and 6-month evaluations, except for a noticeable decrease in peak AM reliability on the 22 Fillmore, in both directions. This suggests that congestion at the Hermann Street “jog” and in the mixed-flow lane north of Market Street is becoming more problematic.

LOCAL CIRCULATION

To test the pilot’s effect on local circulation along Church Street, and potential diversion of traffic to parallel streets, SFMTA compared average traffic volumes along the Corridor and parallel streets before and after implementation. Counts were generally conducted on clear weekdays in November 2012 and November 2013.

Pilot-related delay along signalized Church Street intersections was estimated using the Synchro 8.0 software package, while VisSim simulation software was used to estimate delay at the more complex, unsignalized Duboce Avenue intersection. The change in delay before and after the Pilot was compared to significance criteria established by the San Francisco Planning Department for determining what increases in driver delay warrant closer scrutiny. This significance criteria is summarized in **Figure 6**. When measuring traffic diversion to parallel streets, peak hour traffic volumes needed to (1) change by at least 30 vehicles, and (2) amount to at least a 10% change to be considered significant.

Findings from the analysis are discussed below.

The pilot has not led to a significant increase in delay to personal vehicles along the Church Street corridor, except at the northbound approach to Duboce Avenue.

As **Figure 6** illustrates, with the exception of Duboce Ave, the corridor was operating well within design capacity before the pilot. All intersections along the corridor operated at LOS C or better. Market Street generally contributed the most delay, which makes sense given the number of competing movements at that intersection and long cycle lengths. After the pilot, the corridor generally continued to operate well within design capacity.

While level of service at intersections south of Market largely remained unchanged, delay at Market Street does appear to have increased noticeably, falling from about LOS C to LOS D. This increase is due in part to the reduction in capacity along Church Street, but also in part to additional traffic generated by the new mixed-use development at Dolores and Market. The increase in delay was not, however, large enough to qualify as significant under San Francisco Planning Department guidelines.

Delay along the northbound approach to Duboce Avenue has appreciably worsened.

As **Figure 6** illustrates, average peak period control delay at the northbound approach to Duboce Avenue has increased about one minute. This increase is due in part to (1) the reduction in capacity as a result of the pilot, (2) bus blockages from the 22 Fillmore loading at the curbside lane, and (3) additional traffic generated by the new mixed-use development. This impact may be environmentally significant according to SF Planning Department guidelines, but can potentially be mitigated by either (1) signalizing the intersection, or (2) moving the overhead wires for the 22 Fillmore so that it can safely operate in the center lane north of Market Street.

The pilot has not led to significant traffic diversion to parallel streets.

As **Figure 7** illustrates, no significant increases in traffic volumes were observed along Sanchez Street or Hermann Street during either peak period. While a significant increase in volumes was observed along southbound Dolores Street during the PM peak, these changes appear to be primarily driven by the new mixed-use development at Market Street and Dolores Street, and not the pilot.

DRIVER COMPLIANCE

To test the effectiveness of the red paint treatments at reducing violation rates, we compared violation rates along Church Street to violation rates along Judah Street, between 22nd Ave and 25th Ave. This stretch of Judah Street is a 4-lane facility (2 lanes in each direction) that features fixed rail guideways along center-running transit lanes, along with left-turn restrictions and on-street parking, making it functionally comparable to the transit lanes on Church Street.

No special transit lane enforcement efforts were scheduled along either Church- or Judah Street during November 2013 when the counts were collected, nor had any taken place for at least seven months since the launch of the pilot in March 2013. As the pilot established entirely new transit lanes along Church Street where none existed before, the corridor received special enforcement attention for the first few weeks following implementation. For the first two weeks, the San Francisco Police Department (SFPD) issued advisements to motorists observed traveling within the transit lanes during peak periods. After the two week grace period, SFPD began issuing citations. This special enforcement effort continued for another two weeks. Since then, the Church Street transit lanes have been largely unenforced.

Traffic counts on Church- and Judah Street were collected on two days in November 2013. For Church Street, each incidence of a private vehicle (excluding official medallioned taxis) traveling in the dedicated-lane was noted as a violation, whether they were traveling through or performing an illegal left turn. For Judah Street, each incidence of a private vehicle (excluding official medallioned taxis) traveling in the dedicated-lane during the peak period was noted as a violation, whether they were traveling through or performing an illegal left turn; during the off-peak period, when left turns from the dedicated lanes are allowed, only those vehicles traveling through were noted as violations.

Given that (1) violation rates are very sensitive to congestion (i.e. appear to increase exponentially with congestion), and (2) Judah Street generally does not experience the congestion levels observed on Church Street; in comparing average violation rates, we include only those observations along Church Street where approach volumes are less than or equal to 300 vehicles per hour. This threshold is roughly half the design capacity of an urban roadway, and corresponds to when congestion generally becomes much more noticeable. This theoretical threshold is supported by the count data, illustrated in **Figure 8**, which shows exponential growth in violation rates along Church Street at volumes above 300 vehicles per hour.

Findings from the analysis are presented below:

The red paint treatment reduces transit lane violations by roughly half.

> As **Figure 8** illustrates, the violation rate along the Church Street transit lanes is a little less than half (42%) the violation rate observed along the Judah Street transit lanes, even though average traffic volumes along Church Street are almost twice as high. The average violation rate observed along the Church Street corridor during uncongested conditions was about 7 percent, versus a violation rate of about 12 percent along Judah Street. The difference was statistically significant. Even at the northbound approach to Market Street and Duboce Avenue, where congestion and delay can be quite significant, the observed violation rates are lower than expected given the relatively high volumes. Ranging between 10% and 15%, the violation rates observed north of Market Street are on par with the rates observed on Judah Street, where congestion and delay are not a problem.

RED PAINT DURABILITY

Background

While red paint treatments have generally proven to be effective at protecting the integrity of transit only lanes, whether this solution is more efficient than simply increasing enforcement efforts depends in large part on their long-term durability. The StreetBond150 coating product developed by Quest Construction Products was selected for this Pilot based on its performance in New York City's red transit lane experiment, and SFMTA's past experience using the product to paint green bike lanes throughout San Francisco. The product was applied in March 2013 in accordance with the training guide supplied by Quest, and is expected to last at least 3-5 years.

Methods

To test the durability of the red paint treatments, SFMTA selected nine locations along the corridor, and tracked the rate of deterioration of the paint over time. Three different location types were selected:

1. Immediately adjacent to a transit stop
2. Midblock
3. Intersection without a transit stop

Site visits were conducted every three months, beginning September 2013 and ending September 2014. During each visit, several photos were taken at each of the nine locations, on a sunny day, at a time with no shadows on the red paint. The photos were taken parallel to the street surface, approximately 3.5 feet overhead, on sunny days, with the same camera and exposure settings to ensure uniform digital imaging conditions. The photos were then processed using the digital image processing software ImageJ to determine the percentage of the surface area in each photograph that was still covered by red paint. Two photos were analyzed at each location in order to get an average paint coverage value for the location.

Findings

The results of the analysis, illustrated in **Figure 9**, show that the red paint treatment has deteriorated the most at transit stop locations (70-80% of coverage remaining), followed by intersection approaches, where about 80-90% of coverage remains. Midblock locations—representative of the vast majority of the painted surface area—have fared well, with over 90% of coverage remaining at all locations tested.

This wear pattern makes sense, as transit stops and intersection approaches are generally subject to higher frictional (accelerating, braking, and turning movements) and heat stress (undercarriage of idling vehicles) than midblock locations. Deterioration rates also appear to be affected by pavement quality. For example, location 6 and location 7 are both intersection approaches, but the pavement at location 7 is much smoother than at location 7. The unevenness of the pavement at location 6 magnifies frictional stress, leading to more rapid deterioration (78% remaining at location 6 versus 89% at location 7).

Conclusion
The StreetBond150 coating product is performing as expected. Extrapolating the observed deterioration rates forward, we can expect more than 85% red-paint coverage along most of the corridor after 3 years, falling to 80% coverage after 5 years. Transit stop and intersection approach locations will likely need touchups at the 5-year mark, where coverage will dip below 50%.

CONCLUSION

The Church Street Transit Lanes pilot is an example of how SFMTA brings together technical expertise, industry best practices, and deep community insight to deliver transportation solutions that make the best use of finite public resources, and strike an acceptable balance between competing needs and interests:

The pilot largely eliminates congestion-related delay and unreliability through the corridor.

- The transit lanes on Church Street have largely eliminated congestion-related delay for transit riders (roughly 1,500 people per peak hour) through the corridor, and reduced the interquartile range of travel times. The inbound 22 Fillmore saw more mixed-results, due primarily to overhead wiring constraints that require it operate in the mixed-flow lane north of Market Street.

These benefits come at minimal additional cost to people in personal vehicles.

- The pilot has not significantly increased delay for people who drive (~800 per peak hour) through the corridor, except at the northbound approach to Duboce Avenue, where multiple factors have combined to add up to a minute of delay to an already busy intersection.
- The pilot has not reduced the supply of parking in the neighborhood, and has in fact expanded it by truncating commercial loading hours to better fit local merchants' needs

The benefits were achieved cost effectively.

- Implementation costs—material & labor to restripe/repaint the lanes—were relatively minor (~$140k total or ~$280k per mile)[2]
- The red paint treatment has been an effective passive enforcement strategy.
- The red paint treatment has held up well, with the majority of the painted lanes retaining over 90% coverage after 18 months.

RECOMMENDATIONS

The TEP is as much an ongoing process as it is a finite project. The findings from this evaluation suggest three future enhancements that can squeeze additional benefits out of the dedicated lanes, while further minimizing the costs:

1. **Move overhead wires so that 22 Fillmore can operate in the transit lane north of Market Street, and help reduce delays to both transit vehicles and personal vehicles.** The pilot has proven effective at reducing delays on both the 22 Fillmore and J Church, in both directions, at all times—with the notable exception of the inbound 22 Fillmore. This is primarily due to additional delay encountered north of Market Street, where the 22 Fillmore must merge back into a heavily congested, mixed-flow lane. This not only erodes almost all the travel time savings gained south of Market Street, it also increases delay to personal vehicles because the 22 Fillmore effectively blocks the intersection when loading passengers at the nearside Duboce Avenue stop.
2. **For near-term congestion relief, move the curbside bus stop for the 22 Fillmore to the far-side of the intersection, or consolidate it with the stop at Hermann Street.** Capital projects take time to plan, fund, and implement. Near-term relief for personal vehicles at the heavily delayed northbound approach to Duboce Avenue can be provided by temporarily moving the Duboce Avenue stop from the nearside of the intersection to the farside of the intersection, or consolidating it with the stop on Hermann Street. Since violation rates increase exponentially with congestion, providing near-term congestion relief would have the added benefit of reducing violation rates north of Market Street, further improving transit speed and reliability at this critical juncture.
3. **Signalize the intersection of Duboce Avenue / Church Street to improve transit reliability and minimize conflicts between vehicles, bicyclists, and pedestrians.** Signal designs that prioritize transit vehicles can help keep the Duboce Portal subway entrance clear, reducing conflicts between the N Judah, J Church, and 22 Fillmore, and thus improving reliability. Signalization can also help reduce intermodal conflict, making it safer for all users, and potentially providing some congestion relief to personal vehicles.
4. **Legislate a "Keep Clear" zone at Reservoir Street (entrance to Safeway complex).** Queueing in the northbound mixed-flow lane could be blocking access to Reservoir Street, leading to queuing in the southbound left-turn lane that can affect transit reliability.
5. **Target saturation enforcement efforts periodically at Market Street to reduce violation rates.** The highest violation rates were generally observed at the northbound approaches to Market Street and Duboce Avenue, which makes sense given that violation

[2] Does not include labor required to move overhead wires serving the 22 Fillmore.

rates increase exponentially with congestion levels, and the inbound segment north of Market Street is generally the most congested. Periodic enforcement efforts targeted at these two intersections can help reduce violations, and further improve transit travel times and reliability through the corridor.

6. **Pay special attention to transit stop and intersection approach locations when applying red paint treatments.** Frictional and heat stresses are concentrated at transit stops and intersection approaches, leading to more rapid deterioration. Special precautions should be taken to ensure the pavement at these locations is smooth before the red paint treatment is applied. To reduce lifetime maintenance costs, consider special protective treatments or extra coats of paint at these locations.