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Arterial Speed Management with Control Measures: the Case of San Francisco

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ABSTRACT

High vehicle speeds are strongly associated with both a greater likelihood of crash occurrence and more serious pedestrian injury. This study evaluated the effectiveness of traffic signal progression as a speed management tool in three arterial corridors in the city of San Francisco. Analysis of “before” and “after” field data on traffic volumes and speeds were used in the evaluation supplemented with estimates of air pollutant vehicle emissions. The findings show that the implemented control measure is an effective low-cost method to reduce the average speeds at the selected corridors. The revised signal settings timings also resulted in emissions reduction.

Keywords:
Traffic signals, progression, accidents, pedestrians, emissions

INTRODUCTION

Studies show that the risk of pedestrian injury and death as the result of a collision increases exponentially as vehicle speeds increase [1]. High vehicle speeds are strongly associated with both a greater likelihood of crash occurrence and more serious pedestrian injury [2].

There are several speed management strategies for urban streets. They include design treatments (e.g., vertical or horizontal deflections, roundabouts), informational signs, automated enforcement and traffic signal control [3]. However, most of the design treatments are appropriate for low volume roads and are not applicable on multilane arterial streets with high traffic volumes and pedestrian interactions, typical in large metropolitan cities.

Coordination of traffic signals and optimization of the signal timings is a highly cost-effective measure to reduce unnecessary stops and delays at traffic signals which improves travel times and reduces fuel consumption and emissions [4]. Furthermore signal timing improvements have safety benefits, a reduction ranging from 8% to 18% reduction in all types of intersection crashes according to the Highway Safety Manual [5].

One of the design parameters for signal coordination is the progression speed, i.e., the speed used to set the signal offsets at the successive intersections along the arterial so vehicles can proceed without stopping. By adjusting the progression speed may result in lower or higher travel speeds along the arterial as drivers try to adjust their travel speeds to arrive during the green phase at each intersection. Therefore signal coordination with appropriately selected progression speed is a speed management tool.

The Livable Streets Subdivision of San Francisco Municipal Transportation Agency (SFMTA) as part of the Vision zero for elimination of pedestrian accidents and traffic calming efforts implemented the Corridor Speed Reduction pilot project to better understand signal progression modification as a low-cost method for effectively slowing vehicle speeds and reduce the incidences and severity of collisions on signalized and/or multi-lane corridors.

The objectives of this study are to evaluate the signal control changes implemented on three signalized arterial corridors in the city of San Francisco to reduce vehicle speeds and reduce the frequency and severity of collisions. The paper describes the findings to-date on this ongoing research effort.

The next section describes the selected corridors and the implemented measures. The evaluation methodology and findings are described in the next section. The last section summarizes the study findings and outlines ongoing and future steps in the research effort.

CORRIDOR SELECTION

Recent analysis of collision data found that a minority of streets in San Francisco (roughly 6%) account for a majority of the severe and fatal pedestrian injury collisions. Most of the corridors identified as having a high concentration of pedestrian collisions are arterial streets and streets that carry moderate to high volumes of traffic. Three corridors were selected in order to test the feasibility of the proposed control change in a dense, transit-rich environment like San Francisco. The objective in choosing the test corridors was to investigate the proposed measure on sites with a high occurrence of pedestrian accidents, variety of geometric features, traffic patterns and vehicle composition (private autos and transit). This would help to define a range of costs, required steps and required outreach for this class of project. Figure 1 shows a map of San Francisco and the location of the selected corridors. The selected corridors were:

- Turk Street between Gough and Baker Streets
- Guerrero Street between 15th and 25th Streets
- 16th Street between Bryant and Market Streets (a Muni transit route)

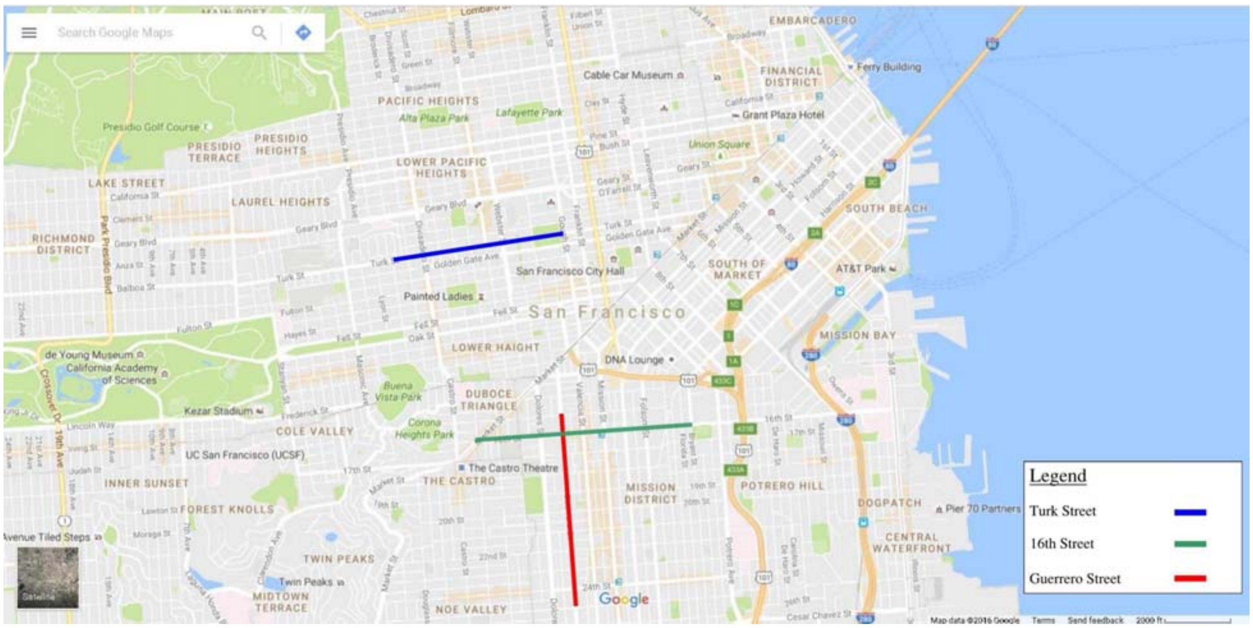


Figure 1. Location of Test Corridors, San Francisco, California

The key characteristics of the each test corridor and the mitigations implemented are described below:

Turk Street

The test section between Gough and Baker Streets includes 10 signalized intersections that are coordinated with progression speed of 30 mph, which is the speed limit for the arterial. However, speed surveys showed an 85th percentile speed of 34 mph. In addition, Turk Street is among the 5% of San Francisco streets that are responsible for 50% of pedestrian injury collisions.

Turk street offers great opportunity for changing the signal settings. It is a one-way street, which provides the most flexibility to determine the signal progression design speed, it does not carry any transit busses, and crosses only one major arterial (Divisadero Street). This relative lack of conflicting transit or coordinated signal corridors reduces the number of constraints to the signal timing design.

The proposed design speed for signal progression is 20 mph, with the signal timing at the intersection with Divisadero Street unchanged to avoid any adverse impacts to transit on that street.

Guerrero Street

There are 10 signalized intersections in this study section with speed limit of 25 mph. However, field surveys show 85th percentile speeds as high as 34 mph. Signal progression exists in certain segments at speeds ranging from 24 to 34 mph in the peak direction. Vehicles in the opposite direction travel at high speeds (of 37 mph or higher) in order to catch the next green light. In the off peak time periods, between 19th and 15th Streets (the core of the identified risk corridor along this street), inbound traffic travels in progression between 27 and 37 mph.

Exploratory analysis showed that a design speed of 13 mph could provide good progression on both travel directions. However, traffic signal progression at this speed on an arterial street might frustrate motorists and would cause traffic to divert to nearby parallel streets, delaying transit on those corridors or degrading the quality of life on residential streets. Therefore, the speed of 23 mph was selected as the progression speed, which is a speed that will improve safety, but still allow for segments of vehicle progression in both travel directions.

16th Street

The selected corridor includes 9 coordinated signalized intersections that provide relatively good directional progression per time of day (eastbound in the AM peak, and westbound in the PM peak), and no progression in the off peak hours. During all of these time periods, the timing at certain arterial sections allows for progressive movements well above the 25 mph speed limit at certain arterial sections. A recent speed survey showed 85th percentile speeds of approximately 35 mph between Guerrero and Dolores Streets.

The implementation of slower speeds through signal timing changes in the selected section of 16th Street phased a number of challenges typical in a dense urban environment including:

- Transit movements: 16th Street carries two Muni lines, the 22 Fillmore and the 33 Stanyan. The SFMTA would not like to cause major delays to Muni, particularly the 22 Fillmore with its frequent service.
- Major crossing arterials: 16th Street crosses several important streets including Mission Street a major transit corridor, and Valencia Street timed to provide good progression for bicycles. In order to avoid transit and bicycle delays on Mission and Valencia Streets, no signal timing changes should be made at the intersections with these streets. Also, South Van Ness Street is another important crossing arterial, plus Folsom and Church Streets that serve transit lines.
- Design constraints: there is only one lane of traffic in the eastbound direction. The number of right and left turns off of 16th Street and the number of pedestrians along this corridor cause long delays for through traffic, including Muni busses. As a result, traffic moves far slower than the theoretical eastbound progression speed through this corridor under existing conditions.

The selected design speed for westbound progression is 20 mph, and the design speed for progression in the eastbound direction is 12 mph. The selected speed values reduce speeding along segments with less congestion, and account for the fact that eastbound traffic is generally unable to move at the existing progression speed anyway due to congestion.

EVALUATION OF SIGNAL CONTROL CHANGES

Data Collection

Transit data: average speeds from city buses traveling on 16th street, excluding door open times and pullout dwell times. The data were collected in October 2013 and September 2015.

Inrix data: The INRIX website provides historical and real-time speed and travel time data on highway facilities, and travel time information to public agencies, businesses and individuals [6]. The data are collected from private mobile phones, trucks, delivery vans, and other fleet vehicles equipped with GPS locator devices. The data is processed in real-time, creating traffic speed and travel time information for major freeways, highways and arterials across North America. The selected data collection periods were November 2014 for the "before" conditions and November 2015 for the "after" conditions, on typical weekdays (Tuesday, Wednesday, Thursday) excluding holidays.

Traffic volumes: 24 hour traffic volumes were collected at two locations along each of the three corridors.

Field Speeds: Speed profiles plus longitude/latitude, and elevation were collected with the GPS loggers using a mobile phone based app, *myTracks*. Two travel runs were made on Turk Street, four runs on Guerrero St. (twice in each travel direction) and four runs on 16th St. (twice in each direction). The field data was collected on Thursday, May 19th 2016 between 4:00 pm and 7:00 pm.

Findings: Travel Speeds

Table 1 shows the average speeds "before" and "after" the signal timing changes. The implementation of new signal timings resulted in decrease in average travel speeds in all test corridors.

Table 1. Average Speeds (mph)

Study Corridor	Data Source	Pre-implementation	Post-Implementation	Change (%)
Turk	Inrix	20.8	17.2	-17.3
	Field	-	20.0	-
Guerrero	Inrix	16.4	12.9	-21.3%
	Field	-	18.1	-
16th	Inrix	15.2	11.4	-25.0%
	Field	-	16.3	-
	Muni	16.1	14.6	-9.3%

The effectiveness of the control measure was examined by time of day and travel direction as shown in Tables 2 and 3 using the INRIX speeds. It should be noted that the afternoon peak exhibited the most significant reduction in speed at the relevant corridors.

Table 2. Average Travel Speeds – Guerrero Street (mph)

Operating conditions	Travel Direction	Time Period AM PEAK	OFF-PEAK	PM PEAK
Before	NB	14.81	14.50	14.04
After		13.50	13.08	10.98
%change		*8.85%*	*9.79%*	*21.79%*
Before	SB	13.50	15.20	14.05
After		12.09	13.69	12.52
%change		*10.44%*	*9.93%*	*10.89%*

Table 3. Average Travel Speeds – Turk Street* (mph)

Operating conditions	Time Period AM PEAK	OFF-PEAK	PM PEAK
Before	18.59	18.82	18.04
After	16.40	16.32	13.56
%change	*11.78%*	*13.28%*	*24.83%*

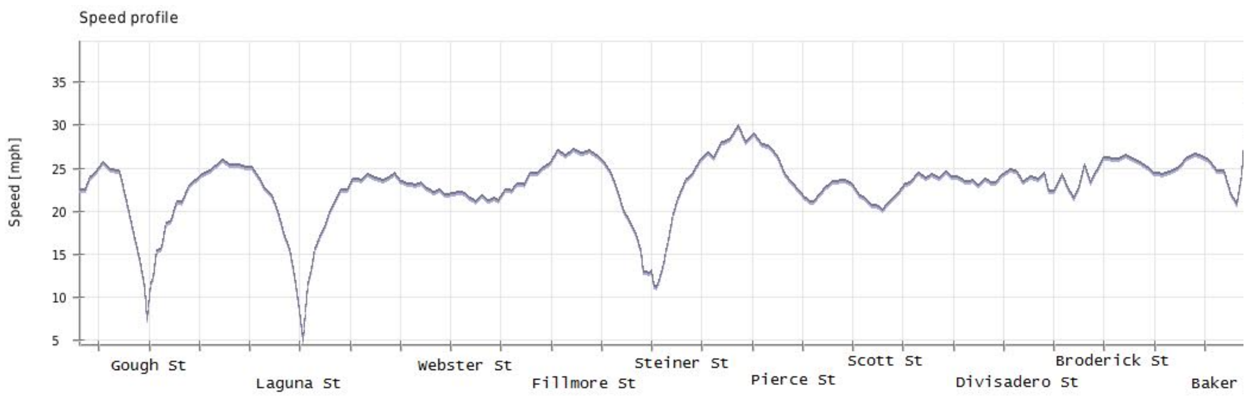
**one way street*

Figure 2 shows the speed profiles on each study corridor based on the field data collected with the GPS logger.

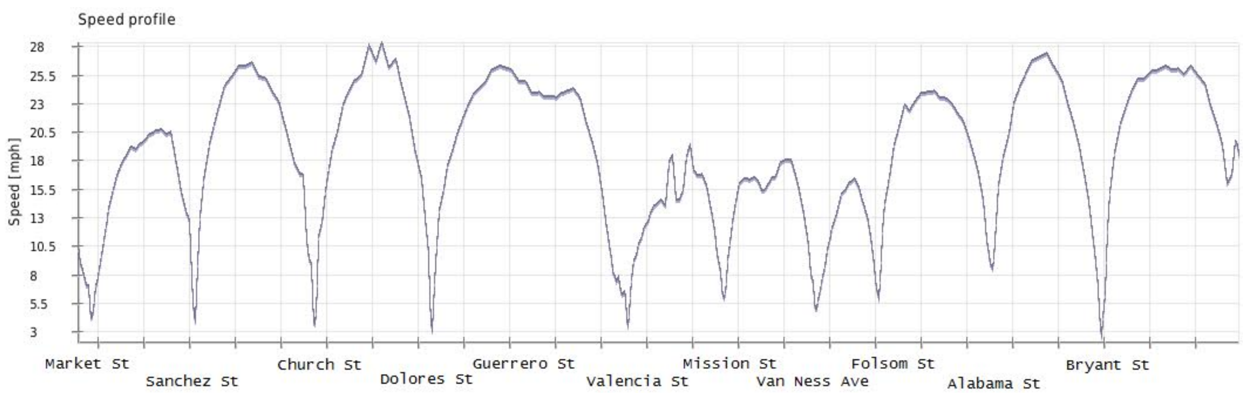
Figure 2(a) slows a sample speed profile for Turk Street. The travel speed is constant at the progression speed is 20 mph, except at locations where vehicles ahead were executing a left or right turn. Maintaining a lower constant speed tends to reduce the collision frequency, and vehicle emissions due to less deceleration and acceleration events.

Figure 2(b) shows a speed profile for 16th St. a commercial, bi-directional street. It can be seen that the test vehicle stops almost at each intersection especially in the NB direction during the PM peak. There is no signal progression as pedestrian and traffic volumes are very high. This may cause diversion to adjacent streets, higher vehicle emissions because of the vehicle idling and high number of acceleration/deceleration events but may reduce accident severity because of the slower speeds.

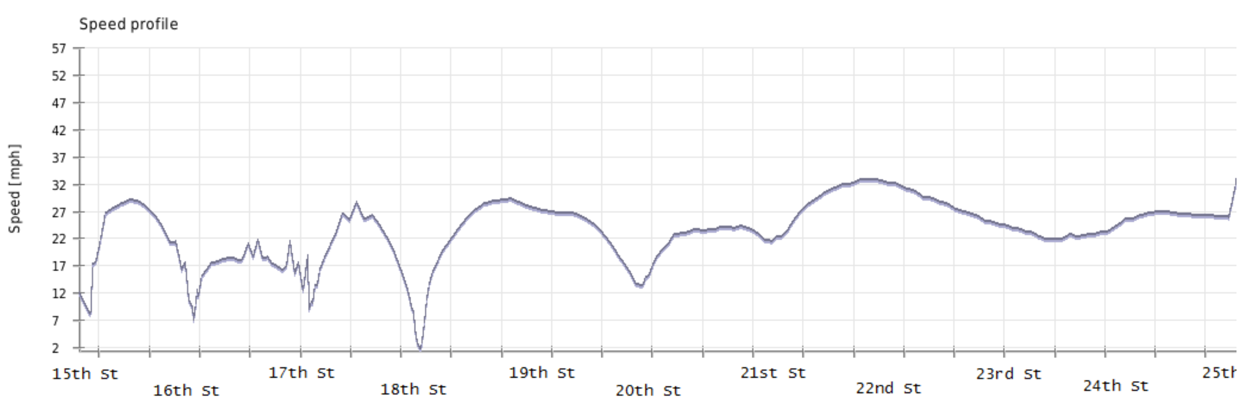
The speed profile for Guerrero Street is shown in Figure 2(c). The signal settings are set for the leading vehicles, so vehicles in the back of the platoon have to stop. Overall, similar to Turk Street there is good progression with expected safety and environmental benefits.



a) Turk Street between Gough Street & Baker Street



b) 16th Street between Market Street & Bryant Street



c) Guerrero Street between 15th Street & 25th Street

Figure 2. Sample Speed Profiles on the Test Corridors

Findings: Traffic Volumes

Table 4 shows the traffic volumes at each test corridor before and after the implementation of the control measure. Turk and Guerrero Streets experience an increase in average daily traffic since the revised progression results in smoother driving conditions through these corridors, that tends to attract additional drivers. 16th Street on the other hand, as mentioned previously, exhibits a high number of stops at the traffic lights, which may lead to decrease in average daily traffic as drivers tend to avoid streets with excessive number of stops at traffic lights. This effect may contribute to less exposure of pedestrians to vehicular traffic with potential safety benefits.

Table 4. Average Daily Traffic (ADT)

Study Corridor	"Before" Nov 14	"After" Nov-15	Change (%)
Turk Street	**10,523**	**12,378**	**17.6%**
16th St-EB	*6,933*	*5,529*	-20.3%
16th St-WB	*5,515*	*5,168*	-6.3%
16th Street	**12,448**	**10,697**	**-14.1%**
Guerrero St- NB	*10,446*	*12,625*	20.9%
Guerrero St - SB	*10,339*	*11,820*	14.3%
Guerrero Street	**20,785**	**24,445**	**17.6%**

Findings: Environmental Impacts

The amount of air pollutant emissions reactive organic gases (ROG), nitrogen oxides (NO_X), particulate matter (PM_{10}) and carbon dioxide (CO_2) were calculated based on California Air Resources Board Based E*MFAC2011LDV* emission factors [7]. Figure 3 shows the emission factors as a function of the average travel speed.

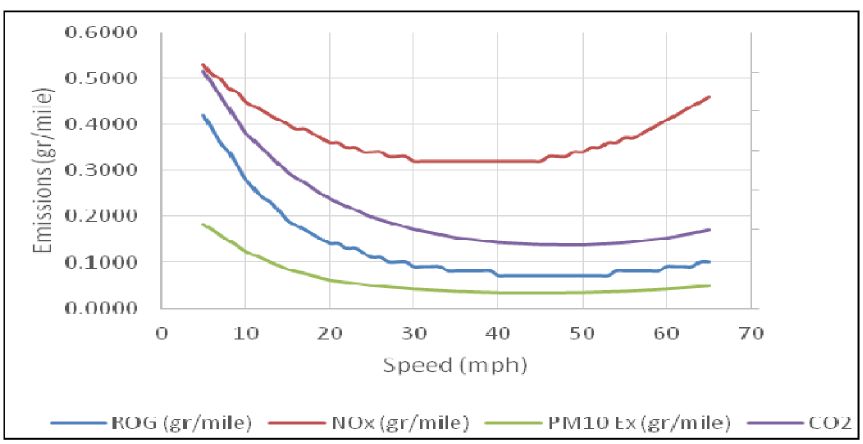


Figure 3. CARB Tailpipe Emission Factors vs. Average Speed [7]

Table 5 below shows the reduction of each of the compound emissions on each test corridor. There were savings in air pollutant emissions especially on Turk and Guerrero corridors mostly due to the improved progression. In the case of 16th St., the emissions were increased because of the higher number of stops in the corridor. However, as shown in Table 5 there was a net benefit because of the reduction of the traffic volumes in the corridor following the signal timing change.

Table 5. Annual Reductions in Air Pollutant Emissions (tons)

Air Pollutant	16th	Guerrero	Turk
1. ROG Emissions	0.0031	0.0447	0.0188
2. NOx Emissions	0.0031	0.0242	0.0125
3. PM Emissions	0.0015	0.0188	0.0110
4. CO2 Emissions	8.354	94.91	56.04

Note that the emissions calculated from the emission factors based on the average travel speeds tend to underestimate the actual emissions and associated savings because do not consider the idling and acceleration/events at traffic signals. Accurate emission estimates can be obtained by considering the actual vehicle activity, i.e., second-by-second speed/acceleration events [8].

DISCUSSION

Lowering injuries and fatalities remains a crucial goal for our cities. In 2011, 4,432 pedestrians were killed and 69,000 injured in motor vehicle crashes, according to the National Highway Traffic Safety Administration (NHTSA). Of the fatalities, 73% occurred in urban areas. This equates to 146 people killed or injured in cities everyday [9]. Measures to reduce the speeds on high facilities may be the single most intervention in reducing pedestrian injury and fatality [10]. This study evaluated the effectiveness of traffic signal progression as a speed management tool in three arterial corridors in the city of San Francisco. The results indicate that the proposed measure is an effective low-cost method to reduce average speeds at the selected corridors. The revised timings also resulted in smoother traffic conditions resulting in reduction of air pollutant emissions. It is expected that the implemented control measure will lead to reductions in frequency and severity of pedestrian accidents. However, collision data post-implementation for a quantitative analysis of the implemented measures on collision frequency and severity was not sufficient as the project was completed recently.

Ongoing work on the selected corridors includes gathering and analysis of collision data to quantify the safety benefits of the implemented measures. Also, monitoring the traffic performance on the particular corridor with the readily available INRIX data, plus data from other sources.

Next steps in improving the operations and safety on the city’s arterial corridors focus on the application of emerging technologies for control and management. A recent proposal by the city is to employ smart traffic signals operating under the Multi-Modal Intelligent Traffic Signal System (MMITSS) [11] and dedicated Short Range Communication (DSRC) technology. This technology in addition to traffic responsive signal timings would provide priority to public transit, and applications for pedestrian and bicycles including travelers with mobility limitations. Exploratory analysis of these concepts is in progress [12].

ACKNOWLEDGMENTS

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