NAPA COUNTY GRAND JURY
2018-2019

JUNE 24, 2019
FINAL REPORT

CITY OF NAPA TRAFFIC SIGNAL SYNCHRONIZATION STUDY

Red Light! Green Light!
Is the City of Napa's Traffic Signal System Up to Speed?

City of Napa Traffic Signal Synchronization Study
Published June 24, 2019

SUMMARY

The 2018-2019 Napa County Grand Jury (Jury) focused its traffic signal synchronization investigation on understanding the current operation of the traffic signal system in the City of Napa. Members of the Jury were of the opinion that the system was not synchronized, creating unnecessary delays and frustration when driving through the City's main corridors. During the course of the investigation, the Jury discovered that coordinating the traffic signal system in Napa is far more complex than wondering why it takes so long for the red lights to turn green. Through interviews with the City of Napa's Public Works Department (PWD), the Jury learned that there are several key factors affecting the programming and timing of traffic signals in the City of Napa. These include antiquated equipment that is not only inefficient to support, but incapable of meeting the dynamic changes in the growing volume of traffic from both tourists and residents.

The PWD maintains a Traffic Operations Division (TOD), which oversees the operational functions of all signalized intersections within the City limits. At the hub of the TOD is the Transportation Operations Center (TOC), which was established in 2017. During a tour of the TOC, the Jury was shown two different state-of-the-art software systems for controlling traffic signals that are being evaluated for purchase. One system was deployed on the Soscol Avenue corridor and the other on Trancas Street in order to compare and evaluate the features of each. The acquisition of this software is included in the City's 2019-2020 fiscal budget effective July 1, 2019.

The Jury found that the TOC is currently understaffed given the recent vacancy of one full-time senior engineering aide. Further, the Jury learned that one of the software systems being tested is on loan from the developer without a firm date when it may be removed by the vendor. The other system under consideration was included in a recent hardware purchase to update signal controllers; however, it is limited to just six signals. The Jury also found that efforts to shift responsibility for maintaining the traffic signals along the Highway 29 corridor from Caltrans to the City of Napa have not been successful thus far. Of particular concern are the signal lights at the intersection of Highway 29 and Redwood Road/Trancas Street. Lastly, the Jury found that the City does not have a Master Plan to address the systematic repair, maintenance, and replacement of traffic signals.

The Jury recommends that the Director of Public Works fill the vacant senior engineering aide position at the TOC by December 31, 2019. Further, the Jury recommends that the City of Napa and the Public Works Department purchase by January 1, 2020, the preferred software system that is currently being field-tested. The Jury also recommends that the City Council and the Department of Public Works enter into meaningful negotiations with Caltrans to gain control of the traffic signals at the intersection of Highway 29 and Redwood Road/Trancas Street. Finally, the Jury recommends that the Director of Public Works develop a Master Plan for the repair, maintenance, and replacement of traffic signals throughout the City.

GLOSSARY

Caltrans: California Department of Transportation
GPS: Global Positioning System
MTC: Metropolitan Transportation Commission
MUTCD: Manual on Uniform Traffic Control Devices
PASS: Program for Arterial Synchronization System
PWD: Public Works department
TOC: Transportation Operations Center
TOD: Traffic Operations Division

BACKGROUND

The 2018-19 Grand Jury chose to investigate the traffic signal synchronization system in the City of Napa partly based on interests expressed by several grand jury members about the seeming lack of traffic signal synchronization on Soscol Avenue, one of the major corridors in the City limits. Additionally, the Jury examined the working relationship between the City of Napa and Caltrans in their joint effort to plan, regulate, and maintain the traffic signal system in the City of Napa. The most recent Grand Jury report on the traffic signal system in the City of Napa was issued in 2012, when the Jury reviewed the efficiency of the Red-Light Enforcement program.[1]

The Jury acknowledges that maintaining an efficient system for the synchronization of traffic signals in the City of Napa is an important step in addressing delays in travel time within the City limits. However, the Jury also learned that traffic signal synchronization is only a small part of the overall traffic-related problems facing the City of Napa. The Jury's decision to narrow its investigation to the traffic signal system was only undertaken to understand one element in a system that has many components.

In the mid-1940s, immediately after World War II, the first signal lights in the City of Napa were installed at the intersections of First and Main Street and First and Jefferson Street.[2] By 1950, the population in the City of Napa was almost 8,000 with three more traffic signals at the intersections of Main and Lincoln, Lincoln and Jefferson, and Third and Jefferson. Today, the City's population is almost 80,000[3] with 78 signalized intersections throughout the City limits and into some parts of the County. (Appendix 1) The City of Napa's Public Works Department (PWD) is responsible for managing the traffic signal system within the City limits. There are 53 signalized intersections in the City limits that are owned and controlled by the PWD. The majority of these intersections

[1] City of Napa Red Light Enforcement: 2010-2011 Napa County Grand Jury Report

[2] Ford, Jim: Napa as it was. Travel on Napa's streets: Napa Valley Register, March 2, 2014

[3] http://www.worldpopulationreview.com/us-cities/napa-ca-population

are located on the four major corridors that crisscross the City: Redwood Road/Trancas Street, Lincoln Avenue, Soscol Avenue, and Jefferson Street. In 2014, as part of a Program for Arterial Synchronization System (PASS) grant, the traffic signals at 14 intersections along these four corridors were synchronized with each other to minimize traffic delay time.[4]

There are also 25 signalized intersections within the City limits that are owned and controlled by the State of California Department of Transportation (Caltrans). Caltrans is responsible for the design, construction, maintenance and operation of the California Highway System, including traffic signal synchronization at these 25 intersections. These traffic signals are located at intersections along Imola Avenue, the Silverado Trail and Highway 29, all of which are considered State Routes, thus within the purview of Caltrans. The Jury did not investigate the operational functions of Caltrans because it is not within its jurisdiction. However, the Jury did inquire about the working relationship between Caltrans and the PWD.

The PWD maintains a Traffic Operations Division (TOD) to regulate its traffic signal system. There are three employees in the TOD responsible for all facets of traffic signals including signal monitoring, timing synchronization, and signal maintenance. The department also relies on electricians from the PWD to handle routine maintenance and trouble-shooting of the entire system. These employees are not dedicated to the TOD alone, and have additional responsibilities within the PWD.

At the hub of the TOD is the newly created Transportation Operations Center (TOC). Although the Jury found the TOC is currently understaffed, it is equipped with state-of-the-art technology, which is currently under evaluation for purchase.

METHODOLOGY

A. Interviews conducted
   1. Five members of the Public Works Department Engineering Division

B. Documents reviewed
   1. California Manual on Uniform Traffic Control Devices for Streets and Highways, Part 4 – State of California
   2. Public Works Department 2019-2021 Budget
   3. Public Works Department Organizational Chart
   4. Program for Arterial System Synchronization (PASS) FY 15/16 Cycle – City of Napa
   5. City of Napa Traffic Signal Jurisdictions and Location Map
   6. Napa Valley Register articles on traffic signal synchronization
   7. City of Napa and Caltrans traffic signal locations

[4] See Appendix 3

8. 2011-2012 Napa Grand Jury Report: Red Light Enforcement Program

C. Conducted a tour of the Napa Public Works Department's Transportation Operations Center (TOC)

DISCUSSION

Much like the population in the City of Napa, the volume of traffic has increased significantly since 1950. Driving across town at peak commute times can be a challenge due to the increase in traffic from commuters entering and leaving the City on a daily basis. Add these numbers to an increase in the number of tourists visiting Napa year-round and you have a significant challenge in managing the flow of traffic throughout the City limits, especially at peak traffic times.

For example, according to data compiled by the Redflex Traffic Systems from the Photo Enforcement Data Repository for the time period from 2014 to 2016, the average monthly traffic volume at the intersection of Soscol & Imola Avenues increased by more than 100,000 vehicles per month. (Appendix 2) The increase in vehicles entering the City limits at this intersection represents a 31% increase over the span of 3 years. This intersection is considered a major gateway into the City of Napa.

The methodology employed by Redflex to count vehicles over the three-year period remained consistent throughout the traffic volume survey, thus validating the accuracy of the data that was collected. However, the Jury discovered through interviews with PWD engineering staff that during this time frame, the South Napa Market Place opened its commercial development that included a movie theater, a new hotel, several restaurants and a fitness center. The PWD staff suggested to the Jury that the increase in traffic volume at this intersection has been partly due to the new commercial development. The closure of the Cinedome movie theater downtown and the opening of the Cinemark Multi-Plex in the South Market Place alone shifted local traffic to this area.

Traffic signals throughout the City are maintained and monitored by the TOD. The design, maintenance, and regulation of traffic signals operated by the PWD follow the guidelines as outlined in the California Manual on Uniform Traffic Control Devices (MUTCD).[5] These guidelines provide cities with uniform standards regarding the installation, removal and regulation of traffic control signals. The MUTCD also provides guidelines in selecting alternatives to traffic control signals.

[5] MUTCD: California Manual on Uniform Traffic Control Devices, January 2019.

Transportation Operations Center – TOC

The TOC is the hub for all traffic signal operations in the City limits. The TOC was established in 2017 for the purpose of remotely monitoring and controlling the signalized intersections along the four main traffic corridors within the City limits. These major corridors include Jefferson Street, Soscol Avenue, Lincoln Avenue and Redwood Road/Trancas Street. Currently, the engineering staff at the TOC is able to monitor and control the timing and synchronization of 18 signalized intersections along these corridors. The TOC does not monitor traffic signals on Hwy. 29, Imola Avenue or the Silverado Trail, because these traffic signals are owned and operated by Caltrans.

Prior to the development of the TOC, repairs to signal malfunctions and timing adjustments were made by physically adjusting controller stations, which are the large electrical panels located at all intersections with traffic signals. The PWD still relies on a staff electrician, however, to make on-site repairs at more than two-thirds of the intersections under their control. The Jury was told the benefits of the TOC include far less downtime on malfunctioning signals and faster turnaround time to get the signals back in service.

One of the special features in the TOC is a large, wall-mounted TV screen showing video from cameras located at 18 signalized intersections that capture real-time traffic flow and signal functions. Six of these intersections are controlled by newly acquired software included with the purchase of new hardware, while the remaining 12 are on the current system. The difference between the 6 intersections on the test system and the 12 on the existing system is that adjustments to the signal protocols can be made remotely from the TOC, while the existing system requires an engineer to physically make adjustments at the site.

By careful analysis of the real-time video, the engineering staff can monitor and adjust the traffic signals at these intersections to optimize the best traffic conditions for the time of the day. The engineering staff at the TOD considers the establishment of the TOC a positive proactive approach to modernizing the traffic signal system in the City of Napa.

A supervising engineer and a senior engineering aide manage the TOC during weekdays from 8 a.m. to 5 p.m. The senior engineering aide position is currently vacant, and according to interviews, may not be filled for several months. The supervising engineer is responsible for other duties within the Traffic Division and is often away from his desk in the TOC. If the open position is filled, duties currently being handled by the supervising engineer would be the responsibility of the engineering aide, thereby allowing more time for the supervising engineer to evaluate and act on information generated from the system. The Jury recommends that the PWD and the City Council expedite the process to replace the vacant senior engineering aide position at the TOC.

A public works electrician spends approximately 70% of the day at the TOC working on signal timing and signal communications. The remaining part of the electrician's day is spent working in the field with signal repairs and routine maintenance. The TOC does not

operate on the weekends or holidays, unless there is a special event in the City such as the BottleRock music festival.

The engineering staff at the TOC told the Jury that during the week the morning peak traffic hours are between 7a.m. and 9 a.m. with a school-to-evening peak time from 3 p.m. to 6 p.m. The Jury was informed that the most congested locations in the City during these periods are the streets surrounding Napa High School, as well as Silverado Middle School.

The Jury was advised that the TOC looked at five different traffic signal control systems and has narrowed them down to the two systems currently being tested in the TOC. Both systems, according to the staff, are highly recommended and used in jurisdictions throughout the state. However, there is a difference in the pricing structure between the two systems, with the more expensive proposal being refined by the vendor. Once the new fiscal budget becomes available, the Jury understands a final selection will be made. The Jury recommends that the TOD purchase the updated hardware platform at the beginning of FY 2019-2020, when funds included in next year's budget become available.

Synchronizing Napa's Traffic Signals on Major Corridors

In August 2014, the City of Napa received a grant from the Metropolitan Transportation Commission's (MTC) Program for Arterial System Synchronization (PASS) to conduct a signal timing study for 14 traffic signals along corridors on Redwood Road/Trancas Street and Soscol Avenue. Project intersections are owned, operated, and maintained by the City of Napa.

The goal of the project was to conduct a timing analysis and implement signal coordination plans during weekday a.m., mid-day, and p.m. peak traffic periods. The project also included peak traffic periods on weekends. To provide a common time-source and enable communication between signals, five ground positioning satellite (GPS) clocks were installed as part of the project. The GPS clocks enable the signal controllers to regularly synchronize their clocks, efficiently deploy the timing plans at the same time, and thus help maintain the efficiency of signal coordination.

The synchronization of traffic lights, combined with new GPS equipment, was meant to create fewer stoppages and quicker trips on these two major corridors. An additional benefit of synchronization of traffic signals is reduced fuel use and less air pollution. According to a senior engineer with the City of Napa's PWD, the synchronization program in 2016 resulted in significantly reducing delay times for motorists traveling within the City limits during peak commute times. (Appendix 3)

The Jury learned that the timing mechanisms in some traffic signal lights are "programmed" to respond to heavy traffic flows such as during the a.m. and p.m. commute times, and remain "free," or non-programmed, during lighter traffic flows such as on weekends. When the traffic signal is in the programmed mode it facilitates traffic

flow in both directions by extending signal times and minimizing interruptions from vehicles entering traffic from side streets. When the traffic signal is in the free mode it relies on the detection sensors at each intersection to control the traffic flow.

During the course of the investigation the Jury learned that the impact of having a well-designed system of traffic signal synchronization benefits motorists at both peak and off-peak travel times. The purpose of synchronizing signal lights is to keep traffic flowing at the speed limit in the major corridors with minimal stops from arterial intersections. The Jury was told that even the most efficient system of signal synchronization can be compromised by factors unrelated to signal programming.

Limiting Factors Impacting the Timing of Signal Synchronization

The Jury was informed that since the 2014 PASS grant synchronization project was implemented, traffic signals at several key intersections have been coordinated. This project did reduce delays along the corridors that were targeted. It was pointed out to the Jury that it is not practical to synchronize all of the traffic signals in the City limits due to some of the factors affecting traffic flow. These factors are structural in nature, such as the need to add or extend left turn lanes at major intersections. For example, the overall distance between signalized intersections such as the four signals on Jefferson Street stretching from Third Street to Clay Street create a unique problem. These signalized intersections are located between very short residential blocks, which don't allow adequate space between vehicles to establish a continuous flow of traffic from one signal to the next. This is more of a structural problem and may only be solved by removing the signal lights at one or two of the intersections. However, the PWD said they were not considering the removal of any traffic signals on Jefferson Avenue.

Signals also can be thrown off of their timing for a variety of reasons. These factors include walk time for pedestrians and the safe movement of emergency vehicles through an intersection.

Emergency vehicles such as fire engines, police cars and EMS transport create a problem to signal synchronization as they have the ability to interrupt the signal phasing at any given intersection during an emergency to provide a safe passage through the intersection. The Jury was told that the interruption of the signal phasing disrupts the signal synchronization timing and it could take up to 15 minutes to reset the timing phase at these intersections before the signals are fully synchronized again. Pedestrians pushing walk signals in multiple directions also throw off timing and signal efficiency. Finally, the Jury learned that with the older system currently in place, the clocks that coordinate the signals have to be re-set each month as they can vary by as much as seven seconds over the course of a month.

The common thread throughout the interviews with the PWD engineers who have worked at the TOD for more than 20 years is that the overriding factor contributing to the delay time is largely due to the sheer increase in traffic volume the City of Napa has experienced in the past few years.

Control of Signal Functions – Caltrans and the City of Napa

In addition to other factors that affect traffic signal timing previously mentioned, the issue of control over the signal operations at selected intersections comes into play when attempting to synchronize a series of traffic signals on the same roadway. Of the 78 signalized intersections in the City limits, the City of Napa controls 53 signals while Caltrans controls 25. Caltrans operates independently from City and County agencies on matters within their jurisdiction relating to traffic management and construction. The control center for traffic signals owned by Caltrans is not located in Napa County.

The Jury learned that the ideal situation would be to have all of the signalized intersections within the City limits under the control of the PWD. The Jury was informed that Caltrans is unwilling to release control of the signalized intersections under their jurisdiction. The Jury was told that the determination for Caltrans to release control of selected traffic signals within their jurisdiction is apparently a district-by-district decision. The Caltrans district currently within Napa County desires to maintain control of all of the signalized intersections along the Highway 29 corridor, as well Imola Avenue and the Silverado Trail.

No definitive reason was given to the Jury as to why Caltrans refuses to give up control of these intersections. It was speculated that the reason is related to the control of traffic flow on Highways 29 and 121.

Local Roadway Seeking Help from Caltrans

One of the major sections of roadway in the City limits controlled by signal lights is at the intersection of Redwood Road/Trancas Street and Highway 29, with traffic signals at California Boulevard to the East of 29 and traffic signals on Solano Avenue to the West of 29. Added to this collection of traffic signals are the Wine Train Railroad crossing signals parallel to Solano Avenue.

None of these traffic signals are synchronized with each other because they are controlled by different entities. Caltrans controls the signals at both the on and off ramps at the intersection of Highway 29 and Redwood Road/Trancas Street. The traffic signals on either side of Highway 29, namely Solano Avenue on the west side and California Boulevard on the east side, are owned and operated by the City of Napa. Additionally, the Wine Train controls all of the signal functions whenever a train crosses the roadway, further complicating the re-adjustment of the timing mechanisms once a train has cleared the intersection.

The PWD would like to control all of the signal lights in this section of roadway in an effort to synchronize the timing of these signals to better optimize the traffic flow that feeds into the busy Bel Aire Plaza shopping center at the intersection of California Boulevard and Trancas Street. The Jury learned that the working relationship between the City of Napa and Caltrans could be much better in their joint efforts to manage the volume of traffic in the City limits.

Funding for the Traffic Operations Division

The Jury was told during interviews with senior administrative staff that the 2019-2021 TOD draft budget calls for $900,000 in capital improvement projects. These projects are necessary to update the infrastructure necessary to control the City's outdated traffic signal system.

There are currently two competing traffic signal improvement systems being evaluated. One is a software-only solution, which would require separate hardware purchases and an integration effort to make it functional. The second is an integrated hardware-software solution, which is currently in beta-testing at six Napa intersections. After further negotiations with the vendors, local PWD officials hope to make a final selection. Eventually, the new solution would be rolled out to 38 intersections under City control. The budget for improvements includes monies from Measure T, the local ballot sales-tax initiative designed to set funds aside for local road improvements.

Master Plan for Systematic Maintenance and Repair of Traffic Signals

During interviews, the Jury discovered that the PWD did not have a Master Plan for the systematic maintenance, repair and replacement of its traffic signals. Routine maintenance on the traffic signal system up to this point is handled on a need to repair basis rather than on a preventive basis. In years past, the traffic volume in the City of Napa has seen moderate growth and the PWD has been able to stay ahead of the curve with minimal urgency to upgrade their equipment or invest in modernized operating systems.

However, the expansion of tourism and the increase in the number of commuters who enter and leave the City on a daily basis calls for long-range planning and a serious look at the traffic issues that are currently in place in the City of Napa as well as the traffic issues the City will face in the coming years.

The Jury found that having a Master Plan would solidify the PWD's future funding projections and provide a clear path to modernization. The Jury was advised that funding to provide new controllers, fiber optic communication lines, and new traffic detection devices would facilitate a more efficient system.

Conclusion

The City of Napa has come a long way since those first traffic lights were installed in the mid-1940s. And while the City of Napa's population has gone from 8,000 to 80,000 in 73 years, the City is still struggling to maintain outdated traffic signal equipment to accommodate the increase in traffic, especially along the four major corridors within the City limits. Further, the recent upgrades in traffic signal synchronization on the major corridors have improved the overall flow of traffic, but the emphasis now must be on modernization of equipment and upgraded technology.

With an increase in the use of automobiles and the freedom to travel comes the increase in traffic. Along with the increase in traffic comes the need to control the flow of traffic from our homes to our jobs to our shopping centers. When properly used, traffic signals are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to various traffic movements and thereby profoundly influence traffic flow.

The Jury concludes that the PWD is systematically making improvements in the traffic signal system in the City of Napa and is determined to operate in a proactive manner in the future to better monitor and regulate the ever-increasing traffic volume in the City limits. An example of the proactive approach to traffic management by the PWD is the installation of new traffic signals at the intersection of Second and Main in downtown Napa featuring a pedestrian scramble system. The new system is designed to allow pedestrians to cross the intersection in all directions during one timing phase while the traffic from all other directions remains stopped.

FINDINGS

The 2018-2019 Napa Grand Jury finds that:

F1. The Transportation Operations Center is understaffed given the recent vacancy of one full-time senior engineering aide. This position is not expected to be filled for several months.

F2. A final purchasing decision on an upgraded system has yet to be finalized while one of the bidders is re-visiting their proposal on pricing.

F3. The traffic signals at the on and off ramps of Highway 29 and Redwood Road/Trancas Avenue are under control of Caltrans making it difficult for the City of Napa to efficiently control the traffic along the Trancas corridor.

F4. The Department of Public Works does not have a Master Plan for the systematic repair, maintenance and replacement of its traffic signal lights.

RECOMMENDATIONS

The 2018-2019 Napa Grand Jury recommends that:

R1. The Director of Public Works fill the vacant Senior Engineering Aide position at the TOC as soon as possible.

R2. When the 2019-2020 fiscal budget becomes effective on July 1, the Department of Public Works finalize the selection of a traffic management software package and initiate the purchasing process for installation commencing by January 1, 2020.

R3. The City Council and the PWD resume negotiations with Caltrans for the release of control of the traffic signals located on Redwood Road/Trancas Street at the intersections of Hwy. 29, by March 31, 2020.

R4. The Grand Jury recommends that the PWD develop a comprehensive Master Plan for the systematic repair, maintenance and replacement of the traffic signals in their jurisdiction by December 31, 2020.

COMMENDATIONS

The Grand Jury commends the PWD for its proactive approach to improving the traffic signal system in the City of Napa with the creation of the Transportation Operations Center and other efforts described herein.

REQUIRED RESPONSES

Pursuant to Penal Code sections 933 and 933.05, the 2018-2019 Napa County Grand Jury requests responses as follows:

From the following within 90 days:

- Napa City Council (F1-F4 and R1-R4)

INVITED RESPONSES

Pursuant to Penal Code sections 933 and 933.05, the 2018-2019 Napa County Grand Jury invites responses as follows:

From the following within 60 days:

- City of Napa DPW Supervising Engineer (F3 and R2-R3)
- City of Napa Director of the Department of Public Works (F1-F4 and R1-R4)

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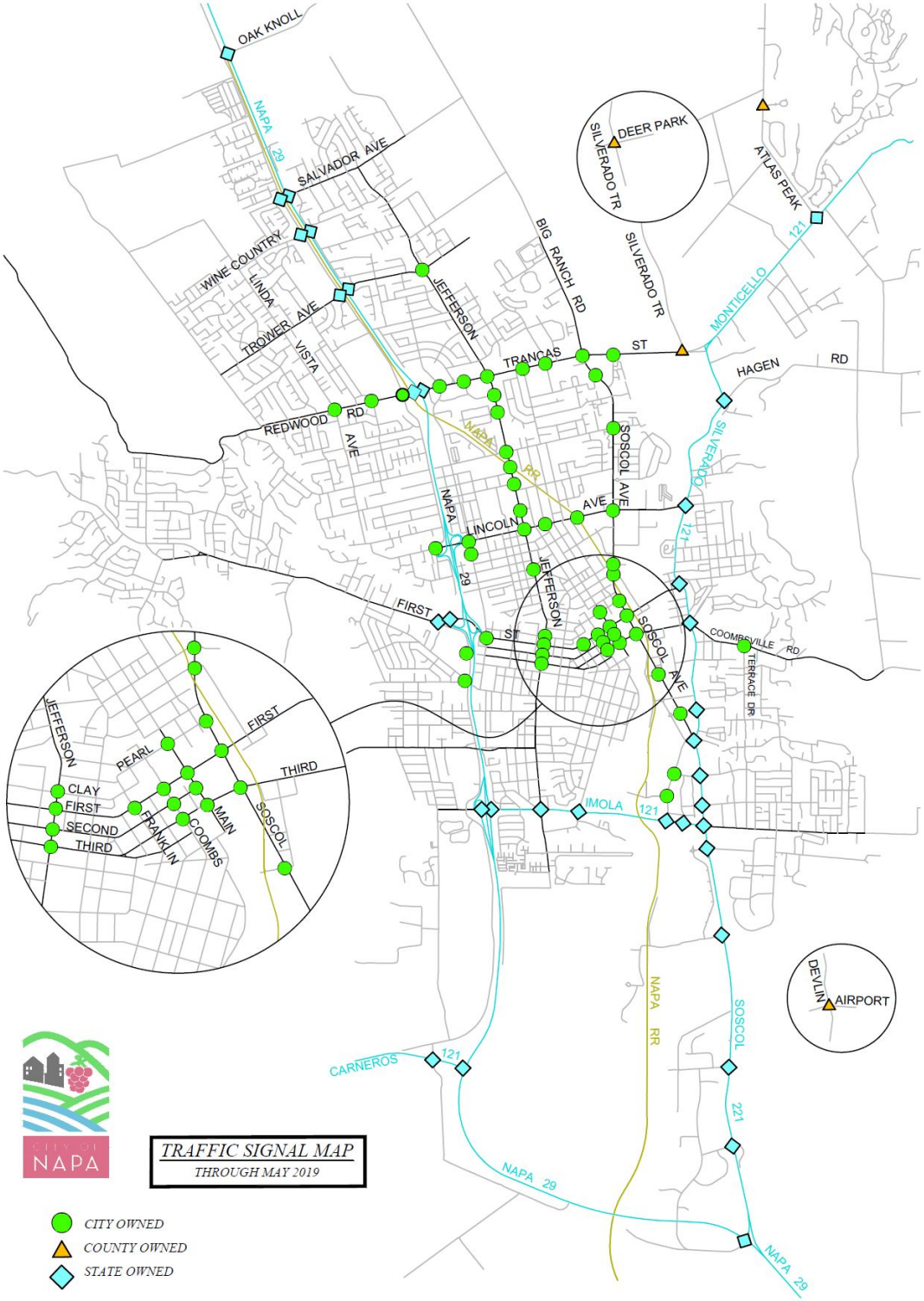
9. Lovett, Ian: To Fight Gridlock, Los Angeles Synchronizes Every Red Light, The New York Times, April 1, 2013.

APPENDICES

APPENDIX #1:

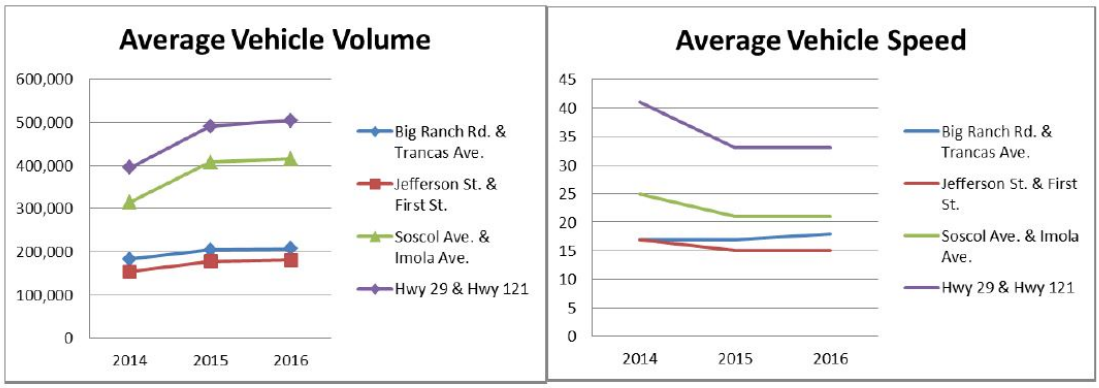
- Traffic Signal Map



APPENDIX #2:

- Redflex Traffic Systems chart showing average monthly traffic volume at selected intersections in the City limits from 2014 to 2016

Average Monthly Traffic Volume vs. Average Vehicle Speed						
	2014		2015		2016	
	Avg. Traffic Volume	Avg. Speed	Avg. Traffic Volume	Avg. Speed	Avg. Traffic Volume	Avg. Speed
Big Ranch Rd. & Trancas Ave.	183,111	17	204,451	17	207,039	18
Jefferson St. & First St.	153,964	17	177,720	15	181,194	15
Soscol Ave. & Imola Ave.	314,795	25	407,301	21	414,963	21
Hwy 29 & Hwy 121	394,896	41	490,106	33	503,873	33



Source: Redflex Traffic Systems, Photo Enforcement Data Repository

APPENDIX #3:

- PASS Grant 2014 Traffic Signal Synchronization Survey

Table 21: Measures of Effectiveness and Benefit/Cost Analysis

Costs	
Consultant Costs (Basic Services/Plans)	$70,600
Consultant Costs (Additional Plans, TSP, IM Flush Plans, etc.)	$0
Other Project Costs (GPS Clocks, Communications equipment, etc.)	$2,500
Agency Staff Costs (Local agency, MTC, Caltrans, etc.)[8]	$17,650
Total Costs	**$90,750**

Benefits				
Measures	***First Year***		***Lifetime (Five Years)[7]***	
	Savings	*Monetized Savings*	*Savings*	*Monetized Savings*
Travel Time Savings (hrs)	107,519	$2,229,022	288,425	$5,979,477
Fuel Consumption Savings (gal)	449,517	$1,382,639	1,205,854	$3,709,007
ROG Emissions Reduction (tons)	1.55	$2,032	4.16	$5,452
NOx Emissions Reduction (tons)	1.09	$20,339	2.91	$54,560
PM2.5x Emissions Reduction (tons)	0.06	$18,042	0.15	$48,399
CO Emissions Reduction (tons)	13.12	$1,065	35.21	$2,858
			Total Lifetime Benefits	**$9,799,753**

Overall Project Benefits	***Auto***
Average Decrease in Travel Time	42%
Average Speed Increase	87%
Average Fuel Savings	33%
Average Reduction in Auto Signal Delay	75%
Average Reduction in Number of Stops	67%
Benefit/Cost Ratio	**108:1**

Notes:

1. General methodology, fuel consumption factors, and health costs of motor vehicle emissions based on California Department of Transportation, Office of Transportation Economics. California Life-Cycle Benefit/Cost Analysis Model and Technical Supplement to the User's Guide, 2009.
2. Benefits claimed include travel time savings, fuel consumption savings, and health cost savings associated with emissions reductions for the coordinated peak periods indicated above. Yearly savings calculated based on 250 days of workdays in a year.
3. Value of time assumed to be 50 percent of the wage rate for off-the-clock travel or $20.09 in 2014 constant dollars. Bay Area average wage rate is $20.82 per hour in 1990 constant dollars, based on Travel Demand Models for the San Francisco Bay Area [BAYCAST-90] Technical Summary, Table 4, page 28, June 1997. Adjusted for inflation using Consumer Price Index (CPI), from US Dept of Labor, Bureau of Labor Statistics, CPI - All Urban Consumers, San Francisco-Oakland-San Jose, CA area, All Items, Not Seasonally Adjusted (Series Id:CUURA422SA0). Vehicle fleet assumed to be 100 percent automobiles.
4. Average vehicle occupancy assumed to be 1.118 persons per vehicle and is used in calculating travel-time savings in autos only. This is based on the San Francisco Bay Area Baycast Travel Model run for the RTP 2009 (using the 2010 network) developed by the MTC.
5. Average fuel cost is from US Department of Labor Bureau of Labor Statistics, CPI - Average Price Data, San Francisco-Oakland-San Jose, CA area, Gasoline unleaded regular per gallon. Average of monthly prices in the Bay Area from January 2014 – December 2014 is $3.73
6. Health cost of ROG Emissions ($1,284 per ton), NOx Emissions ($18,359 per ton), and CO Emissions ($80 per ton) are based on the California Department of Transportation, Office of Transportation Economics from Exhibit III-43, p. III-69 of the California Life-Cycle Benefit/Cost Analysis Model Volume 3 Technical Supplement to User's Guide, Revision 2 (February 2012). The 2014 costs are calculated with a standard assumption of 2% increase per year from the 2011

costs. PM2.5x Emissions ($318,598 per ton) costs, are based on Victoria Transport Policy Institute's Air Pollution Costs, Table 5.10.4-1, page 5.10-10, with 2014 costs calculated with a standard assumption of 2% increase per year from 2007 costs.

7. Project life assumed to be five years. Benefits assumed to be 100 percent on first day after implementation, declining steadily to zero by end of the fourth year. Benefits equivalent to sum of discounted average annual benefits, where averages are 90% of First Year for year 0, 70% for year 1, 50% for year 2, 30% for year 3, and 10% for year four.
8. All public agencies involved staff costs assumed to be 25% of the project consultant costs.

Benefits to Other Modes

Additionally, the PASS project provided an opportunity to update traffic signal timing parameters for consistency with established guidelines as follows:

Traffic Safety Benefit

To enhance traffic safety, the yellow clearance timing parameters were updated based on 2014 California MUTCD standards and the City's recommendations along the study corridor.

Benefits to Pedestrians

The "Walk" timing and "Flash Don't Walk" clearance timing parameters were also updated to provide adequate time for pedestrians to safely cross the intersections, based on the new walking speed of 3.5 feet/second, as specified in 2014 California MUTCD standards.

Benefits to Bicyclists

For improved bike safety, the minimum green intervals were updated to ensure that bicyclists can clear the intersections along Redwood Road/Trancas Street.

Conclusion

The traffic signal coordination plans are expected to promote uniform travel speeds along the study corridor thereby reducing rear-end collisions. Implementation of the timing plans has resulted in reduction in traffic congestion and automobile travel time, allowing reduction in harmful greenhouse gas emissions to be expected. Other intrinsic benefits that were derived from investing in the signal-timing project include minimizing motorists' frustration by reducing traffic congestion and delay and pedestrian mobility in terms of updated signal timing accommodation consistent with current standards and guidelines.