CUYAMACA STREET TROLLEY SIGNAL UPGRADE

WITH TROLLEY PRIORITY

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Introduction

Cuyamaca Street is a major arterial in the City of Santee providing north-south access to the City and carries San Diego Metropolitan Transit System's (MTS) trolley service in the center of the street. San Diego trolley green line enters the City at the southerly border with El Cajon on a single track and ends at the Santee Trolley Square which is the largest shopping center in the area. The Trolley Square Station, located at the northeast corner of Mission Gorge Road and Cuyamaca Street, is the starting point for the Green Line trolley which provides service from east San Diego County to downtown San Diego.

As shown on the map below, there are a total of five city-owned traffic signals and two Caltrans ramps signals along the Cuyamaca Street corridor. Two of them are located in Trolley Square to provide internal crossings in the shopping center. The other five are located on Cuyamaca Street at their intersections with the following streets from north to south:

Mission Gorge Road

Buena Vista Avenue

State Route 52 westbound off-ramp

State Route 52 eastbound off-ramp

Prospect Avenue

As the outbound trolley leaves the Trolley Square station, it travels at a southwesterly direction and preempts the two crossing signals inside Trolley Square. However at the five intersections along Cuyamaca Street no trolley preemption is allowed by City Council, instead the trolley follows the traffic signals at these locations. As the trolley approaches the intersection of Cuyamaca Street and Mission Gorge Road it will have to wait for its turn before crossing the intersection diagonally and continuing south along the center of Cuyamaca Street. The inbound trolley travels on the same track in the reverse direction. Only one trolley is at the station at any given time.

Issue #1 - Signal timing

For years several issues plagued trolley operations, of which the most significant was signal timing. Since Santee Trolley Square is the starting point for the green line trolley traveling toward downtown San Diego, it is critical for trolleys leaving Santee to be on time since any

delays encountered here affect all downstream stations. Since outbound trolleys arrive randomly at the intersection of Mission Gorge Road and Cuyamaca Street the wait could be as long as the cycle length which is 140 seconds long. For years San Diego MTS had wished that trolley delays

in Santee could be minimized in order to improve trolley service, however due to technological constraints the City was unable to do so with its existing system.

Issue #2 – Trolley indications

The old trolley signal used a single "T" indication that comes up to indicate trolley "GO" and turns blank to indicate trolley "STOP". The problem was that the "T" terminates without warning causing trolleys to run the light frequently. This creates a dangerous situation particularly due to trolley's length and weight that requires a significant distance for it to stop.

Solutions

Count-down Timer

Issue #1 was resolved by installing a countdown timer at the trolley station along with signal timing changes. The countdown timer prompts outbound trolleys to leave at the right moment that allows the trolley to proceed through all seven signals in Santee without stopping. Since the key intersection that causes delay to trolleys is the intersection of Cuyamaca Street and Mission Gorge Road, the count-down timer was connected to the controller at this intersection which is 1,500 feet away from the trolley station. Through internal logic programmed the controller resets the count-down timer to count from 30 to 0 at one second interval once every cycle. The timing for the system is programed in such a fashion that as long as the trolley leaves the station at the zero point it will be able to go through all signals in the system without stopping.

Preemption of trolley crossings

The preemption input for the two trolley crossing signals is also generated by the controller at the intersection of Cuyamaca Street and Mission Gorge Road. The signal is interconnected to the two crossing signals and also to a transponder at the trolley station. There is no existing direct interconnect between the transponder and the two crossing signals. The existing interconnect was utilized without installing new interconnect to avoid trenching in trolley right of way.

For an outbound trolley, the trolley operator pushes a button at the zero point of the count-down timer to send a signal through the transponder to the controller at Cuyamaca Street and Mission

Gorge Road which then sends a signal to the two trolley crossing signals to preempt them. For an inbound trolley the controller will send a preemption signal to the two trolley crossings when it detects an inbound trolley and the trolley indication is a "GO".

Internal logics at each of the two trolley crossing signals are programmed with respective delay times based on direction of travel so that they display the trolley "GO" indication at the right moment when the trolley arrives. For example, for an outbound trolley, crossing #1 is preempted at one second after the trolley operator pushes the button, and crossing #2 is preempted at 21 seconds after based on trolley travel speed and signal spacing. Existing on-track detection loops were retained as a fail-safe feature in case communication is disrupted. Detection loops are also used to end the preemption after trolley passes.

Trolley Operation Upgrade

1 - Installing new trolley signal heads

New trolley signal heads with two indications as specified in the latest MUTCD were installed: a vertical indication for trolley "GO" and a horizontal indication for trolley "STOP". By using special timing logics, a flashing interval was displayed at the end of the trolley "GO" indication to warn the trolley the termination of the trolley phase. This provides six seconds of flashing using the yellow phase timing. The deceleration rate for trolleys is lower than a passenger vehicle at 4.4 ft/sec^2. However the travel speed is also low for trolleys at 25 miles per hour. The six second flashing provides adequate warning time for trolleys to stop or proceed through the intersection.

2 – Trolley Priority Timing:

Priority timing was considered for northbound trolleys as part of the overall scheme to improve trolley operations by providing an additional amount of time to the trolley phase. As mentioned previously other treatments implemented have made it unnecessary for outbound (southbound) trolleys. Priority timing can be implemented by either extending the trolley phase or providing an early trolley phase. Only phase extension was used because the northbound progression was such that an early trolley phase will provide little improvement for trolley schedule adherence.

For northbound trolleys the key intersection is the first intersection of the system - Cuyamaca Street at Prospect Avenue. When a northbound trolley approaches the intersection, it may or may not get a trolley indication since its arrival is random. In order to increase the chance of northbound trolley getting through the intersection trolley priority timing was implemented at this location by extending the trolley phase. Trolley phase extension was not implemented at other intersections since it provides little benefit for northbound progression.

The cycle length at the intersection of Cuyamca Street and Prospect Avenue is 70 seconds which is half of the system cycle of 140 seconds in order to improve efficiency at this location. In order

to minimize impact to side streets the rule of thumb for priority timing is that the amount of additional time should be no more than 10% of the cycle, namely 7 seconds in this case.

Since trolley progression was provided by signal timing, the primary reason for using trolley priority was to help the trolley clear the intersection. Due to the length of the trolley it takes a long time to clear an intersection, particularly after MTS added an additional car to the existing two car trolley as a result of ridership increase. The City received numerous complaints on trolley running red light after the three car trolley was put in service. In reality the trolley rarely runs the light by entering the intersection on red as proved by the trolley's dashboard mounted cameras. The three car trolley is 240 feet long and travels at a speed of 25 mph. The width of the intersection is 100 feet. If a trolley enters the intersection at the last moment of the flashing interval it takes 9.3 seconds for the end of the trolley to traverse the 340 (100+240) feet and clear the intersection completely. This means the trolley could still be in the intersection 9 seconds after the trolley phase terminates. As a result drivers on the side street often get the perception that trolley runs red light.

The priority timing for a trolley to clear the intersection was calculated as follows:

Total distance to clear the intersection: 100 + 240 = 340 feet

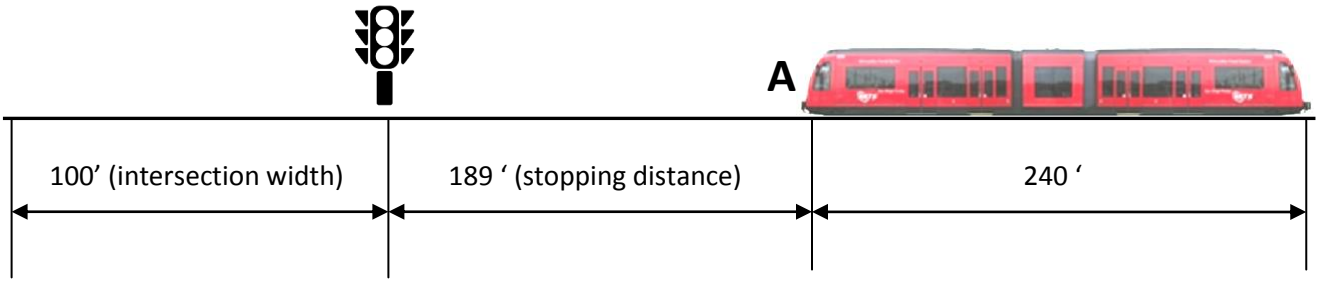
To clear the intersection halfway: 340 – 50 = 290 feet

Trolley speed: 25 mph = 36.7 feet/sec

Time it takes to clear intersection halfway: 290/36.7 = 7.9 second

From the above analysis, a maximum of 8 seconds was selected for the amount of trolley phase extension which allows the trolley to clear the intersection halfway and it is also close to 10% of the cycle length.

The stopping distance for a trolley is calculated at 189 feet using a deceleration rate of 4.4 ft/sec^2. The trolley priority input is provided by a trolley controller box at a trolley gate located 500 feet from the intersection and is triggered by a northbound trolley. When the traffic signal receives the input a delay of 8.5 seconds is applied to allow the trolley to travel the distance (500 – 189 = 311 feet) to point A before trolley priority timing is activated. When an inbound trolley arrives at point A, priority timing works as follows:



1. When there are more than 8 seconds left in the trolley phase - trolley priority will not be activated.
2. When there are less than 8 seconds left in the trolley phase - trolley priority will be activated to extend the trolley phase to terminate up to 8 seconds from this point. For example: if there are 5 seconds left in the trolley phase, 3 seconds will be added.
3. When the trolley phase is showing trolley "STOP" - trolley will stop and wait for its turn.
4. The time for trolley to travel the 189 feet from point A to the intersection is covered by the flashing interval of the trolley phase.

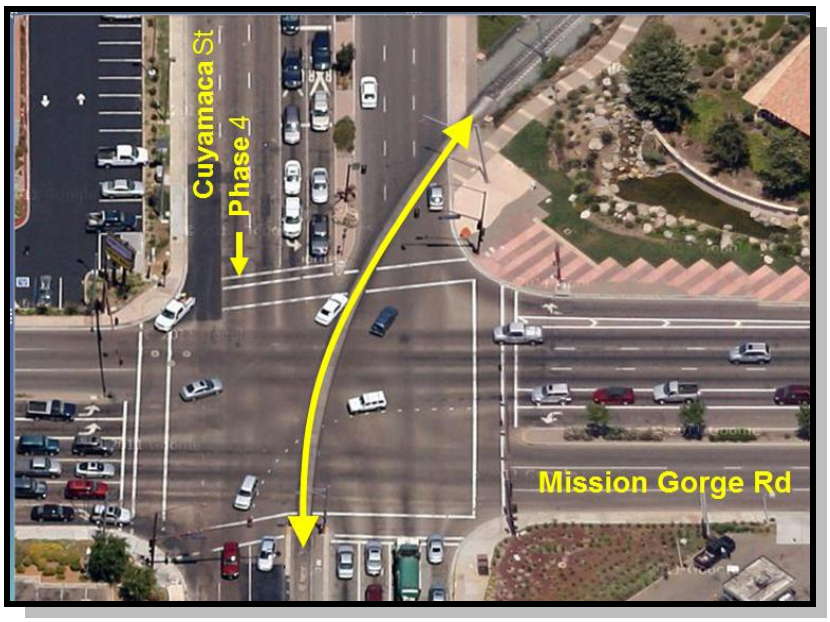
The City uses 170 controllers and McCain 233 program with transit priority feature.

Other Special Timing

In order to achieve all the special functionalities that are not available in the basic timing parameters special timing logics are required at all five project city owned intersections to provide the desired functionalities:

1. **The 9th phase at the intersection of Cuyamaca Street and Mission Gorge Road where trolleys cross diagonally.**

   As shown below trolley crosses this intersection diagonally. The only non-conflicting phase is phase 4 southbound through movement. In order to accommodate the trolley phase a ninth phase is needed. However the standard 233 program for 170 controllers (at the time of the project) can only handle eight phases. Working with the manufacturer of the firmware, McCain Inc., a special 233 chip was developed to accommodate the ninth phase which runs as an overlap with phase 4.



2. **The trolley phase at other locations**

   Special logics were programmed at the intersections of Buena Vista Avenue and Prospect Avenue to run the trolley phase as an overlap with the north and south bound through phases when both phases are green simultaneously. They come up every cycle so no trolley detection is needed at the two intersections.

3. **"NO RIGHT TURN" sign**

   Special logics were programmed for the controller at the intersection of Cuyamaca Street and Mission Gorge Road to bring up a "No RIGHT TURN" LED sign for westbound traffic. The sign is displayed only when trolley is detected in the system and the westbound through movement has the red to prevent conflict between the trolley and the westbound right turn movement. The sign is blank in the absence of trolleys so westbound movement can make right turns on red.

Travel Time Studies

Based on travel studies conducted before and after the project, travel time for trolleys was improved as shown in the table below:

		BEFORE	AFTER	Δ IN TRAVEL TIME	% CHANGE
MORNING	SB	0:03:28	0:02:16	- 01:12.0	-35%
	NB	0:03:00	0:02:57	- 00:03.5	-2%
NOON	SB	0:03:57	0:02:24	- 01:32.7	-39%
	NB	0:03:28	0:02:56	- 00:31.5	-15%
EVENING	SB	0:03:08	0:02:10	- 00:58.2	-31%
	NB	0:04:24	0:03:02	- 01:21.1	-31%

Travel time improvement for vehicles is shown as follows:

		BEFORE	AFTER	Δ IN TRAVEL TIME	% CHANGE
MORNING	SB	0:00:51	0:00:48	- 00:03.8	-7%
	NB	0:01:40	0:01:32	- 00:07.3	-7%
NOON	SB	0:01:15	0:01:10	- 00:05.6	-7%
	NB	0:01:54	0:01:47	- 00:07.5	-7%
EVENING	SB	0:01:00	0:01:00	00:00.6	1%
	NB	0:02:04	0:01:27	- 00:36.7	-30%

Conclusions

Transit priority timing can be useful to improve transit operations. However using it alone will only have limited benefit in the absence of other software and hardware solutions. There are lots of controller firmware functionalities that are usually not used by most practitioners. Using the full extent of the capabilities in controller firmware along with necessary hardware can provide the desired functionalities that are unique, versatile, and reliable. The result is improved efficiency and safety for both transit operations and vehicles.

The project was designed by Kimley-Horn and Associates, Inc. with assistance from McCain Inc. City staff Jeff Morgan also played a key role by developing much of the special timing logics. My sincere gratitude goes to them for their hard work and effort in the success of the project.