Trolley Priority on Signalized Arterials in Downtown San Diego

STEPHEN CELNIKER AND E. WAYNE TERRY

The San Diego trolley, an electrified light rail transit system, has changed its method of controlling trolley movement at signalized intersections on arterials in downtown San Diego. The previous method required a trolley to preempt, or alter, the normal operation of the traffic signals for the trolley to have uninterrupted movement at traffic signals as it traveled between stations. The new method, dubbed the trolley priority system, instead provides favorable timing to the trolley as a part of the normal operation of the traffic signals. The trolley priority system has proven to be more reliable than the preemption system and requires less maintenance. One notable drawback is that the new system sometimes requires the trolley to wait longer in the station before departing than did the previous system. However, since implementation of the trolley priority system, studies have shown that overall trip time has improved in the downtown area. Although at times a train may encounter delay beyond the normal station dwell time, by awaiting the appropriate entrance window on the next traffic signal cycle, the actual operating time between stations is enhanced.

San Diego Trolley, Inc., is a light rail transit (LRT) system serving the greater San Diego area. The system operates mostly within a railroad right-of-way serving communities on the East Urban Line between the cities of San Diego and El Cajon, 18 mi to the east, and on the South Urban Line serving communities between the city of San Diego and the United States/Mexico border, 16 mi to the south of downtown. The LRT system is controlled by an automatic block system (ABS) on the semiexclusive at-grade portions of the right-of-way.

Currently the system operates 337 daily train trips, using a fleet of 71 light rail vehicles (LRVs) to accommodate nearly 60,000 daily users of the system. Service is operated on a 15-min headway during most of the day with 7.5-min service being offered through both morning and evening peak periods.

The importance of a priority in traffic signaling for LRV operations in a mixed traffic environment is paramount in relationship to the safety and efficiency of an operating system in this medium. The mixed traffic street portion of the trolley operation encompasses 3 mi, of which 1.2 mi spans Commercial Street and 1.8 mi is combined between 12th Street and C Street in the center city.

The main concern about operations downtown is the ability of the trolley to travel between stations without having to stop at traffic signals at the intervening intersections (see Figure 1). When the trolley began operation in 1981, a method of signal preemption was established that was intended to provide the trolley with uninterrupted movement through the signalized intersections. As the trolley system expanded and the service frequency increased, it became increasing difficult to maintain adequate signaling windows at intersections shared by vehicular, pedestrian, and LRV traffic.

PREEMPTION

The original method of serving the trolley on signalized arterials downtown was a preemption system. Traffic signals were preempted when the pantograph of the LRV initiated a preemption pulse by striking a contactor on the overhead catenary system in advance of the traffic signals to be preempted. The preemption pulses would temporarily alter the normal operation of the traffic signals and provide for one-way progressive movement for the trolley. The signals would return to normal operation after the trolley had passed. The normal operation of the signals was to favor the vehicular and pedestrian traffic crossing the track on C Street and on 12th Avenue.

Initially the trolley was a rare enough event that the traffic signals served the preemptions and returned to normal operation without causing excessive delays to the cross traffic.

As the trolley system expanded and service became more frequent, so did the frequency of the preemption pulses to the traffic signals. As an example, in 1981 using the previous preemption method, a maximum of eight trains per hour occupied signaled intersections in the downtown area. In 1992 a maximum of 27 trains per hour occupied the same intersections. This represents an increase of 238 percent in train traffic per hour in the center city zone at any given point. These numbers are exclusive of East Urban Line four-car trains that are split into two doubles for inbound peak period trips into the center city. Four-car trains are split as described because city blocks cannot accommodate the train length.

The previous preemption system was unable to accommodate the increased amount of preemption pulses initiated by trains traveling in opposite directions simultaneously. Because the preemption timing could serve trolley movement in one direction only, the trolley traveling in the opposite direction would be stopped by red lights at nearly every signal. Sometimes several trolley preemptions would be entered in rapid succession, creating significant delays for cross traffic and pedestrians as the signals departed from normal operation for several minutes at a time. In a few cases the signals received so many preemption pulses that the equipment malfunctioned, locking up with red lights in all directions, serving

S. Celniker, City of San Diego Engineering and Development Department, 1222 First Avenue, M.S. 503, San Diego, Calif. 92101. E. W. Terry, San Diego Trolley, Inc., 1255 Imperial Avenue, Suite 900, San Diego, Calif. 92101.

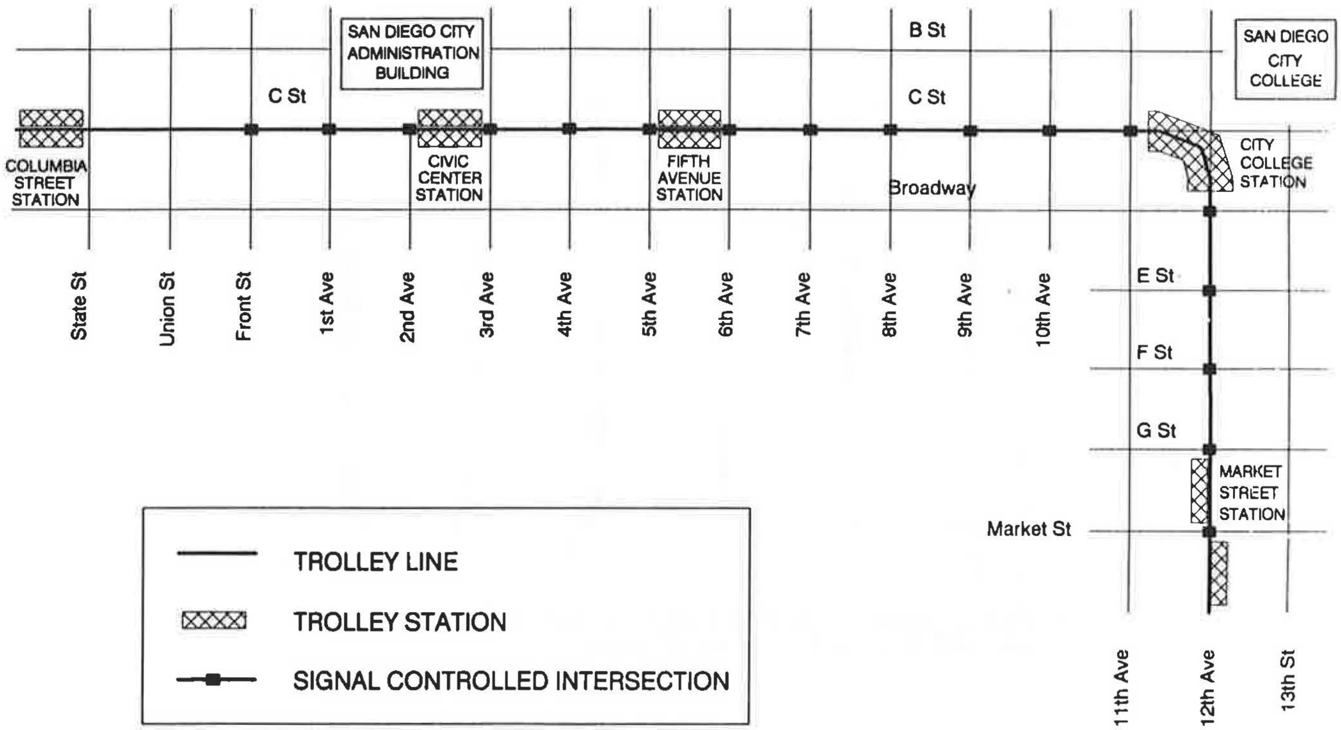

FIGURE 1 Trolley operation on signalized arterials in downtown San Diego.

neither motorists nor pedestrians nor trolleys. The success of the trolley had overwhelmed the preemption system that had been designed to serve it.

TROLLEY PRIORITY SYSTEM

The solution to the preemption problem was technically quite simple. Rather than requiring the trolley to alter the normal operation of the traffic signals to receive favorable timing, instead have the normal operation itself favor the trolley. By favoring the trolley, the system proved more effective for all users because it was time-fixed and more reliable. This concept became the basis of the trolley priority system, which was implemented in 1990 in a cooperative effort between the city of San Diego and San Diego Trolley, Inc. The system works as follows:

- The trolley dwells in the trolley station until the beginning of the next green light at the first downstream signal.
- The trolley departs within 5 sec of the beginning of the green light.
- If the departure window is missed, the trolley must wait until the beginning of the next green light.
- As long as the trolley leaves the station during the departure window, the trolley will receive green lights at all of the signals until it reaches the next station.
- The two-phase, fixed-time signal timing favorable to the trolley is always in place and is fitted into the larger network of signals.

For a time-space diagram illustrating an example of progressive timing for the trolley, see Figure 2.

With some in-the-field fine-tuning of the signal timing, the trolley priority system has proven largely successful. The major beneficiaries have been pedestrians crossing C Street and 12th Avenue. Under the preemption system, pedestrians would frequently be faced with lengthy Don't Walk lights as the signals were serving several preemption pulses in a row, overriding several normal signal cycles. With the priority system, the signal cycles are fixed and the Don't Walk lights stay within the normal range.

Two areas of concern about the trolley priority system remain. First, the waiting period for the next green light sometimes exceeds the time required to unload and load passengers at the station. Train delay is experienced if the train operator is not ready to depart the station in the initial green traffic signal cycle. Second, the departure window is not designated by any special indication, requiring the operators to guess in borderline situations, sometimes missing the window and hitting a red light before reaching the next station. The entrance window is fixed at 5 sec, which if entered properly the train will be allowed to move unimpeded through all intersections located within that particular control zone. The installation of an indicator at control zone entrances, which would signal the entrance threshold to the train operator, is being explored.

TRANSIT OPERATOR'S PERSPECTIVE

The priority system was designed and implemented on a test basis by the city traffic engineers on 12th Avenue several months prior to the system actually being adopted. Testing procedures were prepared and a test zone of five traffic signals

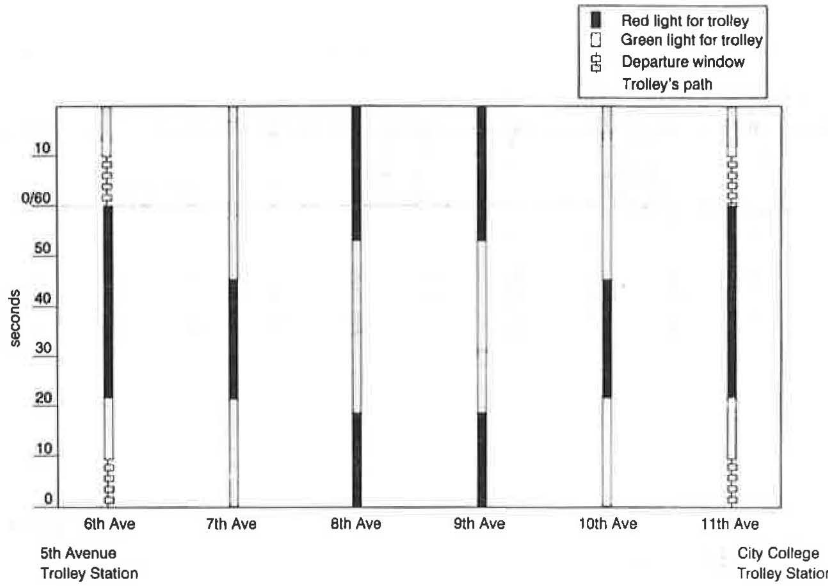

FIGURE 2 Trolley priority system (progressive movement for trolley on C Street between Fifth Avenue and City College Stations).

was established on 12th Avenue between the Market Street Station and the City College Station.

The testing plase proved to be a valuable experience in terms of using the system and monitoring the reliability of its operation. Adjustments were required as attempts were made to perfect the system during the testing phase. Trolley operating staff worked closely with city staff to effect timing changes at various intersections within the testing zone to provide for a smooth flow for trolley traffic in both directions.

During the testing phase, the following two areas of concern were under constant review:

1. The departure window the trolley operator had to enter the test zone, and
2. The length of time each signalized block in the control zone would hold favorable for trolley priority.

During the course of the testing period, the signal sequencing program was continually modified to provide the best possible operating environment for LRV, vehicular traffic, and pedestrians in shared arterials.

OPERATION

It was established that trains must enter the control zone within 5 sec from the time the green aspect illuminates on the traffic signal standard. From that point all signalized intersections in the control zone would change in succession favoring the trolley. Timing was based on an average predetermined train speed. If the control zone could not be entered within the allotted time, the operator is required to wait an entire cycle for the next green traffic signal to be displayed. If the operator disregards the departure window and enters the control zone on a stale green signal (beyond the initial 5 sec), a red traffic signal would normally be experienced at the next intersection.

Initially the traffic signal sequence timing was programmed for what was determined to be the average train speed in the downtown area. The average speed encompasses all factors associated with mixed street operation including station stops, dwell time, delay for train meets, traffic signals, and so forth. Using the time derived from these criteria, an inflated time between stations was used to calculate average train speed.

As a result, the speed used to gauge the signal sequencing proved too slow for trains to sustain the maximum 25 mph between stations, and trains were delayed unnecessarily at intersections within the control zone limits.

Control zones encompass the intersections between stations; typically, three to five intersections are located within the limits of a control zone. In most cases trains enter a control zone when leaving a station platform at the first intersection bordered by that station. If the operator is unable to accept the first green traffic signal, the train will remain berthed on the platform available for boarding until such time as the next favorable signal cycle is displayed.

FINE-TUNING

Based on the initial observations of the traffic signal sequencing plan, it was determined that additional time would be provided for trains to enter control zones. In addition to the entrance window being extended, the timing sequence for the succession of intersections within the control zones was modified to sustain an uninterrupted operation of 25 mph.

The timing sequence of priority signaling is programmed to change during the day to provide for different traffic pat-

Effective Friday, December 21, 1990, the Traffic Engineering Department, for the City of San Diego, will activate the "Center City Traffic Signal Sequencing Plan." The plan will bring all signalled intersections on-line for operation in the downtown area, between Market and Front Streets.

In recent months a test zone has been in operation between Market Street Station and City College Station, on twelfth Avenue. During this period, test results were reviewed and modifications to the system were made to enhance train operations through the zone.

The following will identify the entrance to each control zone location, and establish the procedure by which traffic signal control zones are entered and operated through:

TRAFFIC SIGNAL CONTROL ZONE LOCATIONS:

NOTE: All control zone entrances begin at intersections boardered by a station, except eastbound at Front Street.

Westbound,

1. Market Street zone includes intersections to City College Station.
2. 11th Avenue zone includes intersections to 5th Avenue Station.
3. 5th Avenue zone includes intersections to Civic Center Station.
4. 2nd Avenue zone includes intersections through Front Street.

Eastbound,

1. Front Street zone includes intersections to Civic Center Station. NOTE: Front Street traffic signals will not preempt in advance of train.
2. 3rd Avenue zone includes intersections to 5th Avenue Station.
3. 6th Avenue zone includes intersections to City College Station.
5. Broadway zone includes intersections to Market Street Station.

TRAIN OPERATION WITHIN CONTROL ZONE LIMITS:

1. Trains must enter the intersection of a control zone on a "fresh green signal." A fresh green signal is defined as within five (5) seconds from the time the green aspect appears.
2. If unable to enter the control zone on a fresh green signal, the train must be left available for boarding until the next green signal cycle appears. DO NOT move train over the in-street signal loop in an attempt to recall the signal.
3. If signal sequencing is lost while operating within the limits of a control zone, due to delays, it may be re-established after entering the next intersection on a fresh green traffic signal.

FIGURE 3 Operating procedures.

terns. Traffic signal sequence timing changes are made to accommodate the morning peak, base, afternoon peak, evening, and weekend traffic patterns. Operationally the various signal sequencing patterns work well with some delay being experienced at the transition of each traffic pattern change.

OPERATING HEADWAY

Priority signaling has adequately facilitated train service through control zones in downtown on all headways with one exception. During rush hour, because of short headways it sometimes becomes necessary to allow a train to enter a control zone on a stale green traffic signal to allow the following train to enter the station platform to discharge passengers. This occurs only in the morning peak period when the preferred direction of travel is into downtown.

CONCLUSION

The trolley priority system has proven to be successful at increasing the efficiency of trolley operations through downtown San Diego. The system has been in full service for 1 year and operators have learned to operate their trains in accordance with the standard procedures (see Figure 3). By learning the system and following procedural instructions, operators typically experience a savings in operating time throughout center city by as much as 2 to 3 min per trip.

The trolley priority system is a simple and easily implemented solution to the complex problem of motor vehicles, pedestrians, and trolleys operating together on streets under traffic signal control. Two improvements to the system that are being considered are shortening the traffic signal cycle length to reduce excess dwell time for the trolley and the installation of special T signals that would designate the departure windows to the trolley operators.