1 INTRODUCTION

The Santa Clara Valley Transportation Authority (SCVTA) currently has a number of major programs that are aimed at improving and increasing transit ridership, over the next ten years, in the area of California known as the Silicon Valley.

The SCVTA's Short Range Transit Plan[1] has several foci:

- expand the light rail system to increase transit capacity on major corridors;
- encourage transit-oriented development (TOD) to measure the number of trips able to be accommodated on transit; and
- enhance the efficiency and effectiveness of existing services.

In addressing the third objective, SCVTA has embarked upon a bus rapid transit (BRT) demonstration project on its major bus corridor. DKS Associates is assisting the SCVTA in this first of several elements of a bus rapid transit (BRT) program.

Line 22 is the backbone of the SCVTA bus network[2], providing service along the east-west length of the Santa Clara Valley between the transit center at Eastridge Shopping Center in San Jose and the Caltrain station in Menlo Park. Line 22 is twenty-seven miles long and is illustrated in Figure 1. Buses run every 10 minutes during weekdays, primarily along King Road; Santa Clara Street; The Alameda; and El Camino Real. El Camino Real is a State Highway. Line 22 serves the cities of San Jose, Santa Clara, Sunnyvale, Mountain View, Los Altos, Palo Alto, and Menlo Park. It is SCVTA's most heavily used line, carrying over 23,000 riders daily and representing 16% of SCVTA's total bus ridership. The line operates near capacity with many buses at standing room only.

Line 22 is supplemented by Line 300, a limited stop express service along generally the same corridor. Lines 22/300 connect with regional rail services as well as 55 SCVTA bus lines. A major connection occurs in downtown San Jose, where Line 22 intersects the north-south Guadalupe Light Rail Line. SCVTA's vision for Line 22 is that it operates as a "BRT Corridor." To achieve this vision, SCVTA will implement a variety of improvements over the next four years by providing:

- faster, more reliable service; and
- better passenger and security at stops

A complete package of improvements will be needed to transform Line 22 into a BRT corridor. The design elements will be consistent and integrated to provide the BRT with a distinct identity. This package will include a combination of the following features:

- queue jump lanes at congested locations;
- advanced communication system;
- signal prioritization for buses to reduce delay;
- improved passenger facilities at stops;

[1] Short Range Transit Plan – 2002. S.C.V.T.A. San Jose, 2002
[2] VTA Website (www.vta.org)

- bulb-outs at selected bus stops;
- high capacity, easy-access, and cleaner buses; and
- more frequent and direct service.

This paper provides an overview of the project and describes the traffic engineering elements. The initial signal priority demonstration will include 27 signals over a distance of six miles, grouped into three subsystems.

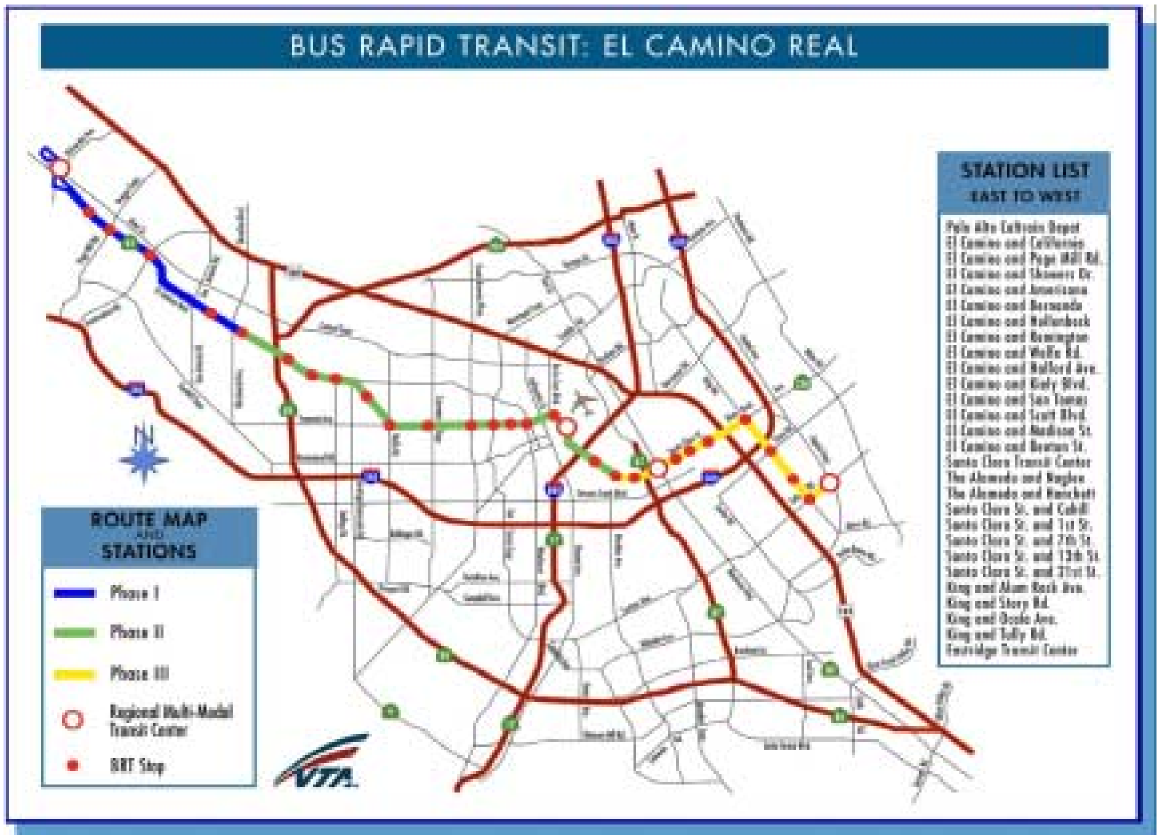

Figure 1 Line 22 location map

2 DEVELOPMENT OF PROJECT ELEMENTS

2.1 New Buses

To address the capacity of the buses, SCVTA is purchasing new articulated buses with a higher passenger capacity than the existing buses. This will allow higher productivity in terms of passengers per trip. The new buses are also expected to have shorter dwell times at stops, because they will provide easier access. To reduce travel times and increase reliability, and therefore make the trip by bus more attractive, various bus priority measures are being introduced; most notably queue jumping facilities and traffic signal priority.

To improve passenger comfort and safety while waiting for buses, new shelters and real-time information signs are proposed.

The arrival of the new buses will permit shorter headways, which will further increase route capacity and also reduce waiting time, again having the effect of making the service more attractive.

A relatively controversial element is the use of bulb-outs at bus stops. This provides a larger area for passengers to wait for buses and also reduces the delay for buses re-entering the traffic stream. There is a range of opinions about the desirability and effectiveness of bulb-outs, and while some local agencies support them, others oppose their use.

2.2 Signal Priority Elements

Much of the demonstration route follows El Camino Real, which is a State highway under Caltrans jurisdiction. All the signals on El Camino Real within the demonstration area have Model 170 controllers operating Caltrans' CTNET coordinated signal system. There are three on-street masters that are interconnected with the intersection controllers to control the coordinated operation, and they have telephone line communication with the central management computers at the District 4 office in Oakland.

The detectors are typically located at the stop line for turning movements. Through movements typically have advance loops and some through movements also have stop line loops.

After some negotiation, it was agreed that traffic signal priority could be provided for the buses, provided the signal operators had the freedom to limit its impact on traffic. This will be accomplished by incorporating a number of user-definable parameters in the software, providing the ability to limit the frequency with which the signals will respond to priority calls, and control the response to priority calls. A major selling point with the signal operators was the ability to integrate the priority calls with the bus schedule, so that the signals need only respond when a bus is behind schedule.

As far as the authors are aware, this is the first time Caltrans District 4 has agreed to provide bus priority at intersections under their control. They agreed to write additional software so that the existing Model 170 controllers could provide the priority.

2.3 Bus Stop Location

The bus stops along El Camino Real are in a variety of locations, but mostly on the departure side of intersections. As a general rule, other stops will be relocated to the departure side of intersections unless there is a strong pedestrian linkage that renders this undesirable.

For departure-side stops, bulb-outs will be used to give a large area for waiting passengers. This can be readily achieved in sections where there is parking, simply by using the curbside lane that is currently accommodating the stopped buses. In sections where there is no parking, there is often a right turn acceleration lane at intersections. By removing the triangular island and incorporating the right turn movement into the signals, the acceleration lane can be used for the bulb-out. This generally has little or no impact on intersection capacity. It is expected to have a minor impact on right turn delay, but may improve safety in locations where the bus stop is actually in the acceleration lane.

2.4 Why Bulb-Outs?

As traffic engineers, we generally aim to smooth traffic flow and minimize the disruptions to flow between signalized intersections. During the 70’s and 80’s it was common in street improvement projects to provide bays at bus stops so that buses could pull out of the traffic stream to stop. The idea was that this:

- Minimized the delay to other traffic when the bus stopped; and
- Reduced the risk of rear-end accidents involving the bus or accidents when following vehicles attempted to change lanes.

There are many examples where these have worked effectively, when vehicle speeds are relatively high, provided the volume in the lane adjacent to the bus stop is not too great. However, in practice there is one serious shortcoming. When volumes increase, the bus driver finds it difficult to merge back into the traffic stream. This has two effects:

- The bus suffers additional delay and
- If the driver forces his/her way back into the traffic stream the risk of accidents increases.

The practical response of bus drivers the world over is to not use the bus bay, but stop (at least partly) in the adjacent traffic lane. (See for example, Fitzpatrick, *et.al.*, 2002) This removes the bus delay and the risk of accident when re-entering the traffic stream. So, on heavily trafficked roads with reasonable speed limit and signal distance, it is overall better to have the bus stop in the traffic lane and accept the lower utilization of that lane and/or the delay to following vehicles.

To minimize these collateral impacts, other measures to minimize the stopped time at bus stops become important.

2.5 Queue Jump Lanes

Several intersections provided the opportunity to construct queue-jump lanes with no right of way take and modest cost. At intersections with a separate free right turn lane on El Camino Real, this lane can be sign posted for use by buses also, allowing them to bypass a queue stopped on red (see Figure 2). Typically there is a triangular island at the end of the right turn lane. It is necessary to reduce the size of the island and move the signal pole(s) to permit the buses to pass straight through the intersection.

Figure 2 Bus queue jump using right turn lane

Although it is not proposed on this route yet, this arrangement is often used elsewhere in conjunction with a bus only signal. This gives the bus a head start and the opportunity to merge into the through lane on the departure side of the intersection, at the head of the departing platoon. An example of such a signal in Monaco is illustrated in Figure 3.

Figure 3 Bus signal and queue jump lane in Monaco

3 PROPOSED SIGNAL OPERATIONS

3.1 Signal Timing

The proposed signal priority is fairly traditional, employing window stretching in response to a priority call. A call during red will reduce the time allocated to other movements and return to through green earlier than normal. This is achieved by advancing the force-off points of other phases, by user specified amounts. A call during green will allow the through phase to be extended by a user-specified amount, if necessary to serve the bus. This is illustrated conceptually in Figure 4.

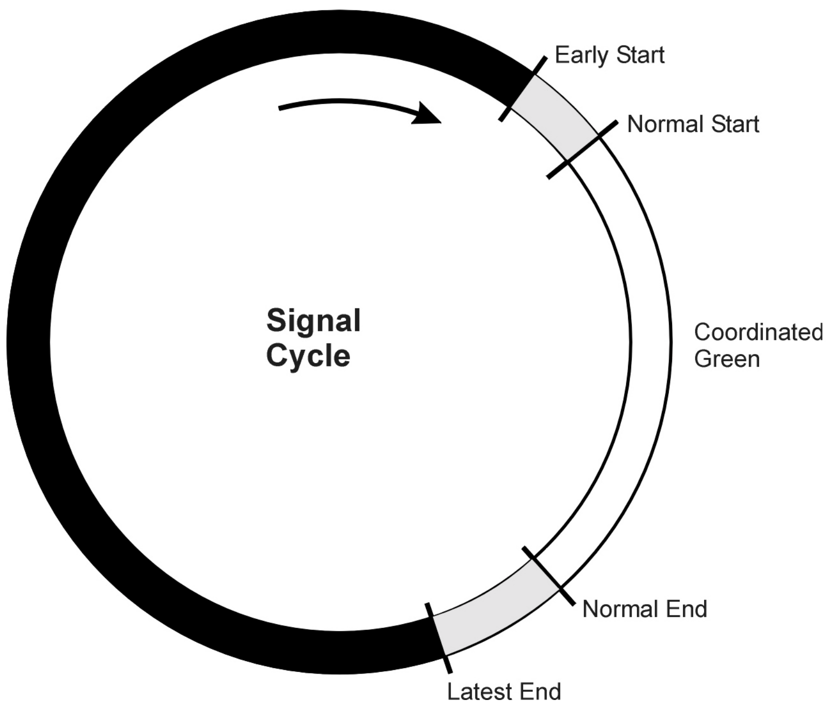

Figure 4 Window stretching for bus priority

The call for priority is picked up by an advance detector, located an appropriate distance from the stop line. In the demonstration, existing advance loops are being employed. These are generally closer than ideal, but far enough back that they will generally detect a bus before the length of the queue on red would prevent a bus from being detected.

The priority call will be cancelled when the bus reaches a check-out detector at the stop line. Ideally this detector should be beyond the stop line, but for the demonstration existing stop-line loops will be utilized. The arrangement is illustrated in Figure 5. In reality this will not affect the operation during the demonstration, because of the logic that will limit re-introduction of priority in consecutive cycles.

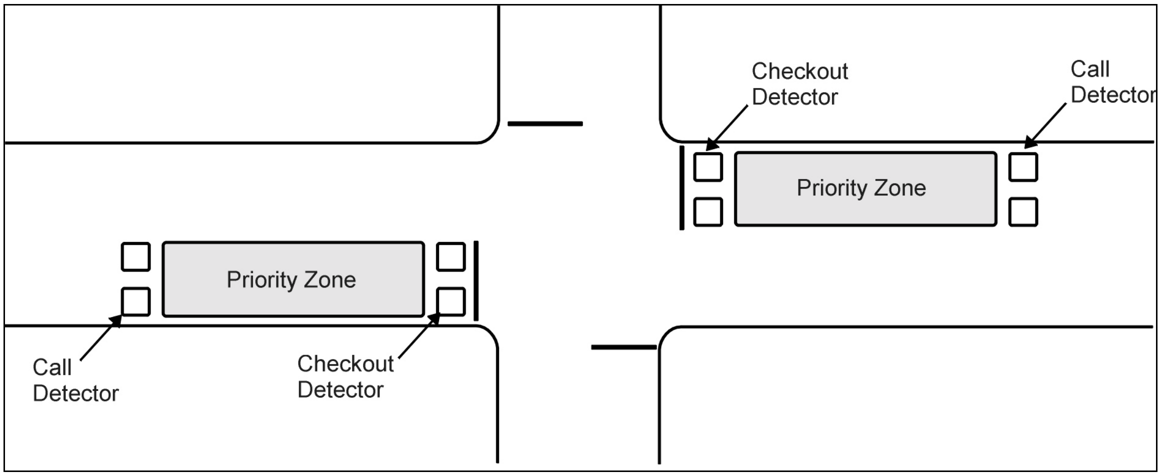

Figure 5 Layout of bus detection

The system will recognize priority calls in opposing directions and, when they are served by compatible phases, serve both calls. The operator will be able to define the recovery time required between subsequent priority services.

A basic requirement for implementation was that no additional or proprietary equipment be used, beyond the normal units employed in the Caltrans implementation of a model 170 controller within a type 332 cabinet. This precluded using existing off-the shelf systems (such as NOVAX Bus Plus[3]) that would require infra-red detectors and a signal priority "black box".

3.2 Detection Equipment

A transponder is installed on the underside of each bus (see Figure 6). This transponder has a unique vehicle ID assigned to it. The signal is picked up by a regular in-pavement loop connected to an IDC detector sensor unit. This has two output channels – one the traditional presence output and the other signaling the detection of a transponder.

The buses have an Orbital AVL system on board, which monitors the bus's schedule adherence. While the bus is on schedule, the power to the transponder is switched off. When the bus falls behind schedule, the AVL system switches on the power to the transponder.

[3] NOVAX Industries Corporation <www.novax.com>

Figure 6 Transponder mounted on underside of bus

3.3 Communications and Data Logging

In addition to new software to provide signal priority within the model 170 controllers, Caltrans is providing new in-field computing equipment to monitor the priority operation and develop a database for analysis and evaluation. This will be in the form of field hardened computers installed in new cabinets adjacent to the existing field masters, and they are referred to as “super masters”. These will communicate with the central computers at the Caltrans District 4 office in Oakland, via Caltrans’ existing communications system.

4 BUILDING ON PREVIOUS WORK

This is not the first time signal priority has been implemented in a Model 170 controller. In 1987, DKS Associates assisted BiTran Systems to develop and implement signal priority for the light rail system in Sacramento, employing either partial priority with similar window stretching or full priority. (See Fehon, *et.al.* 1989) A similar arrangement of advance loops and checkout loops is used in that system. The Sacramento system was relatively simple, with detection limited to loops connected to the intersection being controlled.

A more advanced arrangement was implemented on the Log Beach-Los Angeles Light Rail, employing additional equipment to relay detection and timing information to downstream intersections. (See Taylor, *et.al.* 1989) This type of approach will be useful for bus priority with closely spaced signals. Fortunately, the demonstration covers sections where most of the signal spacing is relatively long, and downstream repeating of detection will not be necessary.

5 INSTITUTIONAL ISSUES

So far, there has been a strong spirit of cooperation among the agencies. SCVTA, as operators of the bus system, desire as much signal priority for buses behind schedule as possible, and to have as many queue-jump lanes and bulb-outs as needed.

Caltrans staff have entered into the spirit of the demonstration and supported the use of priority. However, they would like to see a comprehensive evaluation. The proposed evaluation will cover the impact of the system on buses and other vehicles on all movements at key intersections, and overall impacts on buses along the entire route. The detailed design of the evaluation has yet to be prepared.

The Caltrans operations staff initially wished to place many limitations on the extent to which priority could modify the base signal timings. The compromise reached that allowed this part of the demonstration to proceed effectively, involved writing the software with many user-specified parameters, so that they could control it tightly if necessary, and relax those limitations wherever possible.

The staff of the cities through which the demonstration will run have mixed reactions. Some are eager to encourage transit and are happy with the use of bulb-outs and signal priority. They obviously have concerns about the potential adverse effect of priority on the length of side street queues, and will keep them under observation. Other cities have objected to bulb-outs because they do not want to affect traffic flow through their jurisdiction. The demonstration will provide an opportunity to illustrate the actual impacts of these measures on both buses and automobiles in the various situations.

6 SUMMARY AND CONCLUSIONS

There are many measures that can be taken to improve the attractiveness and performance of buses. Some of these can be implemented with little or no impact on other traffic, while others involve trade offs between the two. BRT is gaining popularity as a means of improving transit, and SCVTA has sponsored an alliance of jurisdictions to demonstrate what can be achieved when complementary elements are put in place together. The results of the evaluation will be used to determine the extent to which these elements are suitable for Silicon Valley and other similar communities.

References

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