APPENDIX E

TRANSIT OPERATIONS

SR 85 Transit Guideway Study: Transit Operating Concepts

Draft Report

Prepared for:

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As part of Task 2 of the transit opportunities study for State Route 85 (SR 85) in Santa Clara County, CHS Consulting Group (CHS) is responsible for examining expanded Santa Clara Valley Transportation Authority (VTA) bus operations on that roadway. Specifically, we are to suggest alternative network concepts for the corridor, as well as evaluate the operating implications of various lane configurations that could facilitate the flow of buses on the freeway. This technical memorandum summarizes our findings in these tasks.

1.0 Travel in the Study Area

Travel characteristics of the study area, summarized in Chapters 3 and 4, serve as a guide for designing transit service in the SR 85 corridor. Among them are the following key findings:

- SR 85 does not directly connect any major activity centers [although a few, like De Anza College, are located nearby].
- The greatest concentrations of population are in the southeast and southern portions of the corridor, while the greatest concentrations of employment are in the northwest and northern portions. Certain adjacent areas like Palo Alto, Mountain View, and the Stevens Creek corridor have relatively high concentrations of both population and employment.
- For the most part, origin-destination pairs in the study area are dispersed, and their travel direction does not necessarily parallel that of the corridor. Many of these trips may not be using SR 85 at all.
- There are some areas along the corridor where the propensity to use transit is higher than average for Santa Clara County. These include the interchanges with US-101 (at the northwest end of the corridor), El Camino Real, Stevens Creek Boulevard, SR-17, Almaden Expressway, SR-87, and US-101 (at the southeast end of the corridor).

Some of these findings do not bode well for transit, which is best suited to areas with relatively high densities of population and employment, and with trip patterns concentrated along corridors. However, the research did suggest that the best opportunities for transit may be in serving relatively short trips, as opposed to the longer trips that begin or end outside of the SR 85 corridor.

2.0 Current Transit Service

Chapter 3 detailed the VTA transit services using the SR 85 freeway. Since that information was compiled, VTA has initiated several service changes. An updated summary of current VTA service using the freeway as of December 28, 2019 is provided below:

- 27-Good Samaritan Hospital-Kaiser San Jose [30- to 45-minute weekday service; 60-minute weekend service]
- 102-South San Jose-Palo Alto [7 one-way trips during each weekday peak period]
- 168- Gilroy Transit Center-San Jose Diridon Transit Center [7 one-way trips during each weekday peak period]
- 185-Gilroy Transit Center-Mountain View [3 one-way trips during each weekday peak period]

- 901-Blue Line (Baypointe-Santa Teresa) light rail [15-minute service weekdays and weekends]

Most of these five routes serve relatively short segments of the freeway southeast of San Jose. Those serving the longest segments of the corridor (Routes 102 and 185) operate few trips, and those trips are restricted to the peak direction of travel during the peak travel period. Thus, there are gaps in service along the corridor during mid-days, evenings, and weekends, as well as in the contra-peak direction of travel during peak hours. Additionally, with the exception of the Blue Line light rail service, these routes do not make stops along the freeway and bypass trip attractors like De Anza College, West Valley College, and Good Samaritan Hospital. As a result, they not only skirt potential destinations desired by Santa Clara County travelers, but they also miss transfer opportunities with connecting bus services at these locations (as well as at the freeway's interchange with El Camino Real).

Whether demand is sufficient to justify all-day, bi-directional operation in the SR 85 corridor will be determined by travel demand estimates yet to be conducted. For the time being, efforts have focused on developing alternative service patterns that could fill the apparent gaps identified in the corridor to date. For the purposes of this memorandum, these service alternatives are referred to as bus rapid transit (BRT). While there are many versions of BRT, the term is used here to denote bus service that is generally characterized by:

- Freedom from delay enabled by priority in traffic (through such measures as reserved lanes and traffic signal priority) and off-board fare collection
- Frequent, two-way operation throughout the day
- Upscale passenger amenities at stations and on the buses, with unique branding to position the service as an improvement over ordinary local bus service.

The intent is not just to speed up buses, but to create a travel experience that can attract the more demanding segments of the market that are reluctant to use public transportation today. Whether or not all of these attributes can be provided, the term BRT is a useful way to describe the premium bus service being examined for the SR 85 freeway corridor.

3.0 Nature of the Service

Many of the characteristics of BRT previously mentioned were recommended in Chapter 4, which stated that effective transit in the SR 85 corridor should serve bi-directional travel demands throughout the day. It further suggested that this service connect with nearby existing local and regional transit lines, link to activity centers in the northwest part of the corridor, and focus on trips that are 3 to 15 miles in length. These criteria have been used as guidelines in developing hypothetical BRT services for consideration in the SR 85 corridor. Each element of these services-- alignment, terminals, stopping points, and schedules is discussed below.

3.1 Alignment

SR 85 would form the major part of the alignment of a BRT service in this corridor, with arterial streets providing access to stations in certain areas. As described in the Basis of Design Report for this project, a number of different lane configurations have been proposed to offer a pathway for buses that would allow them to avoid traffic congestion on the freeway. These configurations include exclusive transit lanes or express lanes. The express lanes would be located along the left (median) side of each direction of travel. In contrast, the transit lanes could be either on the left or right sides, either as new lanes added to the freeway or as conversions of existing shoulders. Bus station designs have been developed for each of these lane configurations. The various arrangements have implications on how buses would access the lanes and serve stations, as discussed later in this memorandum.

3.2 Terminal Points

Numerous locations could serve as the termini of an SR 85 BRT service. Two criteria were used to limit these to a small number for consideration:

- Presence of an activity center, either a major generator of trips or a transfer point for several transit routes
- Proximity to SR 85, desirably no farther than one mile

Using these criteria, the Mountain View Transit Center (at Evelyn Avenue and Castro Street) emerged as the most suitable northwestern terminal for SR 85 BRT. The Transit Center consists of a light rail terminal and a Caltrain station. It is served additionally by two VTA bus routes, as well as public and private shuttles to employment areas. It is also directly adjacent to Downtown Mountain View. The Transit Center is located about a half-mile west of SR 85.

A second possible northwestern terminal was identified in the North Bayshore area of Mountain View (approximately at the intersection of San Antonio Road and Casey Avenue). This location contravenes the one-mile distance criterion (it's approximately 3 ½ miles from SR 85). However, it penetrates an important employment area which is slated for even more workplace development. Buses serving it could stop at the Mountain View Transit Center as a way station. Such a service would provide a one-seat ride to many jobs for those traveling to or from the BRT stations farther south. On the other hand, little demand for travel to this employment area would be expected midday and on weekends. Including this terminal for further study allows its merits and drawbacks to be made explicit.

For the southeastern terminal, two locations were also considered: Santa Teresa Station and Ohlone/Chynoweth Station. Both are existing light rail terminals that are served by VTA buses. Of these, Santa Teresa Station is less promising, as it would entail almost five miles of travel along a section of SR 85 already served by Blue Line light rail service. Because it avoids this duplication, Ohlone/Chynoweth Station makes the most sense. If Santa Teresa were chosen as the terminal, then BRT should serve Ohlone/Chynoweth as a way station (exiting and re-entering the freeway to do so).

In summary, the most cost-effective terminals for SR 85 BRT appear to be Mountain View Transit Center in the northwest end of the corridor and Ohlone/Chynoweth Station in the southeast. However, in order to consider and test a reasonable number of routings, alternatives with terminals at North Bayshore and Santa Teresa have also been included.

3.3 Way Stations

Chapter 4 identified 12 locations that potentially could be served by an SR 85 BRT line. Of these, five were selected for further consideration (in addition to the four mentioned above as terminal stations). These five are located at colleges, hospitals, and transit centers. The transit centers are particularly important because they can extend the range of SR 85 buses by permitting transfers to and from transit lines serving other areas of Santa Clara County.

The following locations were considered reasonable candidates as way stations along the SR 85 corridor:

- El Camino Real: While there is little within walking distance of the interchange of SR 85 and El Camino Real, a BRT stop here would allow passenger transfers to and from two important bus lines in the VTA network, local 22 and rapid 522. The configuration of roadways at this interchange could pose challenges for pedestrians because of the ramps and high-speed traffic, a factor that must be dealt with in the design of the BRT station.
- Stevens Creek Boulevard: This stop would serve De Anza College, with an enrollment of 24,000 students. Classrooms vary from 0.2 to 0.4 miles walking distance from the SR 85 interchange. A transit center at the eastern edge of campus is about 0.6 miles from the freeway and is currently served by five VTA bus routes; only one of these routes passes through the SR 85/Stevens Creek interchange. Due to these distances, some first-mile/last-mile issues are likely.
- Saratoga Avenue: Like El Camino Real, this location has little around it within walking distance. However, Saratoga Avenue is an access route to West Valley College, with an enrollment of 12,000 students. A transit center near the entrance of the college serves three VTA bus routes (only one of which passes through the SR 85/Saratoga interchange). However, West Valley College is about a mile away from the SR 85 interchange with Saratoga Avenue, making convenient first-mile/last-mile connections a must.
- Winchester Boulevard: Should the light rail Green Line be extended south from Winchester Station to Los Gatos, its proposed terminal at Vasona Junction would be close to SR 85 and an ideal place for passengers to transfer to and from the SR 85 BRT line. However, the future of the Vasona Extension is currently uncertain. For this reason, it is primarily included here as a placeholder in case the project again becomes active. The next best station location in this area would be slightly (0.75 miles) farther east at Bascom Avenue.
- Bascom Avenue: The interchange of SR 85 with Bascom Avenue/Los Gatos Boulevard would provide access to Good Samaritan Hospital. In addition to the medical facilities there, connections could be made to two VTA bus lines that serve the hospital complex (only one of which also passes through the SR 85/Bascom Avenue interchange). The distance between the station and the hospital complex is from 0.2 to 0.5 miles, which could create first-mile/last-mile concerns for some transit riders. Should the Vasona LRT Extension be constructed in the future, the Bascom Avenue station should no longer be considered, as a station on the Vasona extension would provide transfers to both light rail and other VTA bus lines.

Thus, of the five way station locations identified, four were selected for further study for SR 85 BRT service: El Camino Real, Stevens Creek Boulevard, Saratoga Avenue, and Bascom Avenue.

The Basis of Design Report examined on-line station alternatives for the median of the freeway as well as along the right side (in each direction of travel). In addition, station locations at the tops of ramps from both the median and right sides of the freeway were considered. From the point of view of overall operations, these various designs will yield similar results in terms of travel time, operating costs, and patronage.

However, an alternative approach for stations is to route buses off SR 85 so that they can travel directly to a destination too distant for comfortable walking from the freeway. This approach would be useful to address the first-mile/last-mile concerns previously mentioned at Stevens Creek Boulevard (for reaching both De Anza College and its adjacent transit center), Saratoga Avenue (for reaching West Valley College), and Bascom Avenue (for reaching Good Samaritan Hospital). As noted in Chapter 4, a transit service that operates strictly along SR 85 will have difficulty attracting riders if it does not provide linkages to these activity centers. The advantage of the off-line approach described here is that BRT would directly penetrate each activity center. The disadvantages are that these diversions will add travel time to the service, raise operating costs, increase the probability of delays and unreliability, and annoy through riders. To help overcome these drawbacks, on-street priority measures for BRT would be necessary.

3.4 Schedules

The discussion thus far has focused on the spatial elements of transit service: alignment, terminals, and way stations. The final elements are temporal: the schedules on which the BRT buses operate, and the span of service each day during which operation is provided. For the purposes of the operating analyses performed in this study, a constant headway of 15 minutes has been assumed. This provides regular and reliable service that could, in reality, be increased during peak travel periods after some operating experience has been gained. Likewise, it may be appropriate to decrease service to every half hour on weekends or late in the evening in order to cost-effectively serve low numbers of riders during these periods. Nonetheless, the 15-minute frequency allows for a consistent basis of comparison among all hypothetical alternatives while maintaining a standard of good service in the corridor.

Another reason for considering 15-minute frequencies on the SR 85 BRT line is that it has the potential of creating a shortcut for riders on many of VTA's light rail lines. Those at the western end of the Orange Line near Mountain View, the southwest end of the Green Line (if extended to Vasona), or the south end of the Blue Line near Ohlone/Chynoweth may find it less time consuming to transfer to the circumferential BRT line on SR 85 to travel to the end of one of the other lines than to travel in the opposite direction and pass through downtown San Jose in order to reach their destination. Since the light rail lines use 15 minutes as a base level of service, the SR 85 BRT line should do the same. Even if timed transfers cannot be guaranteed at the light rail terminals, transferring passengers will not have to endure long waiting times, which would defeat the purpose of the shortcut.

The span of service is assumed to be:

- Monday-Friday 5:00 am – 10:00 pm
- Saturday 6:00 am – 7:00 pm
- Sunday 7:00 am – 7:00 pm

Actual operating experience could reveal that service on Saturdays and/or Sundays is not warranted, but the above spans are appropriate for comparing the alternatives at this point in time.

4.0 Hypothetical Routing Plans

In order to develop estimates of operating needs and costs, four hypothetical routing alternatives were developed. These incorporate the terminals, way stations, and schedules previously described, as well as the concepts of on-line versus off-line stations.

- Alternative 1. Mountain View-Ohlone/Chynoweth with Freeway Stations: This could be considered the base case. Either on-line or ramp stations would be located along SR 85 at El Camino Real, Stevens Creek Boulevard, Saratoga Avenue, and Bascom Avenue.
- Alternative 2. Mountain View-Ohlone/Chynoweth with Off-line Stations: Either on-line or ramp stations would be located along SR 85 at El Camino Real, with off-line stations at De Anza College, West Valley College, and Good Samaritan Hospital.
- Alternative 3. North Bayshore-Ohlone/Chynoweth with Freeway Stations: On-street stops would be located at six locations in the North Bayshore area, as well as the Mountain View Transit Center, with either on-line or ramp stations along SR 85 at El Camino Real, Stevens Creek Boulevard, Saratoga Avenue, and Bascom Avenue.
- Alternative 4. Mountain View-Santa Teresa Station with Freeway Stations: Either on-line or ramp stations would be located along SR 85 at El Camino Real, Stevens Creek Boulevard, Saratoga Avenue, and Bascom Avenue, with an off-line station at Ohlone/Chynoweth.

A composite map of all four alternatives is provided in **Figure 1**, with the separate alternatives depicted diagrammatically in **Figure 2**.

These alternatives represent a range of approaches for providing premium bus service in the SR 85 corridor and utilizing restricted lanes to keep buses moving during congested periods. In reality, several routing patterns could be operated on the freeway simultaneously. For example, in addition to the base case Mountain View-Ohlone/Chynoweth buses, other buses could be operated between Mountain View and the current Winchester light rail terminal. Another variant is for peak-hour express buses to supplement base service along SR 85 by connecting residential areas at the south end of the corridor with employment areas in the north, such as North Bayshore. However, to simplify the process of developing estimates of patronage and operating parameters at this early stage of the project, only Alternatives 1-4 were examined in depth. If it is eventually decided to invest in BRT on SR 85 and equip that facility with transit lanes and stations, more detailed analyses can be undertaken on a wider variety of service patterns.

5.0 Comparative Operating Statistics

REMIX software was utilized to test the alternatives. This program uses a graphical interface and allows the results of different route alignments to be displayed instantly. In running the REMIX model, average running speeds of 31 mph were assumed on the freeway and 18 mph on arterial streets (which are derived from the current operating statistics of Route 102). To this was added an average dwell time of 40 seconds at each station. Layover time at the end of each run was input as 17% of round-trip running time, VTA's current average. Fully-allocated operating costs (as opposed to marginal costs) were calculated at $179 per hour, VTA's current level.

Analyzing the four hypothetical alternatives with REMIX resulted in the comparative operating statistics summarized in **Table 1**. The length of the alternatives ranges from 18.5 to 23.4 miles, with Alternative 1 being the shortest and Alternative 4 the longest. Largely for this reason, Alternative 1 serves a somewhat smaller catchment area of both population and employment than most of the other alternatives. Alternative 4 has the greatest population base. The greatest employment base is encompassed within the catchment area of Alternative 3, influenced mainly by its direct service to the North Bayshore employment area. Running times among the alternatives vary from 40.5 to 58.2 minutes (including station dwell time). They correlate generally with the length of each alternative but are affected further by the amount of arterial street running; again, Alternative 1 is the lowest. With its relatively short running time, Alternative 1 would require only seven buses to operate a 15-minute service. The other alternatives require nine or ten buses to run the same frequency.

The robust 15-minute all-day service hypothesized for the alternatives results in 0.86 to 1.08 million service miles per year and 36,652 to 52,490 annual service hours. These result in annual operating costs of $6.56 million to $9.40 million. In each instance, Alternative 1 is the lowest in the range. Alternative 3 is the highest for service hours and cost, while Alternative 4 is highest for service miles.

6.0 Bus Use of Priority Lanes on the Freeway

Many lane and station configurations for SR 85 were presented in the Basis of Design Report. An important consideration is the ability of BRT buses to access these lanes and stations, especially if difficult maneuvers are required. Comments on each type of design alternative are summarized below:

- Design alternatives with median priority lanes (either express lanes or exclusive transit lanes) but no on-line stations would be impractical for SR 85 BRT service. Since way stations would be an integral part of bus rapid transit in this corridor, BRT buses would have to use on- and off-ramps at the right side of each travel direction to access the stations (whether those stations were on the freeway ramps or were off-line, such as at West Valley College). During periods of heavy traffic flow, buses weaving into and out of the median lanes would entail slower maneuvering speeds and could result in a somewhat more accident-prone operation. One way around this problem would be to construct drop ramps directly to and from the median lanes, but this solution would add considerable cost to each alternative. In this scenario, stations for operating alternatives 1, 3, and 4 could be located at the top of these drop ramps. Stations for operating alternative 2 would be off-line, but the drop ramps would allow BRT buses to access them without weaving to the general traffic ramps at the right-side of the freeway.

- Design alternatives that feature transit lanes and stations along the median of the freeway north of SR 87 would be amenable to operating alternatives 1, 3, and 4. Operating Alternative 2 would require median drop ramps to access off-line stations.
- Design alternatives that offer transit lanes and stations along the right side of the freeway would be useable by all of the BRT operating alternatives (though on-line stations would be unnecessary for operating alternative 2). Any right-side design alternative that would accommodate buses only during peak periods would not be practical for all-day transit use unless buses were permitted to stop at the on-line stations off-peak. Alternatively, buses could use ramp or off-line stops all day, and no stops would be required along the freeway's transit lanes.
- Design alternatives that require buses to transition between median- and side-running priority lanes will necessitate weaving maneuvers for buses. Depending on the magnitude of traffic volumes, the difficulty of those maneuvers could make such alternatives impractical.
- At the north end of the project, the drop ramp suggested for Evelyn Avenue would appear to be essential for those design alternatives with priority lanes in the median in that segment of the freeway. This ramp would avoid the need for weaving maneuvers between the median lanes where buses would operate and the right-side entrance and exit ramps. Likewise, at the south end of the project near Ohlone-Chynoweth Station, some sort of direct connector ramp arrangement would be needed to avoid the weaving that would be required in the alternatives with median priority lanes in that segment of the freeway.

7.0 Ridership

An analysis of the projected ridership that would be generated by each of the hypothetical operating alternatives will be conducted later in this study. Until such time as ridership can be assessed, it would be premature to judge which operating alternative would be better or worse, overall, than the others.

8.0 Conclusions

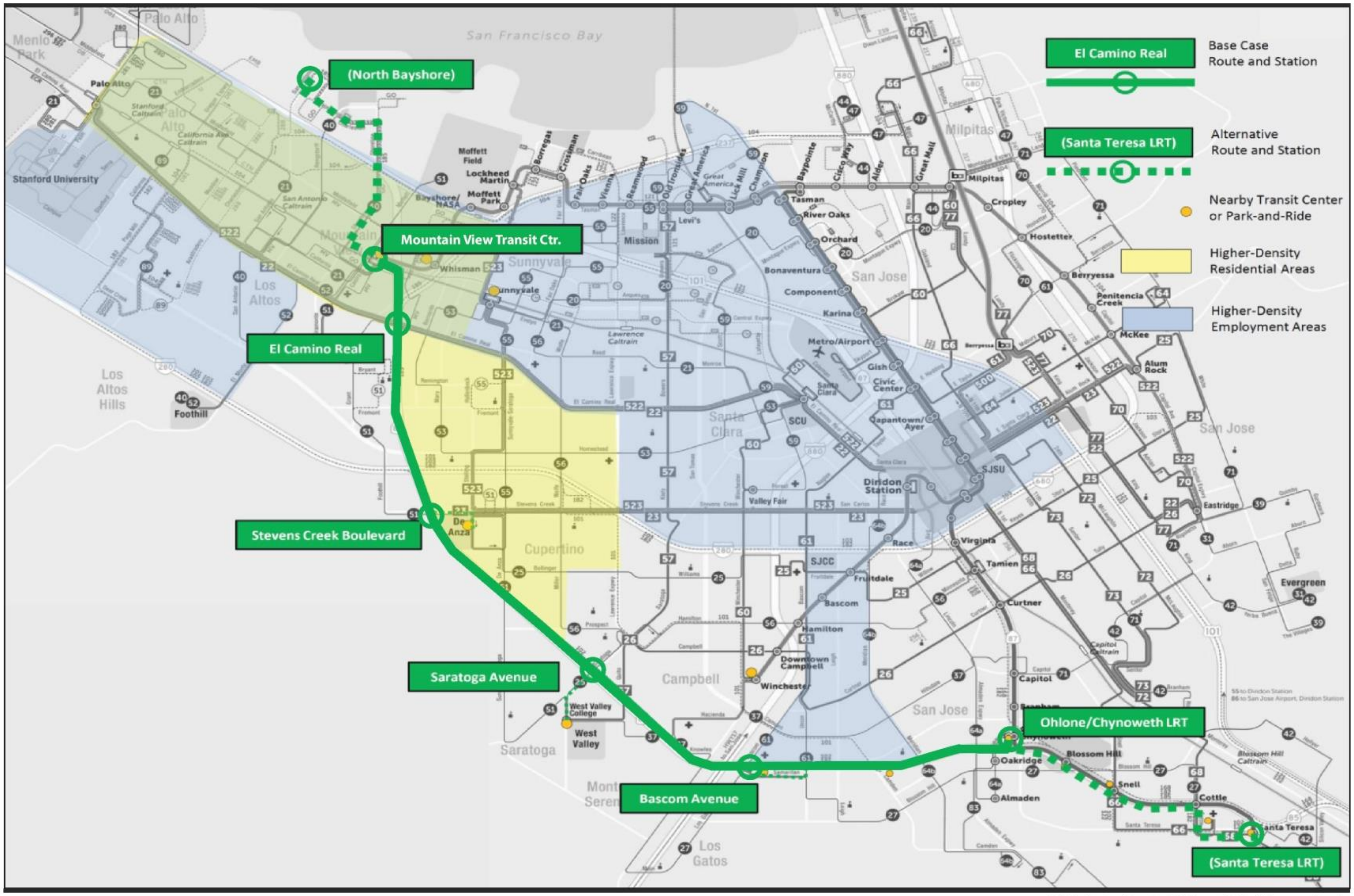
The provision of bus rapid transit in the SR 85 corridor appears to be feasible for several of the design configurations that give buses priority on the freeway and that provide intermediate stations to access activity centers. VTA must assess whether the costs (both capital and operating) of this service are warranted for the ridership that would be expected. Nonetheless, there is no apparent fatal flaw from an operating standpoint for providing premium service in this corridor. The keys for success will be to provide connectivity with destinations and other VTA transit services located along the corridor while maintaining relatively high travel speeds.

Table 1. Results of REMIX Analysis of SR 85 BRT Alternatives

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Terminals	Mountain View	Mountain View	North Bayshore	Mountain View
	Ohlone/Chynoweth	Ohlone/Chynoweth	Ohlone/Chynoweth	Santa Teresa
Station Type	Freeway	Off-line	Freeway	Freeway
Population Served	8,235	8,141	9,691	10,146
Number of Jobs Served	5,024	5,603	9,525	6,094
Number of Stations (one-way)	6	6	13	7
Length of Route (one-way, miles)	18.5	22.2	22.4	23.4
Running Time (one-way, minutes)	40.5	53	58.2	52.7
Running Time (two-way, minutes)	94.8	124	136.2	123.3
Number of Peak Buses Required	7	9	10	9
Annual Service Miles (million miles)	0.86	1.03	1.04	1.08
Annual Service Hours	36,652	47,965	52,490	47,512
Annual Operating Cost (millions)	$6.56	$8.59	$9.40	$8.50

Notes:

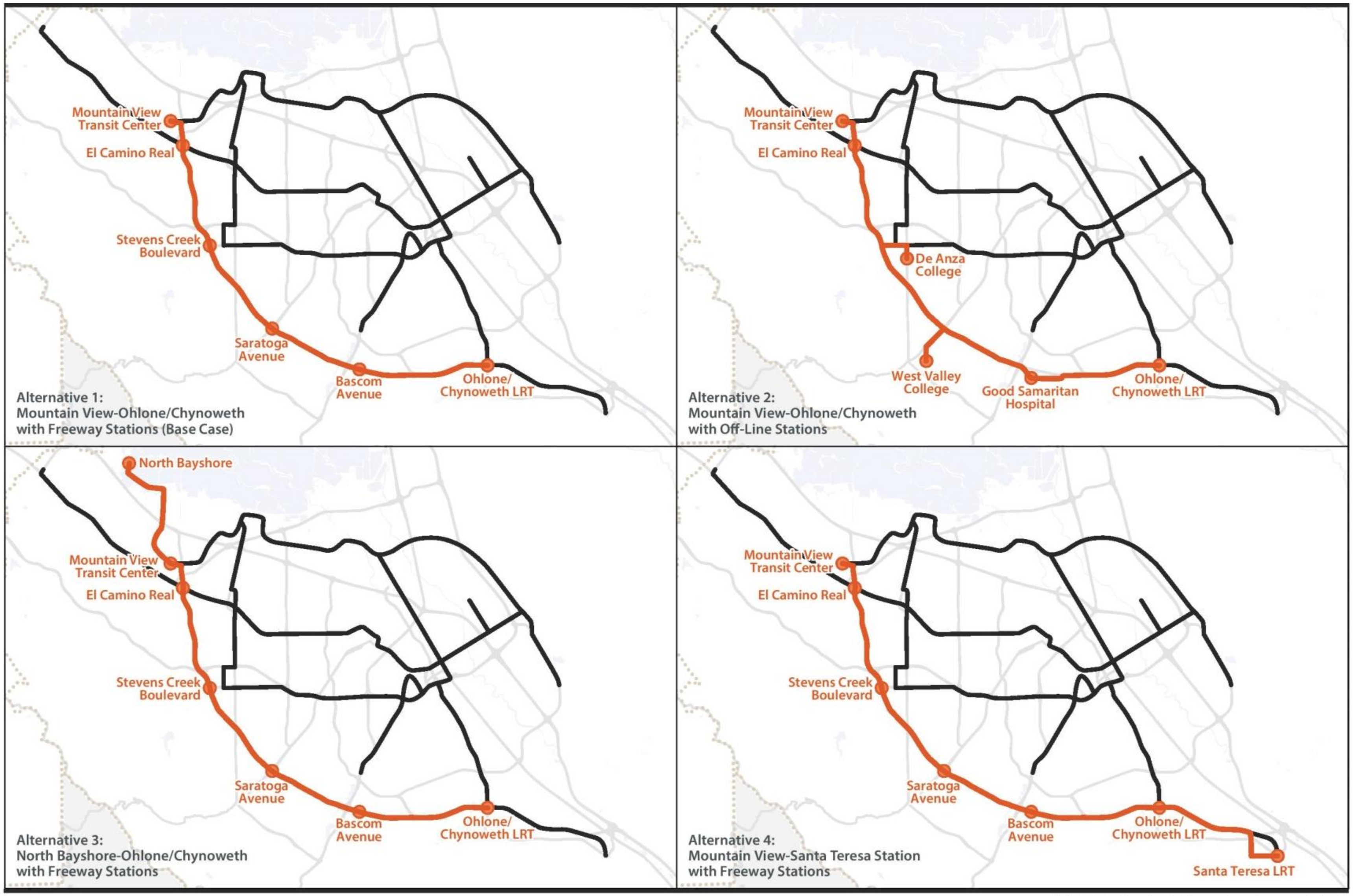
1. Running speeds are assumed to be 31 mph on freeways and 18 mph on local streets.
2. One-way running times include driving time between stations and dwell time at stations (assuming 40 seconds per station).
3. Two-way running times also include 17% layover time.
4. Service is provided at 15-minute headways from 5 am to 10 pm on weekdays, 6 am to 7 pm on Saturdays, and 7am to 7 pm on Sundays.
5. Peak buses do not include spares.



VTA State Route 85 Transit Guideway Study

CHS Consulting Group

Figure 1
Composite Map of BRT Route Alternatives
Studied for SR 85



VTA State Route 85 Transit Guideway Study

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LEGEND

SR 85 BRT Line

Other BRT and LRT Lines

0 1 2 3 Miles

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Figure 2
SR 85 BRT Operating Alternatives

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SR 85 Transit Guideway Study: Bus Travel Time Estimates

Final Report

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This technical memorandum discusses the methodology and assumptions for estimating bus travel times for each alternative in the SR 85 Transit Guideway Study. Bus travel time consists of two parts: running time between stations, and delay associated with way stations. Specific components of this delay include deceleration, acceleration, dwell time, traffic signal delay, re-entry delay, and offline station access delay. They vary based on station configurations, bus types, traffic conditions, and estimated ridership.

As described in project alternative analysis reports, there are three transit lane alternatives (short median, long median, and right side) and two bus-on-shoulder alternatives (median and right side). For each alternative, two routing options have been analyzed: (1) an in-route option with on-line or ramp stations, and (2) a deviation route option with off-line stations. On-line stations are located on the freeway mainline in the median of the roadway or along its right side. Ramp stations are located at the top of the freeway's on- or off-ramps. Off-line stations are located outside the freeway right-of-way at locations where there are activity centers or transfer stations that could generate ridership on the BRT line. Bus travel times are estimated for each alternative, each routing option, and both AM and PM peak periods (6 am to 10 am and 3 pm to 7 pm, respectively) in both directions. Ranges presented by minimum, maximum, and average travel time are included in the estimation.

1.0 Data

1.1 Freeway Speed and Volume Data

Freeway speed and volume data provided by CDM Smith include the speed on the general purpose lanes and the managed lanes (HOV lane/express lane) for each freeway segment. The whole corridor is divided into over 50 segments, with each segment located between two sets of ramps; within each peak period, travel times were tabulated by 15-minute time periods. General purpose and managed lane volumes are also given for each segment in both the AM and PM peak hour.

1.2 Ridership Estimates

Preliminary ridership estimates have been provided by CDM Smith for each station and each routing option. Low or high ridership stations were identified, based on whether the average peak period boardings are expected to be below or over 15 passengers.

2.0 Assumptions for Bus Running Time

2.1 Transit Lane Alternatives

Buses are assumed to run at the speed limit of SR-85, which is 65 mph on a dedicated transit lane.

2.2 Bus-on-Shoulder Alternatives

For the "median bus-on-shoulder" alternative, buses would use the express lane and, when traffic drops below 35 mph, they would exit onto the shoulder to bypass the congestion and run as fast as 35 mph or 10 mph over the express lane speed, whichever is slower. For the "right side bus-on-shoulder" alternative, buses would use the right-most general purpose lane and, when traffic drops below 35 mph, they would exit onto the shoulder to bypass the congestion and run as fast as 35 mph or 10 mph over the adjacent general purpose lane speed, whichever is slower.

2.3 Travel Time between Terminal Stations and SR-85

For all alternatives, buses would run on local streets between Ohlone-Chynoweth terminal and the Santa Teresa Boulevard ramps, and between Mountain View Transit Center terminal and the Evelyn Avenue ramps. The travel times for these segments have been estimated using Google Maps during peak hours. **Table 1** below shows the results.

Table 1. Travel Time between Terminal Stations and SR-85

Direction	AM Travel Time (min)		PM Travel Time (min)	
	Range	Mean	Range	Mean
Between Mountain View Transit Center and Evelyn Avenue ramps				
NB	3-6	4	3	3
SB	3-4	3.5	3-6	4
Between Ohlone-Chynoweth Station and Almaden Expressway ramps*				
NB	4-6	4.5	4	4
SB	3	3	3-4	3.5

*Because of the location limits of freeway speed data, the travel time of segments between Ohlone-Chynoweth Station and Almaden Expressway ramps have been estimated using Google Maps

3.0 Assumptions for Station Area Delay

3.1 On-line and Ramp Stations

Buses would decelerate while approaching an on-line station, stop and dwell at the station to alight and board passengers, and then accelerate and re-enter the travel lane. For ramp stations, buses would decelerate to approach the ramp intersection, wait for the green signal indication, stop at the far-side bus station, wait for passengers to alight and board, and then accelerate and merge back to the mainline travel lane. Assumptions are summarized in **Table 2,** below.

Table 2. Assumption Summary

Factor	Assumption
Deceleration	4 ft/s^2
Acceleration	2.1 to 3.4 ft/s^2 for an articulated hybrid bus, depending on speed
Dwell time	30 or 60 seconds, depending on ridership level
Traffic signal delay	Based on local intersection operation
Re-entry delay	0 to 18 seconds, depending on configuration and traffic lane volumes

Reference sources include *Transit Capacity and Quality of Service Manual, 3rd Edition* (*TCQSM*), TRB's *Transit Cooperative Research Program Synthesis 75* (*TCRP*), and AASHTO's *A Policy on Geometric Design of Highways and Streets, 5th Edition* ("*Green Book*"). Details on assumptions for each delay component are summarized below.

3.1.1 Deceleration

The same deceleration rate is assumed for buses moving from the prevailing freeway speed to the stopping condition at bus stations (for on-line stations) and traffic signals (for ramp stations). It's possible that a bus driver will use heavier braking force on a station at the freeway grade than one on a ramp, but the difference in time were considered negligible for the purposes of this analysis. The same assumption applies to the acceleration rate (below).

According to *TCQSM*, the comfortable deceleration rate on average for a bus is 4 ft/s^2. According to the *Green Book,* this value is lower than a passenger car's deceleration rate of 6-8 ft/s^2 but higher than that of truck at 3 ft/s^2. Deceleration delay and distance will be calculated based on the prevailing speeds for both AM and PM peak hours.

3.1.2 Acceleration

Similarly, the same acceleration rate is assumed from the stopped condition at a bus station to the prevailing freeway speed for both on-line and ramp station alternatives.

Unlike deceleration, however, the acceleration rates depend on both the ultimate speed reached and on the bus type/propulsion system (*TCQSM*). They are lower when accelerating to higher speeds (50 mph) and higher when accelerating to lower speeds (20 mph) **(see Table 3).** For the purposes of this analysis, a 60-foot articulated bus is the most likely to be used for BRT service, based on common practice throughout the country. Moreover, federal regulations have led transit operators away from diesel buses and towards electric propulsion. Given the lack of information currently available for an all-electric bus, this analysis assumes a hybrid articulated bus for BRT service in the SR 85 corridor. Acceleration delay and distance will be calculated based on the prevailing speeds for both AM and PM peak hours.

Table 3. Bus Acceleration Characteristics

	Average Time to Reach Speed (s)			Average Acceleration to Speed (ft/s²)	
Bus Type	**10 mi/h**	**20 mi/h**	**50 mi/h**	**20 mi/h**	**50 mi/h**
40-ft standard diesel	5.0	8.7	33.2	3.4	2.2
45-ft motor coach diesel	4.0	7.4	27.1	4.0	2.7
60-ft articulated diesel	4.0–4.7	9.1	42.3–43.6	3.2	1.7
Double deck diesel	6.2	10.4	43.6	2.8	1.7
60-ft articulated hybrid	3.8	8.6	35.2	3.4	2.1

3.1.3 Dwell Time

The most efficient boarding situation – all-door, pre-paid, and level boarding – is assumed for stations under all alternatives. These attributes are commonly shared by BRT systems operating elsewhere. According to *TCQSM*, the average per-passenger service time is 1.75 seconds (see **Table 4).** For the purposes of assuming a dwell time, corridor stations were categorized in two groups, based on the ridership analysis being performed by CDM Smith: Stations exhibiting the potential for 60 or more boardings per hour are classified as "high ridership" and the dwell time assumed as 60 seconds; stations with lower than 60 boardings per hour are assumed to have a dwell time of 30 seconds. A dwell time of 60 seconds is assumed for both terminal stations.

Table 4. Per-Passenger Service Time

	Average Passenger Service Time (s/p)	
Situation	**Observed Range**	**Suggested Default**
BOARDING		
No fare payment	1.75–2.5	1.75
Visual inspection (paper transfer/flash pass/mobile phone)	1.6–2.6	2.0
Single ticket or token into farebox	2.9–5.1	3.0
Exact change into farebox	3.1–8.4	4.5
Mechanical ticket validator	3.5–4.0	4.0
Magnetic stripe card	3.7–6.5	5.0
Smart card	2.5–3.2	2.75
ALIGHTING		
Front door	1.4–3.6	2.5
Rear door	1.2–2.2	1.75
Rear door with smart card check-out	3.4–4.0	3.5

3.1.4 Traffic Signal Delay

Traffic signal delay is the time waiting at a ramp intersection to get a green indication when buses approach a ramp station. This delay depends on cycle length, split, traffic volume, etc. For this study, half the signal cycle length is assumed to be the average waiting time at an intersection. Further, transit signal priority (TSP) treatments can minimize signal delay by extending the green indication or terminating a red indication early when a bus is approaching to allow the bus to make it through the intersection. Research shows that TSP can reduce bus delay at a signalized intersection by 5 to 15 seconds[1]. On average, 10 seconds of reduction is assumed for this study with the implementation of TSP. **Table 5** below shows signal cycle lengths and traffic signal delay at stations where ramp stations have been considered. Note that TSP treatments will add cost to ramp station alternatives.

Table 5. Traffic Signal Delay at Stations

Station	Cycle Length (s)		Signal Delay (s)	
	AM	PM	AM	PM
Bascom Avenue	116	120	48	50
Saratoga Avenue	120	120	50	50
Stevens Creek Boulevard	124	140	52	60

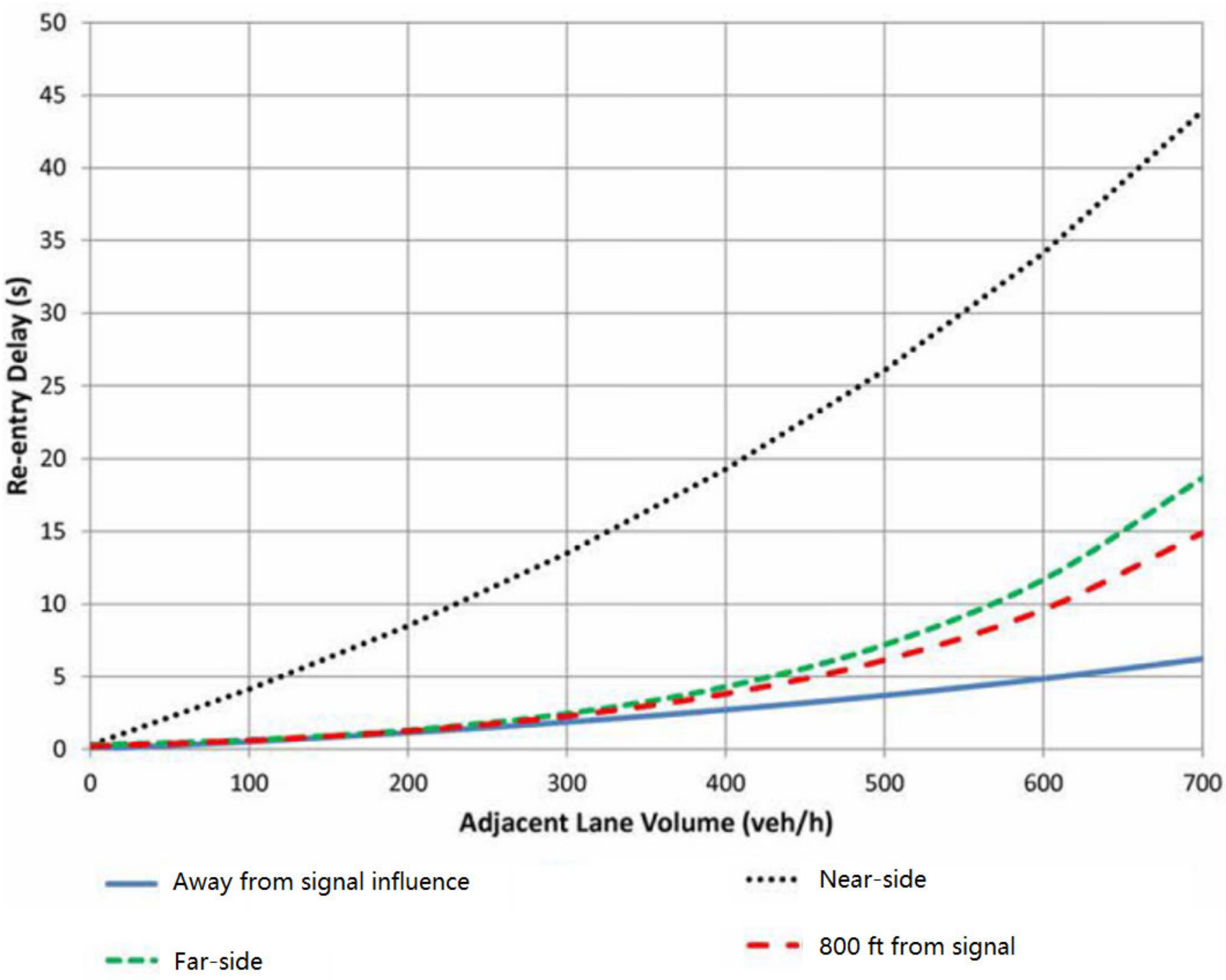
Source: Apple Park Project Draft Environmental Impact Report, Cupertino General Plan Draft Environmental Impact Report, Samaritan Medical Center Master Plan Project Environmental Impact Report

3.1.5 Re-entry Delay

Re-entry delay occurs where bus stations are out of the traffic lane and bus drivers must wait for a gap in traffic to pull back into the lane and continue on their route (*TCQSM*). Re-entry delay typically ranges from 0 to 10 seconds and can be significantly longer at near-side stations at traffic signals, when the bus has to wait for a long queue of vehicles to clear. The delay is determined by traffic conditions and bus station configurations; **Figure 1**, below, presents the results. For this project, far-side stations are preferred, so the re-entry delay will be calculated based on traffic volumes in the adjacent lane.

[1] https://nacto.org/docs/usdg/bus_signal_priority_chada.pdf

Figure 1. Illustrative Re-entry Delay by Station Configuration



3.2 Off-line Stations

The analysis includes three offline stations, located at De Anza College, West Valley College, and Good Samaritan Hospital. Delays for these stations have been estimated using Google Maps. After the bus leaves the off-ramp, it would merge with local street traffic, drop off/pick up passengers at the off-line station, and then use local streets to access the freeway on-ramp. **Table 6** below compares the travel times of running on the freeway without any stops versus diverting to local streets (using either existing ramps or potential direct bus ramps) and the difference between these two (delay). Dwell time would be calculated in the same manner as described in Section 3.1 above.

Table 6. Off-line Station Travel Time Delays

Direction	Scenario	AM Travel Time (min)		PM Travel Time (min)	
		Range	Mean	Range	Mean
De Anza College					
NB	Freeway no stop	6-14	10	1	1
	Use Stevens Creek ramps	9-22	16	8-16	12
	Use Stevens Creek and McClellan ramps	8-20	14	6-13	10
	Delay – Stevens Creek ramps	3-8	6	7-15	11
	Delay – Stevens Creek and McClellan ramps	2-6	4	5-12	9
SB	Freeway no stop	1	1	6-11	9
	Use Stevens Creek ramps	10-15	13	15-22	18
	Use Stevens Creek and McClellan ramps	6-10	8	10-16	13
	Delay – Stevens Creek ramps	9-14	12	9-11	9
	Delay – Stevens Creek and McClellan ramps	5-9	7	4-5	4
West Valley College					
NB	Freeway no stop	2-6	4	2	2
	Use Saratoga and Quito ramps	6-22	14	7-12	10
	Delay – Saratoga and Quito ramps	4-16	10	5-10	8
SB	Freeway no stop	2	2	2-7	5
	Use Saratoga and Quito ramps	6-12	9	6-13	10
	Delay – Saratoga and Quito ramps	4-10	7	4-6	5
Good Samaritan Hospital					
NB	Freeway no stop	6-14	10	3	3
	Use Bascom and Union Ramps	8-18	13	5-10	8
	Delay – Bascom and Union Ramps	2-4	3	2-7	5
SB	Freeway no stop	3	3	8-15	12
	Use Bascom and Union Ramps	5-7	6	10-18	14
	Delay – Bascom and Union Ramps	2-4	3	2-3	2

4.0 Results

The travel time results are shown in **Table 7** below.

Table 7. Travel Time Results (min)

Alternative			3-1 Short Median Transit Lane	3-2 Long Median Transit Lane	3-3 Right Side Transit Lane	4-1 Median Bus-On-Shoulder	4-2 Right Side Bus-On-Shoulder
Option 1 – In Route							
NB	AM	Max	33.4	32.2	33.9	35.2	46.9
		Min	27.7	28.2	28.9	28.4	32.8
		Avg	29.7	29.7	30.4	32.1	40.6
	PM	Max	28.6	30.2	29.9	30.2	35.0
		Min	28.6	30.2	29.9	30.2	33.9
		Avg	28.6	30.2	29.9	30.2	34.5
SB	AM	Max	27.6	28.2	28.3	27.9	32.8
		Min	26.6	27.2	27.3	26.9	31.2
		Avg	27.1	27.7	27.8	27.4	32.0
	PM	Max	31.7	29.7	31.3	32.1	48.2
		Min	26.8	26.7	27.3	27.4	41.9
		Avg	28.9	28.2	28.8	30.0	45.0
Option 2 – Deviation Route							
NB	AM	Max	59.9	58.7	62.8	61.6	71.3
		Min	35.1	35.6	37.6	35.9	37.7
		Avg	46.8	46.7	49.8	49.0	55.8
	PM	Max	57.1	61.7	54.7	58.7	62.9
		Min	40.0	43.6	39.6	41.6	43.8
		Avg	50.1	53.6	48.6	51.6	54.4
SB	AM	Max	49.5	50.1	55.6	49.8	56.1
		Min	36.5	37.1	41.5	36.8	41.5
		Avg	43.0	43.6	49.1	43.3	49.4
	PM	Max	53.5	51.5	59.5	53.7	68.6
		Min	44.6	44.5	50.5	45.1	57.2
		Avg	48.7	48.0	54.5	49.7	62.8

Table 7 arrays all of the results of the travel time analysis, including the minimum, maximum, and average time for each alternative in each direction of travel during each peak period. Unfortunately, the 120 cells in the table make comparing the alternatives difficult. For example, the shortest travel time of 26.6 minutes occurs in Alternative 3-1, Option 1 (southbound in the AM peak), while the longest time of

71.3 minutes occurs in Alternative 4-2, Option 2 (northbound in the AM peak). In order to avoid "apples and oranges" comparisons and simplify the results, **Table 8**, below, was developed. It uses only the average travel times from **Table 7**. Moreover, it homes in on the predominant directions of travel by aggregating northbound AM peak bus travel time with that of the southbound PM peak. Though that aggregate would not be experienced by BRT buses in regular service, it does represent a way of comparing the alternatives during the times most important to commuters.

Table 8. Aggregated Average Roundtrip Travel Time (min)

3-1 Short Median Transit Lane	3-2 Long Median Transit Lane	3-3 Right Side Transit Lane	4-1 Median Bus on Shoulder	4-2 Right Side Bus on Shoulder
Option 1 – In Route (AM from Ohlone to Mountain View, PM back to Ohlone)				
58.6	57.9	59.2	62.1	84.6
Option 2 – Deviation Route (AM from Ohlone to Mountain View, PM back to Ohlone)				
95.5	94.7	104.3	108.4	118.6

Table 8 makes it clear that, as would be expected, Option 2 with off-line stations requiring route deviations entails considerably longer travel time than Option 1 with on-line or ramp stations. For most of the alternatives, Option 2 requires from 62% to 76% more travel time; Alternative 4-2 exhibits a smaller differential, with 39% more travel time. Whether the longer travel times of Option 2 is a fatal flaw will depend on the results of the patronage forecast being developed as a separate component of this study.

Within each option, Alternative 3-2 results in the lowest travel time and Alternative 4-2 the highest. Other than Alternative 4-2, the other alternatives on Option 1 are within about 4 minutes of each other; the spread in Option 2 is greater, with a difference of up to almost 14 minutes. Travel time, of course, is only one aspect of the alternatives that must be considered. The capital cost of each alternative (covered in other reports in this study) must be taken into account, along with the patronage estimates mentioned above.

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