Final Report

University of California, Davis
Transit Signal Priority Implementation Study

Prepared for:

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INTRODUCTION

The purpose of the UC Davis Signal Coordination / Transit Signal Priority Project is to improve Journey Time Reliability (JTR) for Unitrans vehicles as they serve passenger growth both on campus and throughout the City of Davis. In order to do so, Fehr & Peers completed a two phase project that accomplished the following project goals:

- Identify key intersections and corridors that degrade Unitrans on-time performance due to high vehicle / passenger delays. Using NextBus GPS technology, the detailed ranking of the 34 study intersections were evaluated and the Russell Corridor and Richards / Cowell Corridor were selected for detailed VISSIM analysis.
- Using a combination of signal coordination, transit signal priority, and operational improvement strategies were fully analyzed using the VISSIM multi-modal micro-simulation analysis software for weekday AM and PM peak hour conditions.

Table 1 presents the results of the total transit vehicle delay analysis at 34 key study intersections. Total transit delay was calculated by multiplying the number of transit vehicles passing through each intersection by the average delay at each intersection. The table shows that the Russell Boulevard Corridor includes 4 of the top 20 study intersections based in transit passenger delay. The Richards Boulevard / Cowell Boulevard Corridor includes 7 of the top 10 study intersections based in transit passenger delay.

Figure 1 presents the results of the intersection ranking based on ridership delay for AM peak hour conditions. Figure 2 presents the results of the intersection ranking based on ridership delay for PM peak hour conditions. Both figures show that the Russell Boulevard Corridor and Richards / Cowell Boulevard Corridor also rank high based on the number of passengers on Unitrans.

After completing the existing conditions analysis and improved conditions analysis, this Draft Report documents existing conditions within the study area, the analysis methodology for the development of optimized/coordinated signal timings, transit signal priority strategies and the results of the VISSIM analysis.

DISCUSSION OF SIGNAL OPERATIONS

This following section discusses the existing intersection operations on the Russell Corridor (between Arthur Street to the west and A Street to the east) and the Richards / Cowell Corridor (from 1st Street to the north-west and Pole Line Road to the south-east)

Russell Boulevard Corridor

The following three intersections operate as coordinated traffic signals:

- Arthur Road / Russell Boulevard;
- SB SR 113 On/Off-Ramps / Russell Boulevard; and
- NB SR 113 On/Off-Ramps / Russell Boulevard.

Table 1
Summary Analysis of Transit Delay at Signalized Intersections

Intersection		Total Transit Vehicle Delay		Total Passenger Delay		Total Average Delay	
		Sum of All Peak Hours (sec.)	Rank	Sum of All Peak Hours (min.)	Rank	Sum of All Peak Hours (sec.)	Rank
1	Russell/Howard	3758.9	1	4,195.1	2	94.0	17
2	Russell/Anderson	3428.0	2	6,356.3	1	107.1	8
3	Anderson/Covell	2327.8	3	2,936.0	7	101.0	10
4	Russell/B St.	2151.1	4	2,749.5	8	107.6	7
5	Russell/Sycamore	1558.5	5	2,611.4	11	111.3	5
6	Anderson/Villanova	1513.1	6	2,215.6	12	72.2	31
7	Anderson/8th	1447.3	7	2,702.0	9	83.5	25
8	5th/F St.	1408.6	8	1,617.2	17	111.9	4
9	Cowell/Research Park West	1305.0	9	3,299.3	5	110.1	6
10	5th/Pole Line	1284.1	10	1,694.1	16	99.6	12
11	Cowell/Pole Line	1271.8	11	853.0	21	75.3	30
12	5th/L St.	1266.8	12	1,701.2	15	97.6	16
13	Richards/Olive	1238.0	13	3,574.3	3	103.0	9
14	Russell/Arthur	1206.0	14	1,788.3	13	75.4	29
15	Cowell/Drew	1202.4	15	2,645.6	10	98.1	15
16	Anderson/Rutgers	1183.5	16	1,705.9	14	76.8	27
17	Richards/1st	1120.8	17	3,145.7	6	99.4	14
18	5th/G St.	1106.4	18	1,209.8	19	138.3	1
19	Cowell/Valdora	1062.0	19	1,584.2	18	88.0	24
20	1st/D St.	1012.1	20	3,509.6	4	92.0	20
21	Covell/Pole Line	963.3	21	581.9	22	111.9	3
22	Mace/2nd	898.9	22	518.5	23	112.7	2
23	Mace/Chiles	847.4	23	420.3	24	99.5	13
24	8th/F St.	775.9	24	992.7	20	93.2	18
25	Covell/F St.	605.1	25	300.0	29	100.8	11
26	Mace/Cowell	600.2	26	375.6	25	91.9	21
27	Pole Line/Loyola	553.4	27	331.5	26	92.2	19
28	F St./14th	450.1	28	286.4	30	76.6	28
29	Mace/Alhambra	428.7	29	146.2	32	47.5	33
30	Covell/Sycamore	385.4	30	323.5	27	91.2	23
31	Covell/Shasta	327.4	31	310.9	28	91.4	22
32	Covell/John Jones	298.5	32	162.2	31	82.6	26
33	Covell/J St.	277.0	33	128.8	33	50.3	32
34	Covell/Alhambra	188.0	34	68.8	34	38.7	34

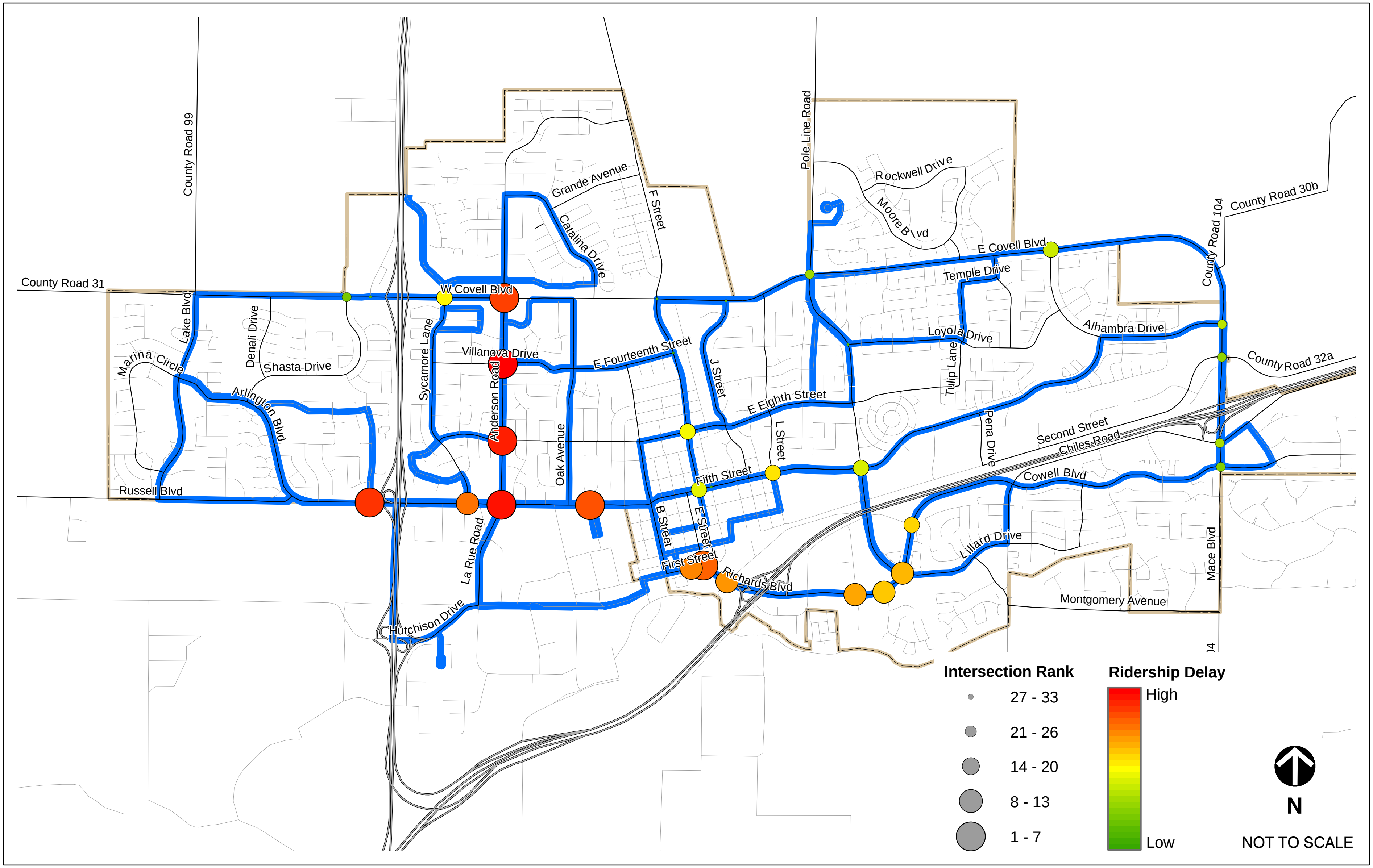
Notes:

Candidate Corridor #1: Russell Boulevard - Sycamore Lane to Howard Way

Candidate Corridor #2: Richards Boulevard/Cowell Boulevard - First Street to Pole Line Road

Total transit delay calculated by multiplying the number of transit vehicles passing through each intersection by the average delay at each intersection.

Total passenger delay calculated by multiplying the number of passengers by the average delay at each intersection.



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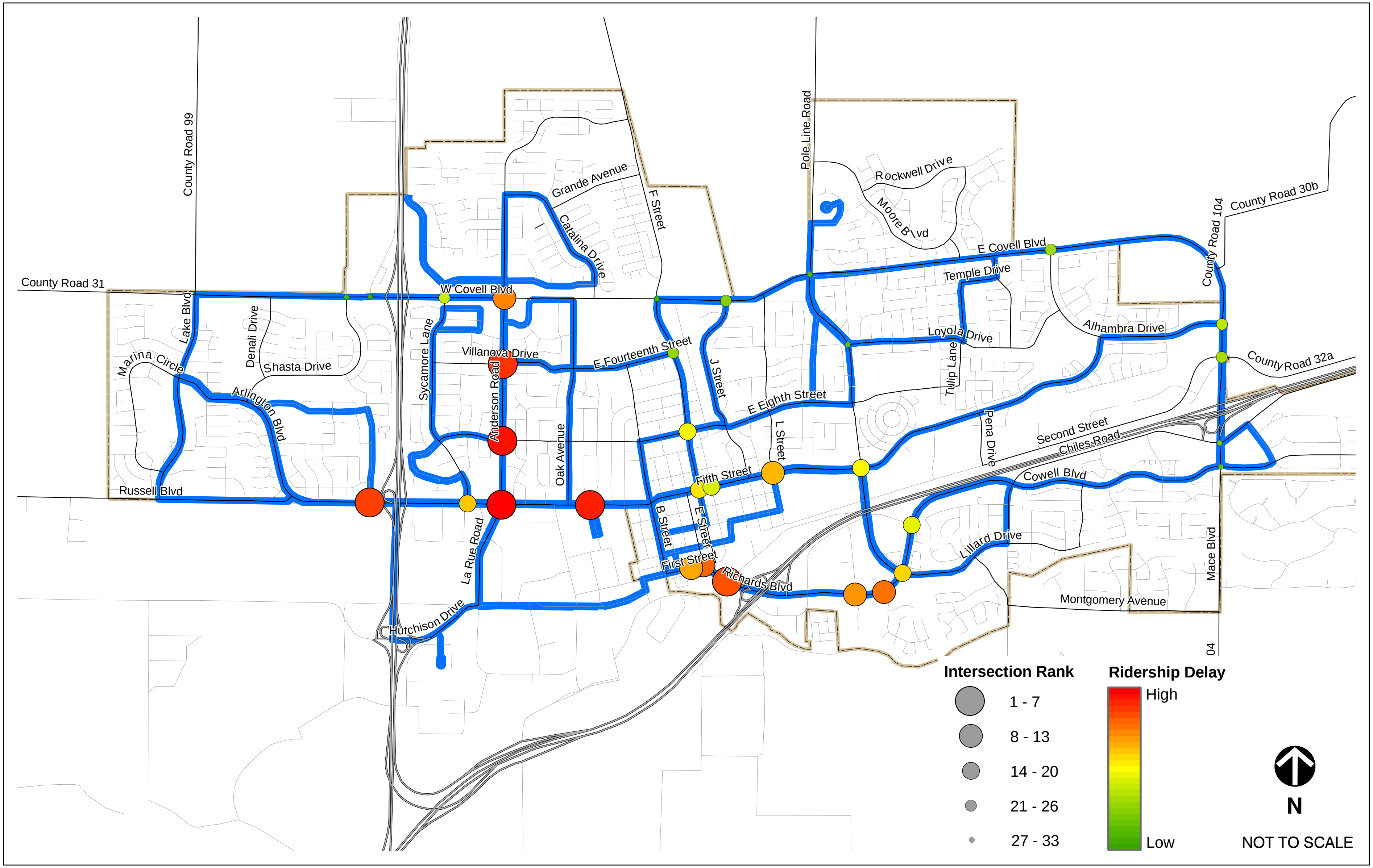
AM PERIOD 7:30 - 8:30
INTERSECTION RANKING AND RIDERSHIP DELAY

FIGURE 1



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PM PERIOD 4:30 - 5:30
INTERSECTION RANKING AND RIDERSHIP DELAY
FIGURE 2

Coordinated traffic signals are defined as intersections that operate with a common cycle length. Detectors on the side street approaches and main street left-turn movements are used by the signal controller to provide green time when a "vehicle call" is detected until a maximum green time is reached. In addition, pedestrian push buttons are used to provide sufficient green time to cross the street when a "ped call" is sent to the signal controller. Any unused green time is given to the main-street "coordinated" phase until the cycle length is reached.

For example, during the morning peak period these three intersections operate with a 75 second cycle length, resulting in 48 cycles each hour (3,600 / 75 = 48). During the evening peak period, these three intersections operate with a 91 second cycle length, resulting in 39.56 cycles each hour (3,600 / 91 = 39.56).

During both morning and evening peak period conditions, the following five intersections operate as actuated / uncoordinated traffic signals:

- Sycamore Lane / Russell Boulevard;
- Anderson Road / La Rue Road / Russell Boulevard;
- Oak Avenue / Russell Boulevard;
- College Park / Howard Way / Russell Boulevard; and
- A Street / / Russell Boulevard.

Actuated uncoordinated traffic signals are defined as intersections that operate with a varying cycle length base on traffic demand until a maximum green time is reached. Detectors on the all movements are used by the signal controller to provide green time when a "vehicle call" is detected. In addition, pedestrian push buttons are used to provide sufficient green time to cross the street when a "ped call" is sent to the signal controller.

For example, during the morning peak period the intersection of Sycamore Lane / Russell Boulevard operates with an actuated uncoordinated cycle length of up to 114.8 seconds. But the average (50^{th} percentile) cycle length is 35.2 seconds and the 90^{th} percentile cycle length is 49.5 seconds. During the evening peak period, the intersection of Sycamore Lane / Russell Boulevard also operates with an actuated uncoordinated cycle length of up to 114.8 seconds. But the average cycle length is 47.6 seconds and the 90^{th} percentile cycle length is 72.9 seconds.

In addition, a pedestrian signal is located at the California Avenue / Russell Boulevard intersection. When a pedestrian call is sent to the signal controller, the eastbound / westbound Russell Boulevard through movements have a flashing yellow indication.

Richards Boulevard / Cowell Boulevard Corridor

During both morning and evening peak period conditions, the following four intersections operate as coordinated traffic signals:

- 1st Street / D Street;
- 1st Street / E Street / Richards Boulevard;
- Olive Drive / Richards Boulevard; and
- Eastbound I-80 Ramps / Richards Boulevard;

During both morning and evening peak period the three intersections on Richards Boulevard operate with a 120 second cycle length, resulting in 30 cycles each hour (3,600 / 120 = 30). The intersection of 1st Street / D Street operates with a 60 second cycle length, a signal timing strategy used by traffic engineers referred to as "a half cycle".

During both morning and evening peak period conditions, the following four intersections operate as actuated / uncoordinated traffic signals:

- Research Park Drive / Richards Boulevard / Cowell Boulevard;
- Drew Avenue / Cowell Boulevard;
- Valdora Street / Cowell Boulevard; and
- Pole Line Road / Cowell Boulevard.

For example, during the morning peak period the intersection of Research Park Drive / Richards Boulevard / Cowell Boulevard operates with an actuated uncoordinated cycle length of up to 127 seconds. But the average (50th percentile) cycle length is 80.4 seconds and the 90th percentile cycle length is 93.0 seconds. During the evening peak period, the intersection of Sycamore Lane / Russell Boulevard also operates with an actuated uncoordinated cycle length of up to 127 seconds. But the average cycle length is 84.7 seconds and the 90th percentile cycle length is 97.4 seconds.

SIGNAL COORDINATION STRATEGY

Before evaluating transit signal priority, we evaluated the following signal coordination strategies for the two study corridors.

- Operate the entire corridor with a common coordinated cycle length;
- Partition the network and operate the corridor with two or more coordinated cycle lengths;
- Partition the network and operate the corridor with both coordinated and uncoordinated cycle lengths.

Russell Boulevard Corridor

Table 2 presents the transit routes, on-time performance, and transit vehicle movements though the following signalized study intersections:

- College Park / Howard Way / Russell Boulevard;
- Oak Avenue / Russell Boulevard;
- Anderson Road / Larue Road / Russell Boulevard;
- Sycamore Lane / Russell Boulevard;
- NB SR 113 On/Off-Ramps / Russell Boulevard. and
- SB SR 113 On/Off-Ramps / Russell Boulevard.

Based on a series of "what if" analysis for both AM and PM peak hour conditions, it was determined that a combination of coordinated cycle lengths between Arthur Road and the NB SR 113 On-Off-Ramps signalized intersections (75 AM and 90 PM) and uncoordinated (100 AM and PM) between Sycamore Lane and A Street provided the best performance for general traffic and transit vehicles.

Table 2
Russell Corridor Intersections –
Ranked Based on Total Transit Vehicle Delay

Intersection	Overall Rank[1]	Transit Routes	Route On-Time Performance[2]	Movement Through Intersection
Russell Boulevard / Howard Way	1	B, F, G, K	B – 99%; F – 98%; G – 95%; K – 97%	NB Left, EB Right
		E, M	E – 94%; M – 99%	NB Right, WB Left
		P, 42B	P – 93%	NB Right, EB Right
		Q, 42A	Q – 82%	NB Left, WB Left
Russell Boulevard / Oak Avenue	N/A	B, G, K	B – 99%; G – 95%; K – 97%	EB Through, WB Through
		P, 42B	P – 93%	EB Through
		Q, 42A	Q – 82%	WB Through
		F	98%	SB Left, WB Right
Russell Boulevard / California Avenue	N/A	B, G, K	B – 99%; G – 95%; K – 97%	EB Through, WB Through
		P, 42B	P – 93%	EB Through
		Q, 42A	Q – 82%	WB Through

Notes: [1]Overall rank based on total passenger delay (min.) experienced during the AM, Midday, and PM peak hours; transit vehicle delay data collected by Unitrans on October 18-22, 2010; total transit vehicle delay calculated by multiplying the number of transit buses traveling through an intersection by the average delay at that intersection

[2]Based on On-Time Performance Statistics from Unitrans for October 2010.

Source: Unitrans, October 2010.

Table 2
Russell Corridor Intersections –
Ranked Based on Total Transit Vehicle Delay

Intersection	Overall Rank[1]	Transit Routes	Route On-Time Performance[2]	Movement Through Intersection
Russell Boulevard / Anderson Road – La Rue Road	2	B, K	B – 99%; K – 97%	EB Through, WB Through
		C	98%	NB Through, EB Right
		G	95%	SB Left, WB Right
		J	80%	NB Through, SB Through
		P	93%	EB Through
		Q	82%	WB Through
		42A	-	WB Right
		42B	-	SB Left
Russell Boulevard / Sycamore Lane	5	B	99%	SB Left, WB Right
		C	98%	SB Left
		K	97%	EB Through, WB Through
		P	93%	EB Through
		Q	82%	WB Through
Russell Boulevard / SR 113 NB Ramps	N/A	D	99%	NB Left
		K	97%	EB Through, WB Through
		P	93%	EB Through
		Q	82%	WB Through
Russell Boulevard / SR 113 SB Ramps	N/A	D	99%	EB Through, WB Right
		K	97%	EB Through, WB Through
		P	93%	EB Through
		Q	82%	WB Through
Russell Boulevard / Arthur Street	14	D	99%	EB Through, WB Through
		K	97%	SB Left, WB Through
		P	93%	EB Through
		Q	82%	WB Through

Notes: [1]Overall rank based on total passenger delay (min.) experienced during the AM, Midday, and PM peak hours; transit vehicle delay data collected by Unitrans on October 18-22, 2010; total transit vehicle delay calculated by multiplying the number of transit buses traveling through an intersection by the average delay at that intersection

[2]Based on On-Time Performance Statistics from Unitrans for October 2010.

Source: Unitrans, October 2010.

Richards Boulevard / Cowell Boulevard Corridor

Table 3 presents the transit routes, on-time performance, and transit vehicle movements though the following signalized study intersections:

- 1st Street / D Street;
- 1st Street / E Street / Richards Boulevard;
- Olive Drive / Richards Boulevard; and
- Eastbound I-80 Ramps / Richards Boulevard;
- Research Park Drive / Richards Boulevard / Cowell Boulevard;
- Drew Avenue / Cowell Boulevard;
- Valdora Street / Cowell Boulevard; and
- Pole Line Road / Cowell Boulevard

Based on a series of "what if" analysis for both AM and PM peak hour conditions, it was determined that a combination of coordinated cycle lengths between 1st Street / E Street and the eastbound I-80 On/Off-Ramp signalized intersections (120 both AM and PM) and uncoordinated (90 AM and 90/120PM) between Research Park Drive and Pole Line Road provided the best performance for general traffic and transit vehicles.

TRANSIT SIGNAL PRIORITY

A key discussion item before we discuss the types of transit signal priority that were analyzed in VISSIM is the fundamental difference between signal preemption and transit signal priority. During preemption, regardless of where the signal is in its operation, a vehicle is automatically provided with a green signal indication, resulting in a major impact to overall traffic operations.

On the other hand, transit signal priority is a traffic engineering strategy that provides a higher percentage of green time when needed, but it is not always provided a green indication. Under priority, a request for priority is sent from the Unitrans vehicle to the signal controller. The signal controller then determines if the request should be accommodated based on pre-determined parameters (i.e. whether the transit vehicle is behind schedule or priority was provided on the last cycle for the same approach). The types of signal priority that are used:

- A transit vehicle could be provided with a "green extension" (of 5 to 10 seconds) that would aid transit operations and far side stop operations. Of all the transit signal priority strategies being used in the traffic engineering industry, this is the most common and also the most effective form of transit signal priority. This is also the type of transit signal priority being evaluated in this study at the eight (8) study intersections on Russell Boulevard and the eight (8) intersections on Richards Boulevard / Cowell Boulevard.

Table 3
Richards – Cowell Corridor Intersections –
Ranked Based on Total Transit Vehicle Delay

Intersection	Overall Rank[1]	Transit Routes	Route On-Time Performance[2]	Movement Through Intersection
First Street / D Street	20	M	99%	WB Through
		W	93%	EB Through, WB Through
First Street / E Street – Richards Boulevard	17	M	99%	NB Left
		W	93%	NB Left, EB Right
Richards Boulevard / Olive Drive	13	M	99%	WB Through
		W	93%	EB Through, WB Through
Richards Boulevard / I-80 EB Ramps	N/A	M	99%	WB Through
		W	93%	EB Through, WB Through
Richards Boulevard – Cowell Boulevard / Research Park Drive	9	M	99%	WB Through
		W	93%	EB Through, WB Through
Cowell Boulevard / Drew Avenue	15	M	99%	WB Through
		W	93%	EB Through, WB Through
Cowell Boulevard / Valdora Street	19	M	99%	WB Through
		W	93%	EB Through, WB Through
Cowell Boulevard / Pole Line Road – Lillard Drive	11	M	99%	EB Right
		P	93%	EB Left
		Q	93%	SB Right
		W	82%	NB Right, SB Through

Notes: [1]Overall rank based on total passenger delay (min.) experienced during the AM, Midday, and PM peak hours; transit vehicle delay data collected by Unitrans on October 18-22, 2010; total transit vehicle delay calculated by multiplying the number of transit buses traveling through an intersection by the average delay at that intersection

[2]Based on On-Time Performance Statistics from Unitrans for October 2010.

Source: Unitrans, October 2010.

- A transit vehicle could be provided with an “early green” arriving during a red phase. This transit signal priority strategy would terminate the green phases for other movements by reducing the “minimum gap” (i.e. from 3 to 1 second) in order to reduce the stop time of the transit vehicle. Please note that this transit signal priority strategy was not included in this study.

- A transit vehicle could be provided an earlier green phase with a “phase rotation” strategy that changes the order of specific phases in order to reduce the stop time for the transit vehicle. For example, instead of providing a leading left-turn for the opposing direction, the through phase for the transit vehicle would be rotated to go first. Please note that this transit signal priority strategy was not included in this study.

- Lastly, a transit vehicle can be provided a special indication with a "phase insertion". This transit signal priority strategy is also referred to as a "queue jump" and is used to reduce the stop time for the transit vehicle. Based on our analysis of the Richards Boulevard / Cowell Boulevard intersection, a phase insertion strategy was included for westbound Richards Boulevard at Olive Drive. For the M and W transit lines, the ability for transit vehicles to serve the near-side transit stop and merge back into the through lane results in significant delays and on-time performance. Therefore, a "phase insertion" transit signal priority strategy for vehicles that are behind schedule was tested at this location.

EXISTING DATA INVENTORY

A variety of traffic data was collected for this project, including peak period turning movement traffic counts, signal timing plans, and field observations of traffic operations on Russell Boulevard and Richards / Cowell Boulevard Corridors.

Peak Hour Traffic Counts

The May 2011 intersection turning movement counts were collected during the AM (7:00 to 9:00), and PM (4:00-6:00) peak periods.

Figure 3 presents the AM and PM peak hour traffic volumes and lane configurations for the Russell Boulevard Corridor and Figure 4 presents the AM and PM peak hour traffic volumes and lane configurations for the Richards Boulevard / Cowell Boulevard Corridor.

Existing Conditions Analysis

The existing intersection volumes, traffic control (e.g., signal timings), and geometrics were used to evaluate intersection operations for Existing Conditions. The VISSIM software package used to evaluate LOS at the study intersections is consistent with Highway Capacity Manual (HCM) 2000 methodologies. Table 4 summarizes the relationships between the average control delay per vehicle and LOS for signalized intersections. At signalized intersections, LOS is based on the weighted average control delay of all movements measured in seconds per vehicle. Peak hour traffic volumes, lane configurations, and signal timing plans are used as inputs in the LOS calculations.

TRAFFIC OPERATIONS ANALYSIS METHODOLOGY

The following methodology was used to analyze intersection traffic operations.

- All intersection operations analyses were conducted using procedures and methodologies contained in the Highway Capacity Manual (HCM), Transportation Research Board, 2000. These methodologies were applied using the VISSIM microsimulation software.
- For signalized intersections, the overall average delay and LOS are reported.
- The truck percentage of 2 percent by approach was used.

Table 4
Signalized Intersection Level of Service (LOS) Criteria

LOS	Description	Average Control Delay (seconds/vehicle)
A	Operations with very low delay occurring with favorable progression and/or short cycle length.	$\leq$ 10
B	Operations with low delay occurring with good progression and/or short cycle lengths.	> 10 to 20
C	Operations with average delays resulting from fair progression and/or longer cycle lengths. Individual cycle failures begin to appear.	> 20 to 35
D	Operations with longer delays due to a combination of unfavorable progression, long cycle lengths, or high volume-to-capacity ratios. Many vehicles stop and individual cycle failures are noticeable.	> 35 to 55
E	Operations with high delay values indicating poor progression, long cycle lengths, and high volume-to-capacity ratios. Individual cycle failures are frequent occurrences. This is considered to be the limit of acceptable delay.	> 55 to 80
F	Operation with delays unacceptable to most drivers occurring due to over saturation, poor progression, or very long cycle lengths.	> 80

Source: *Highway Capacity Manual* (Transportation Research Board, 2000)

The following methodology was used to analyze intersection traffic operations (continued).

- The pedestrian volumes from the traffic counts were entered as conflicting traffic for right turns and left turns, where left turns are permitted, and as pedestrian calls to the pedestrian signal phase.
- The arterial speed was set to the posted speed limit.
- Traffic control information was added from signal timing sheets provided by the City of Davis and from field observations of signal operation.
- Lane configuration and roadway geometry was gathered from aerial photographs and field observations.
- The traffic analysis calibration targets were to be within 5 percent of the overall intersection traffic volume.
- The simulation analysis used a seeding interval of 15 minutes followed by an analysis interval of four 15 minute intervals.
- The analysis results are an average of 24 VISSIM runs to incorporate variations in traffic flow, pedestrian calls, and transit operations.

VISSIM MODEL DEVELOPMENT

The first step of existing operations analysis was to calibrate / validate the existing VISSIM models to ensure that they reflect existing traffic volumes, lane geometrics, and signal timings. The VISSIM model was then calibrated and validated to the traffic volume and field observed vehicle queues. Table 5 shows that the average volume served for study intersections obtained from the model is 99 percent or higher than the counted volume which is also within the validation criteria.

Table 5
Intersection Volume Served Percentages

Intersection	Control	Volume Served from VISSIM Models versus Collected Counts (%)	
		AM	PM
1. Arthur Road / Russell Boulevard	Signal	100%	99%
2. SB SR 113 On/Off-Ramps / Russell Boulevard	Signal	100%	100%
3. NB SR 113 On/Off-Ramps / Russell Boulevard	Signal	100%	100%
4. Sycamore Lane / Russell Boulevard	Signal	99%	100%
5. Anderson Road / La Rue Road / Russell Boulevard	Signal	100%	100%
6. Oak Avenue / Russell Boulevard	Signal	100%	99%
7. College Park / Howard Way / Russell Boulevard	Signal	99%	100%
8. A Street / Russell Boulevard	Signal	100%	100%
9. 1st Street / D Street	Signal	100%	100%
10. 1st Street / E Street / Richards Boulevard	Signal	100%	100%
11. Olive Drive / Richards Boulevard	Signal	99%	100%
12. EB I-80 On/Off-Ramps / Richards Boulevard	Signal	100%	100%
13. Research Park Drive / Richards – Cowell Boulevard	Signal	100%	100%
14. Drew Avenue / Cowell Boulevard	Signal	99%	100%
15. Valdora Street / Cowell Boulevard	Signal	100%	100%
16. Pole Line Road / Cowell Boulevard	Signal	100%	100%

Notes: Volume served is obtained from the Existing VISSIM models.
Source: Fehr & Peers, 2011.

EXISTING NETWORK WIDE ANALYSIS RESULTS

Table 6 presents the network-wide performance for Existing AM and PM Peak Hour Conditions for the Russell Corridor, and Table 7 presents the network-wide performance for Existing AM and PM Peak Hour Conditions for the Richards Boulevard / Cowell Boulevard Corridor. These results will serve as the basis of determining the benefits of the development and analysis of efficient signal timing plans and transit signal priority strategies for AM and PM Peak Hour Conditions.

Table 6
Existing Network Wide Analysis Results – Russell Boulevard Corridor

	AM	PM
Vehicle Hours of Delay (VHD – Hours)	44.9	71.4
Stops	5,345	7,387
Fuel Consumption (Gallons)	228.5	294.2
CO2 Emissions (lbs)	4,342	5,590
EB Travel Speed for all vehicles (MPH)	21	19
WB Travel Speed for all vehicles (MPH)	21	19

Source: Fehr & Peers, 2011.

Table 7
Existing Network Wide Analysis Results – Richards / Cowell Boulevard Corridor

	AM	PM
Vehicle Hours of Delay (VHD – Hours)	61.0	112.2
Stops	6,499	9,923
Fuel Consumption (Gallons)	204.4	278.0
CO2 Emissions (lbs)	3,884	5,282
EB Travel Speed for all vehicles (MPH)	15	14
WB Travel Speed for all vehicles (MPH)	14	13

Source: Fehr & Peers, 2011.

EXISTING LEVEL OF SERVICE ANALYSIS RESULTS

Table 8 shows the intersection operations analysis results for study intersections under existing conditions.

During the weekday AM peak hour, a majority of study intersections operate at LOS C or better, and only three intersections (Elk Grove Boulevard / Franklin Boulevard, Elk Grove Boulevard / E. Stockton Boulevard / Emerald Vista Drive, and Whitelock Parkway / Franklin High Road) operates at LOS D. All 34 study intersections currently operate at an acceptable level of service during the AM peak hour.

During the PM peak hour, a majority of study intersections also operate at LOS C or better, and the same three intersections (Elk Grove Boulevard / Franklin Boulevard, Elk Grove Boulevard / Bruceville Road, and Elk Grove Boulevard / E. Stockton Boulevard / Emerald Vista Drive) also operates at LOS D. Similar to AM and MID peak hour conditions, all 34 study intersections currently operate at an acceptable level of service during the PM peak hour.

Table 8
Intersection Peak Hour Level of Service Operations - Existing Conditions

Intersection	Control	LOS[1] /Delay[2]	
		AM	PM
1. Arthur Road / Russell Boulevard	Signal	16.2 / B	14.9 / B
2. SB SR 113 On/Off-Ramps / Russell Boulevard	Signal	6.2 / A	4.7 / A
3. NB SR 113 On/Off-Ramps / Russell Boulevard	Signal	12.0 / B	19.6 / B
4. Sycamore Lane / Russell Boulevard	Signal	7.8 / A	12.0 / B
5. Anderson Road / La Rue Road / Russell Boulevard	Signal	25.1 / C	30.2 / C
6. Oak Avenue / Russell Boulevard	Signal	3.9 / A	5.1 / A
7. College Park / Howard Way / Russell Boulevard	Signal	14.4 / B	19.1 / B
8. A Street / Russell Boulevard	Signal	6.9 / A	7.0 / A
9. 1st Street / D Street	Signal	6.4 / A	13.7 / B
10. 1st Street / E Street / Richards Boulevard	Signal	20.2 / C	33.1 / C
11. Olive Drive / Richards Boulevard	Signal	10.4 / B	19.7 / B
12. EB I-80 On/Off-Ramps / Richards Boulevard	Signal	30.9 / C	43.9 / D
13. Research Park Drive / Richards – Cowell Boulevard	Signal	16.2 / B	25.1 / C
14. Drew Avenue / Cowell Boulevard	Signal	9.2 / A	14.6 / B
15. Valdora Street / Cowell Boulevard	Signal	16.2 / B	10.1 / B
16. Pole Line Road / Cowell Boulevard	Signal	15.4 / B	16.8 / B

Notes: 1. LOS = level of service
2. Average intersection delay is reported in seconds per vehicle.
Source: Fehr & Peers, 2011.

FINAL IMPROVED SIGNAL COORDINATION AND TRANSIT SIGNAL PRIORITY NETWORK WIDE ANALYSIS RESULTS - RUSSELL CORRIDOR

Tables 9 and 10 presents the network-wide performance results for the Final Improved Signal Coordination and Transit Signal Priority AM and PM peak hour conditions, respectively. The results of the transit signal priority project shows that all six major criteria used to evaluate the proposed implementation of improved signal coordination and transit signal priority would either remain unchanged or would be marginally reduced. More importantly, the analysis shows that the implementation of "green extension" transit signal priority would not adversely impact overall traffic operations or travel times on Russell Boulevard.

Table 9
Final Improved Signal Coordination and Transit Signal Priority
Network Wide Analysis Results – Russell Boulevard Corridor – AM Peak Hour

	Existing AM	Improved AM with Transit Signal Priority
Vehicle Hours of Delay (VHD – Hours)	44.9	43.9
Stops	5,345	5,288
Fuel Consumption (Gallons)	228.5	228.2
CO2 Emissions (lbs)	4,342	4,336
EB Travel Speed for all vehicles (MPH)	21	21
WB Travel Speed for all vehicles (MPH)	21	21

Source: Fehr & Peers, 2011.

Table 10
Final Improved Signal Coordination and Transit Signal Priority
Network Wide Analysis Results – Russell Boulevard Corridor – PM Peak Hour

	Existing PM	Improved \PM with Transit Signal Priority
Vehicle Hours of Delay (VHD – Hours)	71.4	71.2
Stops	7,387	7,423
Fuel Consumption (Gallons)	294.2	293.3
CO2 Emissions (lbs)	5,590	5,573
EB Travel Speed for all vehicles (MPH)	19	19
WB Travel Speed for all vehicles (MPH)	19	19

Source: Fehr & Peers, 2011.

FINAL IMPROVED SIGNAL COORDINATION AND TRANSIT SIGNAL PRIORITY LEVEL OF SERVICE ANALYSIS RESULTS - RUSSELL CORRIDOR

Tables 11 and 12 presents the intersection operations analysis results for the Final Improved Signal Coordination and Transit Signal Priority AM and PM peak hour conditions, respectively.

Table 11
Intersection Peak Hour Level of Service Operations
Final Improved Signal Coordination and Transit Signal Priority
Russell Boulevard Corridor – AM Peak Hour Conditions

Intersection	Control	LOS[1] /Delay[2]	
		Existing AM	Improved AM with Transit Signal Priority
1. Arthur Road / Russell Boulevard	Signal	16.2 / B	15.5 / B
2. SB SR 113 On/Off-Ramps / Russell Boulevard	Signal	6.2 / A	6.1 / A
3. NB SR 113 On/Off-Ramps / Russell Boulevard	Signal	12.0 / B	11.6 / B
4. Sycamore Lane / Russell Boulevard	Signal	7.8 / A	7.4 / A
5. Anderson Road / La Rue Road / Russell Boulevard	Signal	25.1 / C	24.6 / C
6. Oak Avenue / Russell Boulevard	Signal	3.9 / A	3.9 / A
7. College Park / Howard Way / Russell Boulevard	Signal	14.4 / B	14.2 / B
8. A Street / Russell Boulevard	Signal	6.9 / A	7.2 / A

Notes: 1. LOS = level of service
2. Average intersection delay is reported in seconds per vehicle.
Source: Fehr & Peers, 2011.

During AM peak hour conditions, the results of the intersection level of service analysis show that the eight signalized intersections on Russell Boulevard will continue to operate at the same level of service with six intersection having average vehicle delays decrease, one remain the same, and one intersection having the average vehicle delay increase marginally by 0.3 seconds.

During PM peak hour conditions, the results of the intersection level of service analysis show that the eight signalized intersections on Russell Boulevard will also continue to operate at the same level of service with three intersection having average vehicle delays decrease, three remain the same, and two intersections having the average vehicle delay increase marginally by 0.1 to 0.3 seconds.

Table 11
Intersection Peak Hour Level of Service Operations
Final Improved Signal Coordination and Transit Signal Priority
Russell Boulevard Corridor – PM Peak Hour Conditions

Intersection	Control	LOS[1] /Delay[2]	
		Existing PM	Improved PM with Transit Signal Priority
1. Arthur Road / Russell Boulevard	Signal	14.9 / B	14.9 / B
2. SB SR 113 On/Off-Ramps / Russell Boulevard	Signal	4.7 / A	4.5 / A
3. NB SR 113 On/Off-Ramps / Russell Boulevard	Signal	19.6 / B	19.6 / B
4. Sycamore Lane / Russell Boulevard	Signal	12.0 / B	11.9 / B
5. Anderson Road / La Rue Road / Russell Boulevard	Signal	30.2 / C	30.5 / C
6. Oak Avenue / Russell Boulevard	Signal	5.1 / A	5.0 / A
7. College Park / Howard Way / Russell Boulevard	Signal	19.1 / B	19.2 / B
8. A Street / Russell Boulevard	Signal	7.0 / A	7.0 / A

Notes: 1. LOS = level of service
2. Average intersection delay is reported in seconds per vehicle.
Source: Fehr & Peers, 2011.

FINAL IMPROVED SIGNAL COORDINATION AND TRANSIT SIGNAL PRIORITY NETWORK WIDE ANALYSIS RESULTS RICHARDS BOULRVARD / COWELL BOULEVARD CORRIDOR

Tables 13 and 14 presents the network-wide performance for the Final Improved Signal Coordination and Transit Signal Priority AM and PM peak hour conditions, respectively. For the Richards Boulevard / Russell Boulevard Corridor, we analyzed the proposed “phase insertion” queue jump phase for the westbound Richards Boulevard / Olive Drive approach. For the M and W transit lines, the ability for transit vehicles to serve the near-side transit stop and merge back into the through lane results in significant delays and on-time performance. Therefore, a “phase insertion” transit signal priority strategy for vehicles that are behind schedule was tested at this location.

Table 13 shows that the transit signal priority signal coordination project would result in all six major criteria used to evaluate the proposed implementation of improved signal coordination and transit signal priority remaining unchanged or marginally reduced during the morning peak hour. In addition, the analysis shows that the implementation of “green extension” transit signal priority would not adversely impact overall traffic operations or travel times on Russell Boulevard.

Table 13 also shows that the implementation of the queue jump lane for the westbound approach to the Olive Drive / Richards Boulevard intersection would not impact traffic flow and would significantly improve Journey Time Reliability (JTR) for Unitrans routes M and W.

Table 13
Final Improved Signal Coordination and Transit Signal Priority
Network Wide Analysis Results – Richards Boulevard / Russell Boulevard Corridor
AM Peak Hour

	Existing AM	Improved AM with Transit Signal Priority	Improved AM with Transit Signal Priority & Queue Jump
Vehicle Hours of Delay (VHD – Hours)	61.0	57.0	59.5
Stops	6,499	6,282	6,488
Fuel Consumption (Gallons)	204.4	200.9	204.4
CO2 Emissions (lbs)	3,884	3,817	3,884
EB Travel Speed for all vehicles (MPH)	15	15	15
WB Travel Speed for all vehicles (MPH)	14	14	14

Source: Fehr & Peers, 2011.

Table 14
Final Improved Signal Coordination and Transit Signal Priority
Network Wide Analysis Results – Richards Boulevard / Russell Boulevard Corridor
PM Peak Hour

	Existing PM	Improved PM with Transit Signal Priority	Improved PM with Transit Signal Priority & Queue Jump
Vehicle Hours of Delay (VHD – Hours)	112.2	95.9	99.6
Stops	9,923	9,489	9,719
Fuel Consumption (Gallons)	278.0	270.4	275.2
CO2 Emissions (lbs)	5,282	5,138	5,229
EB Travel Speed for all vehicles (MPH)	14	14	14
WB Travel Speed for all vehicles (MPH)	13	14	13

Source: Fehr & Peers, 2011.

Table 14 shows that the transit signal priority signal coordination project would result in all six major criteria used to evaluate the proposed implementation of improved signal coordination and transit signal priority remaining unchanged or marginally reduced during the evening peak hour. In addition, the analysis shows that the implementation of "green extension" transit signal priority would not adversely impact overall traffic operations or travel times on Russell Boulevard.

Table 14 also shows that the implementation of the queue jump lane for the westbound approach to the Olive Drive / Richards Boulevard intersection would not impact traffic flow and would significantly improve Journey Time Reliability (JTR) for Unitrans routes M and W.

Table 14
Final Improved Signal Coordination and Transit Signal Priority
Network Wide Analysis Results – Richards Boulevard / Russell Boulevard Corridor
PM Peak Hour

	Existing PM	Improved PM with Transit Signal Priority	Improved PM with Transit Signal Priority & Queue Jump
Vehicle Hours of Delay (VHD – Hours)	61.0	57.0	59.5
Stops	6,499	6,282	6,488
Fuel Consumption (Gallons)	204.4	200.9	204.4
CO2 Emissions (lbs)	3,884	3,817	3,884
EB Travel Speed for all vehicles (MPH)	15	15	15
WB Travel Speed for all vehicles (MPH)	14	14	14

Source: Fehr & Peers, 2011.

FINAL IMPROVED SIGNAL COORDINATION AND TRANSIT SIGNAL PRIORITY
LEVEL OF SERVICE ANALYSIS RESULTS
RICHARDS BOULRVARD / COWELL BOULEVARD CORRIDOR

Tables 15 and 16 presents the intersection operations analysis results for the Final Improved Signal Coordination and Transit Signal Priority AM and PM peak hour conditions, respectively.

During AM peak hour conditions, the results of the intersection level of service analysis show that the eight signalized intersections on Richards Boulevard / Cowell Boulevard will continue to operate at the same level of service with five intersection having average vehicle delays decrease and three intersections having the average vehicle delay increase marginally by 0.1 to 1.2 seconds.

Table 15 also shows that the implementation of the queue jump lane for the westbound approach to the Olive Drive / Richards Boulevard intersection would not impact intersection level of service conditions and the intersection would continue to operate at LOS B conditions, with only an average vehicle delay increase of 0.2 seconds during the morning peak hour.

Table 15
Intersection Peak Hour Level of Service Operations
Final Improved Signal Coordination and Transit Signal Priority
Richards Boulevard / Cowell Boulevard Corridor – AM Peak Hour Conditions

Intersection	Control	LOS[1] /Delay[2]		
		Existing AM	Improved AM with Transit Signal Priority	Improved AM with Transit Signal Priority & Queue Jump
1. 1st Street / D Street	Signal	6.4 / A	5.9 / A	6.0 / A
2. 1st Street / E Street / Richards Boulevard	Signal	20.2 / C	20.5 / C	20.7 / C
3. Olive Drive / Richards Boulevard	Signal	10.4 / B	11.6 / B	11.8 / B
4. EB I-80 On/Off-Ramps / Richards Boulevard	Signal	30.9 / C	26.6 / C	28.0 / C
5. Research Park Drive / Richards – Cowell Boulevard	Signal	16.2 / B	16.0 / B	16.1 / B
6. Drew Avenue / Cowell Boulevard	Signal	9.2 / A	9.3 / A	9.6 / A
7. Valdora Street / Cowell Boulevard	Signal	16.2 / B	15.8 / B	16.6 / B
8. Pole Line Road / Cowell Boulevard	Signal	15.4 / B	15.2 / B	15.4 / B

Notes: 1. LOS = level of service
2. Average intersection delay is reported in seconds per vehicle.
Source: Fehr & Peers, 2011.

Table 16
Intersection Peak Hour Level of Service Operations
Final Improved Signal Coordination and Transit Signal Priority
Richards Boulevard / Cowell Boulevard Corridor – PM Peak Hour Conditions

Intersection	Control	LOS[1] /Delay[2]		
		Existing PM	Improved PM with Transit Signal Priority	Improved PM with Transit Signal Priority & Queue Jump
1. 1st Street / D Street	Signal	13.7 / B	14.1 / B	14.4 / B
2. 1st Street / E Street / Richards Boulevard	Signal	33.1 / C	33.5 / C	31.9 / C
3. Olive Drive / Richards Boulevard	Signal	19.7 / B	18.9 / B	18.9 / B
4. EB I-80 On/Off-Ramps / Richards Boulevard	Signal	43.9 / D	28.8 / D	27.6 / D
5. Research Park Drive / Richards – Cowell Boulevard	Signal	25.1 / C	22.0 / C	23.2 / C
6. Drew Avenue / Cowell Boulevard	Signal	14.6 / B	14.4 / B	15.2 / B
7. Valdora Street / Cowell Boulevard	Signal	10.1 / B	10.2 / B	10.3 / B
8. Pole Line Road / Cowell Boulevard	Signal	16.8 / B	16.3 / B	16.5 / B

Notes: 1. LOS = level of service
2. Average intersection delay is reported in seconds per vehicle.
Source: Fehr & Peers, 2011.

During PM peak hour conditions, the results of the intersection level of service analysis show that the eight signalized intersections on Richards Boulevard / Cowell Boulevard will also continue to operate at the same level of service with five intersection having average vehicle delays decrease and three intersections having the average vehicle delay increase marginally by 0.1 to 0.4 seconds.

Table 16 also shows that the implementation of the queue jump lane for the westbound approach to the Olive Drive / Richards Boulevard intersection would not impact intersection level of service conditions and the intersection would continue to operate at LOS B conditions, with no change in the average vehicle delay during the evening peak hour.

CONCLUSIONS

Based on the detailed VISSIM microsimulation analysis completed for the Russell Boulevard and Richards Boulevard / Cowell Boulevard Corridors, the following conclusions were determined:

- Improving signal operations and coordination will benefit overall traffic flow and reduce stop and go conditions; therefore, the overall impact of transit signal priority on general traffic would be negligible.
- Vehicle emissions would be reduced and average travel speeds maintained with the implementation of “green extension” for approaching transit vehicles;
- The implementation of a “phase insertion / queue jump lane” for the westbound approach to the Olive Drive / Richards Boulevard intersection would not impact intersection level of service conditions, but would significantly improve Unitrans M and W Journey Time Reliability (JTR);
- The results of this analysis is consistent with national studies that show a large benefit to reducing transit delays, and a relatively small increase in general traffic delays.