Technical Memorandum

Downtown/Riverfront Streetcar Studies

City of West Sacramento

Service Criteria

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SERVICE CRITERIA

1.0 Description of Task

The Service Criteria task is intended to develop a higher level of knowledge about the alignment and stations for the West Sacramento Streetcar, define the service design for the system, and establish how the Streetcar would operate. There are several components of the Service Criteria task. First, the working assumptions used in this task for the project's alignment, station configuration and operating characteristics will be described. Second, the service design will be specified. Third, a timetable will be developed based on assumed station locations and expected running times. Fourth, from the preceding data, information will be developed on system capacity, and generalized operating and maintenance costs will be developed.

This task is intended to describe a reasonable basic system. In some cases options or ranges will be cited where future decisions may be needed.

2.0 Description of Assumptions

2.1 Alignment

The alignment assumed for the development of the Service Criteria task is for a Phase 1 project, which would serve as the basis for future expansion. The Phase 1 alignment assumed in this task serves the maximum number of potential development sites in West Sacramento, and connects with Sacramento destinations in a way that allows maximum use of existing Sacramento RT LRT trackage.

The alignment for this project is assumed to be as follows (see also Figure 1):

Westbound – The line's eastern terminus is a single-track stub terminal on K Street between 13th and 12th Streets in Sacramento, on a block that is now a pedestrian mall. The station platforms are assumed to be separate boarding and alighting platforms, which are provided on a short double-track segment between the junction with the RT light rail tracks at 12th Street and the single stub track. The short single stub track is used only for reversing purposes. This terminal configuration allows multiple cars to reverse and take recovery time at this location without negatively affecting other cars, a capability which may be needed because of the potential schedule issues created by the lift bridge over the Sacramento River.

From this point, the westbound alignment crosses the eastbound LRT tracks at K Street & 12th Street at grade with a new diamond crossing, and merges onto the RT LRT alignment on the K Street Mall, sharing track with LRT trains. The alignment follows K Street westerly to 7th

Street (crossing LRT tracks at grade at 8th Street), and turns south on 7th Street, still sharing the alignment with the RT LRT service. At Capitol Mall, the streetcar alignment diverges from the LRT tracks, and turns right (west) onto Capitol Mall (assumed center median operation – possible grass trackway). The alignment follows Capitol Mall west to and over the I-5 overpass to Old Town Station. Double track ends at the west end of the station, and the line becomes single track for the interlocked crossing of the Sacramento Southern Railroad and the Tower Bridge/Sacramento River. Single track continues west, to the west end of the Tower Bridge. Entering West Sacramento, the alignment returns to double track as soon as possible after leaving the Tower Bridge. The alignment turns south on South River Road, and continues to the intersection with the planned Garden Street. At this intersection, the alignment follows new right-of-way, crossing the site of the current Union Pacific (former Sacramento Northern) yard at an angle, and reaching the corner of Garden Street and West Capitol Street. Here, the alignment turns left onto West Capitol Avenue, and continues to Merkley, where the alignment turns left and terminates at a stub terminal adjacent to the future West Sacramento Transit Center. For purposes of taking recovery time, this terminal would also be configured with separate boarding and alighting platforms, with the stub track used only for the reversing move, similar to the terminal on K Street.

Eastbound - The eastbound alignment is the same as the westbound, with the exception of the portion between Capitol & 7th Street in Sacramento and K Street. The eastbound alignment continues on Capitol to 8th Street, where the alignment turns left onto 8th Street, merging onto RT LRT trackage at this point. The alignment continues north on 8th Street to K Street, where the alignment turns right onto K Street. At K Street and 12th Street, the alignment diverges from the LRT alignment, which turns left onto 12th Street. The streetcar alignment continues straight on K Street into the stub terminal described above.

Note: The exact alignment location in the Triangle Area, particularly on the proposed Garden Street, is subject to decisions on final street alignments. The streetcar alignment and station locations will be adjusted when final street alignment decisions are made.

2.2 Station locations

2.2.1 Station locations

Station locations are shown in Figure 2, and on the system map (Figure 1). In places where the Streetcar shares trackage with RT LRT services, the streetcars stop at the RT LRT stations, with specified boarding locations within the RT station areas. RT stations are sized for 4-car LRT trains, which are approximately 330 feet long, whereas a streetcar is approximately 50-75 feet long. At locations on trackage operated exclusively for the streetcar, new stations would be built at the locations shown in Figure 2 as "New".

Figure 1 –West Sacramento Streetcar Alignment – Phase 1

2.2.2 Distances between stations

The standard for station spacing on the West Sacramento Streetcar is between 1200 and 1400 feet between stations. This is approximately one-quarter mile (0.25 miles) between stations, which is a typical spacing for light rail circulator systems. Local bus systems typically have closer spacing (between 800-1000 feet), and modern line-haul light rail systems typically have longer spacings of up to one mile. A one-quarter mile spacing allows reasonable walking access to stations along the line. This spacing is similar to the existing RT LRT station spacing along the K Street Mall, but closer together than the typical RT station spacing on the line segments outside of downtown. I don't think this adds anything, and could be considered a detractor - Cam

2.2.3 Station Design

This analysis assumes simple station design with right-side boarding platforms in most locations, sized for single-car trains. This means that most stations would have two platforms; one for westbound cars and one for eastbound cars. At Old Town Station, due to potential space limitations within the street right-of-way, it may be desirable to have a shared center-island platform for boarding cars going both directions from the same platform. This would necessitate left side doors on all cars in the fleet, and left-side disabled boarding capability. If it is decided to procure cars with full left-handed boarding capability, then island platforms may be considered as alternatives where desirable in other locations. (Alternatively, as a less desirable alternative, left hand running could be considered in the exclusive right-of-way between Old Town and 8th Street, if necessary.)

The future decision on placement of the trackage within the street right-of-way will, to a large extent, determine the placement of the station boarding platforms. On four-lane arterials, if the trackage is placed in mixed traffic in the center lanes, then boarding islands must be placed in the street right-of-way between the travel lanes, with the outermost lanes weaving around the boarding islands. If the tracks are placed in the right lane of four-lane arterials, the platforms can be designed as sidewalk bulb-outs, similar to the bulb-outs used by the Portland Streetcar. On the Capitol Mall, it is assumed that the trackage is placed in the current grassed median, and that streetcars operate in an exclusive reserved median with right-side boarding platforms built within the median. The median could accommodate a grassed trackway, similar to aesthetic treatments in New Orleans, Bordeaux and Barcelona, so that the current appearance of the median is retained.

2.2.4 Disabled boarding

This paper assumes that disabled boarding will be handled in one of two ways, both relying on car-borne solutions. RT LRT relies on wayside ramps or lifts to allow disabled riders access to the cars. For the Sacramento Streetcar, disabled boarding will be handled through the use of onboard lifts if vintage or replica cars are used, or through carborne bridge ramps if new low floor

Figure 2 - Station Locations

WESTBOUND				
Item	**Location**	**New / Existing**	**Distance from Prior Location**	**Cumulative Distance (ft)**
Stub Terminal	K Street & 13th Street	New		
Station	K Street between 13th and 12th Streets	New	200	200
Station	K Street and 11th Street	Existing	800	1000
Station	K Street and 8th Street	Existing	1300	2300
Station	7th Street & Capitol	Existing	1300	3600
Station	Capitol & 4th Street	New	1350	4950
Station	Capitol & Old Town	New	1175	6125
Station	Raley Field - (South River Road & West Capitol)	New	1525	7650
Station	South River Road (1500 Ft So Of West Cap)	New	1250	8900
Station	Riske Lane - (South River Road & Riske Lane)	New	1350	10250
Station	Triangle - (UP/SN Yard)	New	1375	11625
Station	West Capitol - (West Capitol & Riske Lane)	New	1275	12900
Station	West Sacramento City Hall Transit Center	New	1375	14275
Stub Terminal	West Sacramento City Hall Transit Center	New	200	14475
	WB Subtotal		14475	
EASTBOUND				
Stub Terminal	West Sacramento City Hall Transit Center	New		
Station	West Sacramento City Hall Transit Center	New	200	200
Station	West Capitol - (West Capitol & Riske Lane)	New	1375	1575
Station	Triangle - (UP/SN Yard)	New	1275	2850
Station	Riske Lane - (South River Road & Riske Lane)	New	1375	4225
Station	South River Road (1500 Ft So Of West Cap)	New	1350	5575
Station	Raley Field - (South River Road & West Capitol)	New	1250	6825
Station	Capitol & Old Town	New	1525	8350
Station	Capitol & 4th Street	New	1175	9525
Station	Capitol & 7th Street	New	1350	10875
Station	K Street and 8th Street	Existing	1300	12175
Station	K Street and 11th Street	Existing	1300	13475
Station	K Street between 13th and 12th Streets	New	800	14275
Stub Terminal	K Street and 13th Street	New	200	14475
	EB Subtotal		14475	

streetcars are used, similar to Portland's streetcars. Both of these carborne solutions preclude the need to construct new wayside ramps or adapt RT's ramps and lifts for cars with different floor heights. Carborne solutions also allow the streetcar stops on the K Street Mall to be placed at the middle of the RT LRT stops, at specific intersections, which will assist passengers in identifying boarding locations. Not necessarily true: The stations on "K" are at the top of rail. They would have to be raised in order to use modern low-floor cars. This presents some possible clearance issues with RT's existing fleet of LRVs.

2.3 Track configuration

The optimal configuration for an urban streetcar system is to have all trackage be double-track right-of-way. This eliminates the need to schedule meets for vehicles proceeding in opposite directions, and allows maximum flexibility in scheduling, operations, and recovery from delays. The alignment for the Streetcar is assumed to be entirely double-track, except for the following locations:

- K Street between 12th and 13th Street – Short segment of single track at the stub terminal for reversing
- Capitol Mall/West Capitol Avenue from west of Old Town Station to west side of Tower Bridge – Single track assumed due to weight restrictions on the Tower Bridge and limitation of impacts on historic structure (approximately 1000' of single track)
- West Sacramento Transit Center – Short segment of single track at the stub terminal for reversing

Streetcar and light rail operations are very flexible, and can operate with trackage constructed in a variety of settings, from exclusive right-of-way through mixed traffic operation shared with general automobile traffic. This memo assumes that the track configuration on the Streetcar system is as shown in Figure 3. A schematic track diagram is included as Figure 4.

Figure 3 - Track Configuration

Segment	Track	Configuration
K Street	Double	Exclusive operation in transit mall
7th and 8th Streets	Double (split pair)	Left-side, mixed traffic operation on one-way couplet
Capitol Mall	Double	Exclusive operation in center median private right-of-way
Tower Bridge	Single	Exclusive operation in reserved center median
South River Drive	Double	Center lane, mixed traffic operation or side-of-road with bulbs
Garden Street	Double	Center lane, mixed traffic operation or side-of-road with bulbs
West Capitol Avenue	Double	Center lane, mixed traffic operation or side-of-road with bulbs
Merkley Drive	Double	Exclusive operation in reserved center median (assumed)

The Streetcar system will operate partially on trackage already constructed and operated by the Sacramento Regional Transit (RT) light rail transit (LRT) system, and the streetcars will share

Figure 4 - Track Diagram

trackage with RT LRT trains. Switching on and off of the RT LRT trackage will require construction of new junctions with some form of automatic switch control for facing point switches. Given the low speeds involved and the fact that the vehicles will be moving under traffic signal control, full interlocking may not be needed for these junctions.

The Streetcar system will have four locations where the track goes from double track to single track or single track to double track. At these locations, turnouts can be installed simply as spring switches, normally set for the appropriate move in the facing-point direction (single track to double track). Two of these locations (the terminals), should not require interlocking because of the slow speed operations and line-of-sight control practices common on street railways. The two switches for the section of single track over the Tower Bridge will likely require full interlocking in order to create one multi-functional interlocking between the west end of Old Town Station and Tower Bridge West interlocking. This interlocking is needed to control a complex set of operational circumstances in a very compact area, including the single-track streetcar occupancy signaling for the Tower Bridge, the diamond crossing of the Sacramento Southern Railroad, the Tower Bridge lift operation (and related traffic signals for Tower Bridge traffic), Capitol Ave, the left turn into the hotel, and the westbound exit from Old Sacramento.

In addition, the Streetcar system will have several locations where the Streetcar trackage will cross mainline rail trackage, owned by either the Union Pacific Railroad, Yolo Shortline Railroad or the Sacramento Southern Railroad. These locations will require full interlocking, per California Public Utilities Commission (CPUC) regulations (General Order 33-B)., unless a waiver can be successfully obtained. The Streetcar alignment crosses mainline rail trackage at four locations that are active mainline rail trackage today. Due to changing land uses, the two mainline rail crossings on South River Road may be removed if the businesses there that receive rail shipments close or move. The other two are likely to remain, however.

Locations requiring construction and maintenance of new special work for the Streetcar operation are summarized below in Figure 5. Existing special work on the RT LRT system is not included. It is assumed that the Streetcar system would need to be responsible for the operation, signaling and maintenance for all of this special work.

A future decision will be required as to whether the West Sacramento Streetcar trackage should be built to accommodate RT's Light Rail Vehicles (LRVs), in order to permit operation of special light rail service to special events in Old Sacramento and West Sacramento. A decision to design the system to LRT standards capable of handling full-size LRVs will affect the standards for design and construction of the Streetcar system, as well as the costs for construction.

Figure 5 - Special Work

Location	Type	Explanation
K Street & 12th Street	Power switch	EB streetcar diverges from LRT track
K Street btwn 12th and 13th Streets	Spring switch	Streetcar reverses at stub terminal
K Street & 12th Street	Diamond	WB streetcar crosses existing EB LRT track
K Street & 12th Street	Spring switch	WB streetcar enters LRT track
7th Street & Capitol Mall	Power switch	WB streetcar diverges from LRT track
Capitol Mall & Old Town Interlocking	Spring switch	WB streetcar enters single track, EB streetcar diverges to double track
Capitol Mall at Sacramento Southern	Diamond	Streetcars cross existing mainline railroad
West Capitol Street at Tower Bridge Interlocking	Spring switch	EB streetcar enters single track, WB streetcar diverges to double track
Raley Field	Diamond	Streetcars cross existing mainline railroad (may be removed)
South River Road	Diamond	Streetcars cross existing mainline railroad (may be removed)
Union Pacific West Sacramento Yard	Diamond	Streetcars cross existing mainline railroad. Currently yard, but expected to be reduced to single running track.
West Sacramento Transit Center (City Hall Station)	Spring switch	Streetcar reverses at stub terminal
8th Street & Capitol Mall	Spring switch	EB streetcar enters LRT track

2.4 Terminal configuration

The assumed configuration of the initial system incorporates single-track stub terminals for reversing and layover, with separate boarding and alighting platforms on the adjoining double track sections. This configuration allows multiple cars (up to three) to enter and layover at the terminal at one time. See the schematic track diagram in Figure 4. Switches leading to the single track stub terminal are spring switches, normally set for the diverging move from the single track tail to the departure platform in the double track section.

2.5 Vehicle types and performance

For the type of operation envisioned for the West Sacramento Streetcar, two vehicle types would be appropriate. Both are double-ended and double-sided, with operating controls at both ends. Both can also board passengers from either side of the car. The operating assumptions in this memo could accommodate either of these vehicle types.

The first type of vehicle would be a modern, double-ended, 3-unit articulated streetcar ("two rooms and a bath") such as the Skoda-Inekon T-10 car, as used on the Portland Streetcar and in Tacoma. These vehicles are 66 feet long and 8 feet wide, and have a seating capacity of 41, with a total capacity of 140, including standees. The typical top speed of these vehicles in operation is approximately 30 mph, though they are capable of speeds up to 43 mph if the top speed is not controlled by governing. These cars are partially low floor, and have 3 doors per side of the car for left-side boarding and double-ended operation. Disabled boarding is accomplished in the center low-floor section through use of a bridge ramp which extends out to the curb or platform, and provides level boarding into the low-floor center section.

The second type of vehicle would be similar to the Gomaco replica Birney cars in use in Tampa, Little Rock, Charlotte, and Memphis. These vehicles are 50 feet long, 8 feet 6 inches wide, and have a capacity of 88 (44 seated, 44 standing). They have a top speed of approximately 30 mph. These cars have a high floor with steps, and require the use of an onboard wheelchair lift to board disabled passengers. They have two doors per side, and can accommodate left side boarding. These vehicles would need to be double-ended for operation on this system.

Depending upon interpretation, these streetcar alternatives will not meet some of the stricter readings of the CPUC General Order 143-B, Safety Rules and Regulations Governing Light Rail Transit. If these vehicles alternatives are advanced further into the process of project definition and analysis, this should be brought to the table as one of the matters for discussion between the project management staff and CPUC staff.

Vehicle maintenance and storage is assumed to occur at RT's Academy Way facility.

For more details on vehicles under consideration for this system, see Technical Memorandum on Equipment Analysis.

2.6 Running times

Overall end-to end running time, exclusive of layover time but inclusive of dwell times at stations, is estimated to be 23.6 minutes, for an estimated distance of 2.74 miles. Total cycle time is estimated to be 57.2 minutes, including layover times at the terminals. Layover times are assumed to be 5 minutes on each end of the line. This is slightly higher than the standard 10% of overall travel time often used to calculate layover times, but is prudent on this system

Figure 6 - Running Times

WESTBOUND

Dir	Item	Location	New / Existing	Single / Double Track	Distance from Prior Location (ft)	Cumulative Distance (ft)	Avg Speed (mph)	Running Time Between Stations (min)	Station Dwell Time (min)	Cumulative Travel Time (min)
WB	Terminal	K Street & 13th Street	New	Single			6.5			
WB	Station	13th Street Station	New	Double	200	200	6.5	0.3	0.50	0.8
WB	Station	11th Street Station	Existing	Double	800	1000	6.5	1.4	0.50	2.7
WB	Station	8th Street Station	Existing	Double	1300	2300	6.5	2.3	0.50	5.5
WB	Station	7th Street & Capitol	Existing	Double	1300	3600	6.5	2.3	0.25	8.0
WB	Station	Capitol & 4th Street	New	Double	1350	4950	10	1.5	0.25	9.8
WB	Station	Old Town Station	New	Double	1050	6000	10	1.2		11.0
WB	Interlocking	Old Town Interlocking	New	D to S	150	6150	10	0.2	0.50	11.7
WB	Interlocking	Tower Bridge West Interlocking	New	S to D	1000	7150	10	1.1		12.8
WB	Station	Raley Field Station	New	Double	500	7650	10	0.6	0.25	13.6
WB	Station	South River Road Station	New	Double	1250	8900	10	1.4	0.25	15.3
WB	Station	Riske Lane Station	New	Double	1350	10250	10	1.5	0.25	17.1
WB	Station	Triangle Station - (UP/SN Yard)	New	Double	1375	11625	10	1.6	0.25	18.9
WB	Station	West Capitol Station	New	Double	1275	12900	10	1.4	0.25	20.6
WB	Station	West Sacramento City Hall Transit Center	New	Double	1375	14275	6.5	2.4	0.25	23.3
WB	Terminal	West Sacramento City Hall Transit Center	New	Single	200	14475	6.5	0.3		23.6
		WB Subtotal			14475			19.6	4.00	23.6

EASTBOUND

Dir	Item	Location	New / Existing	Single / Double Track	Distance from Prior Location (ft)	Cumulative Distance (ft)	Avg Speed (mph)	Running Time Between Stations (min)	Station Dwell Time (min)	Cumulative Travel Time (min)
EB	Terminal	West Sacramento City Hall Transit Center	New	Single			6.5			
EB	Station	West Sacramento City Hall Transit Center	New	Double	200	200	6.5	0.3	0.25	0.6
EB	Station	West Capitol Station	New	Double	1375	1575	10	1.6	0.25	2.4
EB	Station	Triangle Station-(UP/SN Yard)	New	Double	1275	2850	10	1.4	0.25	4.1
EB	Station	Riske Lane Station	New	Double	1375	4225	10	1.6	0.25	5.9
EB	Station	South River Road Station	New	Double	1350	5575	10	1.5	0.25	7.7
EB	Station	Raley Field Station	New	Double	1250	6825	10	1.4	0.25	9.4
EB	Interlocking	Tower Bridge West Interlocking	New	D to S	500	7325	10	0.6		9.9
EB	Interlocking	Old Town Interlocking	New	S to D	1000	8325	10	1.1	0.50	11.6
EB	Station	Old Town Station	New	Double	150	8475	10	0.2		11.8
EB	Station	Capitol & 4th Street	New	Double	1050	9525	10	1.2	0.25	13.2
EB	Station	Capitol & 7th Street	New	Double	1350	10875	6.5	2.4	0.25	15.8
EB	Station	8th Street Station	Existing	Double	1300	12175	6.5	2.3	0.50	18.6
EB	Station	11th Street Station	Existing	Double	1300	13475	6.5	2.3	0.50	21.4
EB	Station	13th Street Station	New	Double	800	14275	6.5	1.4	0.50	23.3
EB	Terminal	K Street and 13th Street	New	Single	200	14475	6.5	0.3		23.6
		EB Subtotal			14475			19.6	4.00	23.6

because of the schedule reliability uncertainties created by the Tower Bridge lift operation, which are detailed below in Section 2.8.2. NOTE: These recovery times will not meet RT's contractually required meal and rest break requirements. This will have a detrimental effect on operating costs and may require the use of "fallback" operators. This requirement is part of State law and will affect any operator of the system. Figure 6 details the estimated distances between all stations on the system, assumed point-to-point average operating speeds, running times, and station dwell times. These are added to give total cumulative travel time. Figure 7 calculates the cycle time for operation of the entire line, adding the cumulative travel times to the layover times, resulting in overall cycle times.

Figure 7 - Cycle Time

	Time (min)
WB Travel Time	23.6
West Sacramento Layover	5.0
EB Travel Time	23.6
K Street Layover	5.0
Total Cycle Time	**57.2**

As a practical matter, schedules are likely to be drawn for a cycle time of 60 minutes, which provides a good fit for headways of 5, 6, 7.5, 10, 12, 15, 20 and 30 minutes – intervals divisible into one hour, and including the frequencies at which Streetcar service is most likely to be offered, as discussed below in Section 3.3.

2.7 Operating speeds

Average point-to-point operating speeds are assumed to be 6.5 miles per hour (mph) on the trackage shared with the Sacramento RT LRT service, and 10 mph on trackage not shared with RT. The figure of 6.5 mph was based on current RT scheduled service on K Street and 7th and 8th Streets. Operation on trackage not shared with LRT was assumed to be slightly faster, due to less interference with other services, more reserved right-of-way, and because operation on the K Street mall is restricted due to the presence of pedestrians.

2.8 Operating impacts

A number of conditions are likely to cause operating impacts or delays along the alignment.

2.8.1 Traffic signal delays

Traffic signal delays are assumed to be accounted for in the overall operating speeds assumed for the service. If signal priority measures are installed with the project, operating speeds could be slightly higher on the segments not shared with RT LRT trains.

New traffic signals will need to be installed at a number of locations in order to control traffic to allow the streetcars to make turns, such as at West Capitol Avenue and South River Road near Raley Field, which will be a complex intersection.

2.8.2 Tower Bridge lift operation

This project includes a crossing of the Sacramento River on the Tower Bridge, a lift bridge operated by Caltrans. Regular operation of this bridge will affect streetcar operations several times daily, yet on a somewhat unpredictable cycle. On November 22, 2006, Caltrans District 3 Spokesperson Mark Dinger provided the following information regarding the operation of the Tower Bridge in West Sacramento. Mr. Dinger obtained the information from conversations with the Caltrans Tower Bridge operators.

Number of time bridge cycles per day

From May 1 - November 30, the bridge is tended from 6 a.m. to 10 p.m. It opens approximately 10-12 times per day.

From December 1- April 30, the bridge is tended from 9 a.m. to 5 p.m. It opens approximately 2-4 times per day.

Cycle Time

It takes 10-12 minutes to raise and lower the bridge.

Scheduled Openings

River traffic receives the right-of-way and includes leisure boats that call for unscheduled bridge openings. The only regularly scheduled bridge openings are for the Spirit of Sacramento (a Sacramento Delta cruise boat). The Spirit of Sacramento's schedule varies slightly; however, below is a typical schedule of the ship's passing under the bridge:

Friday	Saturday	Sunday
1105	1035	1035
1245	1215	1215
1835	1935	1735
2115	2215	1915

At some locations in the United States, where lift or draw bridges affect railroad or transit operations, agreements are in place to limit bridge opening to hours outside of peak hours. Such an agreement could be sought for this location, but the outcome of such discussions is unknown at this time. The running time assumptions and the schedule developed for the service assumes additional recovery time at the line endpoints to allow for random bridge opening cycles, and to allow streetcars to get back on schedule if bridge openings occur. Other solutions could be sought, such as turning back cars delayed by a bridge opening, or having the controller direct all cars on the line to operate on the schedules of later cars, so that the operating timetable is restored as quickly as possible.

2.8.3 Single track operation on Tower Bridge

The single-track operation on the Tower Bridge will cause an operating constraint that will restrict scheduling of the services and operations. The single-track segment will be about 1000 feet long, which will take approximately 1.1 minutes for a streetcar to traverse. While a streetcar going in one direction is traversing this trackage, an approaching streetcar from the other direction must wait for the first car to clear the single track before proceeding. This will cause some minor delays, but should be manageable under normal conditions.

This track segment will need to be signalized to control access from the two ends, and to prevent occupancy by two cars at the same time heading in opposite directions. The signalization will have to be part of a larger interlocking system because this segment includes both the Tower Bridge lift span and a diamond crossing of the Sacramento Southern Railroad. All of these will require positive control of a streetcar entering this track segment.

The single-track operation will also force compromises in lane widths and roadway configurations on the Tower Bridge. The assumed configuration for the single-track on the bridge is in a reserved median trackway, because with two-way operation on a single-track, the track cannot be in mixed traffic. In order to retain four lanes on the bridge with the track in a reserved median, the four lanes need to be reduced to approximately 10 feet 3 inches each, which Caltrans considers substandard.

The travel lanes could be maintained at their current widths if double track can be installed on the bridge. Double track could be installed in the existing travel lanes, with streetcars operating in mixed traffic across the bridge. Queue-jump signals, coordinated with traffic signals, could allow the streetcars to enter the bridge in front of automobile traffic. This solution would be much preferable from the streetcar operating point-of-view, and could alleviate some concerns of impacts on the roadway. Additional deck weight and historic preservation issues would have to be addressed as part of this decision.

2.8.4 Railroad crossing delays

As noted previously, this alignment crosses mainline railroad track in four locations. Two of these locations (Sacramento Southern Railroad and the running track at the Union Pacific's West Sacramento Yard) are expected to remain permanently, but the two on South River Road may be removed if land use changes occur as expected. All of the crossings that remain may need to be fully-interlocked per CPUC General Order #33-B. (See comment above) None of these crossings except the Sacramento Southern experience frequent train activity; however the delay caused by a slow freight train crossing the alignment or switching cars in a lineside industry could be significant. The estimated activity at these crossings is shown in Figure 8.

Figure 8 - Railroad Activity

Location	Railroad	Activity	Duration
Capitol Mall between Old Town Station and Tower Bridge	Sacramento Southern	April-September on weekends - 2 steam-powered passenger trains per hour	Estimated at 2 minutes each.
South River Road at Raley Field	Yolo Shortline	Daily switching activity	varies
South River Road approximately 1500 feet south of West Capitol	Yolo Shortline	Daily switching activity	varies
West Sacramento Yard	Union Pacific	Switching activity several times daily	varies

3.0 Service design criteria

This service is envisioned as an urban circulator, and as such would provide transportation for a variety of trip purposes, including journey-to-work, shopping, entertainment, lunchtime trips, and others. For these reasons, the service would need to accommodate people making trips for all of these purposes, and thus must offer convenient, basic transportation that is easy for the riders to use, is understandable from the point of view of how the service operates, and does not require the rider to plan ahead in order to use the service.

One of the goals of the City of West Sacramento is for the Streetcar to contribute to the placemaking efforts in redeveloping the Triangle area. In order for this to occur, the service design must be legible to the rider, offer a high quality of service, and be convenient for the rider to use.

3.1 Days of operation

Streetcar service would operate 7 days per week.

3.2 Span of service

The span of service for the service would be as shown in Figure 9 below.

Figure 9 - Span of Service

Day	Span
Monday-Friday	5am-midnight
Saturday	6am-midnight
Sunday	6am-midnight

3.3 Headways

Headways are assumed to be 7 ½ minutes for all hours of service. This is consistent with the policy direction established by the City of West Sacramento to maintain headways between approximately 5 and 7 minutes. Establishing the headway at 7 ½ minutes allows clock headways to be established, resulting in 8 trips per hour each direction, with departures possible at the same times each hour. Streetcar schedules may then be effectively coordinated with connecting bus services operating at multiples of this headway, such as 15 minutes, 30 minutes or hourly. Also, with a short streetcar headway of every 7 ½ minutes, riders do not need a timetable – they can just walk to the stop and expect a streetcar within an acceptable waiting period. This headway would establish this line as the most frequent single-route transit service in the Sacramento area, and would offer frequency of service comparable to San Francisco Municipal Railway's F-Market line, which is the most successful traditional streetcar operation in the United States.

Headway is a major determinant of operating cost, and in Section 5 below, headway options will be shown to demonstrate the possible operating cost differences possible with different headways. Headways also determine the car requirements, which affect the capital cost of procuring equipment. This will be discussed below in Section 3.5.

3.4 Capacity

Capacity on a transit system is determined by several factors. First, the vehicle size and configuration determines how many passengers can be carried on each individual car. The seating layout inside the car affects the number of riders that can be carried – many transit systems seek to maximize capacity by reducing the number of seats and maximizing standee room. Secondly, the operating characteristics of the line determine the ultimate number of riders that can be carried. Frequency of service (cars per hour) is the prime factor that determines overall line capacity.

A further consideration is that the number of riders can turn over several times over the course of a transit vehicle's progress over the line, especially on long lines on crowded urban systems. With this situation, a line's capacity can be many times the capacity of the individual car, if riders are boarding and alighting for short trips and the car is filling up several times over. The capacity figures in Figure 10 assume that the ridership on each trip does not turn over more than once each trip – the maximum capacity of the car is the maximum number assumed for each trip. Given that the Streetcar is a relatively short line, this assumption is more prudent. Another way to summarize this is that the capacity shown below is the hourly or daily capacity past any single point on the line.

3.4.1 Hourly

The hourly capacity is assumed to be 2240 riders per hour past any one point on the line if Inekon-type cars are used, or 1408 riders per hour if Gomaco Birney replicas are used.

3.4.2 Daily

The daily capacity is assumed to be 42,560 riders per day past any one point on the line if Skoda-Inekon cars are used, or 26,753 riders per day if Gomaco Birney replicas are used. To put these numbers in perspective, Sacramento RT's LRT system carries about 60,000 riders per day (prior to opening of the Amtrak Station Extension), and Muni's F-Market line carries about 20,000 riders per day. NOTE: I'm concerned that we're comparing apples and rocks here. RT's LRT system is over 36 miles long. Muni's "F" line is less than 5 miles long.

Figure 10 - System Capacity

Car Type	Seated Capacity	Standees	Total Capacity	Headway	Cars per hour per direction	Hourly Capacity per direction	Hourly System Capacity	Daily System Capacity
Inekon Trio	41	99	140	7.5 min	8	1120	2240	42,560
Gomaco Birney	44	44	88	7.5 min	8	704	1408	26,752

3.5 Vehicle demand and spares

The requirements for vehicles on a system are determined by two factors. First, the requirement to operate service in the peak hour (known as peak vehicle demand) is determined by the cycle time and the service frequency at the busiest time of the day, when the maximum number of cars are scheduled to be in service. The peak vehicle demand is figured by dividing the cycle time by the peak headway, and rounding up to the next whole number.

In addition, every system needs spare cars so that repairs and cleaning can occur on cars that are not in service without affecting service delivery. Most systems use a 20% spare ratio requirement. For systems with a large fleet, this ratio is adequate, and in some cases may be reduced somewhat based on experience. For smaller systems, if the 20% spare ratio results in only one spare car, the decision is often made to have more than one spare, as having only one spare car leaves a very small margin for unexpected circumstances. For the purposes of this project, a 20% spare ratio is assumed, with a minimum of 2 spares to be provided.

Figure 11 below shows the peak vehicle demand, spare needs and total fleet needs for the system with eight different operating assumptions. For the service design assumed for this project, a peak headway of 7 ½ minutes yields a peak vehicle demand of 8 cars. A 20% spare ratio requires 1.6 cars, which rounds up to two vehicles. Thus, to operate this system with a desired frequency of a streetcar every 7 ½ minutes, a total of 10 cars would be needed. Reducing the frequency would reduce the car requirements. For instance, if the policy decision were made that 15-minute peak headways were acceptable, then only 6 vehicles would be required.

Figure 11 - Vehicle Requirements

Vehicle Requirements - 20% Spares

Cycle Time (min)	Peak Headway (min)	Peak Vehicle Demand	Spares (20%) - Min 2	Total Fleet Needed
57.2	5	12	3	15
57.2	6	10	2	12
57.2	7.5	8	2	10
57.2	10	6	2	8
57.2	12	5	2	7
57.2	15	4	2	6
57.2	20	3	2	5
57.2	30	2	2	4

The costs of procuring vehicles can be one of the major expense items for a system such as this. Therefore the car requirements need to be evaluated carefully to ensure that the system is sized correctly in relation to the expected demand. The Service Criteria task is being performed prior to the development of any ridership demand data. Once those data are developed, the service assumptions should be re-examined and the car requirements should be re-evaluated.

3.6 Operating Scenario

Basic operation on the Streetcar would be street railway line-of-sight operation, controlled at intersections by traffic signals. In locations where signal priority is provided, where RT already has LRV signaling, or where the Streetcar must make a movement not normally allowed for automobile traffic, consistent with current Regional Transit "Rail Operation Rules", control would be provided by white "T" traffic signal indicators coordinated with the traffic signal system. (Operators may proceed with caution through an intersection on a "T" indication; otherwise traffic signals must be obeyed.)

One segment of the line would be controlled by an interlocking signal system - the Tower Bridge segment, where signals would control the interface with the lift bridge, the single track section of track, the Sacramento Southern Railroad diamond and several street intersections. The signal aspects displayed at the interlocking will be designed to be consistent with color signal aspects already provided for in RT rules.

Diverging movements at junctions with Sacramento RT LRT trackage would be controlled by switch position indication lights. Signal aspects would be consistent with current RT operating rules.

4.0 Generalized operations and maintenance costs

4.1 Annual operating costs

The anticipated operating cost for this system was calculated using a cost structure based on current RT experience and costs shown in RT's most recent National Transit Database entries available (FY2004). This method used fully-allocated cost numbers, which take into account all costs involved in operating the transit system – operations, maintenance (both vehicle and non-vehicle costs), and administration. At the current conceptual level of planning , this approach yields order-of-magnitude costs. Once a project begins to be further developed, more detailed cost estimating can be done based on specific details of the project and the operation. In addition, a 35% contingency was added, due to the uncertainties inherent at this early stage of development of the project. As the project is refined, the contingency level can be reduced as decisions are made and uncertainties reduced following preparation of a detailed operating timetable with runcuts, and a labor analysis of the maintenance and operating functions.

The cost structure was developed by first deriving Sacramento RT's annual unit costs for vehicle operations, vehicle maintenance, and non-vehicle maintenance, based on the NTD costs for these activities divided by the size of the RT fleet and the number of track miles in the RT system. These unit costs were then multiplied by the assumed Streetcar quantities for the same activities. Then, a 31% administrative cost was added, based on RT actual costs. After this was totaled, a 35% contingency was added, and the numbers were escalated from 2004 to 2006 at 3.5% escalation annually. This yields an hourly operating costs of $128 per hour, which is similar to the Portland Streetcar's current hourly operating cost. This methodology ensures that the cost structure for this type of operation reflects RT's cost structure, as the most likely operator of the system. (For purposes of comparison, RT's fully-allocated hourly NTD rate for LRV operation is approximately $235 per hour in $2004, or approximately $250 per hour if escalated to $2006.)

The total annual assumed cost to operate the system described in this Technical Memorandum using the method described above is $6,670,945. At this stage of development, however, this number should be considered a very preliminary estimate, and is subject to refinement as the project is more fully defined and analyzed in greater detail.

Figure 12 shows the calculations of revenue hours, miles and costs for the operating scenario described in this Technical Memo.

Figure 12 - Annual Operating Cost

Time Period	Headway	Cycle Time	Peak Veh	No. of Hours per Day	Miles per Cycle	Daily Veh Hours	Daily Veh Miles	Days per Year	Annual Vehicle Hours	Annual Vehicle Miles	Hourly Fully Allocated Cost (See Note)	Annual Operating Cost (Hours x Cost) $2006
Weekday	7.5	57	8	19	5.483	144.4	833.4	261	37,688	217,520		
Saturday	7.5	57	8	18	5.483	136.8	789.5	52	7,114	41,056		
Sunday	7.5	57	8	18	5.483	136.8	789.5	52	7,114	41,056		
Total									51,916	299,633	$ 128	$ 6,670,945

Note: Hourly operating cost calculations in $2006.
- $128/hour rate based on Sacramento RT's 2004 NTD data, pro-rated on a per-vehicle and track mile basis, and escalated to $2006.

The annual operating cost is a direct function of the headway, span of service, and cycle time. To reduce operating costs, headways can be lengthened (a 15-minute headway would cost approximately 50% of a 7 ½ minute headway to operate), span of service can be reduced, or cycle time could be reduced. Cycle time reductions would require speeding up the service through transit priority measures, such as installing signal priority or operating in private right-of-way instead of mixed traffic. Reducing the cycle time would allow more efficient use of fewer resources – basically making the same number of trips with fewer operators and vehicles, because the vehicles are making the cycle faster.

To illustrate the effects of headway on operating cost, Figure 13 below shows the total annual operating cost for different headway options on the assumed system. With different headways, car needs would also vary.

Figure 13 - Operating Cost Comparisons

Headway (min)	Peak Vehicles	Annual Vehicle Hours	Annual Operating Cost
5	12	77,873	$ 10,006,418
6	10	64,895	$ 8,338,682
7.5	8	51,916	$ 6,670,945
10	6	38,937	$ 5,003,209
12	5	32,447	$ 4,169,341
15	4	25,958	$ 3,335,473
20	3	19,468	$ 2,501,604
30	2	12,979	$ 1,667,736

This table demonstrates that, if operating funds are limited, a service with a reduced headway could be introduced on the system with a reduced fleet, and then frequencies could be increased as ridership builds, operating funds are secured, and additional cars are purchased.

4.2 Vehicle Hours and Miles generated

Annual vehicle hours and miles are calculated above in Figure 12. Assuming a 7 ½ minute headway service, annual revenue vehicle hours would be approximately 51,916, and annual revenue vehicle miles would be approximately 299,633. These figures do not include deadheading time or miles needed to move cars between the maintenance facility and the beginning and ending points of revenue service, nor the hours or miles for testing or maintenance moves.

4.3 Cost Categories

Maintenance costs are a component of the fully-allocated annual operating cost shown above in Section 4.1 (and Figure 12). Maintenance costs for vehicle and non-vehicle maintenance can be calculated from the total annual operating costs based on some standard percentages for each activity.

Figure 14 - Cost Categories

	Percent of Cost	Estimated Operating Cost ($2004)	Estimated Operating Cost ($2006)
Annual Total Operating Cost		$ 6,227,399	$ 6,670,945
Cost Categories			
Vehicle Operations	30%	$ 1,879,861	$ 2,013,754
Vehicle Maintenance	15%	$ 933,056	$ 999,513
Non-Vehicle Maintenance	6%	$ 369,976	$ 396,328
al Administration (31% of subtotal)	23%	$ 1,429,995	$ 1,531,846
Subtotal		$ 4,612,888	$ 4,941,441
Contingency (35% of subtotal)	26%	$ 1,614,511	$ 1,729,504
Total	**100%**	**$ 6,227,399**	**$ 6,670,945**

Notes:
1) 2004 estimated operating costs based on an hourly rate of $120 (rounded).
2) 2006 estimated operating costs based on an hourly rate of $128 (rounded)
3) Escalated at 3.5% annually
4) Assumes fleet of 10 vehicles with peak demand of 8 vehicles

The cost categories in Figure 13 are based on Sacramento RT’s cost categories for National Transit Database (NTD) reporting for the LRT system. The costs for the Streetcar operation derived in Figure 12 were divided by the cost category percentages that Sacramento RT experiences to derive estimated costs for each of the major activity areas reported on to NTD.

These categories can be refined as design progresses on the project and more is known about details of the operating and maintenance requirements.

5.0 Draft operating schedule

A draft Operating Timetable is provided in Attachment A. This timetable was created assuming the running times shown in Figure 6, the route alignment shown in Figure 1, and the track configuration shown in Figure 4. This timetable was constructed so that a meet between an eastbound and a westbound streetcar occurs at Old Town Station. In this timetable, a westbound streetcar arrives at the double-track Old Town Station while an eastbound streetcar is on the Tower Bridge. The westbound car waits at the Old Town Station until the eastbound car has cleared the Old Town interlocking junction, moving from the single track for the bridge segment into the double track station. After receiving clearance to proceed onto the single track, the westbound car proceeds onto the single track section of the bridge.

6.0 Issues and Options

6.1 Phasing

One issue with the construction of this project is whether or not the entire Phase 1 project could be constructed at one time, or if it could be phased, and if a phased operation would make sense. The primary unknown is that of the continued operation of railroad freight services in West Sacramento. In order for the entire Phase 1 project to be constructed and operated on a reasonable budget, the Union Pacific Railroad's West Sacramento Yard will need to be moved south to the Port of Sacramento. If this yard is not moved, the Streetcar would most likely need to traverse this area via a bridge or underpass, raising the cost of the project considerably, but avoiding considerable additional streetcar operating delays sure to occur if an at-grade crossing of the railroad were to be built. A phased project could be built only as far west as the Riske Lane Station, which could be operated as a shorter Phase 1. Later, if the yard is moved and as development and redevelopment along the alignment increases, the project could be extended to the West Sacramento City Hall/Transit Center Station. A phased operation to this point only would initially serve fewer destinations and traffic generators in West Sacramento, but it would be operationally feasible. The cycle time would be approximately 12 to 13 minutes shorter, which would reduce vehicle needs and operating costs.

6.2 Transit Priority

To speed up service on the Streetcar, transit priority measures could be added to the project at various locations, reducing the estimated cycle time and making the service more attractive to riders. A typical measure would be installing signal priority equipment at any of the intersections along the Capitol Mall, South River Road or West Capitol Avenue. The project could also be constructed with additional portions of the alignment in reserved right-of-way, to eliminate delays caused by automobiles and trucks, and to increase the streetcar's average operating speed.

The benefit of transit priority measures could be reduced somewhat, however, because of the effect of previously discussed Tower Bridge openings and railroad-related delays.

7.0 Conclusion

The development of this initial service design criteria demonstrates that an attractive service can be designed for the West Sacramento Streetcar, which will provide enhanced transit access to West Sacramento destinations and for West Sacramento residents traveling to Sacramento. By providing transit access to Raley Field, the service would benefit the entire region by allowing car-free travel to events. As residential development increases in West Sacramento, having the streetcar in place can guide and shape West Sacramento's conversion from an industrial area to a dense, transit-oriented neighborhood.