



5.0 Operations and System Planning

There are many significant aspects of the third grouping, Operations and Systems Planning. The City's stated project goals are:

- The capability to successfully tie into the existing light rail system
- Cost-effective stations and vehicles that are accessible and ADA compliant
- A route with limited crossing controls and no grade separations, and
- Preferred headways of five to seven minutes

Due to these are critical issues, the Team combined three major Tasks into this component of the Feasibility Study report.

5.1 Service Criteria and System Characteristics

The Service Criteria task develops a higher level of knowledge about the alignment, stations, the service design for the system, and the operational characteristics. There are several components of the Service Criteria task.

- The working assumptions are specified for alignments, station configuration, and operating characteristics
- The service design is specified
- A timetable is based on assumed station locations and expected running times
- Information is developed on system capacity and generalized operating and maintenance costs will be developed.

Understanding the streetcar system characteristics is important to developing service design criteria, scheduling, and operating and maintenance costs. System characteristics include:

- Alignment
- Stations
- Track Configuration
- Terminal Configuration\
- Vehicle type and performance
- Running Times
- Operating Speeds
- Operating Impacts

As Phase 1 progressed, service analysis was made for the initial alignment selected at the Charrette (Alignment A). Later, a second alternative (Alignment B) was analyzed. Finally, an Initial Preferred Alignment was chosen and final estimates were made.



5.1.1 Stations and Stops

Station Locations – Stop locations are on the alignment figures [Figures 2, 3, and 4] and in Table 7. Where the streetcar shares trackage with RT, the streetcars stop at the existing RT LRT stations, with specified boarding locations within the RT station areas.

Distances between stations - The standard for station spacing on the Downtown/ Riverfront Streetcar is between 1200 and 1400 feet between stations. One-quarter mile spacing allows reasonable walking access to stations along the line.

Station Design - Station design is simple, with right-side boarding platforms in most locations, sized for single-car trains. Most stations would have two platforms; one for westbound cars and one for eastbound cars. At Old Sacramento Station in the median of Capitol Mall, a shared center-island platform will be utilized for boarding cars going both directions from the same platform.

Disabled Boarding - Disabled boarding will be handled through the use of onboard lifts if replica cars are used or through carborne bridge ramps if new low floor 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. Some modification would be required in K Street to accommodate low floor boarding, since existing pavement is at track elevation and the modern cars require a minimum 8" curb height.

5.1.2 Track Configuration

The optimal configuration for an urban streetcar system is to have all double-track within the right-of-way. This method 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 (for Alignment A):

- K Street between 12th and 13th Street – Short segment of single track at the stub terminal for reversing
- Tower Bridge from west of Old Sacramento 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. Consult the Conceptual Track Engineering Technical Memorandum in the appendix for additional detail.



5.1.3 Terminal Configuration

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 the same time.

5.1.4 Running Times

Overall end-to-end running time (for Alignment A), 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. This is prudent because of the schedule reliability uncertainties at the Tower Bridge.

Table 10. 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

5.1.5 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. Speed is 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.

5.1.6 Operating Impacts

A number of conditions could cause operating impacts or delays along the alignment.

Traffic Signal Delays - The operating speeds assume traffic delays. If signal priority measures are installed, operating speeds could be slightly higher on the segment, allowing the streetcars to make turns. Candidate locations include Tower Bridge Gateway/Third Street/ South River Road near Raley Field, which will be a complex intersection.

Tower Bridge Lift Operation - The 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, on a somewhat unpredictable cycle. It takes 10-12 minutes to raise and lower the bridge. From May 1 - November 30, the bridge is tended from 6 AM to 10 PM, opening approximately 10-12 times per day. From December 1- April 30, the bridge is tended from 9 AM to 5 PM, and it opens approximately 2-4 times per day.



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.

Single track operation on Tower Bridge - The single-track operation on the Tower Bridge could cause an operating constraint that will restrict scheduling of the services and operations. The single-track segment will be about 1000 feet long and will require 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.

The track segment needs 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 single-track operation will force compromises in lane widths and roadway configurations on the Tower Bridge. The Bridge Evaluation Technical Memorandum addresses these issues.

Railroad Crossing Delays - Alignment A crosses mainline railroad track in four locations. Two of these locations (Sacramento Southern Railroad and the running track at the Union Pacific's Westgate Yard) are expected to remain permanently, but the two on South River Road are expected to be removed. 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.

5.2 Service Design

The service is envisioned as an urban circulator, and as such would provide transportation for a multiple trip purposes - journey-to-work, shopping, entertainment, lunchtime trips, and others. The service needs to accommodate people making trips for all purposes. Service must offer convenient, basic transportation which 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 for the project is for the streetcar to contribute to the placemaking efforts in redeveloping the riverfront and in developing areas. 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.

5.2.1 Days of operation

Streetcar service would operate 7 days per week.

5.2.2 Span of Service

The span of service for the service would be as shown in Table 11 below.



Table 11. Span of Service

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

5.2.3 Headways

Headways are major factors in operating costs, determine the car requirements, and influence ridership numbers. Headways were analyzed for 7 ½ minutes for all hours of service. This was consistent with the policy direction established by the PSC and TAC to maintain headways between approximately 5 and 7 minutes. Establishing the headway at 7 ½ minutes allows clock headways to be established, resulting in eight trips per hour each direction, with departures possible at the same times each hour. Streetcar schedules may 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. However, more frequent service requires a larger fleet and incurs higher operating costs. Due to budget constraints, a base headway of fifteen minutes and a peak (lunch period) headway of ten minutes have been used for cost estimating and are proposed for further study in Phase 2.

Capacity

Capacity is determined by several factors - vehicle size and configuration, operating characteristics, and the number of riders.

Vehicle Size –The seating and standing layout inside the car affects the number of riders that can be carried on each individual car.

Operating Characteristics - Operation of the line determines the ultimate number of riders that can be carried. Frequency of service (cars per hour) is the prime factor that determines overall line capacity.

Rider Turnover - 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. In 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. A way to summarize turnover is the capacity on hourly or daily capacity.

- Hourly - The hourly capacity is assumed to be 2240 riders per hour past any one point on the line if the modern streetcars are used, or 1408 riders per hour if Gomaco Birney replicas are used.
- Daily - The daily capacity is assumed to be 42,560 riders per day past any one point on the line if modern streetcars are used, or 26,753 riders per day if Gomaco Birney replicas are used.



5.2.4 Vehicle Demand and Spares

Requirements for vehicles on a system are determined by two factors – operating needs and spare cars. 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 is scheduled to be in service.

Every system needs spare cars so 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. For the purposes of this project, a 20% spare ratio was assumed, with a minimum of two spares. Car requirements need to be evaluated carefully to ensure that the system is sized correctly in relation to the expected demand.

5.2.5 Operating Scenario

Basic operation would be the streetcar in line-of-sight operation, controlled at intersections by traffic signals. Where signal priority is provided, where RT already has signaling, or where the streetcar must make a movement not normally allowed for automobiles, control would be provided by white “T” traffic signal indicators coordinated with the traffic signal system.

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

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.

5.2.6 Revision Estimates for the Initial Preferred Alignment

After the PSC/TAC decision to develop the Initial Preferred Alignment (a hybrid between A and B), the team made estimates of round trip times, headways, hours of operation, and annual operating and maintenance costs.

The round trip takes 55 minutes, approximately 28 minutes each way and the estimated operating speed is 6.5 miles per hour on RT tracks, and 10 miles per hour otherwise. The average dwell time at a stop is 25 to 50 seconds, depending on the particular stop. There is a five minute layover at each end of the route.

Headways (time between streetcars) are estimated at 10 minutes. The Planning Criterion for headways is 5 to 7 minutes and operation at that frequency is also feasible; it is assumed that for reasons of managing operating costs, initial headways will be 10 minutes during peak times and 15 minutes in off-peak times. In general, the streetcar operates from 5:00 AM to 12:00 AM, from Monday through Friday and 6:00 AM to 12:00AM on the weekend.

For the preferred route the estimated capital cost is \$53,319,000 or approximately \$14,966,000 per track mile. The Planning Criterion was a project cost to not exceed \$50,000,000; however



the decision to include the loop to Midtown was made with the understanding that the Planning Criterion on cost would be “flexed” to allow a slightly more expensive, but significantly more viable project.

As currently planned, the annual operating costs for an eight car fleet, with 7.5 minute peak-time headways, would be \$3.55 million. If the headways are stretched to 10-minute peak-time service and 15 minutes in off-peak times, the annual operating costs fall to \$2.61 million.

5.3 Equipment Analysis

No element of a rail transit system captures the hearts and minds of the public more than the vehicle itself. Both the riding and non-riding public usually interact with the transit vehicle more than with any other part of the transit system - from actually using it as a means of travel, to sometimes competing with it in traffic, or to recognizing it as a symbol of the transit service. In some cases, such as the cable cars in San Francisco, the vehicle can even become a defining symbol for the metropolitan area. Thus, selection of a vehicle – from the basic type of car to its various specific physical and performance characteristics, cost and aesthetics – is obviously a key decision, or series of decisions, to be taken in the course of a streetcar project.

5.3.1 Streetcar Characteristics

A wide range of alternative streetcars exists for consideration at the onset of a project. Electric streetcars have a long history, stretching back to the late nineteenth century when they supplanted vehicles whose motive force was provided by horses, or by cables propelled by steam engines. For the purpose of this report, streetcar vehicles are first divided into four broad, chronological categories: vintage and replica trolleys, Presidents Conference Committee (PCC) cars, and modern streetcars. Within each category, there are a number of variations and possibilities which will be summarized below. For modern streetcars, often it is a question of the extent of departure from service proven or “off the shelf” designs.

Some of the important configuration and operating considerations that factor into selection of a vehicle are:

- Basic size (length and width), clearance requirements, and capacity
- Performance (top speed, acceleration and braking rates, etc.)
- “Sided-ness” and “ended-ness”, i.e., single-sided, single-ended vs. double-sided, double-ended
- Single unit operation (tow bar or mechanical coupling only) vs. multiple unit operation (mechanical and electrical coupling)
- Floor height (low floor vs. high floor) and the means of accessibility

These and other considerations are reviewed in the following sections.



Vintage Trolley and Replica Streetcars

Early streetcars typically were made with all-wood bodies or composite wood-and-steel bodies with deck roofs and clerestories. The earliest electric streetcars were small, 25 to 30 feet long with a single four-wheel truck, but the popularity of this new technology soon required that operating companies acquire larger cars in the range of 40 to 50 feet in length (Figure 19). These cars typically had two powered trucks, were not articulated, were high floor, were found in both single-sided, single-ended and double-sided, double-ended versions, and normally operated as single units. There were many variations to these generalities. Rehabilitation of historic vehicles is an expensive undertaking. In Sacramento, one historic PG&E car has been restored and operates on the light rail line on special occasions.

Figure 19. Vintage Trolley - Dallas, Texas



Figure 20. Replica Trolley - Portland



Several cities – Portland, Tampa, Little Rock and Charlotte have opted to replicate rather than rehabilitate a vintage trolley (Figure 20), and New Orleans has a large replica fleet in addition to its refurbished cars. Replicating a vintage trolley could involve, for example, the construction of a steel underframe and inclusion of more modern safety features while retaining an original or vintage looking appearance (Figure 21, below). This approach helps guarantee consistency of design and parts, and essentially results in a new product that has a vintage appearance, plus a long economic life ahead of it.

Of particular interest for this project, because they are so similar in appearance to cars operated in Sacramento from the 1920s until the streetcar system's demise in 1947, is the replica double-truck Birney car manufactured by the Gomaco Trolley Company in Iowa. First built for Tampa, additional units have been delivered to Little Rock, Memphis and Charlotte. These cars are 45 to 50 feet in length, 8.5 feet wide, and equipped with about 40 seats.

Figure 21. Replica Double Birney - Tampa



PCC Cars

From the mid-1930s through the early 1950s, the Presidents Conference Committee (PCC) car rose to fame throughout North America, and its design was exported to Europe and elsewhere. Again, while



there were many variations, the PCC car was basically an all-steel, non-articulated car, approximately 50 feet in length, with two powered trucks and high floors.

Figure 22. Rebuilt PCC Car



PCCs were built in both single-sided and double-sided configurations, and they were operated as single cars and in multiple unit consists. The rounded, more contoured look and several performance and passenger comfort improvements generally distinguished the PCC car from older vintage trolleys. Some transit agencies in the U. S. cities, e. g. Boston and San Francisco, have retained and rehabilitated some of their PCC cars, and still operate them in limited or special service. Philadelphia has completed a PCC rehabilitation program (Figure 22), which included substantial changes to the original cars. In New Jersey, NJ Transit has purchased modern vehicles to replace its PCC fleet

for the Newark Subway. Many of these cars were purchased to be used on the San Francisco F Line. These cars were never used in the Sacramento area so are not consistent with local history.

Modern Streetcars

The term “modern streetcar” is meant to encompass new streetcars currently available in the marketplace and generally based on designs, technologies, and product improvements developed within the last ten or so years. However, there is no precise technical definition for a “streetcar”, and, while there is considerable experience in the U. S. with modern light rail vehicles (LRVs), the actual experience with modern streetcars (as generally understood) in this country to date is limited to the Inekon/Skoda vehicle produced for Portland and duplicated with minor exceptions for Tacoma (Figure 23). A similar car is being developed by Inekon for Seattle’s South Lake Union Streetcar project and for the Anacostia Streetcar project in Washington, DC. Most of what is considered modern streetcar experience resides in Europe, and streetcar vehicles there are typically defined more by the characteristics of their rights-of-way (ROW) than necessarily by the characteristics of the vehicle itself. Thus, distinctions between modern streetcars and modern light rail vehicles (LRVs), particularly in the European context, can often be more blurred than instructive.

Figure 23. Modern US Streetcar by Inekon/Skoda - Portland





Figure 24 Replica Vintage Trolley - New Orleans



In Portland, a conscious effort was made to distinguish the city streetcar service and the streetcar vehicle from the regional light rail service and the LRV. Compared to the LRV, the streetcar vehicle is shorter (66 feet vs. 92 feet) and narrower (8 feet vs. 8 feet 8 inches), thus making it less intrusive and more in scale with crowded urban streets and residential neighborhoods (Figure 24).

Portland chose to avoid multiple unit operation, so all streetcar service is with single cars, further enhancing the feel of a smaller scale, urban rather than regional system. Performance parameters are accordingly reduced compared to those of the LRVs which operate at higher speed and on considerable grade-separated ROW throughout the metropolitan area.

Table 12, below, provides a summary of U.S. cities that have some form of vintage trolleys, PCC cars, replica cars, or modern streetcars either in service or in the process of being procured. Also noted are modern light rail vehicles (LRVs) in those cities that have such vehicles as well as streetcar in service. Overall counts of the numbers of cities with various classes of streetcars are: restored vintage trolleys – 10, replica trolleys – 7, restored PCC cars – 5, and new modern streetcars – 3 in service with orders placed by 2 more projects.



Table 12. Survey of US Streetcars in Service or Procurement

City	Historic/Vintage Cars		PCC	Modern Cars	
	Restored	Replica		Streetcar	LRV
Boston	X [a]		X		X
Charlotte	X	X		X[b]	X
Dallas	X		X		X
Kenosha			X		
Little Rock		X			
Lowell		X			
Memphis	X	X			
New Orleans	X	X			
Philadelphia			X		X
Portland		X		X	X
Sacramento	X [a]				X
San Francisco	X		X		X
San Jose	X				X
Seattle	X			X	X
Tacoma				X	
Tampa	X [a]	X			
Washington, DC				X	

Notes: [a] restored vehicles

5.3.2 Criteria for Vehicle Selection

There are obviously different approaches to purchasing rail vehicles. The approach recommended in this report is that resources initially be devoted to deciding the basic type and configuration of streetcar vehicle and to not focus on a specific vehicle or vehicle details until more general considerations are resolved, and the parameters of the overall streetcar project more sharply in focus. Once the basic type of streetcar vehicle is decided and a procurement process started, the procurement documents would list in detail all the specific criteria for evaluation and selection. Typically these criteria include the following major categories:

- Qualifications and experience of the manufacturer and sub-suppliers
- Manufacturing plant (location and capacity of facilities, Quality Assurance program, testing capabilities)
- Conformance of proposed vehicle to technical specifications



- Price (in various aspects)

Characteristics and issues related to the several vehicle alternatives are summarized in Table 13.

Table 13. Summary Comparison of Vehicle Alternatives

Item	Modern	PCC	Replica	Vintage
Initial \$ Each	\$3.0 M	~\$1.5 M	≤\$1.0 M	~\$1.5 M
Cost: 5 or 8 cars	\$15 M/\$24M	\$7.5 M/\$12M	\$5 M/\$8 M	\$7.5 M/\$12 M
Meet project schedule?	Yes	Doubtful [a]	Yes	Doubtful [a]
Accessibility	Low Floor w/Level Boarding	Lift (Rear Door)	HiBlock or Lift (Front Door)	HiBlock or Lift Major Modification to Car
LRT Compatibility?	[b,c]	[b]	[b,c]	[b]
Double Ended, Double Sided	Yes	No	Yes	Some
Electrification (voltage)	750 vdc	600 vdc [f]	600/750 vdc	600 vdc[f]
Fit Sacramento History	No	No	Possible [d]	Possible [e]
a- Must undergo painstaking and time consuming restoration of PCCs or historic carbodies. b- May need to adjust streetcar anticlimber to match LRV anticlimbers if there is shared track. c-Need upgrade carbody compression to 2g per GO 143B, or obtain waiver (does not affect cars built prior to 1956). d- Gomaco Birney cars close in appearance to 1920s PG&E American cars used in Sacramento. e- Car 35 (operational) and FLRT carbodies - all old Sacramento trolleys, but limited in number. f- Propulsion system usually can be modified to work with 750 vdc TES.				

5.3.3 Summary

Either replica vintage trolleys or modern streetcars could work successfully in the context of initiating a streetcar circulator between West Sacramento, Sacramento, and the riverfront. Vintage trolleys or PCCs, while potentially available, will likely to require a restoration and rebuilding effort that will exceed the project timeline. Primary issues to consider are image, cost, availability and accessibility.

- **Cost:** Replica cars are likely to have an initial cost about one-third as much as modern streetcars
- **Regulatory Issues:** Conforming to California Public Utility Commission regulation, or seeking relief from them
- **Availability:** Both replica and modern streetcars can be purchased from existing suppliers, using existing designs
 - **Replica** – Gomaco (double truck Birney)
 - **Modern** – Any of several global suppliers, if willing to build a small order or able to combine with another city's order



- **Accessibility:** Both replica and modern cars can be equipped to meet ADA
 - **Replicas** – Lift in right front door at each end of car (e.g., Gomaco Birney)
 - **Modern** – Level boarding from raised platform at mid-car door; however, raised platforms pose a design issue, especially on any trackage shared with RT Light Rail, which has some downtown station platforms at rail height (street) level.

Whichever approach is chosen, the basic vehicle configuration should be double-sided, double-ended and, for planning purposes, the basic vehicle width should be no wider than RT's existing LRVs since shared track is contemplated. While the capital cost of modern streetcars would be higher compared to replica trolleys, modern streetcars provide improved performance and passenger comfort, quieter operations, higher capacity, a better long-term accessibility solution, and greater ease in expanding the system beyond a short starter line.