



# Memo

Date: Tuesday, December 06, 2016

Project: Redwood City Downtown Transit Center and Broadway Streetcar/Urban Circulator Study

To: Diana O'Dell, City of Redwood City

From: Cathy LaFata and Jim Hecht, HDR

Subject: **Streetcar Alternatives Definition and Initial Screening**

Under subcontract to and in coordination with CDM Smith, HDR has developed several alignment alternatives for potential streetcar service along the approximately 1.8-mile Broadway corridor within the City of Redwood City. Each of the alignment alternatives extend from Second Avenue westward to the vicinity of Redwood City's Downtown Transit Center and include eight to nine transit stops. The following sections provide an overview of the alternatives, the features and proposed transit stop locations of each alternative, and the service level assumptions and requirements. Estimates of the service run time and order-of-magnitude operating and capital cost estimates for one alternative are also discussed.

## I Alternatives Considered

The streetcar alternatives presented in this memorandum are defined as follows:

<u>Alternative</u>	<u>Street</u>	<u>Limits</u>
1A	Broadway	2nd Avenue to Winslow/Marshall
1B	Broadway	2nd Avenue to Arguello
2A	Broadway	2nd Avenue to Winslow/Middlefield Loop
2B	Broadway	2nd Avenue to Winslow/Main Loop
3	Broadway/Marshall	2nd Avenue to Arguello
4A	Broadway/Marshall	2nd Avenue to Winslow/Middlefield Loop
4B	Broadway/Marshall	2nd Avenue to Winslow/Main Loop

The goal of developing these alternatives is to connect the Caltrain station in downtown Redwood City to the Stanford complex while maintaining existing facilities, including roadways, sidewalks, and parking. All of the alternatives contain a common side-running segment between Second Avenue and Maple Street. Alternatives 1A, 1B, 2A, and 2B will continue along Broadway; while alternatives 3, 4A, and 4B turn onto Spring Street and continue to follow Marshall Street.

### Common Segment

Between 2nd Avenue and Maple Street, there are five platform stops that feature a center-platform terminus station west of 2nd Avenue. The remaining four platform stops are located east of Douglas Avenue, west of Charter Street, east of Chestnut Street, and east of Maple Street.

### Alternatives 1A and 1B

Alternatives 1A and 1B continue onto Broadway and transition into a two-way center-running streetcar at Maple Street. Both alternatives have two platform stops east of Main Street and Middlefield Road.



Alternative 1A has a west-end terminus west of Winslow Street with an option of a side platform and Alternative 1B has a west-end terminus east of Marshall Street on Arguello Street.

**Alternatives 2A and 2B**

Alternatives 2A and 2B introduce a loop for continuous service through the downtown area. Alternative 2A will have the westbound track remain on Broadway to Winslow Street while the eastbound track will loop around Winslow Street to Middlefield Road to connect back to Broadway. This configuration creates a pedestrian- and transit-only plaza on Middlefield Road. There are platform stops located on the east side of Main Street, the west side of Middlefield Road, and on Winslow Street by the Caltrain station.

Alternative 2B is similar to 2A, but it extends the loop to Main Street and will have additional platform stops on the west side of Winslow Street and on Main Street south of Broadway.

**Alternative 3**

Alternative 3 turns onto Spring Street towards Marshall Street. There are platform stops located west of Main Street and west of Middlefield Road, as well as a center-platform terminus station west of Marshall Street on Arguello Street.

**Alternatives 4A and 4B**

Alternatives 4A and 4B combine elements of Alternatives 2A, 2B, and 3. Both alternatives follow Spring Street to Marshall Street and continue to Winslow Street. With Alternative 4A, the eastbound track loops around Winslow Street to Middlefield Road and then turns right onto Broadway. There are 4 platform stops located west of Main Street, west of Middlefield Road, on Winslow Street by the Caltrain station, and on Main Street south of Broadway. Alternative 4A also creates a pedestrian- and transit-only plaza on Middlefield Road, similarly to Alternative 2A. Alternative 4B will continue the loop onto Main Street and turn right onto Broadway. Its platform stops are located west of Main Street, west of Middlefield Road, on Winslow Street by the Caltrain station, east of Jefferson Avenue, and on Main Street south of Broadway.

**Summary of Features and Transit Stops**

The features and locations of transit stops for the common segment and each of the seven alternatives are summarized in Table 1 below and shown in the accompany exhibits.

TABLE 1. FEATURES AND TRANSIT STOP LOCATIONS OF EACH ALTERNATIVE

Alternative	Limits	Features	Stops
Common Segment	Broadway - 2nd Avenue to Maple	<ul style="list-style-type: none"> <li>• 2nd Ave terminus station - center median</li> <li>• two-way side-running streetcar</li> </ul>	<ul style="list-style-type: none"> <li>• west of 2nd Avenue</li> <li>• east of Douglas</li> <li>• west of Charter</li> <li>• east of Chestnut</li> <li>• east of Maple</li> </ul>
Alt. 1 A	Broadway - Maple to Winslow/ Marshall	<ul style="list-style-type: none"> <li>• transition to two-way center-running at Maple</li> <li>• west-end terminus west of Winslow, before curve to Marshall</li> <li>• optional side platform at Winslow (Option a)</li> </ul>	<ul style="list-style-type: none"> <li>• east of Main</li> <li>• east of Middlefield</li> <li>• west of Winslow</li> </ul>
Alt. 1 B	Broadway - Maple to Arguello	<ul style="list-style-type: none"> <li>• transition to two-way center-running at Maple</li> <li>• west-end terminus west of Marshall on Arguello</li> </ul>	<ul style="list-style-type: none"> <li>• east of Main</li> <li>• east of Middlefield</li> <li>• west of Marshall (on Arguello)</li> </ul>



Alternative	Limits	Features	Stops
Alt. 2 A	Broadway - Maple to Middlefield Loop	<ul style="list-style-type: none"> <li>• transition to two-way center-running at Maple</li> <li>• two-way along Broadway to Middlefield</li> <li>• westbound remains on Broadway to Winslow</li> <li>• eastbound loop around Winslow to Middlefield</li> <li>• Middlefield becomes ped-transit-only plaza</li> </ul>	<ul style="list-style-type: none"> <li>• east of Main</li> <li>• west of Middlefield (WB)</li> <li>• Winslow, by station (EB)</li> <li>• Middlefield (plaza), south of Broadway (EB)</li> </ul>
Alt. 2 B	Broadway - Maple to Main Loop	<ul style="list-style-type: none"> <li>• transition to two-way center-running at Maple</li> <li>• two-way along Broadway to Middlefield</li> <li>• westbound remains on Broadway to Winslow</li> <li>• eastbound loop around Winslow to Main</li> </ul>	<ul style="list-style-type: none"> <li>• east of Main (WB)</li> <li>• west of Middlefield (WB)</li> <li>• Winslow, by station (EB)</li> <li>• Winslow, east of Jefferson (EB)</li> <li>• Main, south of Broadway (EB)</li> </ul>
Alt. 3	Marshall - Maple to Arguello	<ul style="list-style-type: none"> <li>• follows Spring past Maple, to Marshall</li> <li>• turn right onto Arguello (west-end terminus)</li> </ul>	<ul style="list-style-type: none"> <li>• west of Main</li> <li>• west of Middlefield</li> <li>• west of Marshall (on Arguello)</li> </ul>
Alt. 4 A	Marshall - Maple to Middlefield Loop	<ul style="list-style-type: none"> <li>• follows Spring past Maple, to Marshall</li> <li>• westbound remains on Marshall to Winslow</li> <li>• eastbound loop around Winslow to Middlefield</li> <li>• Middlefield becomes ped-transit-only plaza</li> <li>• eastbound continues to Marshall, then right</li> </ul>	<ul style="list-style-type: none"> <li>• west of Main</li> <li>• west of Middlefield (WB)</li> <li>• Winslow, by station (EB)</li> <li>• Middlefield (plaza), south of Broadway (EB)</li> </ul>
Alt. 4 B	Marshall - Maple to Main Loop	<ul style="list-style-type: none"> <li>• follows Spring past Maple, to Marshall</li> <li>• westbound remains on Marshall to Winslow</li> <li>• eastbound loop around Winslow to Main</li> <li>• right on Broadway</li> </ul>	<ul style="list-style-type: none"> <li>• west of Main (WB)</li> <li>• west of Middlefield (WB)</li> <li>• Winslow, by station (EB)</li> <li>• Winslow, east of Jefferson (EB)</li> <li>• Main, south of Broadway (EB)</li> </ul>

## II Service Considerations

Given the capital cost investment of a streetcar system, it is typically expected that a streetcar system would operate most of the day and evening with fairly frequent service. Generally, annual operations and maintenance (O&M) costs of a streetcar service are closely correlated with the the assumptions for service headway, span of service, and run times (based on end-to-end distance, dwell times, number of stops, and average running speeds). If any of these basic assumptions are changed, the O&M costs would change accordingly.

### Headway and Span of Service

For the purpose of this memorandum, the following potential service levels are assumed:

#### MONDAY THROUGH FRIDAY

- 15-minute service from 6 am to 7 pm
- 30-minute service from 7 pm to midnight



**SATURDAY**

- 30-minute service from 7 am to midnight

**SUNDAY AND HOLIDAYS**

- 30-minute service from 8 am to 10 pm

**Run Time**

For the purpose of this memorandum, an estimate of run-time has been prepared for Alternative 1A, Broadway from 2nd Avenue to Marshall Street. The end-to-end distance is 1.75 miles, with 8 stops in each direction. The assumed average running speed accounts for acceleration, deceleration, and street-running operations, as well as 20 seconds of dwell time at each stop, 30 seconds of average delay per traffic signal, and 15 seconds per stop sign. This estimate shows a run time of 12.77 minutes from end-to-end (an average speed of 8.2 miles per hour), with approximately 2 minutes to “turn the train” (i.e. the operator moving from the cab at one end of the streetcar to the cab at the other end of the streetcar) at each end of the line, resulting in a cycle time of 30 minutes (see Table 2). In order to provide 15-minute headways, two streetcars must be in service; to provide 30-minute headways, one streetcar must be in service. A spare vehicle must be provided for maintenance purposes, so the fleet size would be three.

TABLE 2. RUN TIME CALCULATIONS FOR ALTERNATIVE 1A

Stop Name	Distance (miles)		Assumed Speed (mph)	Travel Time (minutes)				Cumulative Time (minutes)		
	Cumulative	Increment		Running Time	Dwell Time	Delay <sup>a</sup>	Total Time	Train #1	Train #2	Train #1
1 Marshall	0.00	-	-	-	-	-	-	0.00	15.00	30.00
2 Middlefield	0.16	0.16	15	0.64	0.33	1	1.97	1.97	16.97	31.97
3 Main	0.32	0.16	15	0.63	0.33	1	1.96	3.93	18.93	33.93
4 Maple	0.46	0.15	15	0.59	0.33	0.5	1.42	5.35	20.35	35.35
5 Chesnut	0.76	0.30	20	0.89	0.33	0.5	1.72	7.07	22.07	37.07
6 Charter	1.14	0.38	20	1.14	0.33	1	2.47	9.54	24.54	39.54
7 Douglas	1.38	0.24	20	0.72	0.33	0.5	1.55	11.08	26.08	41.08
8 Second Ave	1.73	0.35	20	1.04	0.33	0.25	1.62	12.71	27.71	42.71
8 Second Ave	1.73	0.00	0	0.00	2		2.00	14.71	29.71	44.71
7 Douglas	1.38	0.35	20	1.04	0.33	0.25	1.62	16.33	31.33	46.33
6 Charter	1.14	0.24	20	0.72	0.33	0.5	1.55	17.88	32.88	47.88
5 Chestnut	0.76	0.38	20	1.14	0.33	1	2.47	20.35	35.35	50.35
4 Maple	0.46	0.30	20	0.89	0.33	0.5	1.72	22.07	37.07	52.07
3 Main	0.32	0.15	15	0.59	0.33	0.5	1.42	23.49	38.49	53.49
2 Middlefield	0.16	0.16	15	0.63	0.33	1	1.96	25.45	40.45	55.45
1 Marshall	0.00	0.16	15	0.64	0.33	1	1.97	27.42	42.42	57.42

a. Intersection Delay: 30 seconds per signal, 15 seconds per stop sign



### III Order-of-Magnitude Cost Estimates

#### Annual Operations and Maintenance Cost

The service scenario described above, that includes the need for a fleet of three vehicles, results in 9,672 streetcar service hours per year. Assuming an operating cost per vehicle of \$200 per service hour, the total order-of-magnitude O&M cost is \$1.9M per year (see Table 3).

TABLE 3. ORDER-OF-MAGNITUDE OPERATIONS AND MAINTENANCE COSTS

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Hours: Peak	13	13	13	13	13	0	0
Hours: Non-Peak	5	5	5	5	5	17	14
Vehicles: Peak	2	2	2	2	2	2	2
Vehicles: Non-Peak	1	1	1	1	1	1	1
Vehicle-Hours	31	31	31	31	31	17	14
Vehicle-Hours per Week		186					
Vehicle-Hours per Year		9672					
Operating Cost per Vehicle Hour		\$ 200					
Operating Cost per Year		\$ 1,934,400					

#### Capital Cost

A rough order-of-magnitude capital cost estimate has been prepared for Alternative 1A, Broadway from 2<sup>nd</sup> Avenue to Marshall. Note that no design has been performed, no identification of conflicts with utilities or other infrastructure in the corridor has occurred, and no determinations have been made as to any unique circumstances that would need to be mitigated in order to accommodate the installation of a modern streetcar system. The estimate is based simply on the length of track; the number of turnouts, platforms, and vehicles; and the need for an Operations and Maintenance Facility to store and service the streetcar fleet and to serve as a base for operations. Unit costs are from “U.S. Modern Streetcar Projects Cost Comparison Summary Report” that was prepared by the Community Streetcar Coalition in March 2016.

Note that costs can vary significantly from one modern streetcar project to another depending on design standards, the level of amenities provided at the stations, the sophistication or simplicity of the electronic systems, the approach taken with utilities, and the extent of roadway, sidewalk and traffic signal reconstruction. This estimate is based on the average experience of about a dozen different modern streetcar projects constructed between 2001 and 2016. Also note that the costs associated with property acquisition for the Operations and Maintenance Facility, the amount of property initially used for the facility, and the property to be set aside for future expansion can have a significant impact on the cost.

Modern streetcar vehicle prices continue to increase significantly with the continual advancement of sophisticated on-board systems. Significant cost savings could be achieved by using historic or replica streetcars. The major disadvantage of historic or replica streetcars is the inability to offer level boarding. In addition, streetcar projects are complex and challenging to implement, and professional service costs are significant. As much work that can be performed efficiently in-house would reduce professional service costs.



Table 4 presents the order-of-magnitude capital cost estimate for Alternative 1A in 2016 dollars, with a 40% contingency given that no design has been performed. The total is \$146 million, or \$84 million per mile. This is the upper end of the range of U.S. modern streetcar project costs; however, it is typically better to start with a conservative estimate than to underestimate the costs. There are many modern streetcar projects that have been completed for \$50 million per mile. If that were achieved for this modern streetcar project in Redwood City, the total cost would be \$87 million.

TABLE 4. ORDER-OF-MAGNITUDE CAPITAL COSTS

SCC Code	Item	Unit	Unit Cost	Quantity	Total
10.1	Embedded Track	Track-Mile	\$ 3,500,000	3.46	\$ 12,096,212
10.2	Turnouts/Diamond Crossings	EA	\$ 100,000	7	\$ 700,000
20.1	Platforms	EA	\$ 100,000	14	\$ 1,400,000
30.1	Maintenance and Storage Facility	EA	\$ 8,000,000	1	\$ 8,000,000
40.1	Utilities/Sitework	Track-Mile	\$ 5,000,000	3.46	\$ 17,280,303
50.1	Systems <sup>a</sup>	Track-Mile	\$ 4,500,000	3.46	\$ 15,552,273
10-50	Construction Subtotal				\$ 55,028,788
60.1	Right-of-Way-MSF	LS	\$ 10,000,000	--	\$ 10,000,000
70.1	Vehicles	EA	\$ 5,000,000	3	\$ 15,000,000
80.1	Professional Services	LS	30%	--	\$ 24,008,636
	Contingency	LS	40%	--	\$ 41,614,970
	Total				\$ 145,652,394
	Cost per mile (millions)				\$ 84

a. Systems includes: Traffic Signals, Train Signals, TPSS, OCS, Communications, Fare Machines, Changeable Message Signs, Cameras

## IV Summary of Alternatives

While a full analysis of the alternatives that evaluates each alternative against a set of performance measures has not yet been completed, the following observations about the alternatives can be made.

### Design Advantages and Disadvantages

#### COMMON SEGMENT

Advantage: All alternatives would run along Broadway, a major corridor in the city identified for future enhanced transit.

Disadvantage: At the east terminus, the westbound track will need to merge into traffic.

#### ALTERNATIVE 1A

Advantage: The west terminus utilizes the existing crosswalk to connect streetcar passengers to the nearby Caltrain platform.

Disadvantage: At the west terminus, the eastbound track will need to merge into traffic; along Broadway, the streetcar will operate in a shared travel lane. There is a potential safety conflict with the turnout location near the platform.

#### ALTERNATIVE 1Aa (SIDE PLATFORM OPTION)

Advantage: The west terminus provides easy access to existing Caltrain platform.



Disadvantage: At the west terminus, a controlled streetcar-only phase at Winslow Street will be required for the westbound track to enter the platform. The eastbound track will need to merge back into traffic; along Broadway, the streetcar will operate in a shared travel lane.

**ALTERNATIVE 1B**

Advantage: If the Caltrain station is relocated north of Broadway/Marshall with the addition of the Dumbarton rail line, this alternative provides direct access to the new station.

Disadvantage: At the west terminus, passengers will need to cross the street twice to get to the existing Caltrain platforms. Parking is eliminated on Arguello Street. Along Broadway, the streetcar will operate in a shared travel lane.

**ALTERNATIVE 2A**

Advantage: Platform on Winslow Street is in close proximity to the existing Caltrain platforms. Pedestrian- and transit-only on Middlefield Road.

Disadvantage: Requires a separate westbound through movement or yielding on Winslow Street for the streetcar to make the left turn, and the same for the eastbound track making a right onto Broadway. This can generate traffic build-up in both eastbound and westbound directions. Along Broadway, the streetcar will operate in a shared travel lane.

**ALTERNATIVE 2B**

Advantage: Platform on Winslow Street is in close proximity to the existing Caltrain platforms. Provides direct service to Main Street.

Disadvantage: Requires a separate westbound through movement or yielding on Winslow Street for the streetcar to make the left turn, and the same for the eastbound track making a right onto Broadway. This can generate traffic build-up in both eastbound and westbound directions. Along Broadway, the streetcar will operate in a shared travel lane.

**ALTERNATIVE 3**

Advantage: If the Caltrain station is relocated north of Broadway/Marshall with the addition of the Dumbarton rail line, this alternative provides direct access to the new station.

Disadvantage: There could be traffic build-up when the streetcar stops at platform west of Main Street. At the west terminus, passengers will need to cross the street twice to get to the Caltrain platforms. Parking is eliminated on Arguello Street. Potential safety conflict with the turnout location near the platform.

**ALTERNATIVE 4A**

Advantage: Platform on Winslow Street is in close proximity to the existing Caltrain platforms. Pedestrian- and transit-only on Middlefield Road.

Disadvantage: There could be traffic build-up when the streetcar stops at platform west of Main Street. Requires a separate westbound through movement or yielding on Winslow Street for the streetcar to make the left turn, and the same for the eastbound track making a right onto Broadway. This can generate traffic build-up in both eastbound and westbound directions.

**ALTERNATIVE 4B**

Advantage: Platform on Winslow Street is in close proximity to the existing Caltrain platforms. Provides direct service to Main Street.



Disadvantage: There could be traffic build-up when the streetcar stops at platform west of Main Street. Requires a separate westbound through movement or yielding on Winslow Street for the streetcar to make the left turn, and the same for the eastbound track making a right onto Broadway. This can generate traffic build-up in both eastbound and westbound directions.

### **Service and Cost Comparisons**

The service levels would be the same regardless of alignment alternative selected. If service characteristics are changed, the effect on each alternative would be roughly the same. The O&M costs would not vary much by alternative, as the same number of vehicles operating with the same service plan along a comparable length is assumed for each alternative.

Similarly, capital costs would not vary much by alternative. One of the key elements in determining capital cost is the length of the alternative, which is shorter for Alternatives 1A, 1B, 2A, and 2B due to the more direct alignment along Broadway than for Alternatives 3, 4A, and 4B that utilize Marshal Street west of Maple Street. Track length is also a differentiator among capital costs, and alternatives that include a turn-around loop at the west terminus will have higher costs reflected in the trackwork elements. Considering the track lengths of each alternative and applying the same conservative estimates indicated in Table 4 for estimating purposes, the capital cost estimates of the alternatives are as follows, showing minimal variation among them:

Alternative 1A:	\$145.7M
Alternative 1Aa:	\$145.5M
Alternative 1B:	\$148.3M
Alternative 2A:	\$146.7M
Alternative 2B:	\$149.8M
Alternative 3:	\$151.2M
Alternative 4A:	\$151.7M
Alternative 4B:	\$152.1M