CONCEPTUAL ENGINEERING REPORT

May 2013
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1 INTRODUCTION

1.1 Project Background

Winston-Salem is conducting an Alternatives Analysis (AA) to further investigate opportunities for the implementation of an Urban Circulator in downtown, building upon the Winston-Salem Streetcar Feasibility Study (completed in 2006) and recommendations developed as part of the Regional Transit Development Plan, Forsyth and Guilford Counties Transit Vision for 2025 (completed in 2010), the 2030 Legacy Comprehensive Plan Update (2012) and The Downtown Plan (completed in 2007). This AA will develop and evaluate transit alternatives to best meet project goals and will establish a Locally Preferred Alternative (LPA) describing the preferred transit route and technology.

The Urban Circulator Study is conducting more detailed planning analyses for a potential circulator project to connect the city’s most active educational, medical and employment destinations to the central bus hub. The study area is focused on an approximately 4-mile corridor that extends west to east through downtown Winston-Salem and surrounding neighborhoods, from Wake Forest Baptist Medical Center through downtown, Piedmont Triad Research Park and Winston-Salem State University, to East Winston.

At this stage of the study process, a "selected route", which is shown in the figure below, has been advanced for further analysis.

Figure 1: “Selected Route” Advanced for Further Analysis

1.2 Purpose of Document

This report documents the streetcar-oriented conceptual design elements that were reviewed as part of the AA study including track alignment, stop locations, systems aspects, and the location of a Vehicle Maintenance Facility. Additionally, this report summarizes the findings of more specific reviews of key design challenges along the potential route alignments. It is important to note that all observations and
conclusions are based on conceptual level analysis only; all elements discussed herein will be examined in more detail as part of future preliminary engineering efforts (and beyond into final design).

Although the AA study considered both streetcar and enhanced bus options, streetcar-oriented design elements are the focus of this report, because rail-based technology is more restrictive in terms of design requirements. The infrastructure associated with the enhanced bus option would generally consist of platforms at stops, given that the vehicles operate on rubber wheels and tracks are not necessary.

2 DESIGN PRINCIPLES

At the AA phase, the main project components are defined conceptually, including track, major roadway items, major structural items (including stations, bridges and retaining walls), and major systems elements (including traction power elements).

The Vehicle Technical Alternative report discusses the design requirements associated with streetcar vehicles. Modern streetcar, for the purpose of the applicability of this document, denotes an urban transit system technology with the following characteristics:

- Vehicles with articulated sections to navigate tight curves;
- Low Floor vehicles to accommodate reduced platform heights;
- Electrical propulsion motors;
- Steel wheels that run along steel rails;
- Power generally drawn from an overhead wire or from an onboard battery; and
- Travel along both city streets (mixed-traffic or non-exclusive right-of-way) and dedicated rights-of-way with street crossings (semi-exclusive right-of-way).

The general principles that guided the design process are detailed below.

2.1 Track / Guideway Element

Streetcar systems generally operate in an urban, in-street environment. The benefit of an in-street alignment is a minimal amount of right-of-way acquisition, challenging designers to “fit” the system into existing roadway. The conceptual design focused on the horizontal alignment, station stop locations, maintenance facility layout, and potential property impacts. Future design phases will also consider the vertical profile, which generally follows the existing roadway profile.

In general, the following design criteria were used to develop streetcar alignments at a conceptual level:

- Track gauge = 4’-8 ½” (distance between inside edge of each rail);
- Track slab width = 8 feet;
- Rail type: 115 lb. rail encapsulated within a rubber boot
- Horizontal tangents shall be used in areas of special trackwork (turnouts, crossovers, etc) and stop platforms:
  - Minimum horizontal tangent beyond stop platform = 15 feet;
  - Minimum horizontal tangent between curves = 40 feet;
  - Minimum horizontal tangent between switches = 60 feet;
- Offset distance from centerline of track to edge of platform = 4.2 feet; and
- Minimum horizontal turning radius = 65 feet.
- Maximum vertical grade = 9.0% for short distances

An image showing a typical in-street installation is shown in Figure 2, and a typical roadway cross-section with embedded streetcar track is illustrated in Figure 3.
2.2 Roadway

The streetcar mode is intended to integrate into the existing roadway infrastructure. The track designer considers the existing roadway configuration (curves, intersections, vertical grades, travel lanes, traffic signals, pedestrian crosswalks, property impacts and roadway cross section) when laying out the streetcar’s horizontal alignment. By following the existing physical features of the roadway, streetcar trackways avoid major reconstruction of the remaining lanes. This method of avoiding reconstruction also
allows existing drainage patterns to be maintained. In general, the following design criteria were used at a conceptual level:

- Minimum shared travel lane width = 11 feet, 10.5 feet absolute minimum
- Minimum adjacent parking lane width = 9 feet; and
- Minimum sidewalk width = 5 feet (wider sidewalks needed at platform sites).

In some track slab installations, the entire roadway surface may be treated in some manner to enhance the overall benefit of the streetcar and leave the adjacent roadway paved surface in a much improved state. If reconstruction of the entire roadway is required, the cross slopes presented in the above graphic can be improved upon to achieve a more desirable cross slope.

Several factors influence the decision-making process when selecting the lane to place streetcar tracks on a multi-lane street: existing and future traffic volumes; presence of existing utilities; presence of on-street parking; and desired platform configuration. A typical cross-section for a street with one travel lane and on-street parking in each direction (such as 1st between Hawthorne Rd. and I-40 Business Ramp) is shown in Figure 4. Street dimensions vary throughout the alignment; therefore, a number of typical cross-sections are required. A complete set of the various typical cross-sections is included on the plan sheets in Appendix A.

Figure 4: Multi-Lane Cross Section of 1st between Hawthorne Rd. and I-40 Business Ramp
2.3 Stops

The Proposed Stop Locations Memorandum identifies stop locations proposed during the initial conceptual design effort. The identified stop locations would function regardless of the selected transit mode (streetcar or bus), but for planning purposes, the stricter site requirements of a streetcar vehicle (e.g. typically an extended sidewalk platform or "bulb-out") was taken into account. The proposed stop locations are as follows, and are shown on the map in Figure 1 (and are more precisely placed on the plan sheets in Appendix A):

<table>
<thead>
<tr>
<th>Proposed Stop Location</th>
<th>Potential Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFBMC / Hawthorne Rd.</td>
<td>Center boarding</td>
</tr>
<tr>
<td>1st St. / Hawthorne Rd.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>1st St. / Burke St. (EB only)</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>2nd St. / BBT Ballpark (EB only)</td>
<td>Left-side boarding</td>
</tr>
<tr>
<td>Burke St. / Brookstown Ave. (WB only)</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Burke St. / 1st St. (WB only)</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>4th St. / Spring St.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>4th St. / Spruce St.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>5th St. / Marshall St.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>5th St. / Trade St.</td>
<td>Center boarding</td>
</tr>
<tr>
<td>Patterson Ave. / 5th St.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>4th St. / Research Park Blvd.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Research Park Blvd. / 2nd St.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Research Park Blvd. at railroad</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Rams Dr. / Research Park Blvd.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Martin Luther King Jr. Blvd. near Rams Dr.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Union Train Station</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>Martin Luther King Jr. Dr. / 2nd St.</td>
<td>Right-side boarding</td>
</tr>
<tr>
<td>5th St. / Martin Luther King Jr. Dr.</td>
<td>Right-side boarding</td>
</tr>
</tbody>
</table>

Stops for this project were identified as at-grade platforms on the sides of the street; with two median platforms in the center of the street, included at the WFBMC end-of-line and Transportation Center. As a default assumption, the same stop platform design would be used for both the streetcar alternative and the enhanced bus alternative. In general, the following design criteria were used at a conceptual level:

- Platform length = 66 feet (minimum of 45 feet);
- Platform height = ramp up to a height of 10 inches above the top of street pavement. Typically, sidewalks have a height of approximately 6 inches above the top of street pavement);
- Platform width = 8 feet; and
- Shelter width = 5 feet.
- ADA accessibility requirements

Stops generally are intended to include the following furnishings; more detailed platform-specific design will occur in the future preliminary engineering effort:

- Simple shelter at back of platform;
- Electronic message board on shelter;
- One ticket vending machine;
- ADA tactile warning strip along platform edge; and
- Simple signage (like WSTA sign).

Examples of the typical stop layouts are shown in the following figures.
2.4 Systems

Systems include the streetcar power supply and distribution systems, traffic signals with streetcar only signal, corrosion control and communications. Streetcar traction power supply and distribution system requirement highlights are presented below.

2.4.1 Low Power Substations

Electrical substations are small buildings that contain the equipment necessary to supply the vehicles with operating power. Low power substations are defined as having a rated power of 500 kW or less. It is recommended that smaller “low-power” substations be used rather than larger “high-power” substations, given the potential cost savings resulting from the following:
- No underground or overhead parallel feeder wires;
- Utility service from common distribution circuits;
- Lower return rail voltages and lower stray current levels reducing utility relocations;
- Smaller land acquisition requirements; and
- Greater flexibility in the siting of substations.

Typical spacing is approximately one unit per one-half mile and it is estimated that eight low-power substations will be needed along the preferred alignment. A standard low-power substation is approximately 25 feet by 18 feet in size as shown in the typical site plan in Figure 9.

**Figure 9: Typical Low Power Substation Site Plan**

Low power substations can be designed as either a basic pre-fabricated enclosure or as a stand-alone building. Installations have been made in pre-fabricated units ready to set in place or as individual assemblies of equipment which can be installed in a specially built enclosure in locations such as building basements and parking garages. A typical pre-fabricated substation is shown in Figure 10.

Architecturally treated low power substations can be integrated into areas with high design standards or historic districts. Figure 11 shows an application where two parking spaces of an existing parking area were modified to accommodate a low power substation.
2.4.2 Traction Power Supply and Distribution

Traction power is distributed from the substations to the vehicles via an overhead contact system (OCS). Poles are spaced at regular intervals along the entire alignment with a resulting design standard of two or three poles per block depending on the maximum span length of the OCS and the length of the blocks. Generally, for a trolley wire system, the maximum distance between poles is 100-120 feet. The distance actually used in the design is 10 feet less than the maximum span length to permit flexibility in citing the poles and foundations to avoid underground structures and utilities found during construction of the line.

The proposed trolley wire system relies on a single contact wire to distribute power to the vehicles, limiting visual impacts.
2.4.3 Traffic Signals

Traffic signals would be needed to accommodate some of the traffic flow changes to facilitate streetcar movements, including bi-directional transit operation. Streetcar through and left-turning movements can create conflicts with opposing traffic if left unsignalized. The conceptual design (plan sheets are included in Appendix A) identified a new traffic signal at Burke St. at 4th St.

Some intersections through the proposed alignment are currently signalized, but modifications are needed to accommodate the streetcar and facilitate vehicle preemption/priority. Potential signal modifications were identified at:

- Hawthorne Rd. and 1st St.
- 5th St. and Church St.
- 5th St. and Patterson Ave.
- Research Park Blvd. and Rams Dr. (assumes Research Park Blvd. will be constructed, completed and signalized in the future build year)
- Martin Luther King Jr. Dr. and 5th St.

Streetcar movements in the existing traffic lanes will be controlled by normal traffic signal operations. At locations where sight distance is limited or the streetcar must make a left-turn movement, transition into or out of special lanes, or transition into semi-exclusive operations, special transit-only signals will be provided. These transit signals will be physically separated from the traffic signals and will use transit-only display indications consistent with the Manual on Uniform Traffic Control Devices (MUTCD).

2.5 Vehicle Maintenance Facilities

For the streetcar “build” option, a Vehicle Maintenance Facility (VMF) is needed to provide vehicle storage and maintenance services, including vehicle inspection, exterior washing, interior cleaning, repair activities, and spare parts storage. Space for operations and administrative functions would also be included. The facility must accommodate a minimum of eight streetcar vehicles (seven active vehicles and one spare), based on a preliminary assessment of vehicle requirements for the project. A general guideline for property sizing requirements is 0.20 - 0.25 acres per stored vehicle, based on typical sizes of other functioning streetcar facilities and local environmental and topographic conditions. Thus, a site with a minimum size of 1.6 – 2.0 acres is needed to support streetcar operations for the potential project. The option to acquire additional acreage would be beneficial to accommodate more vehicles if the fleet size grows.
The Vehicle Maintenance Facility Site Options and Evaluation Technical Memorandum identifies candidate locations for a facility and evaluates specific site options. The VMF site at Union Station was selected as the preferred option, since that property was recently purchased by the City of Winston-Salem. For bus-based alternatives, it is assumed that existing WSTA facilities could accommodate additional buses, and no new VMF would be needed.

At the Union Station Site, constructing a new stand-alone VMF or retrofitting the basement level of existing train station were both considered. Constructing a storage yard at street level and utilizing the basement level of the existing structure was deemed not to be feasible due to the following:

- The vertical difference between street level and the basement level of Union Station results in the need for a lead track to be approximately 900 feet, which cannot be achieved due to the geographical limits of the site;
  - The vertical difference between street level and the basement level of Union Station is approximately 26 feet;
  - Considering a maximum grade of 9%, roughly 300 feet of track length would be needed;
  - Plus two vertical curves (crest and sag) of approximately 300 feet each would be required;
- Even if the 900-foot length was achievable a curve with a minimum radius of 65.6 feet would be required to make the U-turn. However, a tight radius is not desirable on a 9% grade; and
- The streetcar vehicle is too long to fit within the basement level of Union Station and a building extension would be required.

Figure 14 shows the configuration for the conceptual VMF at the preferred site.

If a “build” alternative is selected as the Locally Preferred Alternative, the VMF will undergo much more extensive design in future efforts, which may result in a design framework that varies significantly from the preliminary layout shown in this document.
3 EVALUATION OF DESIGN CHALLENGES

There were several areas throughout the study corridor that were identified as areas that could constrain the streetcar design. An investigation of these areas was performed to review the existing conditions, explore options for use with modern streetcars, summarize modifications required for streetcar applications, and provide conceptual level cost estimates for the anticipated work. Figure 15 illustrates some of the locations of design issue areas. The following subsections provide additional details about ways to overcome the design challenges.

Figure 15: Design Challenges
3.1 End-of-Line Stop near Medical Center

To serve the employee entrance of Wake Forest Baptist Medical Center (WFBMC), a proposed stop is located on Hawthorne Rd. near Queen St. This proposed stop location is the natural location where the streetcar reverses direction, which is referred to as the “end-of-line”.

The end-of-line would consist of a stub end turnaround track that is also referred to as a fish-tail, because of the way it looks from above. After the streetcar operator has stopped at the platform to let passengers get on and off the vehicle, the streetcar will reverse direction on the fish-tail and the operator will walk to the other end of the vehicle to switch cabs.

WFBMC will begin developing a revised master plan in the near future. Based on the outcome of that plan, WFBMC may prefer a route that has an end-of-line on Beach St. The exact location of the end-of-line may need to be refined in the future.

3.2 Vertical Clearance on 5th Street

A set of railroad tracks separates downtown from Piedmont Triad Research Park (PTRP). To move from one part of the City to the other, either at-grade crossings at 3rd St. and 4th St., or an underpass at 5th St. could be used. The underpass on 5th St. was identified as preferable given that streetcars should not traverse freight railroad tracks.

The vertical clearance of the 5th St. railroad underpass is 12’–4”. Most modern streetcars have a height of 12’ to the top of roof-mounted equipment. With the pantograph in a locked down position, a minimum of 14’ operating height from the track top of rail to the overhead wire is required.

In the vicinity of the underpass, 5th St. is roughly 30’ wide and consists of an eastbound lane, westbound lane and a two-way left-turn lane (TWLTL). To overcome this design challenge, the TWLTL on 5th St. between Church St. and Patterson Ave. could be eliminated to accommodate a two-way streetcar-only lane. This streetcar-only lane could be lowered by roughly 3 feet under the bridge to meet the minimum height requirement. One benefit of this approach is that it will reduce the cost to lower the entire roadway under the railroad bridge. Jacking the existing railroad bridge was considered, but discarded since the required maximum grades for freight tracks would prohibit raising the bridge.

3.3 Vertical Clearance on 4th Street

Another set of railroad tracks that bisects PTRP is now unused. PTRP and City officials have initiated a Rail-Trail project, with the goal to turn the railroad beds into greenways for walking and biking. The selected route travels along 4th St. under the Rail-Trail Bridge and an elevated walkway between Piedmont Leaf Lofts and the industrial building to the south.

The vertical clearance of the underpasses on 4th St. is 13’–4”. The approach being considered is to lower the entire cross-section of 4th St. by roughly a foot under the bridges to meet the minimum 14’ operating height.

3.4 Vertical Clearance on Research Park Boulevard

The selected route travels along Research Park Blvd., which is currently under construction. Based on engineering plans provided to the study team, the vertical clearance between Research Park Blvd. and the bridge carrying I-40 Business is 15’–7”, which meets the minimum 14’ operating height. As the roadway construction is completed and this urban circulator is advanced for further study, the vertical clearance at this location should be confirmed.
3.5 Roundabout at Research Park Boulevard and 3rd Street

The selected route travels along Research Park Blvd. through the roundabout at 3rd St. A roundabout is a type of circular intersection in which roadway traffic is slowed and flows almost continuously in one direction around a central island to several existing intersecting roads. In a modern roundabout, entering traffic must yield to the traffic that is already in the circle.

Streetcars have a turning radius of 65.6 feet, which is too large to be accommodated by most roundabouts. Therefore, designing an alignment that goes through a roundabout is typically the preferred approach. This approach does have its drawbacks. Streetcars going through the roundabout could conflict with the vehicular traffic that is “already in the circle”. This approach also creates driver confusion because most would not be anticipating a streetcar vehicle to punch through the intersection. Stop bars or signalized movements are recommended to stop vehicular traffic and reduce the potential conflicts with the streetcar vehicle.

Figures 16 and 17 show examples of how streetcars (also known as “trams” in Europe) operate in roundabouts.

Figure 16: Streetcar Intersecting Roundabout in Norway
3.6 Grade on Research Park Blvd

The selected route travels along Research Park Blvd., which is currently under construction. Based on engineering plans provided to the study team, Research Park Blvd. has a 9% grade in the vicinity of Rams Dr. Streetcars, for a short distance, can handle maximum grade of 9%, which equates to 9 foot vertical rise in 100 horizontal feet of road. Fortunately, Research Park Blvd. meets this minimum. As the roadway construction is completed and this urban circulator is advanced for further study, the as-built grade at this location should be confirmed. In addition, the 9% grade prohibits the construction of a station stop because of its steepness.

3.7 Rams Drive

The selected route travels along Rams Drive between Research Park Blvd. and Martin Luther King Jr. Dr. The distance from curb to curb on Rams Drive is approximately 34 feet wide and consist of an eastbound lane, westbound lane and a TWLTL. There is an opportunity to reduce the cost of the overall design by creating a two-way streetcar-only lane adjacent to the existing travel lanes on Rams Drive. Less track work would be required as a result, but operations must take into consideration the length of the proposed two-way single track.

Figures 18 and 19 show examples of rail infrastructure in exclusive lanes adjacent to mixed traffic.
3.8 Vertical Clearance on Rams Drive

The vertical clearance of the underpasses on Rams Drive is 13’–9”. The two-way streetcar-only lane can be slightly lowered under the bridges to meet the minimum 14’ operating height.
3.9 Structural Assessment of Bridges

The selected route travels over the existing bridges described in the table below.

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Approximate Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rams Dr. bridge over US 52</td>
<td>72 feet</td>
</tr>
<tr>
<td>Martin Luther King Jr. Dr. bridge over railroad tracks</td>
<td>78 feet</td>
</tr>
<tr>
<td>Martin Luther King Jr. Dr. bridge over I-40 Business (60 feet)</td>
<td>66 feet</td>
</tr>
</tbody>
</table>

At this conceptual level of design, structural engineering assessments were not performed. As the project progress, further evaluation is recommended to determine the condition of the existing bridges and if the structures have sufficient capacity to carry the proposed streetcars.

3.10 End-of-Line Stop in East Winston

This proposed stop location is the natural location for the streetcar reverse direction, which is referred to as the “end-of-line”. The select route will extend north on Martin Luther King Jr. Dr. to 5th St. There are many locations in this area where an end-of-line stop could be located (place where the streetcar reverses direction). Martin Luther King Jr. Dr. is a heavily travelled automobile-oriented corridor. Locating the end-of-line on a side street would reduce the need for passenger vehicles to stop or slow due to the streetcar operations, and may also reduce potential pedestrian conflicts. The proposed end-of-line location is located on the north side of 5th St. near Winston Mutual. The exact location of the end-of-line may need to be refined in the future.

The proposed end-of-line consists of a dedicated bi-directional single track that diverges into a double track station platform. The purpose of this design configuration is to ensure that streetcars will not be forced to queue in this location.