DRAFT

Fort Worth Modern Streetcar

DESIGN ASSUMPTIONS

JUNE 17, 2010

1.0 Introduction

1.1 Purpose and Scope

The purpose of this Design Assumptions Technical Memorandum is to establish the framework and general assumptions that will guide alignment development and design for the Fort Worth Streetcar Project. The material contained herein is intended to provide a uniform basis for the planning and design of any streetcar project that might be undertaken by the City of Fort Worth (City). Its purpose is to provide sufficient information to allow the development of preliminary and final designs including estimates of capital, operating and maintenance costs, and determination of the potential impacts of operations and construction on the communities.

The following design criteria provides the basis for uniform design and is not a substitute for engineering judgment and sound engineering practice that will be encountered during project development. It is the responsibility of the designer to expand upon the general framework and criteria to a level of detail consistent with the level of design. The designers are encouraged to analyze alternative approaches to solving design problems to determine the most cost-effective, environmentally sound, and sustainable solution.

This technical memo is to be used by the City's streetcar project team and partners to develop designs that meet the intent stated and to evaluate concepts and alternatives within the engineering framework and assumptions.

1.2 System Technology Description

Modern streetcar, for the purpose of the applicability of this document, denotes an urban transit system technology with the following characteristics:

- Low-floor vehicles with articulated sections to navigate tight curves
- Electrical propulsion motors
- Steel wheels that run along steel rails
- Power generally drawn from an overhead wire or from an onboard battery

- 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).

1.3 System Technology Description

The material contained in the following sections provides a uniform basis for design and is expected to be refined and expanded during preliminary engineering and final design.

This design assumptions memo represents a recommended set of uniform and minimum guidelines for use in the development, design, engineering, and implementation of the streetcar project. It is not a specification and therefore, the following criteria are intended to set minimum and typical guidelines to assure design uniformity and consistency of systems, components, and facilities of streetcar infrastructure.

These criteria serve as guidelines and do not substitute for engineering judgment and sound engineering practice. More detailed design criteria not deemed broad enough for this memo will be included in the Engineering Design Criteria Manual.

1.4 Codes and Standards

In general, codes, criteria, and standards that are promulgated by third parties and regulatory agencies and that are applicable to the design of City-owned facilities govern the design of each engineering discipline. Unless stated otherwise, designers shall verify that they are working with the most recent editions of such documents.

Where facilities that are constructed under a City project will be owned and/or maintained by others, the designer shall verify what criteria that entity may require and obtain same including published criteria, applicable standard drawings, directives, manuals, specifications, as well as any revisions thereto. The designer must keep such criteria up-to-date during the entire design phase of the project.

1.5 Project Goals

The primary goal of a streetcar project is to provide passengers with the benefits of improved public transportation service in a safe, cost-effective, environmentally sensitive, and socially responsible manner. To this end, the following policies shall be adhered to:

- **Proven hardware** - The streetcar system shall be designed to use proven subsystems hardware and design concepts.
- **Design life** - The streetcar system's fixed facilities (structures and buildings) shall be designed for continued operation over a minimum period of 50 years before complete refurbishment and renovations are necessary due to wear and tear and obsolescence. Vehicles and equipment shall be designed for a minimum of 30 years before complete replacement becomes necessary.
- **Service integration** - The streetcar route is to be part of the overall local and regional transportation system. Specific provisions shall be made for the efficient interchange of passengers with private and other public transportation modes.
- **Land use** - The streetcar system should be designed, where possible, to stimulate urban development and redevelopment while avoiding drastic changes that disrupt the public commerce or social interaction. Creation of physical barriers to land use functions and reduction in traffic circulation capacity shall be avoided to the extent it is practicable to do so.
- **Urban design** - The design of the streetcar system shall consider the viewpoint of the user, the adjacent residential or business community, and the nearby pedestrian or motorist. Streetcar design elements (trackway, stations, etc) should, to the maximum extent possible, minimize impacts to environmental, cultural, historic, and social resources and shall match the existing area as much as possible.

2.0 Alignment & Track

2.1 Track Alignment

Streetcar track alignment, geometry, clearances, and type are all established during conceptual engineering based on the following inputs:

- Physical operating environment of the system (urban, in-street, etc)
- Type of streetcar vehicle desired
- Design guidance and reference to local and national standards.

The streetcar system will generally operate in an urban, in-street environment. The benefit of an in-street alignment is a minimal amount of construction, challenging designers to “fit” the system into existing roadway rights-of-way. Most, if not all, streetcar vehicles available are designed to run in this type of track environment.

The track alignment for an urban, in-street system will generally follow standards and specifications established by local rail agencies (The T and DART) and rail transit industry standard practice documents and specifications. Local standards and specifications are advantageous as they provide a familiar source of design details and specifications that can aid designers and contractors, even if the reference agency is not the project's sponsor. The list of industry standard practice documents includes, but is not limited to:

- AREMA Manual for Railway Engineering and Portfolio of Track Work Plans;
- TCRP Report 57 "The Track Design Handbook for Light Rail Transit"
- APTA Guidelines for Design of Rapid Transit Facilities

2.2 Design Criteria

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

- Track gauge = 4'-8 ½" (distance between inner and outer rail)
- Track slab width = 8 feet
- Horizontal tangents shall be used in areas of special trackwork (turnouts, crossovers, etc) and station platforms.
  - Minimum horizontal tangent beyond station platform = 15 feet
  - Minimum horizontal tangent between curves = 40 feet (or 3*mph)
  - Minimum horizontal tangent between switches = 60 feet
- Minimum vertical tangent beyond station platform = 15 feet
- Minimum vertical tangent between curves = 40 feet (or 3*mph)
- Minimum vertical tangent between switches = 60 feet
- Offset distance from centerline of track to edge of platform = 4.2 feet
- Minimum design horizontal curve radius = 82 feet
- Maximum design grade = 8%; 2% at stations
- Minimum design vertical curve = 620 feet
- Maximum design vertical curve = 820 feet
- Minimum design spiral length (assuming no superelevation) = 30 feet

3.0 Roadway

3.1 Effects on Roadway

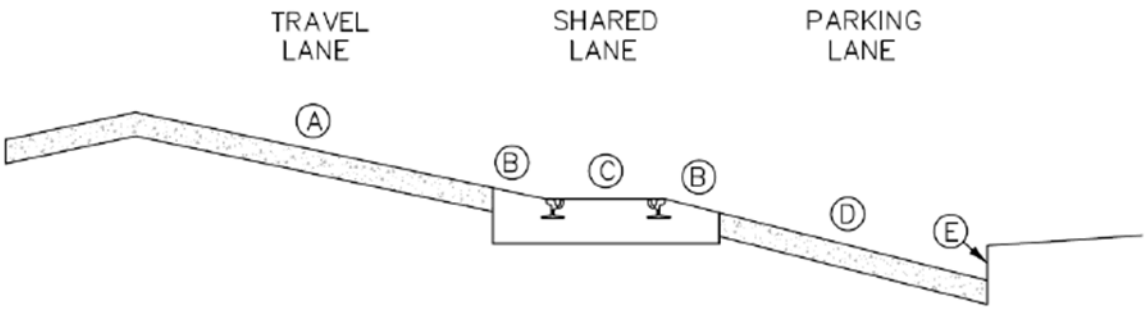
The effects of streetcar construction and operation on the adjacent roadway network are designed to be minimal. As described above, streetcar trackway slabs are 8 feet wide and can be placed within existing travel lanes without shifting traffic. The track designer will consider existing roadway geometry (curves, intersections, and cross section) when laying out the streetcar's horizontal alignment and vertical profile. 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, further reducing costs by eliminating the need to reconstruct catch basin inlets and other drainage facilities.

3.2 Roadway Cross Section

Track slabs are designed to provide a flat (0%) slope between the rails. Any slope greater than 0% between the rails in tangent track, or reverse super-elevation in curved sections, is undesirable and can in uneven rail and wheel wear. A level (0% cross slope) slab should be used between rails for all tangent track except in highly restrictive grading situations where some cross slope may be required to accommodate existing roadway cross slopes. A slight cross slope can be introduced to reduce pavement reconstruction or drainage impacts, but the best solution is to provide a 0% cross slope between rails with flexible 1.5-feet 'wings' on the outer portions of the guideway that vary in slope (0% to 3%) to accommodate for the overall (or "effective") cross slope of the existing roadway.

As described above, the track design will attempt to limit roadway reconstruction to only that required for the construction of the track and installation of relocated utilities. Figure 1 illustrates the approach for defining the limits of roadway reconstruction.

Figure 1 – Proposed Roadway Cross Slopes for Use in Final Design



	Desirable	Maximum	Minimum
A	2%	3% or Existing	1% or Existing
B	0%	3% or Existing	1% or Existing
C	0%	0%	0%
D	4–6%	7%	1% or Existing
E	6 in	12 in	4 in

In some installations, often the entire roadway surface by 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.

3.3 Lane Selection

When selecting the lane to place a streetcar trackway, several factors affect the decision-making process. Existing and future traffic volumes, presence of existing utilities, presence of bicycle lanes and on-street parking, and desired station configuration all influence the lane selection of streetcar tracks on a multi-lane street. For early alignment evaluation purposes, or determining alignment options in a corridor, a default assumption (typically right-lane with side stations) will be used and then refined once an alignment is selected.

Figures 2 and 3 illustrate streetcar trackways with side stations and median stations, respectively.

Figure 2: Typical One-Way Roadway with Streetcar Station

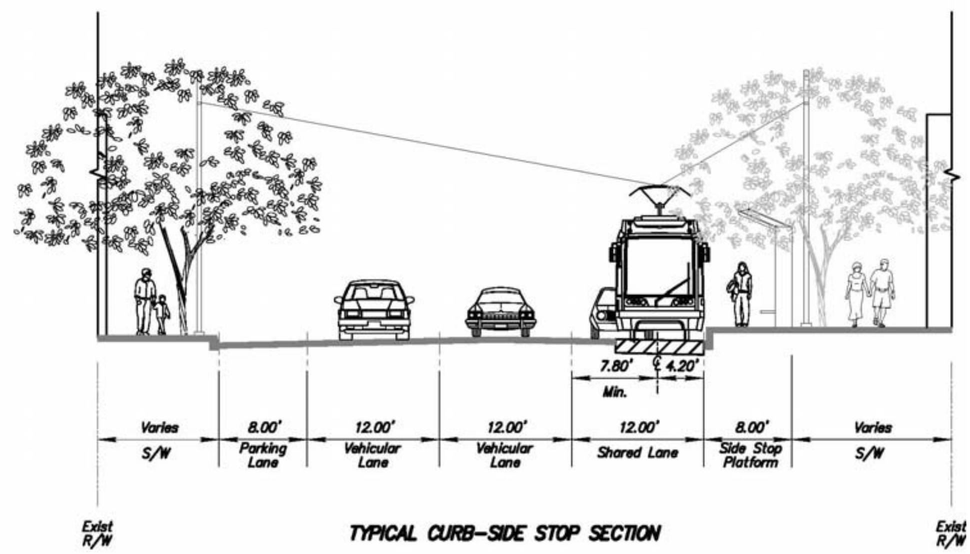
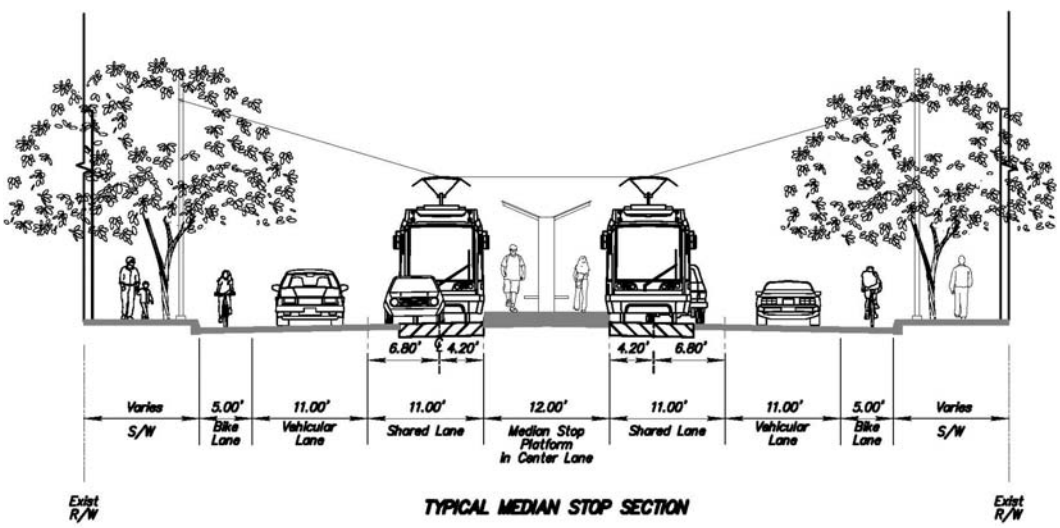


Figure 2: Typical Left-Lane Streetcar with Station



4.0 Station Stops/Footprint

Streetcar stations (or stops) are one of the most defining elements of the system. Although specific design guidance and criteria will be provided in later project phases, this section describes the basic civil engineering criteria to be used in the preliminary design of stops associated with the streetcar project.

4.1 Streetcar Stop Design

The layout and design of a streetcar stop will be dependent upon a number of factors including:

- location of the stop in the roadway (curb-side or median)
- location of the stop with respect to an intersection (prior to or beyond an intersection)
- dimensions and configuration of the streetcar vehicle
- availability of space (including sidewalk) behind the street curb
- type of shelter (if desired/required) to be provided at a stop
- presence or absence of on-street parking at the site of the stop
- codes, regulations, and standards such as:
  - Americans with Disabilities Act (ADA) Standards for Accessible Design
  - Uniform Building Code
  - National Fire Protection Association (NFPA) Standards (NFPA 130, NFPA 72, NFPA 70, and NFPA 101)
  - State/ local codes and regulations.

4.2 Length of Streetcar Stop

The length of the streetcar stop can only be assumed in early project phases because it is dependent upon the location of the doors on the streetcar vehicle. As discussed in the Vehicle Technical Requirements Memo, the length of the platform should match the low-floor boarding area of the streetcar between doors. Since that length can vary among streetcar manufacturers, the City has the luxury of establishing criteria for platform lengths that accommodate parking and access to the stop. Many cities choose 66’ as a starting point for length of curbside stops, roughly equivalent to the loss of three 22’ parallel parking spaces. It is recommended that a minimum of 66’ be used for side stops, which allows ample space for a boarding platform, access ramps, and a basic level of amenities at the stop.

4.3 Width of Streetcar Stop

There are a number of factors that influence the width of a streetcar stop. First, since the raised platform curb constitutes a drop-off, the edge of the streetcar stop must have a 24-inch wide detectable warning strip running the full length of the raised curb as noted in Section 10.3.1(8) of ADA. Second, as noted in Section 4.3.3 of ADA, the minimum clear width of a sidewalk that is providing an accessible route through the streetcar stop shall be 36 inches. It should be noted that a sidewalk width of 60 inches is more desirable than this minimum width and is recommended if site conditions permit. Section 10.2.1(1) of ADA further requires that an access pad be provided with a minimum clear length of 96 inches (measured from the curb or vehicle roadway edge) and a minimum clear width of 60 inches (measured parallel to the vehicle roadway) in areas where a lift or ramp is to be deployed.

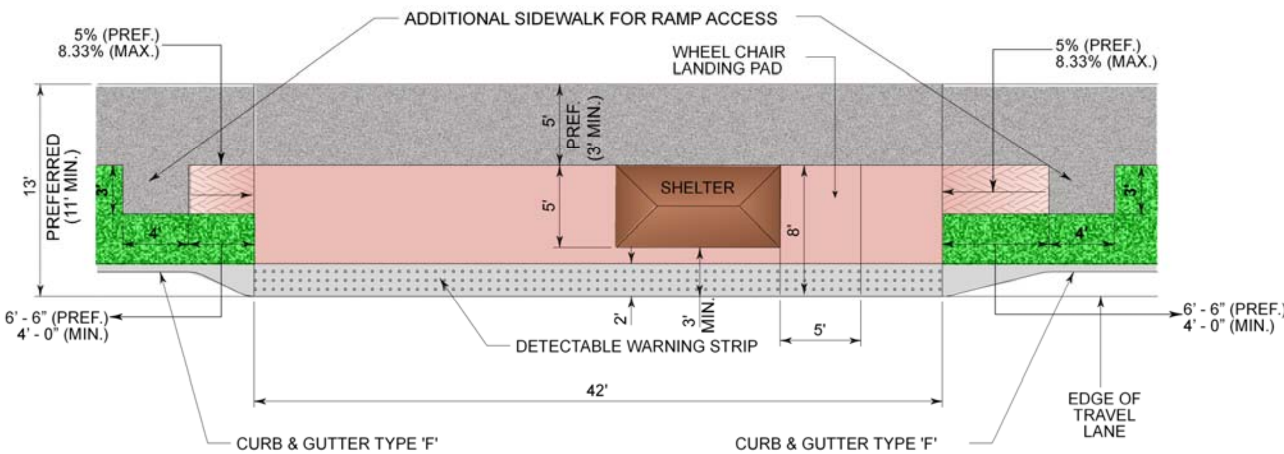


Figure 4

Station Stop without Parking; Sidewalk behind Shelter

Given these requirements, the minimum width of a curbside streetcar stop is 8 feet (96 inches) to provide for the ADA access pad that includes the 24-inch wide detectable warning at the curb and a minimum accessible route (sidewalk). However, this width does not specifically address the inclusion of other elements, such as shelters, at the streetcar stops. Median stops serving two tracks should be a minimum of 12 feet wide to accommodate the detectable warning strip on both sides.

4.4 Streetcar Stop Shelter

A shelter must have at least a minimum clear floor area of 2’-6” wide by 4 feet deep entirely within the shelter perimeter as required in Section 10.2.1(1) of ADA. There is a variety of commercially available shelters that could be used on the streetcar system. These shelters can be enclosed or freestanding. Similarly, the City could choose to design and construct shelters rather than installing pre-fabricated ones. Given that a decision has not been made on the type of shelter to be used on the streetcar system, the information hereafter is based on an enclosed shelter in recognition of its lower cost and increased spatial requirements.

Allowing for 6 inches on each side of an enclosed shelter’s exterior gives a typical shelter width of 5 feet while a self-supporting shelter would not require this additional space. A shelter must also maintain a minimum of a 1-foot clearance from the back of the shelter to a wall or other obstruction. If the shelter were to be placed at the end of the 8-foot access pad, then the minimum width of a stop would be 14 feet (including the 1 foot clearance) depending upon the type of shelter.

4.5 Stop Locations, Bicycle Lanes, and Parking

Placement of streetcar stops must consider other uses of the roadway: traffic conditions, bicyclists, parking, and pedestrians. Modern streetcar vehicles are designed with low floor doors on both sides of the vehicles, allowing the system flexibility to have right side or left-side boarding. The location of the track within the roadway often follows desired stop placement; the location of stops and the location of track are inter-dependent and are designed and tested against each other during preliminary engineering.

Curb side stops are typically proposed when the following conditions are encountered:

- Single track on the roadway (in a couplet or single track operation)
- Narrow roadway width (too narrow for median stop); or a wide roadway with multiple lanes in each direction
- Side stop would enhance pedestrian activity and streetscape
- Parallel parking adjacent to curb can be removed for a streetcar stop 'bump-out'

In addition, if the streetcar track is located on a one-way street, a left-side curbside stop may be desirable when the right lane moves slower due to on-street parking or when a bicycle lane is present.

Median stops are typically proposed when the following conditions are encountered:

- Bicycle lane and/or heavy bicycle traffic would be impeded by a curbside stop.
- Dual streetcar tracks (one in each direction) with ample space in between for a median stop
- Parallel parking or other curb-side features that cannot be removed

5.0 Traffic Design

This section establishes the basis for engineering criteria to be used in the design of a modern streetcar system. It includes requirements for traffic control devices and criteria for the design of the traffic signal systems, signing, and pavement marking as they apply to interfacing the streetcar lines with the street and highway network.

5.1 Applicable Codes

Traffic vehicle and pedestrian signals, signs, and markings shall be in accordance with the Transportation Access Management Guidelines for the City and with the *Manual on Uniform Traffic Control Devices* (MUTCD) published by the US Department of Transportation (USDOT).

Materials and equipment used in each installation and/or modification of traffic signal systems, signing, and paving markings shall conform to the latest specifications contained in the standards of the City.

5.2 General Design Criteria

Where streetcars operate in a lane of traffic, the shared lane shall at least be as wide as the dynamic outline of the streetcar vehicle. If the streetcar operates in a semi-exclusive guideway, it shall be delineated or physically separated from parallel general traffic on that street. The majority of the project will be a mixed traffic operation.

Guideways and passenger station stops shall be designed so as not to create any unnecessary interference with pedestrian or bicycle movements. Where pedestrians and/or bikes must cross streetcar tracks, appropriate control devices shall be provided. Where a pedestrian and/or bike crossing is part of a signalized street intersection, control shall be provided by means of standard vehicle, pedestrian, and/or bike traffic signals. At other locations, at the direction of the City, these devices may be supplanted or supplemented by passive signs, active signs, flashing beacons, movable gates, or any combination thereof.

Where traffic signal modifications or new installations are being completed, signal push buttons will be relocated/installed to meet current ADA requirements. Signals downtown default to walk cycles for pedestrians; therefore, no signal push buttons are required in this area.

Traffic signals along the streetcar route will generally provide two-phase operations. Protected left-turn phases will be limited to intersections with higher turn volumes. Where the streetcar operates in mixed flow in the existing traffic lane, streetcar movements 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 MUTCD.

6.0 Utilities

Impacts to existing utilities are an important consideration when selecting streetcar routes and trackway locations. Streetcars, as with other urban rail transit systems, pose challenges to utility companies by limiting the access to facilities in close proximity to the trackway (both above and below ground), and by the introduction of stray electric current that may trace back to metallic pipes buried in the ground. The impacts can be classified by the following:

- Underground utility lies parallel and directly beneath proposed trackway, affecting access and stray current;
- Underground utility lies parallel and offset from proposed trackway, requiring analysis of access and stray current;
- Underground utility lies perpendicular to proposed trackway, requiring offset of stray current and sleeving requirements

- Overhead utility directly over or in close proximity to trackway, affecting clearance of OCS and pole locations.

For early analysis purposes, existing “major” utilities will be located using base maps and other available information to determine their presence in a proposed streetcar alignment. No determination will be made at this time as to their specific location in the roadway. Major utilities are defined as follows:

- Water and sewer: 10” pipe and larger
- Storm drain: 24” pipe and larger
- Gas: 4” transmission pipes and larger
- Dry utilities (cable, electric, fiber optic, telephone): Duct banks and major transmission lines, vaults

7.0 Maintenance Facility

7.1 Introduction

The maintenance and storage facility (MSF) is an integral part of the Fort Worth Modern Streetcar system in terms of its both function and location. Functionally, the MSF provides for the maintenance, cleaning, and secure storage needs of the system and will include equipment, tools, parts, and space for maintenance and operations staff.

The location of the MSF is important in the unique respect of its small size and proximity to the streetcar route. Unlike bus and larger rail maintenance facilities, streetcar facilities are generally compact and can blend in with their adjacent surrounding environment. They are often tucked away on otherwise vacant land, or can be placed on ‘leftover’ public agency property. Other systems have placed the facilities as part of a mixed-use development (e.g. Seattle Streetcar), or have planned for them to be a visible landmark identifying the importance of the system and its integration into the community (e.g. Tucson Modern Streetcar). Portland Streetcar took advantage of unused space below a freeway overpass for its MSF.

Figure 5 – Seattle MSF (integrated into mixed-use development)

Figure 6 – Portland MSF (under freeway overpass)

7.2 Facility Characteristics

The space and functional characteristics of the MSF are dependent upon a number of factors:

- Number of streetcars in initial operating fleet
- Number of streetcars in ultimate operating fleet (determines available capacity increase before a second facility is needed)
- Number of staff assigned to the facility
- Operating functions of the facility: maintenance only, or operations, safety, and administration
- Level of service and repair performed at the facility (automatic washer, body work, etc)
- Regulatory requirements for parking, landscaping, access, etc.

The MSF should include sufficient space for a maintenance building, shop area, parts storage, offices, and tracks for storing vehicles. A typical maintenance building for a starter system includes a minimum of two service bays, one with an underground pit for servicing the underside of streetcar vehicles. An elevated platform, or work mezzanine, allows access to the roof mounted equipment. An overhead crane allows the streetcar vehicle to be lifted to service the trucks and is used for transporting heavy materials. Component repairs are performed in a shop area with adjacent parts, tool storage, and loading dock. Offices, work areas, file rooms, break rooms, and lockers should all be considered when developing the maintenance building program.

Outside of the maintenance building, a typical site for a starter system includes storage tracks, outdoor parts storage area, delivery truck access to a loading dock, and areas for parking, building entrance and exit, and trash collection. A traction power substation to power the yard and lead track are convenient to locate on site. The facility is typically secured by walls and/or fences and is lighted for overnight servicing and storage.

Ideal locations for maintenance facilities allow for the expansion of the facility as the system grows. They also allow the initial facility to be easily transformed and/or retrofitted as the needs change. The first growth is typically adding additional streetcar vehicles to the existing fleet, without route expansion, allowing for increased frequency of service. The facility should accommodate the initial streetcar vehicle fleet plus an additional number of streetcar vehicles for expansion. Later phases of expansion include expanding the route and adding more streetcar vehicles. At that point in time, additional facility locations could be considered as ‘auxiliary’ maintenance and storage facilities. These could be used to supplement the ‘main’ facility as it transforms to add additional repair services, such as a body shop, wheel truing, etc.

The following characteristics can generally be used for early planning and site evaluation for the Fort Worth Modern Streetcar maintenance and storage facility:

- Building footprint ranging in size from 8,000 to 18,000 SF depending on fleet size
- Two to three streetcar service bays
- Includes underbay for servicing the underside of vehicles, and overhead walkway and gantry crane for servicing roof-mounted equipment

- Space for offices, shop, and tool storage
- Site that accommodates parking, traction power substation, trash enclosure, truck delivery access, and drainage
- Storage tracks with enough capacity to store entire fleet overnight, plus room for initial fleet expansion

7.3 Location Characteristics

After a general size requirement for the facility is known, a site must be selected. The selection process for a maintenance and storage facility location typically involves the following factors:

- Land use and context
- Property ownership
- Proximity to streetcar alignment
- Physical, environmental, and social factors

The selection process begins with an inventory of available properties, either public or private, that fit the land use and context of a streetcar maintenance facility. The facility can adapt somewhat to different neighborhoods, from industrial to historic warehouses. The location of the maintenance facility can be located off the alignment a short distance, keeping in mind the length of track required to access the facility from the main line.

Once a list of candidate sites are identified, the selection process typically involves listing property ownership, conversations with agency staff with knowledge of the sites, and a field visit. A short qualitative evaluation of physical, environmental, and social factors includes existing utilities, floodplain delineation, brownfield and soil investigation, noise, vibration, and air quality, and traffic access.