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1. Transit Technology Assessment

Corridors with high-grade transit reserve exclusive space for dedicated facilities and have a greater propensity to increase capacity for years to come. Long term visioning of the transportation modes that deserve prioritization in a corridor is critical for those modes to fit within right-of-way constraints.

This section reviews transit technologies (including service types, modes, interaction with other modes, equipment, and travelway characteristics) that may be suitable for a Waco transit investment corridor. These technologies are presented in a way that allows their inherent characteristics to be explored based on their ability to fit the needs of Waco residents. Preferred technologies along the corridor will be selected as part of the design criteria and public engagement portion of the Waco Rapid Transit Corridor (RTC) Feasibility Study.

1.1 Alternatives Identification and Screening Process

The transit technology alternatives pass/fail analysis compares each transit service type in order to evaluate the viability of each transit technology. The transit technology alternatives will ultimately help select a preferred technology alternative. The evaluation criteria associated with each step includes a combination of quantitative and qualitative performance measures. Early steps apply fewer and broader measures, including information from previous corridor/area studies. Later steps apply more and finer performance measures, including highly-specific Federal Transit Administration (FTA) performance criteria. This multi-step process will result in the identification of a Locally Preferred Alternative that not only meets the locally-identified project Purpose and Need, but is also competitive for federal funding.

1.2 Transit Technology Assessment

The purpose of the technology assessment is to review transit technology types to find a right fit for the selected Waco RTC and the selected corridor. With such a wide array of available transit technologies, the process can seem a little daunting at first glance. A quick review of local conditions and technology characteristics produces a reasonable set of technologies for review. Other technologies may emerge through the public engagement and can be included in the review.

Before reviewing technology types, it is important to review the overall project goal: introduce a premier transit service type in Waco that meets project objectives. Regional transit investment corridors can be classified in many ways including by speed (“rapid transit”), capacity (“intermediate” or “high-capacity”), level of investment (“major transit investment corridor”), and general quality (“really great transit”). These terms can be used interchangeably. Most regions develop a branding name for the service type that highlights its most popular characteristics.

As a rule, the more operating advantages the transit service offers over other transportation modes, the higher the demand will be to ride the service. These advantages vary widely and can include advantageous placement in the streetscape, signal priority, reserved lanes, or complete separation from other traffic (such as a private travelway or vertical separation like an elevated guideway). Through securing priority treatments for transit, the corridor has a greater propensity to achieve and maintain strong ridership and cost efficiencies.
1.3 Existing Characteristics

Waco’s urbanized area has a population of roughly 183,000. It is home to Baylor University, a major higher education institution with a student population that has a high propensity to ride transit. The premier transit corridors in university cities of similar size to Waco are generally considered successful if they carry between 5,000 and 10,000 daily riders when school is in session. Waco likely has little need for a regional transit technology that carries more riders than this range.

Waco’s existing transportation infrastructure includes major highways that generally run southwest to northeast, including Interstate-35 and US-84. Major arterials run parallel to these highways, including Franklin and LaSalle Avenues. Highway connectors intersect arterial and local streets to form the central city grid. The Union Pacific Railroad passes through the middle of downtown adjacent to Waco Creek. Some abandoned railroad right-of-way remains intact through the city’s core.

Using the assessment of roadways and intersections from the Existing Conditions Memo, it was revealed that the existing transit infrastructure is not well suited for immediate implementation of a major transit investment corridor. The limited availability of existing infrastructure, however, provides the opportunity for Waco to develop a system that meets current and future needs.

The current transit service utilizes a flag stop system and therefore fixed stop locations are not prevalent along the corridors that are being analyzed. The southern and northern corridors considered show that there is ample right-of-way to allow for the possible implementation of larger bus stops or stations with sidewalk bulb outs (to enable transit vehicles to stop inline), as well as the possibility for transfer locations with other fixed routes. The central area has a more limited right-of-way and constraints. Transit stops on these streets may impede traffic and larger stop facilities may not be possible to maintain proper ADA sidewalk widths and access. The existing intersections do not contain transit priority equipment at traffic signals, nor do most contain full pedestrian facilities that meet ADA compliance. There are minimal pedestrian and/or bike facilities available along many of the corridors as well.

2. Transit Technology Alternatives

Given the above-mentioned capacity requirements in Waco, very high-capacity and grade-separated transit modes (such as rail rapid transit or a people mover technology using a fully exclusive right-of-way like an aerial guideway or subway) are not recommended. Long-distance passenger transportation modes, such as a freeway motor coach, intercity passenger rail, MagLev, or other long-distance technologies are also not recommended for cross-town trips in Waco. A single station designed for these long-distance modes could exceed the cost of a high-quality transit corridor using arterial roadways or at-grade rights-of-way.

Based on the characteristics of the existing corridor, transit technology alternatives recommended for consideration include:

- **No-Build**, a continuation of the flag stop operation with little restructuring or expansion.
- **Route Restructuring**
  - **Local Bus**, a formalization of the existing operation with some consolidation of bus stops and limited improvements to waiting environments;

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- **Enhanced Bus**, route restructuring to provide frequent transit service in the areas with highest demand, transit-priority treatments at some problematic congestion pinch points and signals, and waiting environment improvements at high-demand locations.

- **Higher-Capacity Transit**
  - *Bus Rapid Transit (BRT)*, investment in high-quality stations that are spaced for efficient cross-town trips, innovative fare payment methods to speed passenger boarding and limit dwell times, and priority intersections. A higher level of investment can include reserved lanes or semi-exclusive right-of-way;
  
  - *Light Rail Transit (LRT)*, a transit technology that is more common in larger metropolitan areas with higher-capacity demand and longer transit travel distances. Light rail vehicles are most commonly electrified but can also use self-powered vehicles with a variety of propulsion types (similar to Austin’s diesel-powered railcars). LRT provides limited stops and can operate in a street (usually with dedicated lanes and signal priority or pre-emption) or in a reserved right-of-way;
  
  - *Streetcar/Tram*, a technology featuring small to medium-sized light rail vehicles in street operation. It has frequent stops and often travels in lanes shared with other traffic. Streetcars are designed for shorter, local trips. This technology has a reputation for improving property values and thus is often sponsored by development interests; and
  
  - *Commuter Rail* or a similar technology using existing and/or improved railroad corridors. Commuter Rail most commonly uses passenger rail-type trainsets pulled or pushed by locomotives. This type of service is common in large metropolitan areas to address peak long-distance demand. Other services operate more like light rail and provide trips throughout the day and before and after peak commutes.

*Figure 1* includes sample images of higher-capacity transit technology vehicles. *Figure 2* provides an operational and capital cost comparison of these technologies. Information in the summary table is based on FTA-funded projects in recent years.

*Figure 1: Vehicles Associated with Higher Capacity Transit Modes*

<table>
<thead>
<tr>
<th>Bus Rapid Transit (BRT)</th>
<th>Light Rail Transit (LRT)</th>
<th>Streetcar</th>
<th>Commuter Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
</tr>
<tr>
<td><img src="image5.png" alt="Image 5" /></td>
<td><img src="image6.png" alt="Image 6" /></td>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
</tr>
<tr>
<td><img src="image9.png" alt="Image 9" /></td>
<td><img src="image10.png" alt="Image 10" /></td>
<td><img src="image11.png" alt="Image 11" /></td>
<td><img src="image12.png" alt="Image 12" /></td>
</tr>
</tbody>
</table>
2.1 Transit Technology Recommendation

The Study Team recommends Bus Rapid Transit as the preferred transit technology for higher-capacity transit in Waco. This recommendation assumes pursuing a dedicated transit travelway (reserved lanes) where achievable and where the greatest benefit can be realized from this investment. The following factors influenced this recommendation:

- **Corridor Length:**
  - The analysis corridor, roughly 13 miles in length, is too long to be effectively served by a streetcar investment, effectively eliminating that mode for the full corridor length. Modern streetcar corridors typically require private champions and/or local improvement districts to partner with the capital investment. Selecting BRT for the regional mode does not preclude a future streetcar investment in the city’s core.
  - Commuter Rail corridors are rarely shorter than 20 miles in length and too few stations would be available to serve prioritized transit destinations in central Waco.

- **Capital Cost:**
  - BRT’s capital cost range starts at roughly $2 million per mile, the lowest cost of all considered technologies. The listed high-end cost for BRT represents a separate right-of-way, such as a highway facility with a station in a median and vertical bridge circulation for customer access. BRT on arterial streets without reserved lanes fall into the lower end of the cost spectrum. LRT rarely is achieved for less than $50 million per mile.

*Figure 2: Comparison of Higher Capacity Transit Modes*

<table>
<thead>
<tr>
<th></th>
<th>Commuter Rail</th>
<th>LRT</th>
<th>Streetcar</th>
<th>BRT</th>
<th>Waco Existing Conditions</th>
<th>Recommended Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AVERAGE PER MILE CAPITAL COST</strong></td>
<td>$29 million</td>
<td>$63 million</td>
<td>$50 Million</td>
<td>$17 million</td>
<td></td>
<td>BRT</td>
</tr>
<tr>
<td><strong>RANGE OF PER MILE CAPITAL COSTS</strong></td>
<td>$11 m - $68 m</td>
<td>$42 m - $87 m</td>
<td>$48 - $53 m</td>
<td>$2 m - $63 m</td>
<td></td>
<td>BRT</td>
</tr>
<tr>
<td><strong>TYPICAL DAILY RIDERSHIP</strong></td>
<td>4,000 - 70,000</td>
<td>7,000 - 50,000</td>
<td>500 - 20,000</td>
<td>7,000 - 50,000</td>
<td>4,263*</td>
<td>BRT</td>
</tr>
<tr>
<td><strong>STATIONS</strong></td>
<td>5 miles apart</td>
<td>1 mile apart</td>
<td>1/4 - 1/2 mile apart</td>
<td>1 mile apart</td>
<td>N/A</td>
<td>BRT</td>
</tr>
<tr>
<td><strong>ROUTE LENGTH</strong></td>
<td>20 - 50 miles</td>
<td>10 - 30 miles</td>
<td>1 - 5 miles</td>
<td>5 - 30 miles</td>
<td>12.5 miles</td>
<td>BRT</td>
</tr>
<tr>
<td><strong>FIXED GUIDEWAY?</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>BRT</td>
</tr>
<tr>
<td><strong>FREQUENCY</strong></td>
<td>Commuter</td>
<td>All Day</td>
<td>All Day</td>
<td>All day</td>
<td>All Day (5:00 a.m. - 8:00 p.m.)</td>
<td>BRT</td>
</tr>
<tr>
<td><strong>VEHICLES</strong></td>
<td>5-7 car trains</td>
<td>2-3 Car Trains</td>
<td>1-2 car trains</td>
<td>40’ or 60’ bus</td>
<td>30’ - 35’ Bus</td>
<td>BRT</td>
</tr>
</tbody>
</table>

*Estimated daily Waco Transit Ridership; does not include Silos.*
The substantial capital cost for LRT is rarely supported by regions with fewer than 1 million residents and is unlikely to meet FTA cost effectiveness in Waco.

- Rider Capacity:
  - Both BRT and LRT provide appropriate capacity levels that start at under 10,000 riders per day. While a BRT corridor with in-street operation is generally considered cost effective with fewer than 10,000 riders, LRT usually demands more riders. Waco does not show demand on a regular basis for LRT capacity.

The Alternatives Analysis process will determine which roadway segments are appropriate for shared lane vs. dedicated travelway BRT service. It will also clarify the level of investment required to implement a BRT corridor meeting the project’s Purpose and Need. The following sections consider in further detail essential aspects of a successful Waco Enhanced Transit or BRT corridor.

2.1.1 Transit Access and Egress, and Waiting Environment

It is important to understand how customers will access a new BRT corridor. In outer areas, station parking may be needed to attract riders. Others will connect via intersecting bus routes, shuttles, taxis and ride share services. Transit riders always have some portion of their trip as a pedestrian and the trip often includes non-motorized and local assist modes (such as bikes, scooters, skateboards, etc.). For this reason, accommodating pedestrians, bikes and other modes in a transit corridor is crucial. A transit trip can be divided into three categories:

1. Getting to and from the transit vehicle (first and last mile),
2. Waiting for the transit vehicle, and
3. Riding transit.

To support transit access and egress, non-motorized transportation improvements must be considered along any transit corridor. Urban corridors typically prioritize the walking and biking environment.

The experience of waiting for transit is typically perceived as taking twice as long as it actually does. Waiting is often the most uncomfortable part of a transit trip. Small improvements in the shelter, comfort for riders, waiting environment improvements to maximize shelter, personal comfort, customer information and the perception of safety make waiting for your ride more pleasant.

2.1.2 Transitways and Guideways

Local bus services operate on public roads, typically in shared lanes. As such, local buses can be affected by traffic, often causing route delays. Enhanced Bus and BRT routes also operate on public roads, but with priority treatments for transit. “Dedicated” BRT routes provide reserved transit lanes, which are situated either in the center of the road or along the curb edge so that the busway is clear of traffic for higher efficiency. These lanes may be separated from general traffic by means of striping, a painted or physical buffer or barrier, a bike lane, rumble strips, lights or reflectors, or traversable domes. Some BRT corridors provide a semi-exclusive travelway and mix with other traffic only at crossings. Contraflow can also be utilized in dedicated BRT lanes, which allows buses to travel in the opposite direction of traffic or to even switch the direction of a bus lane during peak hours. Maintenance of the transit travelway and/or reserved guideway should be included in project cost assumptions.
2.1.3 Stations
Many local bus stops have few amenities, such as an identifying sign, bench and/or small shelter. The stop elements typically fit within the public right-of-way. More complex enhanced bus systems may require additional space for additional station amenities. BRT stops typically include level boarding for customers using wheelchairs or with strollers or luggage. They may also offer off-board fare collection to minimize station dwell times. BRT stations are often larger and may require significant right-of-way reservation. These stations often include other amenities such as a signature landmark design, comfortable seating, convenience outlets, lighting for visibility and safety, bike share facilities or storage, wayfinding and concession or vending opportunities. All stations must be ADA compliant to accommodate persons with disabilities. Consideration should also be given to the maintenance requirements at each station, which may require accommodations for power, water and hoses for wash down, and pull-offs for maintenance vehicles.

2.1.4 Vehicles
BRT Vehicles are typically 60’ articulated vehicles. Local buses are often smaller and require more step-climbing than some of the more advanced vehicles that may be used in BRT systems. Specialized BRT vehicles can have lower floors to make boarding easier and can have a greater capacity. Buses on BRT systems may be equipped with specialized technology to allow operators to be more precise in docking the BRT vehicles. This minimizes gaps between the platform and the BRT vehicle for the safety and comfort of passengers as they board and alight. Often, BRT buses are branded, creating an original and cohesive look for the system. BRT systems should consider whether the orientation of their stations will require buses that can be boarded from either side, and also consider the positive effects on access/egress time when multiple doors are available. Additional amenities that can be provided onboard transit vehicles include bike storage, audible annunciation of stops, WiFi, security cameras, ADA tie-downs, and automated passenger counters.

2.1.5 Fare Collection and Equipment
Local bus routes often utilize pay-as-you-board methods, which reduce the amount of equipment needed but also increases dwell time as each individual rider provides their fare upon boarding through one door. This can be further complicated where customers pay upon exiting and must negotiate a crowded bus aisle in order to exit. As previously mentioned, BRT systems often utilize fare collection machines at their stations, which allow riders to pay their fares and collect their tickets before the transit vehicle arrives. Consideration should be given to the number of fare collection machines needed for current ridership as well as for the future. As technology evolves, more advanced fare collection machines utilize tap and go payments for digital passes and mobile devices play an increasing role. Random fare checks by security personnel can increase the customer’s perception of safety.

2.1.6 Intelligent Transportation Systems
By creating an advanced and efficient system that can be monitored and controlled remotely, Intelligent Transportation Systems (ITS) technology can greatly enhance the general flow of traffic along any congested corridor. Signal prioritization offers extended or early green time to BRT vehicles at signalized intersections and can be provided throughout a corridor with ITS. Traffic signal systems can offer other transit priority measures such as queue jumps, which offer transit vehicles their own signal phase. ITS can enable transit vehicle locations through coordination with Automatic Vehicle Location (AVL) systems. AVL also provides the ability to monitor schedule and reliability of the transit vehicles and can be used to provide real-time arrival information for customers, available through multiple media sources.
2.1.7 Ancillary, Maintenance and Storage Facilities
Articulated BRT vehicles require specialized areas for servicing. Emerging bus propulsion systems, such as alternative fuels and battery operation, add specialized vehicle maintenance needs. Buses require storage areas when not in use as well as maintenance facilities for regularly scheduled and unanticipated maintenance. Transit terminals and maintenance barns can range in size and should be built to handle the scale of the system in use. Maintenance of stations and equipment necessary for operation of a transit system is also needed, which requires support vehicles, equipment and staffing.

2.1.8 Safety Considerations
Transit system safety considerations include, but are not limited to; station security, transit vehicle security, pedestrian and bicycle access, and driver training. Station and transit vehicle security may involve illumination, clear lines of sight, emergency call buttons, CCTV monitoring, customer information and police monitoring. The goal of these elements is to ensure transit patron, employee and public safety.

In addition to providing a safe environment at stations and onboard vehicles, it is also necessary to provide safe access to the transit service. Safe and convenient pedestrian and bicycle access, particularly near the station, is integral to a successful transit investment. Bicycles must be able to move both along and across transit operating in roadways, which may demand separated travelways (such as protected bike lanes or cycletracks and island transit platforms). Intersections and station locations will require specific elements to ensure pedestrian and bicyclist safety. Connecting pedestrian networks include and are not limited to: continuous and barrier-free sidewalk or path networks to stations, convenient station locations, ramps to access high platforms, and mid-block or grade-separated crossings where station locations are not at walkable intersections.

Adequate ADA features, including tactile warning at pedestrian ramps and platform edges, are important for the safety of all riders and should be located at all locations. ADA requirements vary for different modes of transit. Crossing traffic or standing at unsafe locations should be deterred using railings or other deterring devices such as pyramids. Trash receptacles should be blast and fire resistant and away from congregating passengers.
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