General Design and Engineering Principles of Streetcar Transit

AS THE STREETCAR REGAINS POPULARITY AS A MODE OF TRANSIT, TRANSPORTATION PROFESSIONALS WILL HAVE TO REACQUAINT THEMSELVES WITH SOUND PRINCIPLES OF DESIGN AND ENGINEERING TO REWORK THIS OLD STANDBY INTO THE CONTEMPORARY DESIGNS OF TODAY'S ROADWAYS.

BY JACK W. BOORSE, P.E., P.L.S., MATT HILL, P.E., PTOE, AND ALAN DANAHER, P.E., PTOE, PTP

INTRODUCTION

Recently, a particular version of railway transit has enjoyed a growing resurgence. It features modest-size vehicles, usually single-car units, operating on tracks located within a street's right of way (ROW), more often than not in lanes that are also open to general traffic. These lines are a rebirth of a transport technology that was once predominant in medium- and large-size cities around the world—streetcar transit.

Several factors have converged to encourage this resurgence. There is strong and growing interest in transport modes that are not petroleum dependent and are less damaging to air quality. A streetcar is powered by electricity from a remote source and is itself a "zero emission" vehicle. An increasing number of urban land developers value rail transit above other modes because of its "promise of permanence," in that a rail line cannot be rerouted overnight and its construction is a long-term commitment. The streetcar mode is versatile and can operate underground, on aerial structures, and in reserved ROWs and can also travel along streets mixed with general traffic, allowing lines to be installed in existing public streets with little or no requirement to acquire private land. For both social and economic reasons, modes that avoid the need for major property taking and have modest construction costs are more attractive.

In areas where streetcar transit is becoming (or has already become) popular, it would seem that the professional responsibility of transportation engineers might be to step away from focusing almost entirely on bus and off-street rail modes and to prepare ourselves to work with planners, developers, and governmental agencies to produce designs that will blend streetcar operation with that of other road users. In the half-century since streetcars disappeared from all but six North American cities, there has been little need for these design and engineering skills, and they are now largely unlearned.

This article identifies and discusses, at a conceptual level, some of the design and engineering principles that are involved in the development of new streetcar lines.

ROUTE PLANNING

A streetcar's intended service is as a local distributor and not for long-haul operation like many of its rail counterparts. Stations or stops along a streetcar line are often spaced two or three blocks apart, providing linkages between neighborhoods, downtown destinations, and higher-capacity transit services. In general, routes should also be planned to minimize circuitousness, as many turns in a route can take away from the intuitiveness of the route as well as have negative operational and travel time impacts to the route itself.

When planning a new streetcar route, one of the keys to safe operation is to keep in mind that the streetcar is an element of the general traffic operation (Figure 1 illustrates a modern streetcar design). The deceleration and acceleration profiles of a modern streetcar are similar to that of buses, and the streetcar's operating speed tops out at approximately 45 miles per hour (mph). It is preferred that a streetcar should follow the same path as general traffic between stops. For instance, if the streetcar route includes a left-turn at a particular intersection, it is desirable for that turn to be executed from the same left-turn lane/pocket used by general traffic. This minimizes the need for any special treatments to address potential conflicts of the streetcar with general traffic and makes for a more intuitive roadway network. It is understood that special treatments may be required for the streetcar at specific locations, but all things being equal between alignment scenarios, the scenario that minimizes the use of special

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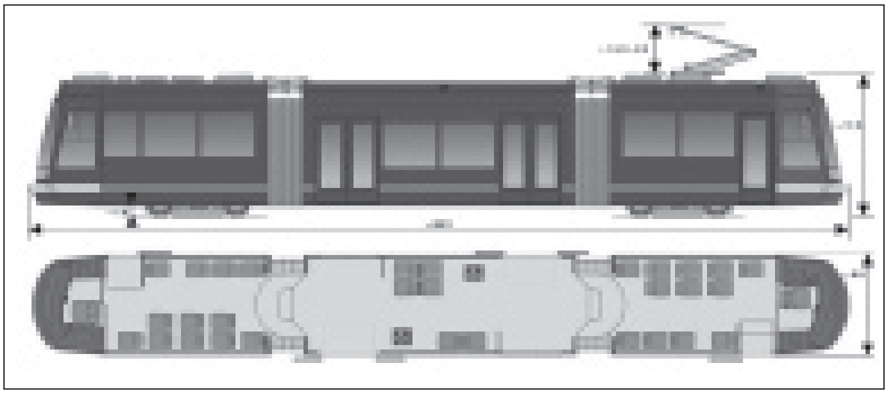

Figure 1. Typical modern streetcar schematic.

Figure 2. Curbside bulb-out for platform—Little Rock, Arkansas, USA.

treatments to address streetcar and general traffic conflicts should be favored.

When the streetcar route is to operate within a shared ROW with general traffic, planners and engineers are often considering whether the route should be along the right side of the roadway, the left side, or a combination of the two. Each of these alignments has different challenges that must be considered, and the following sections discuss these in more detail.

RIGHT-SIDE OPERATION

In general, a streetcar track should not be installed in a lane that directly abuts a curb. Such lanes are commonly used for parking and loading zones. It is not always practical to ban these uses, which are incompatible with streetcar movements. Even if these practices are legally prohibited, unless a very vigorous enforcement program is in place, there could be instances when unattended vehicles would be stopped at the curb, potentially blocking the passage of a streetcar.

If operation on the curbside of a street is desired, the track should be installed in the outside (right-most) travel lane that does not facilitate parking or loading zones. Sidewalk boarding and alighting can be achieved by means of a bulb-out, as illustrated in Figure 2. This keeps the track and the streetcars in a moving travel lane and allows curbside parking and/or loading zones at the curb throughout most of the block in which the stop is located.

Any parking/loading lane that is adjacent to a travel lane with streetcar movements should be slightly wider than the customary 8 feet. Some trucks have a body width of 8.5 feet with protruding mirrors. Moreover, codes generally allow vehicles to be positioned some distance away from the curb face without being considered illegally parked. Stationary vehicles must not protrude into the dynamic envelope of a passing streetcar. Ideally, these lanes would have a minimum width of 10 feet (although this is not always achievable), and the outer limit should be marked with an edge line (Figure 2 also illustrates this edge line).

LEFT-SIDE OPERATION

Modern streetcars can have doors on both sides. This gives them the capability of serving a passenger stop situated on either side of the track. That stop could be on the left-hand side of a one-way roadway or a two-way roadway with a median.

This left-side option provides some additional design flexibility to accommodate local conditions. Should there be a bus route operating along the same roadway, this configuration would allow each mode to move independently of the other in different lanes (see Figure 3). In the event that the right-hand side is determined to be preferable for the rail line, common bus and streetcar stops may not be desired, as not all bus styles are compatible with the platform elevation required by modern streetcars, and to a lesser concern, there is an increased risk for additional delay to both modes from interacting at the same stop location.

Figure 3. Separated bus and streetcar operation—Tacoma, Washington, USA.

Figure 4. Left-side platform—New Orleans, Louisiana, USA.

A track along the middle of a two-way roadway may be constructed in the inner general traffic lanes or between those lanes in a reserved ROW. Each option presents its own challenges, most of which relate to the treatment of stops.

The first option closely approximates the configuration of many of the original streetcar lines. These lines had stops in nearly every block, but more often than not there was no loading platform. On the new streetcar systems, the stops are more widely spaced, but they always have some type of platform.

In segments where there are no stops, a streetcar operation is not materially different from that of a bus route with the same pattern of stops. Intersections in these segments may be stop-sign controlled if conditions do not satisfy any signal warrants. Left turns from and onto the street where a streetcar operates may be allowed, including to and from midblock driveways.

At stops, the platform theoretically could be placed on either side of the track. In practice, if at all possible, it should be on the left (see Figure 4). A platform on the right would necessarily sit between two travel lanes, essentially creating a midstreet obstruction. Even if equipped with a flashing beacon, reflective signing, and appropriate pavement markings upstream, it would still be vulnerable and would need an impact attenuator.

A stop on the left would avoid those problems, but, depending upon the existing geometry, it might require some roadway modifications. If the roadway already has a median (raised or flush), it might be adapted to accommodate a platform. In that case, it is possible the roadway geometry could be left undisturbed, with the tracks following the alignment of the inside lanes. If there is no existing median, one would have to be created, and the roadway geometry would need to be altered to accomplish this. Where both directions of a streetcar line are present on the same two-way roadway, the opportunity for shared platforms exists within the median.

The second option is to exclude general traffic from the inside lanes, which would then create a median. At intersections of cross-streets with low volume where signalization is not warranted, the median should have no opening, and only right-turn movements would be permitted. All intersections with a median opening would need to be signalized. Left turns from lanes parallel to the track would be executed from a pocket lane. At intersections that include a stop, the platform would be situated on the far side of the intersection in the downstream "shadow" of the left-turn lane.

This option would have significant traffic operations and capacity impacts, and this exclusive trackway configuration is uncommon on modern streetcar lines and is more appropriate for high-capacity light-rail systems.

SIGNAL OPERATIONS

Transit Only Phases

As discussed earlier, streetcars generally follow the conventional rules of the road when operating in mixed traffic and obey traffic signals as any other vehicle on the roadway. There are, however, situations where a unique streetcar-only phase may be appropriate in order to eliminate a conflict with other roadway users, the most likely example being when a streetcar route turns at an intersection and its sweep path conflicts with other vehicles (see Figure 5). The addition of streetcar-only phases can be detrimental to general traffic progression patterns within a downtown area, and therefore the use of these treatments should be done sparingly.

When these transit-only phases are required, they are typically activated by a streetcar approaching in an exclusive lane. The streetcar is detected by the signal controller, and all conflicting movements are cycled to show a red signal display. The streetcar-only phase is then displayed using a special signal head for the streetcar only, so as not to confuse general motorists. The signal then resumes normal operation after servicing the streetcar-only phase.

Transit Signal Priority

Transit signal priority (TSP) may also be considered for streetcar routes. TSP is a less aggressive method to integrate preferential transit service into traffic signal operation when compared with preemption. It allows for extension of the green or an early return to green for an approaching streetcar or other transit vehicle. TSP also maintains signal coordination in a system. and several constraints can be placed on how the TSP operates.

TSP applications are typically found on roadways feeding into downtown areas and not the downtown areas themselves. TSP is often not practical in a downtown environment, as it can be detrimental to the general traffic progression. The reduction of green time to the conflicting (non-transit priority) phases can increase delay and/or reduce progression to these movements, quickly leading to queuing conditions between closely spaced intersections in a downtown environment. Care must be exercised in selecting the locations where TSP is to be used to ensure the needs of the transportation network can still be met acceptably.

With respect to the use of TSP near streetcar stops, it is generally less desirable to use TSP at intersections with a near-side stop (stop on the approach side of an intersection). This is due to the fact that the extra variable of stop/station dwell time is introduced into estimating when the streetcar vehicle would theoretically be traveling through the intersection. As dwell time can vary greatly based on the number of passengers boarding or alighting at a station, it is possible for the streetcar vehicle to still be dwelling at the station and miss the transit priority phase entirely. A far-side stop (stop on the departure side of the intersection) is preferred when using TSP, as the variable of stop/station dwell time is removed from the equation of estimating when the streetcar will be traveling through the intersection, leaving travel speed and distance. It is also desirable for there to be at least two travel lanes in the direction of streetcar travel with far-side stops so general traffic can get around the streetcar and reduce the risk of queues spilling back through the preceding intersection.

Figure 5. Streetcar-only phase—Seattle, Washington, USA.

PASSENGER LOADING AND UNLOADING

The modern streetcar is an upgrade of its venerable ancestors. It is quieter, more energy efficient, and usually air conditioned, but it is still basically the same conveyance—with one marked difference. In response to the Americans with Disabilities Act (ADA), all new streetcars must be accessible to people with disabilities. Streetcars of yesteryear were not. This new requirement influences the design of not only the vehicles but also the wayside stops where passengers board and alight.

Pursuant to the ADA, passengers in wheelchairs or otherwise unable to negotiate steps are entitled to ride and must be accommodated in some manner. There are a few instances where mechanical lifts are used to move a passenger between the ground and the floor of the streetcar, but the procedure is cumbersome and time consuming. Another method utilizes a ramp from the sidewalk up to a small platform at floor height. Neither of these methods has gained popularity.

By far, the most common method of providing accessibility is to acquire what is termed "low-floor cars." In cars of this type, a portion (sometimes all) of the interior floor is much lower than the traditional height and is only 12 to 14 inches (30 to 36 centimeters) above the elevation of the street surface and the embedded rails. At the stops, a platform of the same height is constructed and, to satisfy ADA guidelines, set at a distance of no more than 3 inches (76 millimeters) horizontally from the threshold of the doors. This provides "level boarding" for all passengers, including those using wheelchairs or otherwise unable to step up or down.

Ideally, stops should be at or near signalized intersections to expedite access and egress. With curbside stops, nominally half of the passengers will need to cross the street where the streetcar operates either before boarding or after alighting. In the case of a median stop, all of the passengers would have to cross one of the two roadways before boarding and after alighting. Many passengers would also have to cross the intersecting street, which may also be facilitated by signalization.

BICYCLE CONSIDERATIONS

On two-way roads, streetcar operation on the curbside may be more likely to interface with bicycle movements when compared with other alignments. Traffic ordinances generally require bicyclists to ride in the right-most lane if they are traveling at a speed significantly lower than that of general traffic, and this would tend to concentrate their operation in a curbside track lane. A bike ridden in that lane would

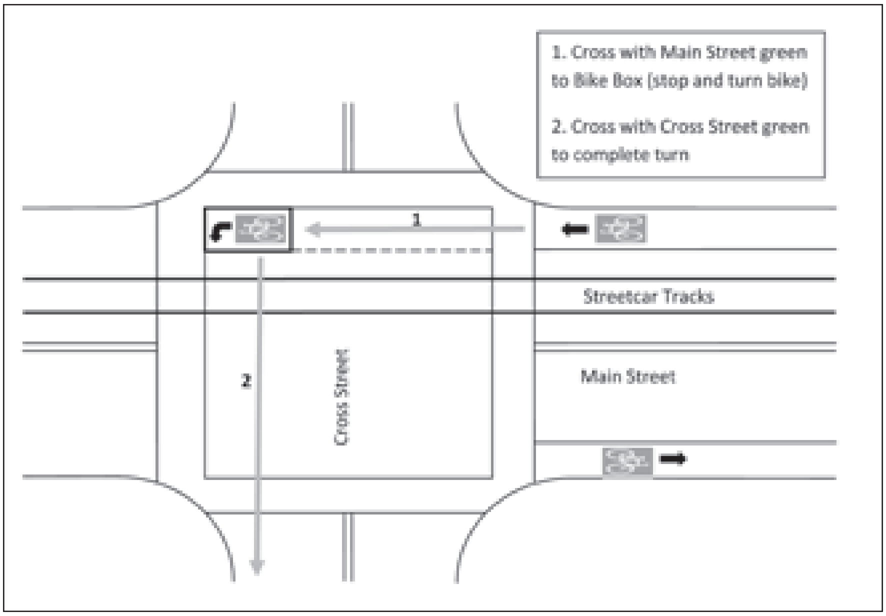

Figure 6. Two-stage bicycle turn at signalized intersection.

inhibit the progress of traffic following it. While general traffic, including buses, might have the opportunity to transition into and out of the lane on the left to overtake the bike, that option is obviously not available to streetcars. In practice this has not been reported to be a significant issue.

The issue for cyclists is the need to traverse one rail when entering and leaving the lane in order to ride in its center. There is a groove on the inside edge of each rail that is needed to accommodate the flanges on the streetcars' wheels. This narrow flangeway is easily bridged by the tires of autos, trucks, and buses. However, the narrow tires of a bicycle wheel could drop into the flangeway if it is steered across a rail at a small angle.

In cities where streetcar tracks are common, bicyclists are aware of this and have learned to steer a short "S" pattern across the rail so the tires cross the flangeway at a safe angle. Other innovative bicycle treatments are starting to gain popularity that also encourage a safer crossing angle at tracks, including the two-stage turn for bicyclists illustrated in Figure 6. When new streetcars are being introduced in a city, the implementing agency should work with the communities and the local bicycle organizations to administer an educational program.

Another bicycle-related matter is the riding surface in a traffic lane with a track. Except for the presence of the two rails, the paving surface in a track lane is usually comparable to the other lanes in the streets, although the specific material might be different for structural reasons (finished concrete is the most common).

A decision regarding the establishment of bike lanes on a roadway that has a streetcar operation would hinge on factors such as roadway width, curb lane usage, and perhaps the proximity of parallel streets with such lanes. The presence or absence of streetcar movements in a travel lane would not be a factor.

Streetcars and bicycles are not mutually exclusive. Their ability to successfully coexist is exemplified in many European cities where both streetcars (trams) and bicycles are abundant.

SUMMARY

The resurgence of the streetcar mode of transit presents challenges that are new to most traffic engineers. Where these new lines are built, or seriously planned, it is likely that roadways and traffic control systems will need to be redesigned to take into account the characteristics of streetcar operations. The key to successful engineering design of a streetcar route is to realize that every block is unique and requires flexibility and creativity, as there is rarely a "one size fits all" design solution.

In closing, there are many unique design and engineering considerations specific to the streetcar mode of transit, and it is in the best interest of the engineering and planning communities to refamiliarize themselves with these considerations so as to equip roads to meet the ever-growing demand for this mode of transit. ■

JACK W BOORSE, *P.E., PLS is a principal professional associate with Parsons Brinckerhoff and has been involved in designs and studies of light-rail transit lines and systems in more than 30 cities, primarily addressing the blending of rail and roadway traffic operations. Prior to joining PB, he was chief traffic engineer for the city of Philadelphia, PA, USA, where streetcars are still a significant component of the transit system. He has a B.S. in civil engineering from Drexel University and is a member emeritus of the Transportation Research Board's Committee on Light Rail Transit. He also chairs the TRB Subcommittee on Light Rail Circulator Systems and is a lifetime member of ITE.*

MATT HILL, *P.E., PTOE is a lead engineer with Parsons Brinckerhoff and received his B.S. in civil engineering from the Michigan State University Honors College in 2001. His experience is in transportation planning and traffic engineering with special emphasis in microsimulation and signal optimization. He is a member of ITE.*

ALAN DANAHER, *P.E., PTOE, PTP is a senior supervising engineer with Parsons Brinckerhoff and has more than 35 years of experience in transit planning and traffic engineering. He specializes in transit priority systems and bus rapid transit and streetcar operations. He has a B.S. in civil engineering from Purdue University and an M.S. in civil engineering from Northwestern University. Alan is a fellow of ITE and currently serves as vice chair of the Transit Council. He also chairs the TRB Transit Capacity and Quality of Service Committee.*