Development of Guidelines for Modern Streetcar Vehicles

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ABSTRACT

Since the implementation of the first U.S. modern streetcar system in 2001, there has been rapidly increasing demand throughout the country for more such systems. At the same time, agencies and suppliers have had limited familiarity with both the vehicles themselves and many of the basic technical and operating concepts associated with the streetcar mode. This has been especially true with many "non-traditional" organizations involved in delivering streetcar projects such as municipal governments, business improvement districts, non-profits and other organizations which may have limited familiarity with transit in general, and rail in particular. With no comprehensive source of modern streetcar recommended practice guidance available, the APTA Streetcar Subcommittee felt that a coordinated industry effort was needed to help the streetcar mode to reach its full potential.

Beginning in 2010, the Subcommittee undertook a project to create a guideline document to promote understanding of the core technical and operational issues relating to vehicle selection. From this understanding, agencies will be able to better navigate the process of specifying a vehicle and designing compatible infrastructure. Similarly, suppliers will be provided with a better understanding of the differences between North American and world operating and regulatory environments.

It is estimated that North American agencies will spend over $2 billion dollars for the purchase of modern streetcar vehicles during this decade. If this industry segment can do an effective job of internal education and related standards work, vehicles and systems will better match, and cost savings will follow. It is hoped that the guideline project will help facilitate the adaptation of existing modern streetcar designs for the North American market and help make domestically produced vehicles a competitive, world-class product for all markets.

This paper describes the process used to develop the *Modern Streetcar Vehicle Guideline* and provides an overview of its content. The guideline is scheduled for release through the APTA Standards Development Program in 2012/13.

BACKGROUND

The APTA Streetcar Subcommittee was formed in 2000 with a mission to "promote the development of heritage trolley and modern streetcar lines in urban centers, to foster information exchange among those planning or operating such lines, and to encourage reasonable technical and safety standards".

In 2009, the Subcommittee recognized that despite the growing number of projects in various stages of development, there was no comprehensive source for recommended practice guidance for modern streetcar systems or vehicles. Further complicating matters was the fact that many projects were being advanced not by transit agencies, but by other non-traditional project sponsors with varying levels of transit operating experience. Building on the successful experience of having produced an APTA standard for heritage trolley vehicle equipment in 2005[i], the Subcommittee embarked upon a project to create a comprehensive guideline document for modern streetcar vehicles.

Figure 1. Modern streetcar in Tacoma, Washington

A working group was assembled from amongst the active ranks of the Subcommittee, supplemented with several key agency personnel from U.S. and Canadian streetcar properties. At the group's initial meeting in January 2010, a set of project goals was agreed upon along with a draft outline. A project website, www.modernstreetcar.org, was established shortly thereafter to facilitate information sharing and encourage interest in the project. The Subcommittee also worked closely with APTA staff to determine where in the APTA Standards Development Program this effort would best fit, and where synergies might exist with other committees.

PART 1- INITIAL RESEARCH

A large body of global knowledge

Work began with a thorough literature search. From the U.S., several useful TCRP research projects were identified, including Report 2 *Applicability of Low-Floor Light Rail Vehicles in North America* (1995). Previous APTA standards and guidelines also provided ideas for how to approach the subject at hand. The search also looked to Europe, with emphasis on identifying standardization efforts in the tramway field, as well as any similar guideline efforts. The European literature search provided a significant reservoir of information, including the *Light Rail Thematic Network* (LibeRTiN) project, English language translations of the German *BOStrab* tramway standards, and the UK Office of Rail Regulation *Guidance on Tramways* (2006) and *Tram Design and Construction Supporting Guidance* (2010) documents. The results of the literature search were published on the project website. The search for relevant documents and related standards work also continues as an ongoing activity.

Carbuilder survey

As a next step, a carbuilder survey was conducted. The fortunate timing of the bi-annual Innotrans trade fair in September, 2010 allowed subcommittee representatives to meet with carbuilders to discuss the survey and its role in the guideline project. Each carbuilder was subsequently asked to provide answers to a technical questionnaire and to provide detailed information on the product(s) they would offer in response to an inquiry from a U.S. purchaser. In addition to gathering together useful comparative data about the different streetcar vehicles being offered in the U.S. market, it also helped clarify what options carbuilders viewed as "standard" versus custom features. The process also served to engage carbuilders in the guideline effort. A total of seven carbuilders participated in the 2010 survey, and nine are participating in the 2012 update.

Recognizing that running gear represented an area where modern streetcar vehicles were particularly innovative, specific information was obtained for each vehicle and included in the survey. The running gear classification system in TCRP Report 2 was adopted, although it was quickly discovered that of the report's 18 running gear categories, only three were still in use for new vehicles being offered to the U.S. market. Six additional categories were created to classify the new running gear types. With continuing advances in traction motor technology, it was also noted that some of the new 100-percent low-floor designs now incorporated once-familiar running gear elements such as solid axles and rotating trucks. These seemingly fundamental concepts in running gear were actually not common in the first generation of 100-percent low-floor vehicle designs, where fixed trucks and independent wheels predominated.

Concurrent with the survey, an effort was made to better understand the global market for light rail and streetcar vehicles. Trade articles such as the annual updates on worldwide low-floor vehicle orders by Dr. Harry Hondius (published annually in Metro Report International) were consulted, along with numerous additional resources provided by Subcommittee members.

It was found that of the more than 8,000 low-floor light rail and streetcar vehicles built or placed on order in the 25 years since the advent of modern low-floor technology, about half are 100-percent low-floor. In the United States as of July 2012, there were 1,040 partial low-floor vehicles in service or on order, and five 100-percent low-floor vehicles (altogether representing a modest 13 percent of world production of low-floor rail vehicles). In Canada, Toronto has a total of 386 100-percent low-floor vehicles on order to replace its existing streetcar fleet and equip its new light rail network. Recent western European orders suggest that the market trend is decidedly in favor of 100-percent low-floor vehicles for tramways and streetcars, with the 70-percent configuration still popular for LRVs, including the emerging Tram-Train application[ii]. It was further noted that the European approach seemed to put less emphasis on differentiating between what we in the U.S. call "streetcar" and "light rail", with the term "tramway" covering a broader range of applications.

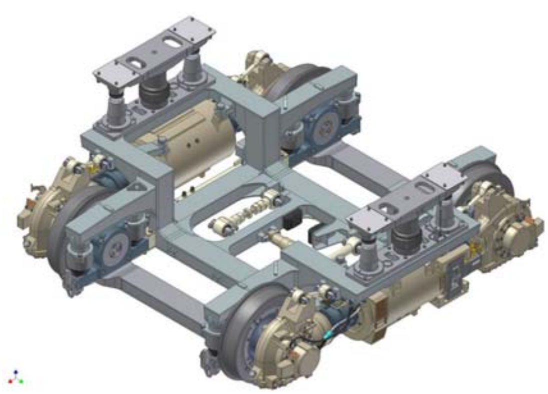

Figure 2. Example powered truck for 100-percent low-floor vehicle

Operating environments compared

Another early step in the project was to compare European and North American streetcar operating environments to identify where differences might impact vehicle design or operation. A number of excellent resources were found to support this effort including TRB Special Report 257 *Making Transit Work- Insights from Western Europe, Canada and the United States* (2001) and the *Light Rail Thematic Network* (LibeRTiN) topic reports. A peer reviewer from the UK also joined the working group at this time. The research was summed up in an *Operating Environment Research* working paper that contrasted U.S. and European practice in numerous key areas including duty cycle, passenger interface and expectations, street geometry, interaction with traffic, climatic conditions, fare collection methods, as well as several key standards related topics.

The primary conclusions were that U.S. operating environments alone were not different enough from those in Europe to require significant change in vehicle configurations. It was also noted that some European countries (for example France), had a parallel experience with the U.S. in having abandoned almost all of their first generation streetcar/tramway systems, followed in recent decades by a return of modern systems. As in the U.S., Europe was noted to have a wide variety of street geometries, climatic conditions, and other physical conditions. Passenger expectations were thought to be somewhat different due to the differences in cultural acceptance of transit, but the impact of the automobile was still a strong factor in both the U.S. and Europe. As a general message from the European experience, streetcar / tramway lines were found to be most effective when implemented as part of a "transit first" approach to traffic management, which had the added benefit of creating more pedestrian-friendly streets.

From the vehicle perspective, the most influential differences were found to be in the area of standards. Separate standards development efforts in the U.S. and Europe have led to different standards covering the same topics. For example, differences in accessibility standards (tolerance of a slightly greater vertical step in Europe) impacted the overall approach to level boarding and the need for vehicle features such as load leveling and bridgeplates. Differences in crashworthiness and fire safety standards were also noted. This area was identified as needing additional research.

The *Operating Environment Research* document was updated numerous times through June 2011 and posted on the project website.

PART 2- GUIDELINE TOPICS

The process of developing the *Operating Environment Research* document distilled out five topic areas for inclusion in the guideline:

- Vehicle Configuration
- Vehicle / Platform Interface
- Vehicle / Track Interface
- Power Supply
- Standards* (now a separate project)

The top-level goal for the guideline is: *To facilitate the successful introduction of modern streetcar vehicles into North American systems by promoting understanding of the core technical and operational issues.* Recognizing that streetcar and light rail systems operate in more than 400 cities throughout the world, with considerable variation in form and function, the approach for each topic is to identify and explain the underlying principles and interdependencies, and to examine the pros and cons of the various different design approaches. Throughout the document, heavy emphasis is also placed on the need to treat vehicles, infrastructure and operations as a *system*.

At the conclusion of each subtopic, concise “guidance” paragraphs summarize the topic and provide direction. The document also makes extensive use of graphics to help explain the subject matter (Figure 3 provides an example).

Guideline Introduction

In discussing the draft guideline with persons engaged in different phases of streetcar project development and design, it became clear that many decisions relating to the alignment (which in turn impact the vehicle) get made very early in the process, sometimes with only minimal consideration of vehicle and maintenance issues.

The Introduction is aimed at project planners and others involved with the early phases of project development. It begins emphasizing the importance of a balanced approach to design (recognizing trade-offs and avoiding over-use of design minimums and maximums) and starts the discussion about defining certain standard ranges of vehicle design characteristics, providing a means to identify areas where imposing requirements on the wayside infrastructure is preferable to modifying the vehicle, and vice-versa.

Topic 1- Vehicle Configuration

Key messages for this topic area include:

Modular vehicle designs- carbuilders have developed modular product lines that permit multiple vehicle configurations and visual design elements based around standardized vehicle "platforms." Within these modular product families, customers can select from a catalog of "standard" options to tailor the vehicles to their system. An example is vehicle width; there are three "standard" widths used by virtually all new tramway systems; 7 foot 6.5 inch (2.3 m), 7 foot 10.5 inch (2.4 m) and 8 foot 8 inch (2.65 m).

Understand and communicate duty cycle- the adage "begin with the end in mind" applies. The first step in selecting a vehicle is to understand exactly how it will be used, and to be able to communicate that information as part of a vehicle procurement. The guideline provides users with a "duty cycle checklist".

Optimize the vehicle for the streetcar operating environment- modern light rail and streetcar vehicles are fundamentally very similar, the differences having largely to do with how they are applied. The primary difference between the two modes is the degree of integration into the urban environment and the scale of the associated infrastructure. This difference in application makes some common LRV design features unnecessary for streetcar application, but may also require the use of other features that may or may not be incorporated into a typical light rail vehicle. An explanation of key vehicle features is provided.

Consider capacity- System planning should address the issue of how capacity will be expanded in the future to accommodate growth in demand. Although the first generation of U.S. modern streetcar vehicles were all 66 feet (20 m) in length, longer vehicles are also readily available. The 66 foot (20 m) length represents the short end of the global spectrum of modular vehicle lengths (and thus capacity), being only slightly longer than a typical articulated bus, with similar capacity. Streetcar vehicle lengths in the range of 98 feet (30 m) are more common in other parts of the world, reflecting their use as high-capacity transit.

Partial and 100-percent low-floor- More than twenty years after their debut in Europe, 100-percent low-floor vehicles are now appearing in North America. The 100-percent low-floor configuration offers further access improvements, but at the price of more complicated running gear due to limitations on space for conventional suspension and drive elements. Pros and cons of both configurations are examined.

Topic 2- Vehicle / Platform Interface

Key messages for this topic area include:

ADA Compliance- Both near-level and fully-level boarding have been used to achieve ADA compliance. The pros and cons of the two approaches are explored in depth, along with discussion of the many factors that influence this key decision.

Bridgeplates (if used)- the numerous configuration and operating issues surrounding bridgeplates are explored in detail, and a recommendation made for further industry study.

Streetcar and bus sharing a platform- The nature of the streetcar mode is such that streetcar and bus routes may overlap. This may present opportunities for different types of vehicles to share stops, improving passenger convenience and reducing costs by facilitating transfers and saving space in dense urban settings. Depending on the nature of the transit services using the stop, separate stopping places may also be desirable. Implementing shared stops involves a number of variables centering around the height of the platform. Generally, as streetcar platform heights increase above 8 inches (203 mm), additional design coordination is required to ensure compatibility with buses.

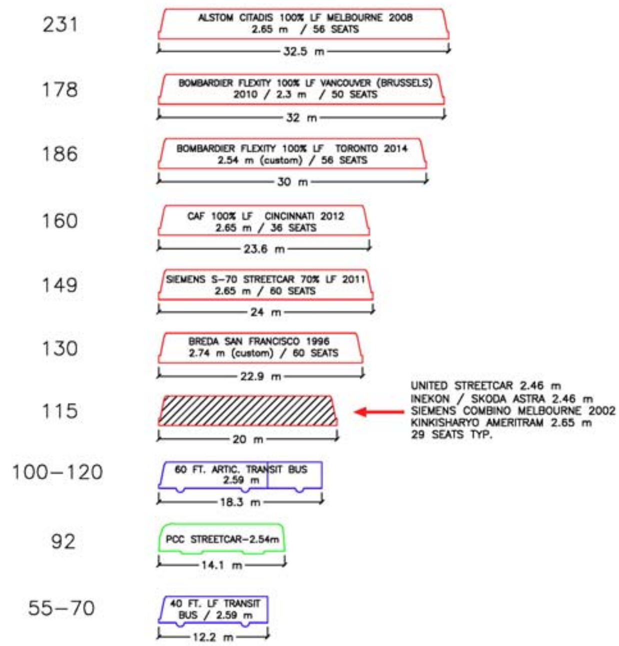

Figure 3. Example graphic from the document; comparison of vehicle lengths / capacities

Topic 3- Vehicle / Track Interface

The essentials of this very complex topic are already well covered by other resources, such as TCRP Report 155 (2012), which is the revised version of Report 57 *Track Design Handbook for Light Rail*. This chapter of the guideline focuses on identifying areas where streetcar track and vehicle design are unique from light rail, centered largely around the sharper curvature typically needed to integrate into the urban environment. A top-level checklist is also included to provide a concise but more comprehensive overview of vehicle/track interface design considerations.

Recognizing that streetcars have changed significantly with the advent of low-floor vehicle technology, the draft guideline advises: “Track design for new streetcar systems should be undertaken specifically with the use of low-floor vehicle technology in mind. Track designers should understand that modern streetcar vehicles are significantly different from earlier vehicles, having evolved into designs with smaller body sections and a greater number of articulations, and incorporating special running gear to accommodate the low-floor section(s) of the vehicle.”

Other important sub-topics include discussion of turning radius, gradients and track twist / wheel unloading. The special running gear used in low-floor vehicle designs is also reviewed along with related wheel maintenance issues.

While it is acknowledged that the nature of a streetcar alignment is such that sharper curvature and steeper gradients than light rail may be necessary, emphasis is also placed on treating track, vehicle and operations as a *system.* The draft document emphasizes: “Because of the inherent flexibility of the light rail/streetcar mode, it is *possible* to operate over extremely demanding alignments in terms of curvature and gradient. However, minimizing the use of such extremes brings numerous benefits in terms of passenger comfort, higher operating speeds, lower operating costs and the ability to purchase “standard” vehicles from multiple suppliers.”

Topic 4- Power Supply

This chapter provides an overview of basic traction electrification system concepts and their relation to new power supply technologies now being introduced for vehicle propulsion. More than any other section of the document, this topic is the most fluid in terms of the speed with which the technology is evolving. Consequently, the content merely reflects the current state of the industry, with the expectation that it may be distinctly different in the near future. A brief discussion of OCS aesthetics is also included, as it was felt that this topic is strongly connected to the subject of off-wire streetcar operation.

Key messages for this topic area include:

OCS aesthetics matter- Good OCS design practice recognizes the importance of context-sensitive aesthetics and treats in-street and other sensitive areas accordingly.

Energy storage has multiple roles- Some alternatives to using only OCS power distribution have now entered the marketplace. New types of ground-level power supply systems are now in limited use, and onboard energy storage capabilities are becoming increasingly common to reduce energy costs. Also, some vehicles can now be equipped with enough energy storage capacity to permit short range off-wire operation. Vehicles with longer off-wire range are also in development.

Examine life-cycle cost when comparing technologies- When considering off-wire capable vehicles, recognize that while infrastructure may be made less costly to build and maintain, the opposite will happen to the vehicle; it will become more technically complex, and may also become heavier, more costly to purchase and maintain, and operationally less flexible. For these reasons, system size and future expansion impact the comparison of power supply options.

Operating scenarios for off-wire capable vehicles must also take charging time into account, and recognize that vehicles may need to operate in a reduced performance mode when “off wire” in order to reduce energy consumption and lengthen operational range. It is also important to make all technology comparisons on the basis of life-cycle cost, incorporating consideration of maintenance costs over the life of the system. This is especially important with consumable energy storage devices (e.g. batteries) which will have a finite number of operating cycles and a substantial replacement / disposal cost.

Apply new technology in a manner that minimizes impacts of proprietary designs- Because energy storage systems are still largely in a developmental stage, they can be expected to continue changing rapidly as the technology evolves. The ability to add energy storage equipment to the vehicle in a manner which minimizes the risks associated with the use of proprietary technology is therefore an important consideration.

Figure 4. Modern streetcar in Reims, France

Topic 5- Standards (separate project)

The research undertaken at the beginning of the guideline project provided these key observations relating to standards: that the U.S. comprises only a modest share of the global market for streetcar/light rail vehicles and; parallel but separate standards efforts have occurred in Europe and the U.S. for several key areas impacting vehicle design including accessibility, crashworthiness and fire safety. It was further observed that a comprehensive European standard exists for braking rates[iii] (covering all types of mass transit vehicles), but that no such national standard exists in the U.S.

After preparing an initial draft of this chapter and circulating it for comment, it was decided that due to its complexity, this topic would need to be addressed in a separate work effort. Also, carbuilders are still examining the differences between the U.S. and European standards in order to understand where design changes may be necessary in order to comply with U.S. standards. Further research is required in order to fully understand the implications of the differences between these various standards.

Appendices- 2012 Carbuilder Survey

The appendix will include an updated (2012) version of the carbuilder survey. Each carbuilder was again asked to provide detailed information on the product(s) they would offer in response to an inquiry from a U.S. purchaser. Carbuilder response to the survey has once again been very strong and a detailed compendium will result.

Figure 5. Off-wire operation in Nice, France

Document Completion

The subcommittee is currently circulating a draft of the complete document for industry comment. It will then go through the APTA balloting and approval process. Throughout the course of developing the guideline, it has facilitated industry dialogue on numerous streetcar-related topics. In some cases these discussions ended up being broader or more detailed than what was appropriate for the guideline, so a number of topics have now been identified for follow-up research and future work.

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[i] APTA Standard for Vintage / Heritage Trolley Vehicle Equipment (APTA SS-HT-001-05)

[ii] "Long Term Orders Dominate the Market" H. Hondius article in Metro Report International, 2010

[iii] EN 13452 Mass Transit Brake Systems, -1 Performance Requirements, -2 Methods of Test