North American Application of

Modern Streetcar Vehicles

Operating Environment Research

Comparison of North American and World Operating Environments

APTA Streetcar Subcommittee
DRAFT Revised 6/4/11

North American Application of Modern Streetcar Vehicles

Operating Environment Research

Comparison of North American and World operating environments

As the basis for developing North American modern streetcar guidelines, the APTA Streetcar Subcommittee conducted a review of previous work in several key topic areas and researched the differences between North American and World tramway / streetcar operating environments. It asked questions in several key areas:

- Are streetcar operating environments in North America different from other parts of the world? If so, how?
- Given that the majority of modern streetcar designs originate outside North America, are there existing vehicle design characteristics that might be incompatible with North American operating environments or standards?
- Which operating environment differences (including standards) have the highest potential to impact vehicle cost?

The project to prepare a Guideline Document "North American Application of Modern Streetcar Vehicles" is being undertaken by the APTA Streetcar Subcommittee. The Subcommittee welcomes the participation of interested parties. An initial version of this outline was discussed during the Subcommittee's meeting in Seattle, Washington on January 24, 2010. Additional information about the project's progress and upcoming meetings is available on the project website at www.modernstreetcar.org. Please send comments on this draft document to project manager John Smatlak at info@modernstreetcar.org

Contents

1) Duty Cycles, including Average Speeds and Headways

Question: Are streetcar / tramway duty cycles more (or perhaps less) demanding for the North American market?

Related Vehicle Design Issues: performance requirements, number of powered axles

Discussion: The answer to this question depends in part how you define streetcar/tramway. For purposes of this document, Streetcar/Tramway can generally be defined as described for "Network Type A" in the Libertin Topic Report "Derailment Prevention and Ride Quality"[1]

> ***5.1 Network Type A***
> *This network type covers urban tramways with significant on-street operation. In previous versions of this specification it was known as 'Street Tramway' but this has been changed at the request of the UITP Light Rail Committee. These networks are characterized by grooved rail, tight curves and line-of-sight running at relatively low speeds. They may also have sections of ballasted track with speeds of up to 70km/h (perhaps slightly higher where national regulations allow). Almost all networks of this type will specify a low floor at least in the entrance area for new vehicles, and some will require low floor throughout the passenger area. The unidirectional (doors on one side, cab at one end) and bi-directional (doors both sides, cab at both ends) vehicle types may both be found on this type of network. Vehicle width can be up to 2.65 m but (particularly on existing networks) the vehicles may be narrower. A wide range of track gauges may be found on this type of network, the most common being 1435mm and 1000mm. Values for track gauge are considered elsewhere in this specification, and the other parameters are applicable to all track gauges unless noted otherwise.*

Although systems vary throughout the world, duty cycles are generally within a similar range on most traditional streetcar/tramway systems. Most are characterized by closely spaced stops in urban centers and further spacing elsewhere. Legacy systems will typically have closer stop spacings than new start systems. Table 1 provides a sampling of stop spacings on various US and EU tramway systems.

[1] ftp://ftp.ttk.de/libertin/topicreports/derailment.pdf

Table 1-Stop spacings for EU and USA tramway systems, a casual survey. *Data from Scott McIntosh (EU) and John Smatlak (USA)*

SYSTEM	Number of lines	System length (km)	No. of stops	Average spacing (m)
Bordeaux	3	21.3	51	417
Caen	1	15.7	34	462
Croydon	3	28	38	760 (507 in urban section)
Dublin	2	23.2	36	680
Edinburgh	Line 1	16	21	761
Freiburg	4	24.1	46	536
Grenoble	2	19.1	35	546
Lille	2	22	36	611
Little Rock USA	1	5.5	14	391
Lyon	2	23.7	48	494
Marseille	1	3	9	333
Montpellier	1	15.2	28	543
Nancy	1	11	31	355
Nantes	3	34.9	78	447
New Orleans USA	(St. Charles Line)	11.3	52	217
Philadelphia USA	Subway-Surface Route 10	9.4	39	239
Philadelphia USA	Surface Route 15	13.5	56	240
Portland USA	1	11.6	25	463
Rouen	2	15.8	31	509
San Francisco USA	(F Line)	9.3	30	311
Seattle USA	1	2.1	7	299
Sheffield	3	29	48	620
St.Denis-Bobigny	1	12.0	26	461
St.Etienne	1	9.3	26	357
Strasbourg	4	26.8	46	583
Tacoma	1	2.6	5	515
Tampa USA	1	4.3	11	395
Average stop spacing for EU systems shown				**542 m**
Average stop spacing for USA systems shown				**341 m**

While all streetcar/tramway vehicles can be expected to meet certain minimum performance requirements, local conditions should be carefully considered. For example, a sizeable portion of a run (>1 mile / 1.6 km) with closely spaced stops or steep gradients could impact vehicle and traction power performance requirements.

The vehicle's ability to meet duty cycle requirements is a function of the thermal limit of the systems due to passenger load, gradient and length of grades, and whether the vehicle has all or a fraction of its axles powered.

Other key issues include climatic conditions, extended running downgrade, rescue scenarios (towing a dead vehicle) and control (and cutout) of individual axles versus the whole truck. Duty cycle should be defined as specifically as possible, including how many hours at each level of loading, going up or down what gradients for what distance.

It is important that the agency thoroughly understands the duty cycle for its existing and future (expansion) streetcar lines and clearly communicates this information in its vehicle procurement documents. Changing the performance characteristics of established vehicle designs can be expensive, the art is in designing a commercially attractive system within the performance characteristics of a readily available vehicle.

2) Passenger Interface Including Passenger Expectations And Behaviors

Question: Do North American streetcar/tramway passengers have different expectations and behaviors than their counterparts in other parts of the world? Are there significant differences in the size of passengers, enough to change seating requirements?

Related Vehicle Design Issues: passenger accommodations and amenities. While seated-to-standee ratio can be considered a local agency decision dependent on passenger loading standard, typical journey time, headway etc., it can have a major impact on weight / axle loading.

Discussion: This issue is related to the differences between the North American and EU mindset on transit. Government investment in transit sets the tone, and transit typically accounts for 10 to 20 percent of urban trips in Western Europe, (it is the predominant mode in busy urban centers such as London, Berlin, Zurich) but only two percent in the US. Canadians also use transit about 10 percent of the time.[2] This disparity is also reflected in the world percentage of railcar orders; the US has only 5% of the worldwide transit railcar fleet (all rail transit modes), Canada/ Mexico has 2%, and Europe 35%.[3]

The private automobile remains less convenient and more costly to operate in Western Europe than in the US. In 2010, EU gas prices average more than double of those in the US, with taxes accounting for the majority of the difference in prices. The supply of parking is also substantially lower. Despite these

[2] TRB Special Report 257 “Making Transit Work, Insights from Western Europe, Canada and the United States”

[3] GAO Report 10-730, June 2010 “Transit Rail, Potential Railcar Cost-Saving Strategies Exist”

facts, the per capita percentage of car ownership in Western Europe is high and growing, though EU families are less likely to own a second car and will use their cars less frequently than in the US. A transit-first approach to traffic management also pervades Western Europe, with transit vehicles given priority[4].

In some EU cities, residents have also grown up with trams in a more compact urban environment so trams and other forms of public transit are simply a part of everyday life. In other EU cities, the experience parallels that of North America where tramway systems disappeared entirely and have only returned in relatively recent times. Anecdotally, most people queried for this report also expressed the opinion that in general, public transportation enjoys broader cultural acceptance in Europe than in the United States. Consequently, it was felt that Europeans were more likely than Americans to view efficient public transit as an essential "public utility" that everyone should have access to. This societal attitude is reinforced by continuing government investment in public transit.

Another contributing factor is that American urban areas typically cover more land than their Western European counterparts. Western European central cities also contain a larger share of the urban population- most containing half or more, compared with a median of less that one-third for the US[5].


Figure 1- US light rail and streetcar systems typically attempt to accommodate bicycles on board. EU practice varies widely; none of the UK tram systems allow bicycles, but other EU countries do. Policies vary from country to country and even line to line. This is an area where more research would be helpful. The photo at left shows a designated bike area on a modern tram in Amsterdam (*David Murray photo)* and at right in Orleans France.

[4] TRB Special Report 257 "Making Transit Work, Insights from Western Europe, Canada and the United States"

[5] TRB Special Report 257 "Making Transit Work, Insights from Western Europe, Canada and the United States"

As to the physical size of passengers, on average, Americans are not taller than Europeans; average male and female heights are greater in several EU countries than in US. US passengers are, however, larger on average; the US leads the world in the prevalence of obesity, although this is a global problem. E.g.: US male population 42% prevalence of obesity, German male population 29%. In 2011, the US Federal Transit Administration proposed raising the average passenger weight used in bus testing calculations from 150 to 175 pounds. Seat pitch is also a function of trip length, and in general passenger comfort issues are part of the process of winning transit market share.

In summary, there are some differences in passenger behaviors / expectations based in part on the differences in cultural acceptance of transit, but the impact of the automobile is a strong factor in both the US and EU. Streetcar / tramway lines are also most effective when implemented as part of a "transit first" approach to traffic management, which has the added benefit of creating more pedestrian-friendly streets.

---

3) Station Designs

Question: Are streetcar / tramway stops in North America fundamentally different than in other parts of the world?

Related Vehicle Design Issues: vehicle layout

Discussion: In comparison to North America, the EU has more legacy streetcar / tramway systems, and these have been incrementally upgraded over time. Vehicles evolved from the earlier high floor types to partial low-floor (in many cases retrofitting older vehicles with low-floor sections), and now in many cases, to 100 percent low-floor. This evolution was driven by a desire to improve service efficiency; making access easier for all passengers reduced dwell time at stops. Platforms have also evolved in the EU, although in many cases passengers are still required to step up into the tram. This “one step boarding” is however a significant improvement over boarding a high-floor vehicle. In some cities platforms have also been upgraded to achieve “fully level boarding” or conditions closer to it.. As seen in Figure 2, some EU tramways have low-floor vehicles but still have some boarding directly from the street, with no platform of any kind.

Figure 2- Use of a low-floor tram with no platform, Graz, Austria. *Georg Hoffer photo*.

Figure 3- “dynamic stop” example, Graz, Austria. *Georg Hoffer photo*.

Vehicle / platform interface is thus an example of an issue where conversion of an existing system is different than a new start. The legacy system in Toronto, for example, will soon operate new 100% low-floor vehicles with street level boarding on several routes, providing "one-step" boarding in lieu of “level boarding” where no platform is available(although ramps will be employed to accommodate wheelchair access at all locations including from street level). Another example is Melbourne, Australia which is in the midst of an ongoing conversion program. Melbourne currently operates a mixed fleet of high and low-floor trams and is adding platforms to a system which historically had utilized street-level boarding and in-street “safety islands” almost exclusively.

It is also worth noting that Melbourne Australia and several EU tramway systems use alternative stop designs such as “Dynamic Stops” (Figure 3) wherein tram services and other traffic share the boarding area but are time-separated. At a “Dynamic Stop” tram service and roadway traffic share a portion of the street space, and traffic controls are used to separate the two. This can be done with or without modification to the roadway. Passengers can either step down from the curb and walk to the tram through the designated traffic lane space under the protection of a traffic signal or other control, or the section of traffic lane may also be elevated to curb height to assist with boarding. Pavement ramps permit traffic to pass through these raised lane sections when there is not a tram calling at the stop.

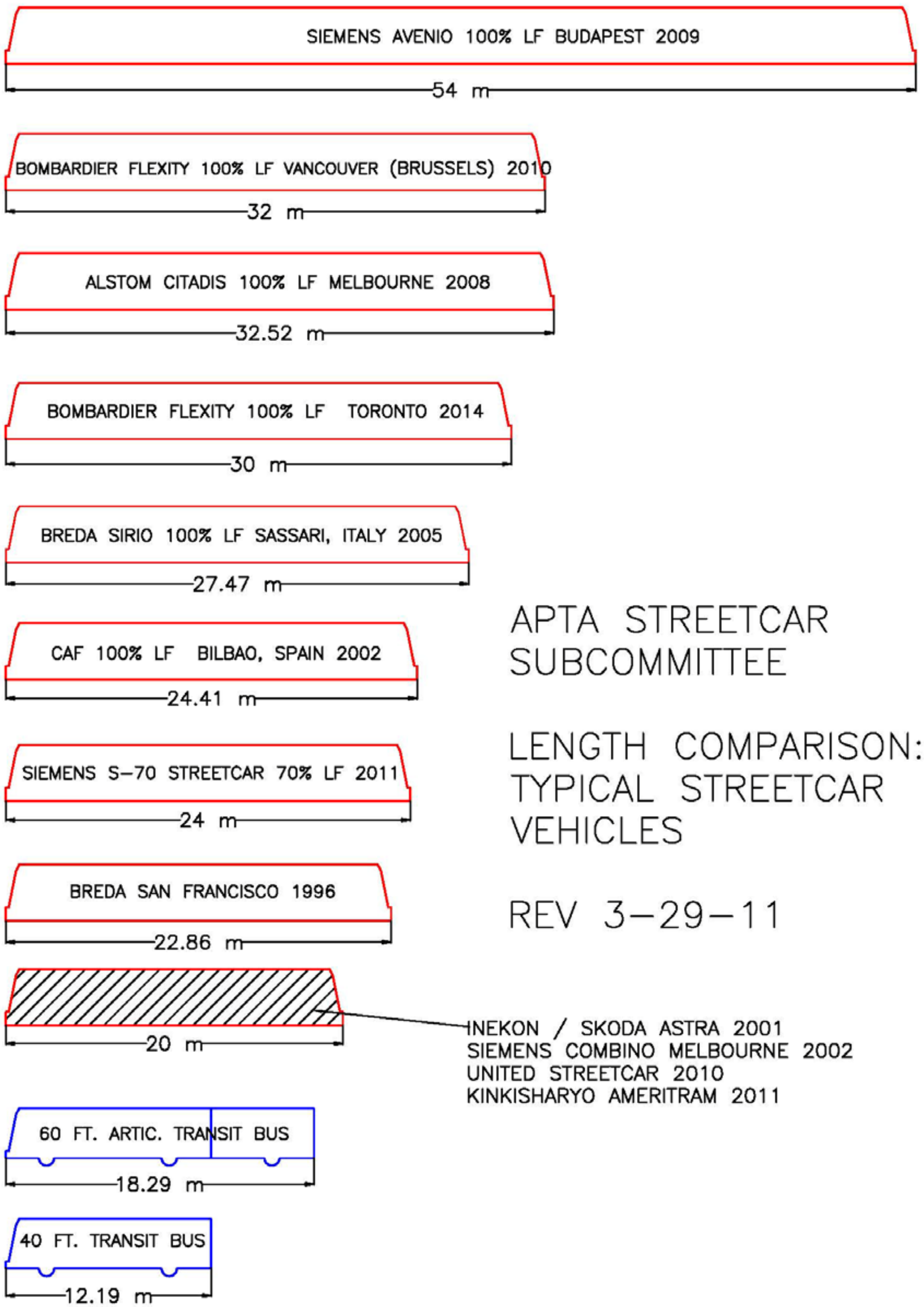
Basic station design concepts are similar throughout world, although climatic conditions have significant local impacts. As in the US, new EU tramway systems typically have platforms to maximize the benefits of low-floor vehicles and take advantage of their length. A nominal 350mm (14 inch) floor height is most common for low-floor vehicles, and the corresponding platforms typically range from 200mm (8 inch) (“nearly level” boarding) to 355mm (14 inch) (“fully level” boarding). Refer to Table 2 for a survey of low floor streetcar / light rail platform and vehicle floor heights Because the US ADA regulations require a tighter tolerance for vertical step than in the EU (5/8 inch versus 2 inch), the tradeoffs associated with the two basic alternatives (“nearly level” versus “fully level”) may be evaluated differently for American systems.

Table 2. Low-Floor Streetcar and LRV Platform and Floor Heights

City	Platform Height		Entrance Floor Height / Main Floor Height		Bridge Plates?
	(in.)	(mm)	(in.)	(mm)	
Boston Green Line	0-4?	0-101?	14	355	yes
San Diego LRV	8	203	14 / 15	355 / 380	yes
Berlin, Germany	8.7	220	11.6 / 14	295 / 355	manual only
Milan, Italy	8.7	220	13.8	350	Yes
Nantes, France	9.8	250	14.6	370	yes
Portland LRV	9.8	250	14	355	yes
Portland Streetcar	9.8	250	13.8	350	yes
Seattle Streetcar	9.8	250	13.8	350	yes
Tacoma Streetcar	9.8	250	13.8	350	yes
Melbourne tramway	11.4	290	11.8	300	yes*
Nottingham UK LRV	12.5	317	13.9	352	Gap fillers
Charlotte NC LRV	14	355	14	355	no
DC Streetcar	14	355	14	355	no
Houston LRV	14	355	14	355	no
Phoenix LRV	14	355	14	355	no
San Jose LRV	14	355	14	355	no
Seattle LRV	14	355	14	355	no
Dallas LRV "C" car	15.5	394	16	406	no

The length of modern streetcar vehicles varies considerably, ranging from approximately 15 to 60m (although 20 to 40m is the most common range). A few representative samples are illustrated in Figure 4, including several North American examples.

Figure 4- Lengths of various low-floor trams / streetcars, with transit buses shown for comparison



4) Interoperability with Other Transit Vehicles

Question: How is North America different from other parts of the world with regard to streetcar / trams sharing streets and stations with bus and light rail?

Related Vehicle Design Issues: vehicle layout

Discussion: The basic concepts of the vehicle interfacing with the platform are similar throughout world, with the previously noted differences between US and EU practice concerning the acceptability of a vertical step. It should also be noted that the US and EU have different approaches to trams and trains sharing track, a topic which is outside the scope of this paper.

The ability of a streetcar and a bus to share a common travel lane and a platform is a function of several variables beginning with the ability of the bus to access to the platform; will the bus and streetcar be sharing the lane immediately adjacent to the platform or will the bus be required to maneuver to the platform into and out of traffic lanes? In the latter case, the approach and departure angles to the platform must be considered (buses may also use a guidance system). Note that many European cities are using specially shaped curbs (e.g. Kassel Kerbs) to facilitate bus docking, including at shared bus / tramway stops. The shape of these curbs is specially designed to assist with docking the bus as close to the curb as possible, while protecting tires and vehicle edges.

The platform height must also be compatible with both vehicles; outward folding bus doors, for example, must be able to deploy without contacting the platform. If the bus uses a wheelchair ramp, there must be adequate room for the ramp to deploy onto the platform. Finally, the respective lengths and door locations of the vehicles must be considered.

Figure 5- Rear doors on bus blocked by 355mm (14 inch) streetcar platform

5) Street Geometry

Question: How is North America different from other parts of the world with regard to street and lane widths, grades and other street geometry issues?

Related Vehicle Design Issues: Vehicle width, turning radius, gradeability

Discussion: Europe has both "new" and "old" cities related in part to post WWII reconstruction. In the EU there are generally far fewer grid type street patterns, and thus less route flexibility, especially in older cities with narrow streets and high density. Consequently, extreme track design values may be applied more frequently to EU new start systems as compared to North America.

Figures 6 and 7- Augsburg, Germany and Brussels, Belgium provide examples of legacy systems with impaired clearances that are obligated to use narrow-width vehicles (in these cases 2.3m or 7 ft. 6 in.) This width precludes the use of 2+2 seating inside the vehicle, *Ernest Kers photos*

Street geometry varies widely throughout the world, North America included. Lane widths vary from nation to nation, but within reasonably narrow ranges: typically 9.8 to 12.3 feet (3.0 to 3.75 m) for arterials, and 9 to 12 feet (2.75 to 3.65 m) for local roads. Narrow tramcars / streetcars are found on legacy systems with impaired clearances, but a number of EU new start systems have opted for wider 2.65m vehicles because these vehicles can incorporate 2+2 seating. The new replacement fleet being built for the legacy streetcar system in Toronto are a non-standard 8 feet, 4 inches (exactly 100 inches) (2.54 m).

6) Interaction with Traffic Including Other Vehicle Types And Driver Behaviors

<u>Question:</u> How is North America different from other parts of the world with regard to the way streetcars / trams interact with other traffic? Are the vehicles they share the road with different (larger, smaller, more / less of them)? Are driver behaviors quantifiably different?

<u>Related Vehicle design Issues:</u> performance requirements, vehicle leading end design (including couplers), crashworthiness

<u>Discussion:</u> The average automobile size is larger in the US than in the EU, although SUVs have also made some inroads in EU markets. Maximum widths for commercial vehicles are similar throughout the world: US and Canadian federal maximum width for commercial vehicle is 8 ft. 6 in. (2.6m), the same as in Western Europe except the UK which is slightly less at 8 ft. 4 in. (2.55m). US height restrictions vary by state between 13 ft. 6 in. and 14 ft. 6 in. (4.1m - 4.4m), which is less restrictive than most EU countries which are at 13 ft. (4m). One notable difference concerning commercial vehicles is that implementation of time windows and other access restrictions for truck deliveries in urban areas is more prevalent in the EU than in the US[6].

Some EU countries also have stricter automobile safety and inspection standards than the US. It is perhaps worth noting that the US does have among the highest number of traffic-related deaths per capita in the world. "The United States ranks 42nd of the 48 countries measured in the number of fatalities per capita, according to the Organization for Economic Cooperation and Development and the International Transport Forum. Australia, Britain, France, Germany and Japan all did significantly better". "And in what many safety experts consider a more precise measure, fatalities per distance driven, the United States was No. 1 in 1970 with the lowest death rate among industrialized countries reporting data. It now ranks 11th, with some countries reporting rates that are 25 percent lower"[7].

Refer also to the comments in question 2 above on the differences between the US and EU mindset on transit; coupling new streetcar / tramway lines with a transit-first approach to traffic management. In France, for example, new tramway lines are brought into the street where the road space can be reshaped to promote public transport and pedestrians over cars.

It is also worth noting that the majority of the world's countries drive on the right. Notable exceptions (driving on the left) include the UK, Ireland, Australasia and Japan.

<u>Road conditions and driver behaviors vary around the world, and streetcars/ trams in any country should be optimized for in-street operation. They must also be designed for the possibility of a collision with other roadway traffic. In general, streetcar / tramway lines are also most effective when implemented as part of a "transit first" approach to traffic management, which has the added benefit of creating more pedestrian-friendly streets.</u>

---

[6] Visser "Urban Freight Transport Polocies and Planning in Europe: an Overview and Classification of Policy Measures"

[7] Source NY Times 2007

7) Climatic Conditions

<u>Question:</u> How are climatic conditions in North America different than in the EU?

<u>Related Vehicle Design Issues:</u> HVAC requirements including maintaining climate control with multiple doorways (typically using on-demand door operation). Performance requirements including unpowered axles. Selection of materials / resistance to corrosion from road salt and other snow/ice issues. Running gear / motor design (vulnerability to snow / salt infiltration)

<u>Discussion:</u> A range of climatic conditions is found in both North America and Europe. Europe has tramway systems in the far north (Bergen) further north than any Canadian system and standard European trams will soon be operating in Dubai, almost as far south as Miami, Florida. Europe has both mild maritime climates and more extreme continental climates. Many of the biggest tramway cities (Berlin, Budapest, Moscow, Vienna) are in the continental weather areas.

A range of climatic conditions are also found in North America, with climatic extremes not uncommon; the intensity and duration of heat and humidity for example. As in the US, some EU cities don't have road salt to deal with, others do. Some EU tramway systems are still purchasing new trams without air conditioning, which seems unlikely to occur in the US. At the other end of the spectrum, suppliers are already dealing with the need for enhanced air conditioning as they enter the Middle East market.

<u>Because extreme climatic conditions will influence many aspects of vehicle design (e.g. HVAC requirements and carbody materials selection), agencies should carefully examine these potential impacts as part of the vehicle procurement process.</u>

A low-floor tram boarding in the snow, Helsinki, Finland. A range of climatic conditions is found in both North America and Europe, the impacts of which need to be carefully considered during the vehicle procurement process.

8) Security

Question: With regard to vehicle design, are the security concerns of North American transit agencies different from their counterparts elsewhere in the world?

Related Vehicle Design Issues: Vehicle interior layout including driver protection, passenger seating, cameras and passenger-activated alarm devices.

Discussion: In terms of vehicle design, security concerns are similar throughout world. Cab layout will also be related to fare collection method and the preferences of a particular property, or the property's willingness to accept someone else's design because that is what is readily available.

---

9) Fare Collection Methods

Question: Is it practical/desirable to run low-floor streetcars with fare collection other than proof-of-payment or conductors? Are any EU agencies running low-floor vehicles with driver-collected fares?

Related Vehicle Design Issues: Vehicle layout. Cab design is particularly impacted if operator is collecting fares. May also impact location of bridge plates or lifts.

Discussion: In general, the world's bus /streetcar / tramway systems continue to move towards proof-of-payment (or conductors such as in Amsterdam, Sydney, Nottingham). There are also differences in approach to fare enforcement between North America and the EU.

Low-floor streetcars with multiple entrances are designed to work with proof-of-payment fare collection, although a few systems employ conductors instead. Operator-collected fares would be counter-productive to having multiple doors and other key accessibility elements of a low-floor design such as the reduction of dwell time made possible by multiple doorways.

---

10) Track Standards

Question: 100% LF streetcars require special running gear such as fixed trucks or axle-less designs. What track design standards are most important to ensure their successful introduction? What track maintenance parameters will have the most significant impacts on ride quality and safety from derailment?

Are track maintenance standards different on existing North American systems (especially legacy systems) when compared to EU and other world systems which are now operating the current generation of low-floor modern streetcars? Is a higher level of track maintenance required for 100% low-floor vehicles to be successful? Do 100% low floor designs with fixed trucks cause more track wear than conventional vehicles?

Related Vehicle Design Issues: Running gear, vehicle ride quality, safety against derailment

Discussion: Additional research is required in this area. Initial study suggests that the special running gear designs for 100 percent low-floor streetcars require higher track maintenance tolerances and standards than those required for previous 70 percent low-floor and other more conventional designs in order to maintain ride quality and safety against derailment at acceptable levels. Because streetcar / tramway systems generally attempt to follow the established horizontal and vertical alignment of the roadway, the acceptable degrees of track twist and curvature also become important issues.

Through additional research and coordination with other APTA committees, the team will seek to better understand and quantify track design and maintenance issues that impact low-floor vehicle performance, using input from both suppliers and EU systems that have gone through the process of introducing 100% low-floor vehicles.

---

11) Staff Familiarity and Training

Question: It is well-known that streetcar systems are much more pervasive in the EU than in North America. Would a disparity of staff expertise and training competencies, if it exists, impact vehicle designs being offered to North American systems?

Related Vehicle Design Issues: Maintainability and repairability. DBOM issue is also relevant here; in some cases vehicle suppliers are also maintaining the equipment.

Discussion: In general, agencies around the world have always had to adapt to new technologies and figure out how to make them work locally. It is also worth noting that the experience of some EU countries (e.g. France) has paralleled that of North America, although on a more advanced timetable. In these cases, all but a few legacy tramway systems were abandoned, with new starts created only in recent decades.

EU transit agencies that operate legacy tramway systems will expectedly have a higher level of related expertise in-house when compared to North American cities developing new-start streetcar systems. Some people interviewed for this report expressed an opinion that in general EU transit agencies appeared to have greater employee stability, including top management positions, thus improving in-house expertise in many areas. Consequently, it was also felt that EU transit agencies generally relied less on outside consultants than their US counterparts.

While it is unlikely that suppliers will change the basic product being offered, reparability is an important issue. How well the new generation of low-floor vehicles will hold up to the typical urban collisions (both small and large) remains to be seen.

The agency should seek to understand the maintenance and repair technologies involved with their new rolling stock (as well as related requirements such as track maintenance tolerances) as part of the vehicle procurement process.

12) Braking and Acceleration Rates

Question: Do braking and acceleration rates being specified for North American streetcar / tramway applications differ from other parts of the world? If so, why?

What standards should North American agencies look to for streetcar braking rates? What factors (eg: weight) could impact the use of these standards?

Related Vehicle Design Issues: Streetcar / tramway braking rates are to some extent adjustable. Acceleration and braking rates are related to vehicle weight, local adhesion limits, locally acceptable jerk rates and the number of motored/braked axles.

Discussion: Braking and jerk rates are dependent on the ability of the passenger to remain standing in comfort when the vehicle is moving. Significant research was performed on this in the 1930s by the ERPCC during development of the PCC streetcar. Streetcar / tramway acceleration and braking rates are therefore typically specified within a fairly narrow range worldwide, although there seems to be widely varying sources for specifying braking rates in North America, where unlike the EU, no national standard currently exists.

Additional industry discussion is needed in the area; consideration should be given to the adoption the EU standards (EN 13452-1 Braking Requirements and EN 13452-2 Testing Methods) for modern streetcar vehicle procurements in North America.

---

13) Gradeability, Curving Radius and Other Factors Especially Significant to Legacy Systems

Question: Urban geography varies widely throughout the world, including within North America. Do existing vehicle designs already have adequate performance capabilities for use in North America?

What vehicle design factors impact curving radius and gradeability? What range of values have suppliers structured their modular product lines to? What are the tradeoffs for a vehicle that will be outside of these values?

Related Vehicle Design Issues: Vehicle width, turning radius, gradeability, articulation joint design

Discussion: Track twist and wheel unloading are major factors for modern articulated vehicles. Additional considerations include compound horizontal and vertical curves, gradient and length of grades, transition curves (spirals) and cross-overs on grades.

Figures 8 and 9-Legacy systems exist throughout the world that require sharper curves and steeper gradients than might otherwise be specified for a new-start system. These examples from Pittsburgh and Melbourne illustrate extreme horizontal curve radius.

Legacy streetcar / tramway systems exist throughout the world that require sharper curves and steeper gradients than might otherwise be specified for a new start system. An example is horizontal curve radius; 40-50 foot (12.2-15.2 m) centerline radius curves are found in many parts of the world, but US has most extreme curvature in its remaining heritage cities; Philadelphia being the worst case at 35 feet (10.7m). Similar examples in Canada and the EU include Lisbon (old network) and Toronto, both at 36 feet (11 m).

Carbuilders have structured their current modular product lines for between 18 and 25m (59-82 ft.) minimum curve radius, depending on the particular carbuilder. The trade-off for specifying a vehicle outside of the standard values for a given product family is a custom vehicle with higher cost, especially in small order quantities. Additionally, there may be impacts on seating and other interior arrangements in the areas over the running gear. Vehicle design factors that impact curving radius and gradeability include:

- Running gear type (including use of fixed trucks)
- Articulation arrangement
- Number and lengths of carbody sections
- End overhang
- Motorization ratio

Additional research is needed in this area. Different technologies for streetcar body configuration and running gear may have different strengths and weaknesses with regard to their suitability for local conditions. Some technologies may require an easier alignment to be successful. The important thing is to adopt a technology that fits the city – NOT attempt to rebuild the city to accept the chosen technology.

14) Standards- Buff load and crashworthiness

Question: What are the differences between North American standards (may require further breakdown between US and Canada) and those applicable in other parts of the world?

What standard should an agency include in their vehicle technical specification, and what are the supplier-related implications of including it? How are EU standards different? What are the differences between EN 15227 and ASME RT-1? What standards do the current lines of modular streetcar designs meet?

Related Vehicle Design Issues: Vehicle frame design, vehicle leading end design (CEM), testing methodologies, weight (and motorization if weight is heavier).

Discussion: Different approaches have evolved between North America and World, and separate standards exist (US=ASME RT-1, EU= EN 15227). Leading up to these new standards, the United States has, since the early 1970s, had higher buff strength requirements for light rail vehicles, often twice that of comparable European vehicles. The first light rail vehicle design to adopt the new RT-1 standard (and the only one so far as of this writing) is the KinkiSharyo vehicle for Phoenix, delivered in 2008. In Canada, Toronto has adopted a modified (more stringent) version of the EN standard for crashworthiness, survivable volume, side impact strength etc. for its current procurement of streetcar and light rail vehicles.

Additional research is required in this area to understand the differences between the current US and EU standards and their implications. This topic has the potential for major cost impacts.

---

15) Standards- Accessibility

Question: What are the differences between North American standards (may require further breakdown between US and Canada) and those applicable in other parts of the world?

Related Vehicle Design Issues: Interior layout (door and aisle widths, wheelchair space allocation), vehicle suspension. Meeting ADA vertical step requirement with a vehicle already designed with load leveling is relatively straight-forward, adding load leveling to a design without one is a greater issue.

Discussion: The same concept of providing accessibility to all is in place throughout world, but separate standards exist (including between countries within the EU). Because more original tram systems survived in the EU than in North America, they have more retrofit situations to deal with than North America. ADA created an almost “clean start” in US because so few legacy streetcar systems remained at the time of its implementation.

The EU and ADA guidelines are generally compatible; EU requires slightly wider openings, larger chair space, etc, so typical EU values meet ADA requirements, EXCEPT in vertical step, where ADA requires a much tighter tolerance, which in turn brings load leveling or bridge plates into the discussion, much more so than in the EU.

The US perhaps has a unique situation with regard to accessibility in that ADA has provided a comprehensive national standard since 1990. ADA requires a significantly tighter tolerance for vertical step than EU guidelines / standards, consequently US streetcars will require load leveling or boarding assistance devices such as bridgeplates. Because there may be more demand for these features in North America than in other parts of the world, additional research and industry discussion would be helpful, including dialogue on how the relative merits of these options (eg: load leveling, bridgeplate) should be evaluated.

---

16) Standards- Fire Safety

Question: What are the differences between North American standards (NFPA 130) (may require further breakdown between US and Canada) and those applicable in other parts of the world (EN 45545)?

What standard should an agency include in their vehicle technical specification, and what are the supplier-related implications of including it? What standards do the current lines of modular streetcar designs meet?

Related Vehicle Design Issues: Vehicle floor and roof design, testing methodologies, weight (and motorization if weight is significantly heavier).

Discussion: Different approaches have evolved between North America and World, and separate standards exist (USA=NFPA 130, EU= EN 45545). NFPA 130 uses a "one size fits all approach" whereas EN 45545 (proposed) utilizes Hazard Levels based on "Operation Categories"; Trams are in Category 1 "Vehicles that are not designed or equipped to run on underground sections, tunnels and/or elevated structures and which may be stopped with minimum delay, after which immediate side evacuation to a place of ultimate safety is possible". Pending the formal adoption of EN 45545, the UK currently allows tramways operating exclusively on a line-of-sight basis to meet the same fire protection standards as a transit bus.

There is also a question about whether NFPA 130 makes adequate allowance for low-floor vehicles, which have virtually all of their propulsion control equipment on the roof instead of under the floor as with the previous generation of vehicles.

Additional research and standards work is required in this area to understand the differences between the US and EU standards and their implications. This topic has the potential for major cost impacts.