Development of Guidelines for Modern Streetcar Vehicles

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BACKGROUND

- No single comprehensive source of modern streetcar info
- U.S. has relatively small number of modern streetcars in service now, but demand is rapidly increasing
- Limited industry familiarity in North America; light rail and streetcars have much in common, but there are also significant differences in application
- If we can do an effective job of internal education and standards work, vehicles and systems will better match, and cost savings will follow
- ***Project Goal:*** *To facilitate the successful introduction of modern streetcar vehicles into North American systems by promoting understanding of the core technical and operational issues.*

PROJECT OVERVIEW

- ✓ Form working group
- ✓ Find the right place in the APTA Standards Development Program for our effort
- ✓ Seek participation of North American agencies doing streetcar projects
- ✓ Develop initial document outline
- ✓ Document previous work in the topic areas
- ✓ Create project website
- ✓ Background research- comparison of North American and EU Operating Environments
- ✓ Carbuilder Survey
- ✓ Prepare initial drafts for each topic area, select appropriate format
- ✓ Circulate drafts internally for review and revision
- Circulate drafts externally for comment
- APTA balloting process

BACKGROUND WORK (2010)

- Literature search
- Compared North American and European operating environments / standards
- Observed that differences in standards have high potential to impact costs
- Carbuilder survey (available on modernstreetcar.org website)

APTA STREETCAR SUBCOMMITTEE CARBUILDER SURVEY 2012 DRAFT				WIDTHS				CAPACITY			
VEHICLE COMPARISON CHART (SEE INDIVIDUAL VEHICLE PAGES FOR MORE DETAIL)			MIN/MAX LENGTHS	2.3 m	2.4 m	2.46 m	2.65 m	2.4 m TOTAL and (SEATED)	2.65 m TOTAL and (SEATED)	MIN. RADIUS (IN-SERVICE)	LOAD LEVEL OPTION?
BOMBARDIER FLEXITY FREEDOM	4.2 m; 17.7 m	100% LF	20.7–30.8 m				●	—	113 (34)	25m std 18m opt	YES
CAF– URBOS (CINCINNATI)	6.9 m; 18.2 m	100% LF	21.9–44.5 m		●		●		112 (24)	18 m	YES
INEKON PORTLAND/SEATTLE	5.8 m; 12.0 m	50% LF	20m			●		115 (29)	—	18 m	YES
KINKISHARYO AMERITRAM	10.0 m	100% LF	20–40m			●	●	109 (28)	115 (28)	18 m	YES
SIEMENS S–70 STREETCAR	9.0 m; 14.4 m	70% LF	24.2m				●	—	147 (60)	25m std 18m opt	YES
BROOKVILLE LIBERTY	5.8 m	50% LF	20m			●	●	126 (41)	138 (47)	18 m	YES
UNITED STREETCAR USC 100	5.8 m; 12.0 m	50% LF	20m			●		115 (29)	—	18 m	YES
VOSSLOH TRAMLINK	4.9 m; 17.3 m	100% LF	21.5–43 m		●		●		131 (50)	18 m	YES

DRAFT REV 11/07/12 JCS

ACCESSIBLE LOW–FLOOR DOORWAY

OTHER LOW–FLOOR DOORWAY

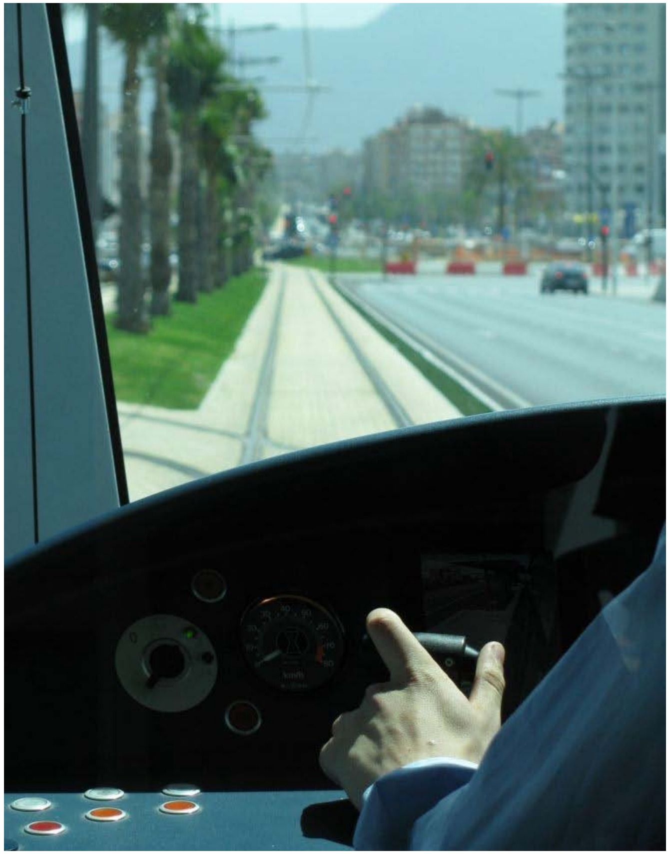
BASE MODEL LENGTH SHOWN, DASHED LINE INDICATES LONGEST VERSION (WHERE AVAILABLE)

S STEP–ENTRY DOORWAY TO HI–FLOOR SECTION

FOUR TOPIC AREAS

* Introduction

1. Vehicle Configuration
2. Vehicle / Platform Interface
3. Vehicle / Track Interface
4. Power Supply



INTRODUCTION

- Streetcar projects take many forms (over 400 streetcar/tram/LRT systems worldwide, 8,000+ low-floor vehicles)
- What vehicle information is needed in early design phases (alternatives analysis)?
- Standard “ranges” of vehicle capabilities. Understand where imposing requirements on the vehicle is preferable to imposing requirements on the infrastructure (and vice-versa).
- Vehicle and Infrastructure-
  it’s a SYSTEM!

MARKET DIRECTION

- Worldwide 8,000+ low-floor LRVs and trams since 1984, about half are 100% LF
- North America, delivered / on order:
  - **USA: LRV**: 992 partial LF. **Streetcar**: 44 partial LF, 5 100% LF
  - **Canada: LRV**: 182 100% LF. **Streetcar:** 204 100% LF
- 18% of world production of low-floor vehicles
- Market Trend: 100% low-floor vehicles dominate recent EU orders for tramways (70% still popular for Light Rail and Tram-Train)

1. VEHICLE CONFIGURATION

THE STREETCAR OPERATING ENVIRONMENT

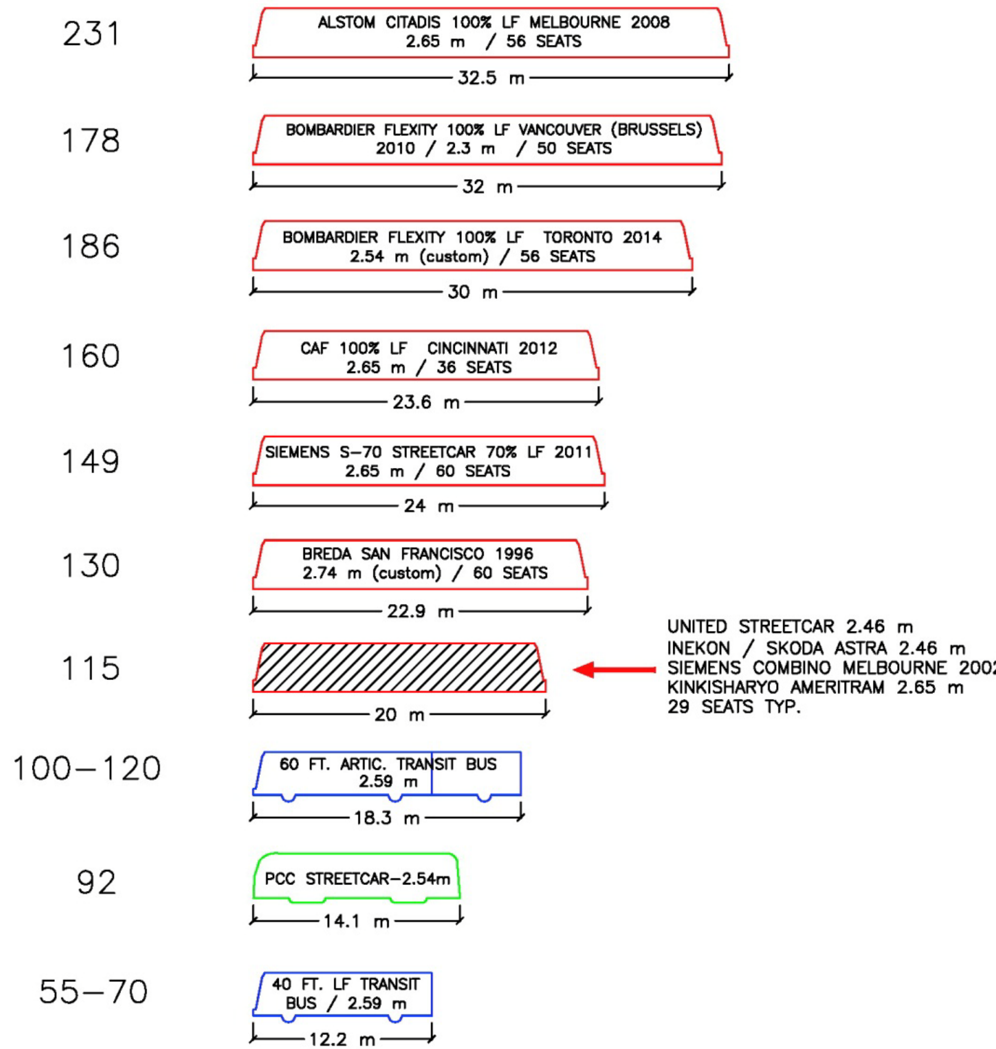
- An entirely in-street operation is very different than typical light rail alignment
- Forward / side visibility is key in a street-running vehicle
- Full skirting with no protruding couplers (per ASME RT-1)
- Low floor streetcars are designed to work with off-vehicle fare collection (some cities use roving conductors or TVMs on vehicle), maximizing benefits of multiple doorways and stepless entry

CAPACITY

- The streetcar **development / mobility** mix**.** How will the ratio change as the system grows? How can both be maximized?
- How will capacity be expanded to accommodate growth in demand?
  - Use of longer vehicles
  - Increasing fleet size
  - Increasing operating speed
- Labor is largest component of operating cost
- Overcrowded vehicles = longer running times = higher operating costs
- Longer vehicles (e.g. 30 versus 20m) make sense where demand is high, taking advantage of rail's high capacity features and encouraging ridership growth

CAPACITY

It's important to make "apples-to-apples" capacity comparisons!
(use seats + 4 passengers/m^2 for standees)

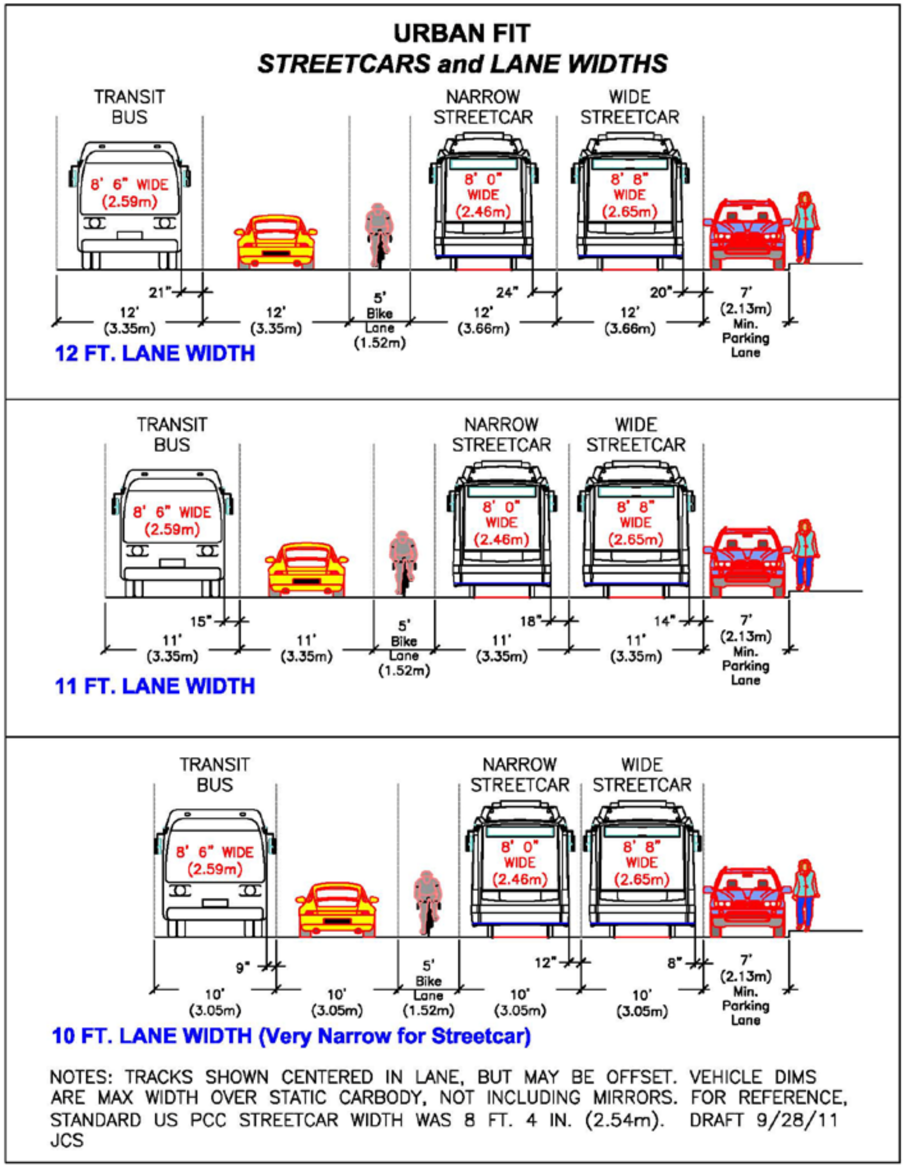


INTERIOR LAYOUT

- Streetcars typically have large “multi-purpose” areas without seats. Streetcar trips tend to be shorter, standing is more acceptable.
- Any low-floor vehicle configuration requires some form of interior compromise; there will always be some restriction on floor space:
  - Steps inside the vehicle (partial low floor)
  - Narrowed aisles around the running gear (100% low-floor)
- In all configurations, only specific sections of the vehicle are typically arranged to accommodate wheelchairs

VEHICLE WIDTH

- 3 well-established "standard" widths in world LRV / streetcar market; **2.3m**, **2.4m** and **2.65m** (7 ft 6.5 in / 7 ft 10.5 in / 8 ft 8 in)
- US "Portland" type streetcar is 2.46m (8 ft 0.9 in) (difference to 2.4m is negligible, especially with "near level" boarding)
- Both 2.4m and 2.65m are common on new streetcar / tram systems
- US Light Rail systems generally use "standard" 2.65m width, but consider "urban fit" when choosing streetcar width



Vehicle Width vs. Capacity

Number of passengers for different vehicle widths*:

Length	2.3 m	2.4 m	2.65 m
18 m	103	109	122
27 m	160	172	192
36 m	222	236	264
45 m	279	296	331
54 m	340	362	404
63 m	396	420	470
72 m	457	486	542

* Standing room and seats
Bi-directional vehicle, standing room 4 persons per m²

VEHICLE WIDTH

Why is the Vehicle Width Decision so Important?

- Initial vehicle purchase "locks in" location of platforms relative to track
- Is a future upgrade to light rail possible? If so 2.65m has important advantages
- Width impacts capacity, interior layout
- Selecting a non-standard width will impact availability of competitive bids, especially in small order quantities

PARTIAL & 100% LOW-FLOOR OPTIONS

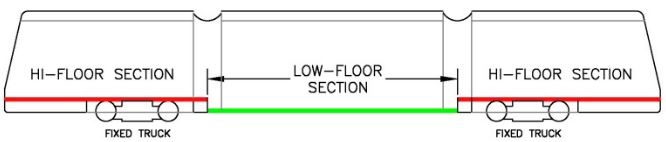
Partial Low Floor

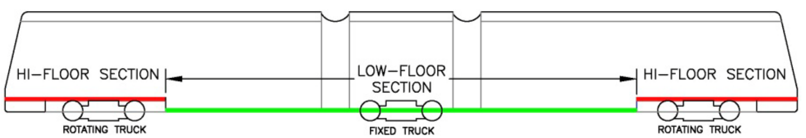
PLUS

- Room for conventional running gear (at least at outer ends), large body of US experience, lower maintenance costs.

MINUS

- Steps inside car
- Fewer low-floor doors





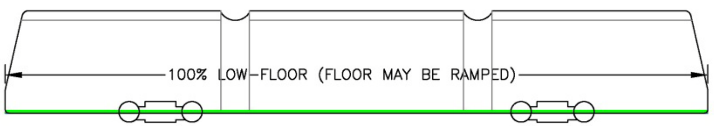
100% Low Floor

PLUS

- No steps in passenger compartment
- Low-floor doors possible along entire length of vehicle
- Can minimize dwell time when combined with full length platforms

MINUS

- Space constraints require special running gear- more technologically complex (may impact maintenance costs, suspension may be stiffer)
- No steps, but interior layout / aisle is impacted by running gear "wheel wells"



1. VEHICLE CONFIGURATION

Guidance:

- Begin with the end in mind. Understand duty cycle and communicate it during the procurement process
- Optimize the vehicle for the streetcar operating environment
- Consider capacity- vehicle interior arrangement, width, length
- Both partial and 100% low-floor configurations are an option

2. VEHICLE / PLATFORM INTERFACE

1. PLATFORM DISCUSSION

Legacy system with no platforms

"Dynamic Stop" alternative

Streetcar platforms require flexible thinking

Buses don't work well with 14-inch platform

"FULLY LEVEL BOARDING"

Vehicle Floor = 14" Platform = 14"

- Requires active suspension (load leveling) for ADA compliance
- Bridge plates not needed (also no room to deploy- located under car floor and require clearance for operation)

ADVANTAGES

- Eliminates vertical step into vehicle- best passenger experience
- Eliminates bridge plates (simplifies vehicle, reduces maintenance)
- Best dwell time- significant in high ridership applications.

DISADVANTAGES

- More demanding on infrastructure- no room to play with on platform location
- 14 in. platform not compatible with buses (unless special measures applied)
- 14 in. platform more challenging to blend with sidewalks / roadway
- Locating a level platform on a curve is difficult (easier to do with the "near-level" platform combined with bridge plates).
- Depending on carbuilder, active suspension may be higher cost or a custom feature. Active suspension also has its own maintenance issues.

"NEAR LEVEL BOARDING"

Vehicle Floor = 13-14"   Platform = 10" typical

- Requires bridge plates for ADA compliance

ADVANTAGES

- Less demanding on infrastructure tolerances
- More compatible with buses sharing streetcar stops
- Lower platform height easier to blend into sidewalks
- With bridge plates, the near-level platform can be located on a curve

DISADVANTAGES

- Use of bridge plates may increase dwell time, which may be a significant factor in high ridership applications or alignment where stopped streetcar blocks traffic.
- Bridge plates add further complexity to already complicated door systems
- Bridge plates are subject to maintenance issues, particularly in snow / ice conditions. (Load leveling is not without maintenance issues also).

2. VEHICLE / PLATFORM INTERFACE

Guidance:

- Understand the trade-offs between “Near Level” and “Fully Level” boarding
- Bridgeplate issues
- Streetcar / bus sharing platform

3. VEHICLE / TRACK INTERFACE

UNIQUE ASPECTS OF STREETCAR TRACK

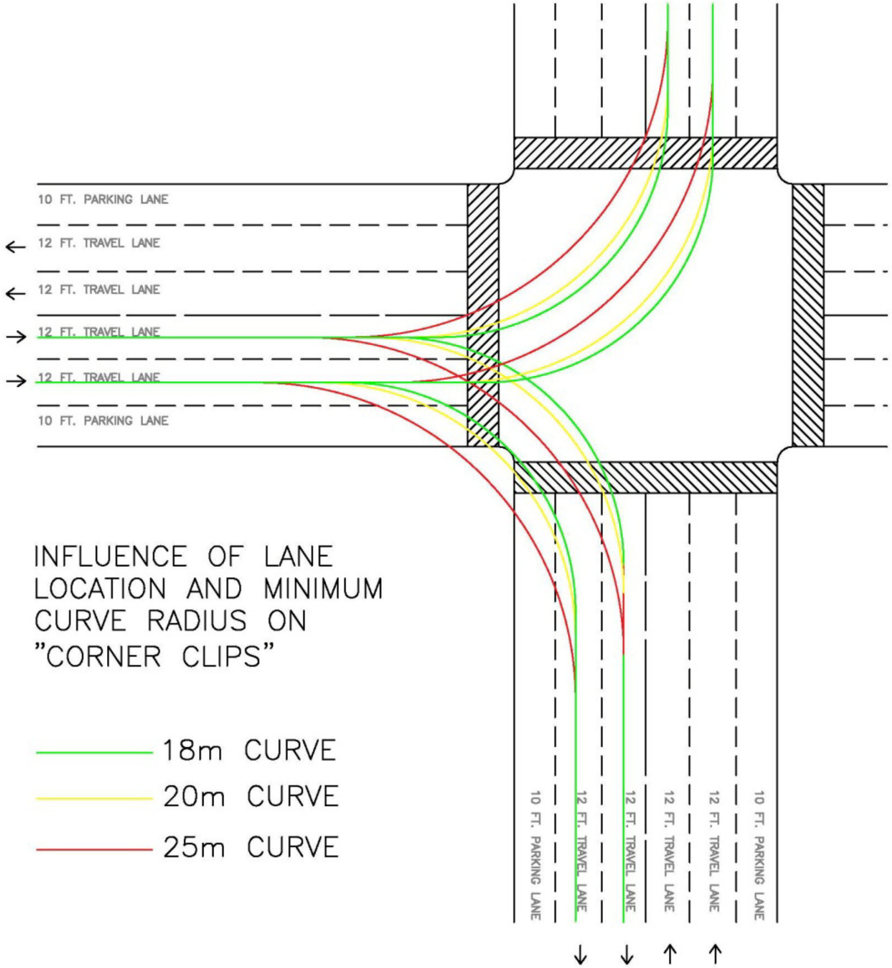
- The urban nature of Streetcar systems often require sharper curve radii and steeper gradients than Light Rail systems
- Streetcar alignments must typically follow existing roadways through constrained urban areas. Track twist and wheel unloading are major factors for modern articulated vehicles.
- New or Legacy System?

Legacy systems require even sharper curves and steeper gradients than would otherwise be specified for a new system

E.g.: horizontal curve radius: Philadelphia 35 feet (10.7m). Lisbon (old network) and Toronto, both at 36 feet (11 m)

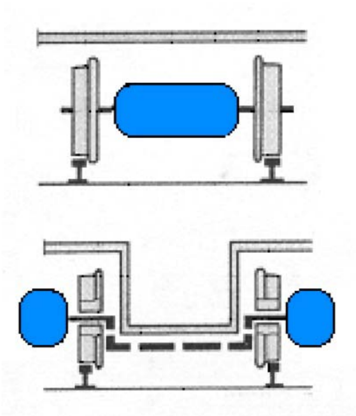
TURNING RADIUS

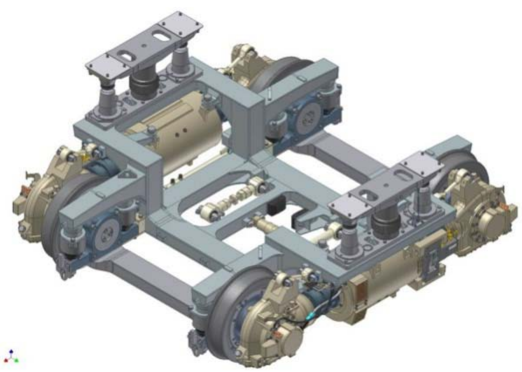
Horizontal Curvature and Standard Vehicle Designs*		
Minimum radius		
meters	(feet)	
25	82	LRT standard- unlimited vehicle selection, but may not always be practical for typical streetcar alignment
20	66	20 m is a commonly used minimum for streetcars, wide range of vehicle choices
18	59	18 m has a smaller range of vehicle choices, but is not uncommon. Below 18m, custom vehicle is required.
* Mainline curvature, yard curvature (operated only with empty vehicles) may be less		

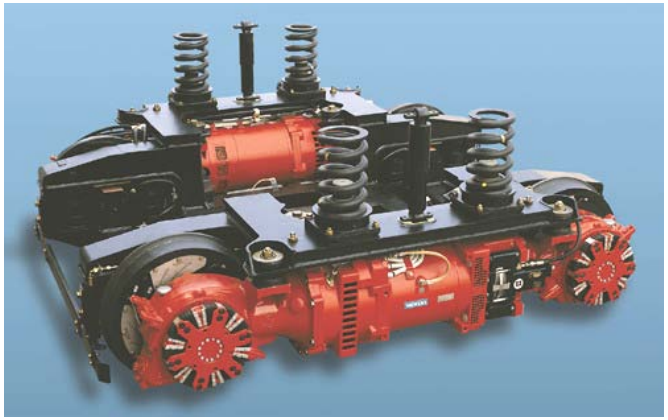


UNIQUE ASPECTS OF STREETCAR VEHICLES

- Low-floor vehicles use special running gear due to lack of room for conventional drive and suspension elements
- Fixed versus rotating trucks, designs with and without conventional axles.
- How do new designs impact track design and maintenance criteria?
- Designs continue to evolve, what's ahead?







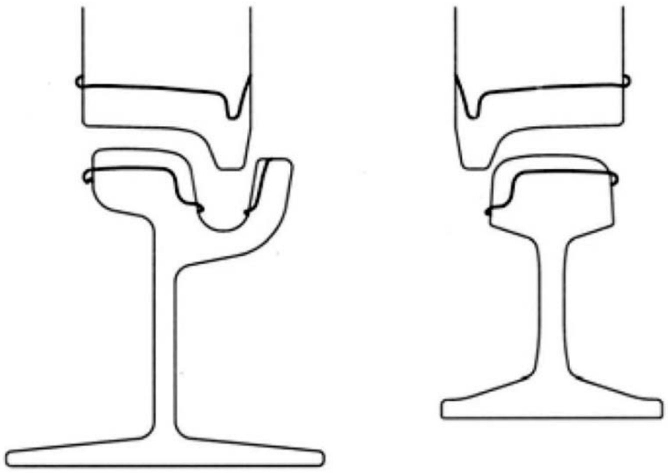
RUNNING GEAR MAINTENANCE

- How will you re-profile wheels?
  - Use a drive-over wheel truing machine
  - Take the wheel tires off and have them machined
  - Take whole trucks to another location where there is a wheel truing machine
  - Use a portable wheel-truing machine

- Wheel removal can be much more complicated on 100% LF vehicles (drive train is in front of wheels in some cases)
- In general, vehicles are designed to minimize need to remove running gear (assuming you have drive-over wheel truing)

VEHICLE / TRACK INTERFACE

Guidance: "Because of the inherent flexibility of light rail / streetcar mode, it is possible to operate over extremely demanding alignments in terms of curvature and gradient. However, avoiding 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"

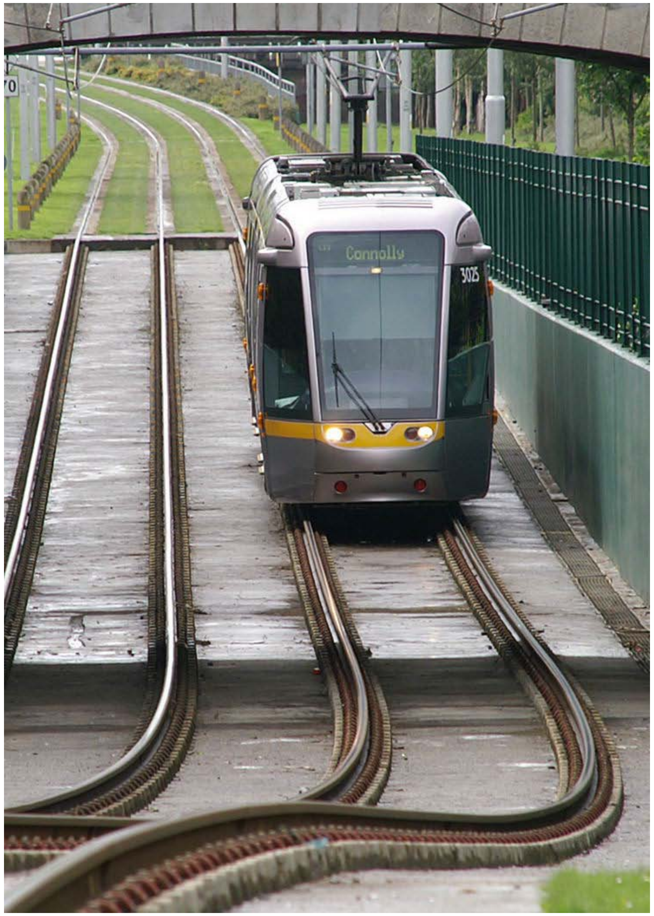


- Don't design only to minimums and maximums! Apply minimums and maximums thoughtfully, and in the context of a SYSTEM approach that considers the vehicles to be used and balances operational benefits with the related tradeoffs.
- Whether an existing system introducing new vehicles, or a new start, a SYSTEM approach is required- ensure that those parties responsible for vehicles and track design are working in concert to produce optimum compatibility.
- TCRP Report 155; a significant new resource.

3. VEHICLE / TRACK INTERFACE

Guidance:

- Unique aspects of streetcar track
- Unique aspects of streetcar vehicles
- Vehicle and track are a SYSTEM
- Don’t design only to minimums and maximums!

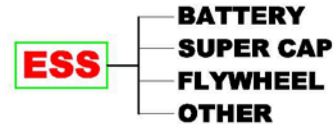


4. POWER SUPPLY

SPEAKING THE SAME LANGUAGE

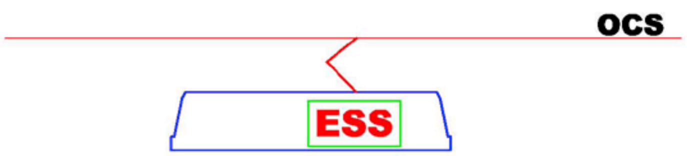
STREETCAR / LRT POWER SUPPLY

ENERGY STORAGE SYSTEM (ESS) TYPES



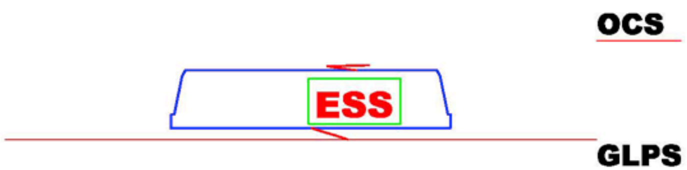
CONVENTIONAL SYSTEM

OCS IS PRIMARY POWER SOURCE.
ESS USED FOR ENERGY SAVINGS. CAN ALSO BE USED AS EMERGENCY BACKUP POWER SOURCE.



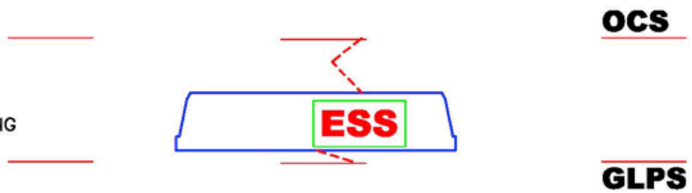
GROUND-LEVEL POWER SUPPLY

GLPS / OCS IS PRIMARY POWER SOURCE.
ESS USED AS EMERGENCY BACKUP POWER SOURCE IN CASE OF GLPS SEGMENT OUTAGE



OFF-WIRE CAPABLE VEHICLE

ESS IS PRIMARY POWER SOURCE IN SECTIONS WITHOUT EXTERNAL POWER. RECHARGING VIA REGENERATIVE BRAKING AND INTERMITTENT OCS or GLPS.



"HYBRID"

(ADDS GENERATOR)
ESS IS PRIMARY POWER SOURCE.

WHY ELIMINATE OVERHEAD WIRES?

- Aesthetic concerns- e.g. historic district
- Route optimization-
  - Solution to a specific problem- e.g. impaired clearance, narrow right-of-way, utility conflict
  - Simplifying a complicated crossing, junction or other unusual wire arrangement
- Cost? (not a simple equation)

OCS AESTHETICS

High Impact (visually prominent)

Low Impact (hardly noticeable)

"The visual impact of OCS can only be reduced if such reduction is made a specific goal throughout the design process" *-TCRP Report 7*

OFF-WIRE CAPABILITY

- Vehicle can use external power supply *or* on-board energy storage
- Recharge by capturing regenerative braking energy and while operating on powered alignment sections
- Off-wire “range” dependent on alignment and operating conditions
- Batteries and Super Caps most common for energy storage (flywheels and other technologies also in development)
- Small number of vehicles in revenue service; Nice, France; Seville and Zaragoza, Spain. Other lines under construction; one entire direction (downhill) of new Seattle line to be off-wire, Dallas to use off-wire on bridge
- **Consider life-cycle cost when comparing technologies**

EXTENDED OFF-WIRE OPERATION

What would it take to build an entire line without overhead wire (or GLPS)?

- Vehicle range dependent on alignment and operating conditions
- External power source still needed for recharging
- How long does recharging take? How will this impact the number of vehicles required?
- What happens when the line is blocked or a charging station goes out?
- What happens if initial line later becomes part of a larger system?
- “Hybrid” vehicle is another option
- **The trade-off: infrastructure becomes less complicated, but vehicle becomes more complex**

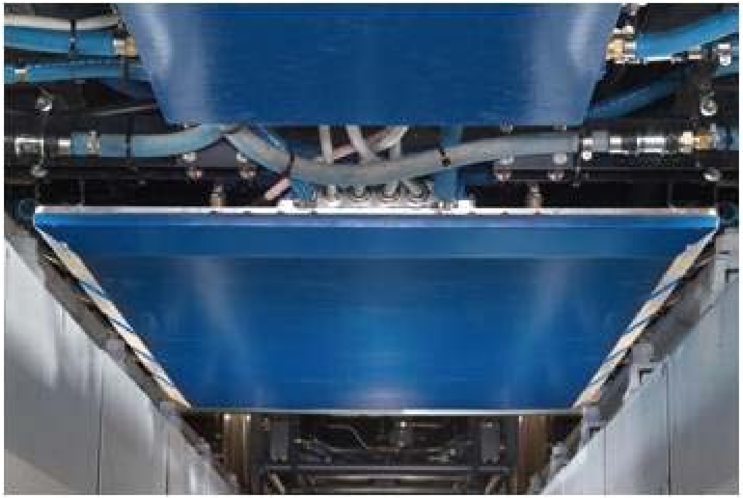
GROUND-LEVEL POWER SUPPLY

- External to the vehicle- puts the power supply on the ground instead of in the air
- Segmented power supply between rails- segments energized only when vehicle is over them
    - “Contact” type system- embedded third rail
    - “Contactless” type system- induction coils
- Significantly higher technical complexity / highly proprietary
- Complicates track design and installation
- To date, most installations cover only a portion of an otherwise conventionally-powered system

“CONTACT” TYPE SYSTEM

- Embedded third rail
- In service in Bordeaux (13 km 2003), Angers (1.5 km 2011), Reims (2 km 2011) and Orleans 2 km (2012)
- Under construction in Tours and Dubai
- Test installation in Naples
- Vehicles have battery backup in case a segment fails
- No installations to date in snowy climates; snow and ice issues are an unknown

“CONTACTLESS” TYPE SYSTEM



- Inductive transfer of power- no physical contact
- Batteries provide vehicle energy storage, guideway power installed only on portions of alignment (at stops and where vehicle is accelerating)
- DC converted to AC for guideway power, converted back to DC inside vehicle
- Contactless power transfer expected to help with snow / ice issues
- Test installation in Augsburg, 2011. Also being tested on buses.

4. POWER SUPPLY

Guidance:

- Energy storage has many roles
- OCS Aesthetics matter! (think context-sensitive)
- Apply new technology in ways that minimize impacts of proprietary designs
- Examine life-cycle cost when comparing technologies

STANDARDS

Many issues here- standards discussion became a separate project

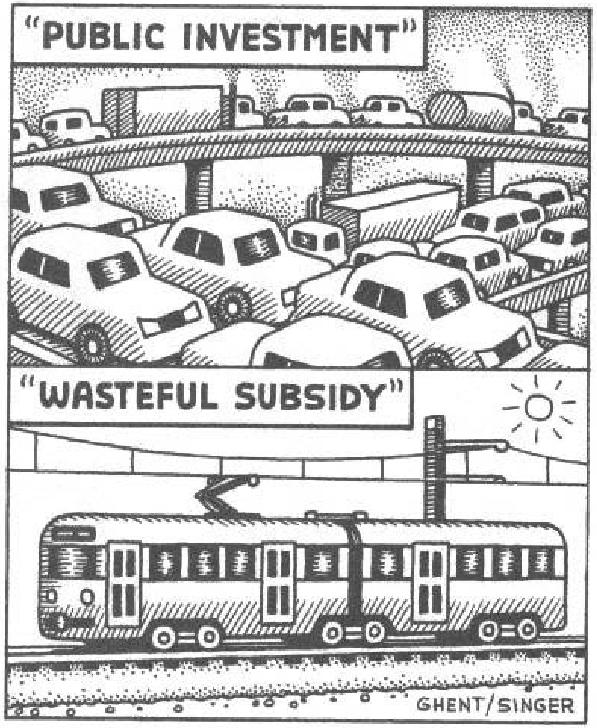
Crashworthiness-

- ASME RT-1 and EN 15227
- APTA working with California PUC. CPUC is revising GO-143 and is considering substituting RT-1 Standard for the current fixed 2g buff strength approach.

Fire Safety-

- Does NFPA 130 take low-floor vehicles into account (almost all equipment on the roof instead of under the floor)?
- Differences between NFPA 130 and EN 45545- “one size fits all” versus operating environment categories.
- Pending new EU standard, current UK standard allows L-O-S operated tramways to meet same fire standards as buses.
- High potential to impact vehicle cost

MODERN STREETCAR VEHICLE GUIDELINES



For more information, contact project manager John Smatlak: info@modernstreetcar.org, and check out the project website www.modernstretcar.org

The main website for the APTA Streetcar Subcommittee is: www.heritagetrolley.org