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State-of-the-Art in Tramway Safety Technology

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Overview

The spectrum of rail operating environments

Mixed traffic / Line-of Sight Driving

Driverless Metro

Streetcar / Tramway already a very safe mode, but the industry continues to develop further safety improvements

- **Baseline**
- **Innovations**
- **Research & Industry Standards**

Part One- Baseline

Background- Defining “State of the Art”

- Light Rail from a global perspective
  - US has relatively small share of world market for streetcar/light rail/tramway
  - Impact of EN standards; most tram vehicle (and subsystem) designs outside US must all meet a common set of EN standards
  - Impacts of differing project delivery methods

Background- System Safety Baseline

- Technology offers many helpful tools, but is not a substitute for a system-level approach to safety management (SMS)
- Line-of-Sight operation in an urban environment has many design and operating challenges
- Infrastructure must be optimized at the best level the corridor will permit:
  - Clearances
  - Sight lines
  - Segregation from mixed traffic (including minimizing left turns) and signal priority
  - Vehicle/infrastructure interfaces

Background- Vehicle Baseline

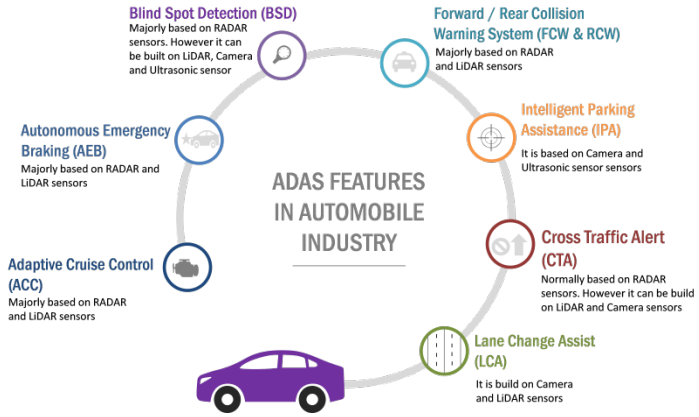
Safety "Checklist" for tramway operating environment

- *General:*
  - Low-floor design w/ level boarding
  - High-performance braking
  - Door obstacle detection (anti-entrapment)
  - Driver Vigilance System (deadman) and Event Recorder
  - Video Surveillance (including in-cab camera) / silent alarm
  - Use of industry standards for CEM carbody, RAMS, Fire Safety
- *Tramway Specific:*
  - Full skirting including trucks and ends, no exposed coupler
  - Rounded ends / low bumper (deflect, not trap, objects)
  - Improved cab visibility and operator ergonomics
  - Lighting and audible warnings optimized for operating environment
  - Adequate standee accommodations, limit movement during hard braking

Part Two- Innovation

Innovations

- The Connected Vehicle
- Driver Assistance systems
- Autonomous tram prototypes



The Connected Tram- O&M Support

Harnessing all that data being collected by the vehicle's subsystems

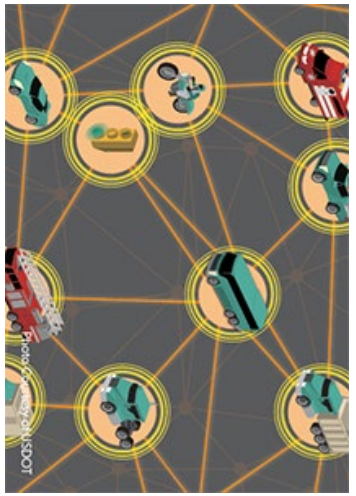
- **Asset Preservation**
- **Performance Monitoring**
- **Safety Management**

- **Applications:**
  - **Maintenance support**
  - **Safety review support: play back trips to understand the conditions which have led to an incident**
  - **Safety review support: recognize and compare connections between driving behavior and recorded alarms / alerts on the train HMI**
- **Example Products:**
  - **Siemens Tram Assistant**
  - **RATP Tachytram**

The Connected Tram- Big Picture

Multi-Modal Intelligent Traffic Safety System (MMITSS)

- **Next generation of traffic signal systems providing a comprehensive traffic information framework to service all modes of transportation**
- **Overarching system optimization:**
  - **Transit and freight signal priority**
  - **Preemption for emergency vehicles**
  - **Pedestrian movements**
- **Maximize overall arterial network performance**
- **2019 MMITSS Prototype project on Portland Streetcar**



Driver Assistance Systems

- Application of automotive collision avoidance technologies to trams and buses
- Driver vigilance and speed enforcement taking on new urgency following recent accidents
- Driver assist as a step towards driverless operation

Driver Assistance

Informative presentation by Michael Rüffer of VGF Frankfurt at 2016 IOT/M2M Conference (available on YouTube)

- **Possible Functions:**
  - **Activation of different braking systems**
  - **Traction power interrupt**
  - **Optical/acoustic warning**
  - **Speed limitation or reduction**
  - **Switch or signal monitoring**
  - **Monitoring of clearance outline in front of the vehicle**
  - **Communication with other trams or cars**
  - **Warning of crossing pedestrians**
- **Other “assist” functions:**
  - **Provision of energy efficient driving advice (“Eco Driving”)**
  - **Platform spotting assistance, wrong-side door inhibit**
  - **Automatically sound audible warning**

Driver Assistance

Tram Assistant

Controller

Camera

Radar

Siemens ADAS, Ulm

Integration Levels:

Low:

› "Stand-alone-System" without integration: separate indicator/buzzer

Medium:

› Hardwired signal to open safety loop

High:

› SW Integration into train/brake control

› Hardwired signal to initiate Full Service Brake. Driver can overrule the system reaction.

Driver Assistance

Driver Assistance (and beyond) in use / testing:

- **Bombardier/Bosch Radar/Camera applications in Frankfurt and Hannover**
- **Many bus applications; survey underway to identify other rail applications**
- **Alstom Pegasus System presentation 2016**
- **Seeing Machines, Guardian system driver fatigue detection system, applied to Croydon Tram 2017**
- **Siemens ADAS pilot project, Ulm 2017**
- **Basel, Switzerland Tram Collision Avoidance System test installation. Stadler/BLT/Bosch 2018**
- **Paris, Alstom RATP driverless tram testing (stabling) 2017-18**
- **Knorr-Bremse testing in Hannover, Vienna 2017-18**
- **Casablanca, Alstom driverless tram testing in yard 2018**
- **Siemens autonomous tram demonstration, Potsdam 2018**
- **PC Transport, announcement of autonomous tram testing Moscow 2019**

Speed / Signal Enforcement

Levels of Integration:

- Alerting the driver
- Communicating driver non-compliance to control
- Preventing overspeed / signal violations through technology (ATP)

Some examples:

- SIMOVE (GPS-based speed enforcement), developed by tram operator in Tenerife, Spain
- Alstom Pegasus- Brussels, Marseilles, Rouen, Constantine trams
- Siemens CTS/M- Portland Streetcar- train stop on bridge shared with LRT, Houston LRT signal enforcement
- Siemens Tram Assistant
- Croydon Tram, contract for PPOS automatic braking overlay awarded to ESG (sub to Sella Controls)
- Tempe Streetcar crossing of LRT

Siemens Autonomous Tram Demo 2018

Siemens autonomous tram demonstration on Potsdam tram system in conjunction with Innotrans 2018

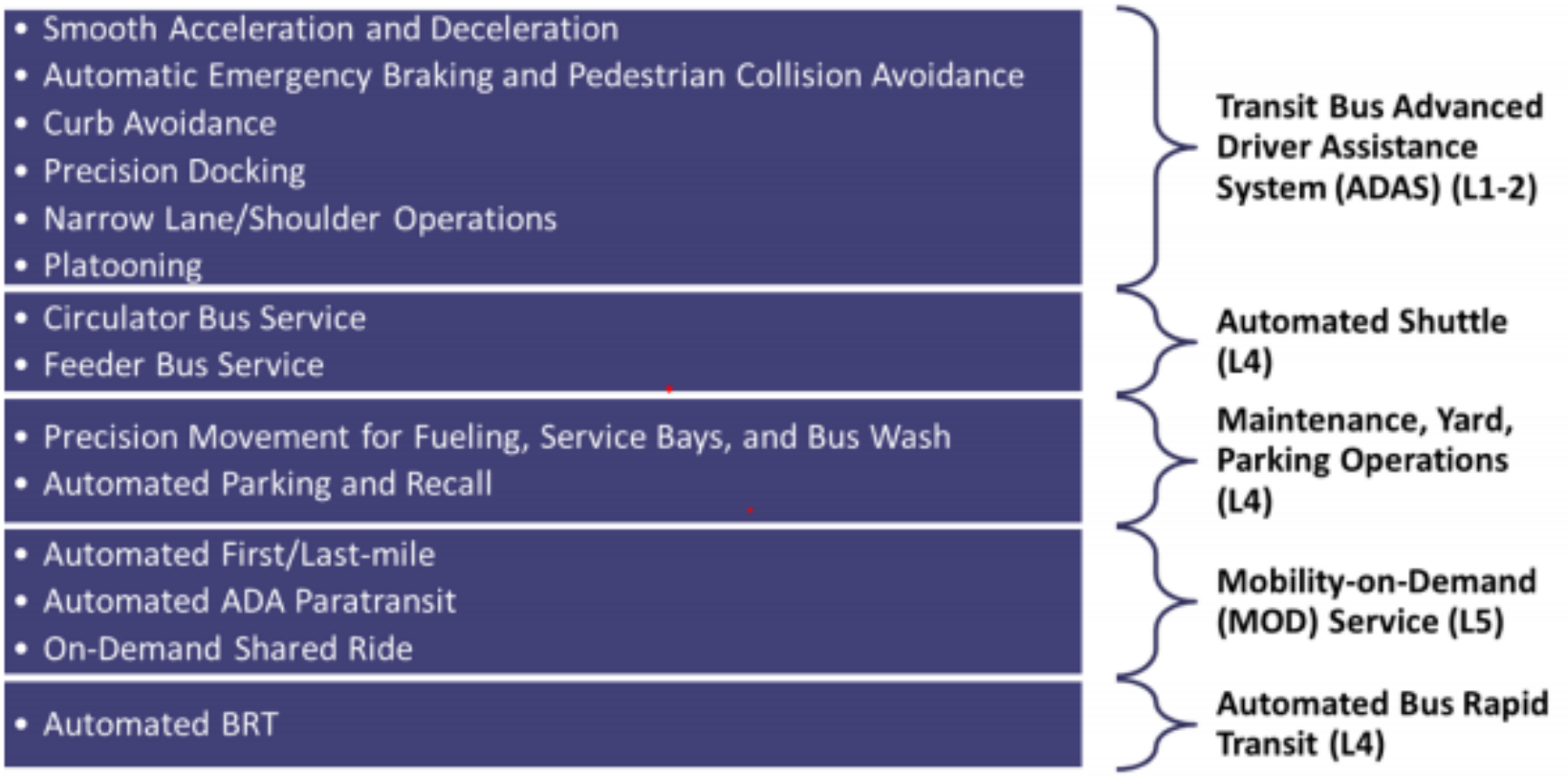
Part Three-Research and Industry Standards

FTA Strategic Transit Automation Research (STAR) Plan

Advancements in technology are rapidly transforming the transportation system and provide potential to improve transit systems. FTA's Office of Research, Demonstration and Innovation is exploring the use of vehicle automation technologies in bus transit operations by:

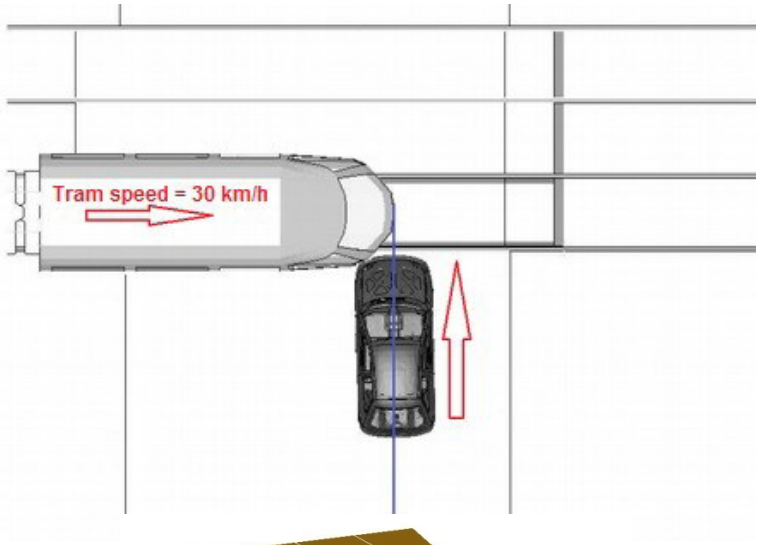
- **Conducting research to achieve safe and effective transit automation deployments**
- **Identifying and resolving barriers to transit automation deployment**
- **Leveraging technologies from other sectors to advance the transit automation industry**
- **Demonstrating market-ready technologies in real-world settings**
- **Transferring knowledge to the transit stakeholder community**

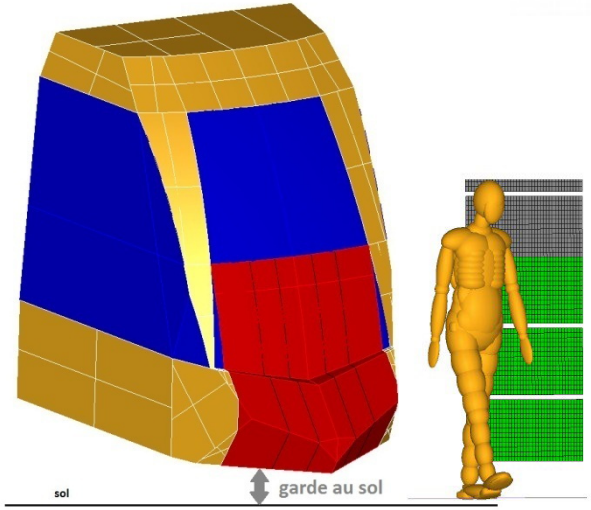
FTA Strategic Transit Automation Research (STAR) Plan



Refinement of Leading End Geometry

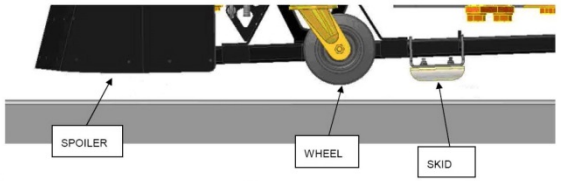
- **New (2016) STRMTG (France) *Tramway Front End Design* standard requires:**
  - **Designing and validating shape of leading end to minimize pedestrian injury**
  - **Validating effectiveness of underrun protection**
  - **Evaluating propensity to derail when struck in a perpendicular collision with auto at front corner**
  - **W1750 Working Group- heading towards a Euro Norm**

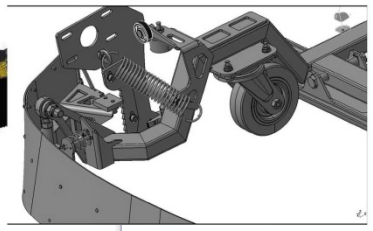


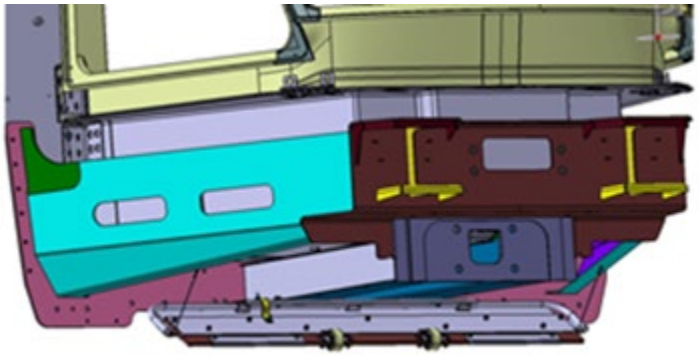


Refinement of Leading End Geometry

- **Supplementing bumper / underrun protection**
  - **Alstom underfloor fender (PACM) in use**
  - **Bombardier airbag (concept)**
  - **CAF obstacle deflector (in use)**







Driver Vigilance Systems

- Technology advances include application of facial scanning technology for fatigue detection (e.g. Croydon Tram application of Seeing Machine "Guardian" system, or "OptAlert")

2017 STRMTG Standard *Fonction de veille des tramways* (Driver vigilance systems for tramways)

- Developed based on analysis of accident statistics (passenger injuries from deadman penalty applications)
- Considers high level of driver distractions present in mixed traffic tramway operations ("cognitive overload")
- Recommends timing values and braking performance to limit the severity of the consequences of a deadman penalty application
  - Monitoring periodicity, event recorder requirements
  - Warning preceding penalty stop, stop at full service instead of max brake
  - Max brake and deadman applications retrievable

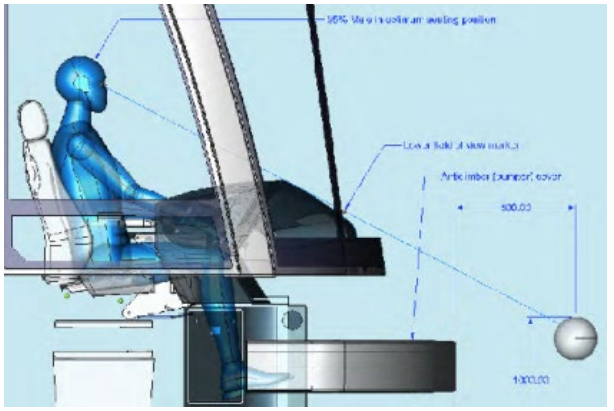
Currently in French only

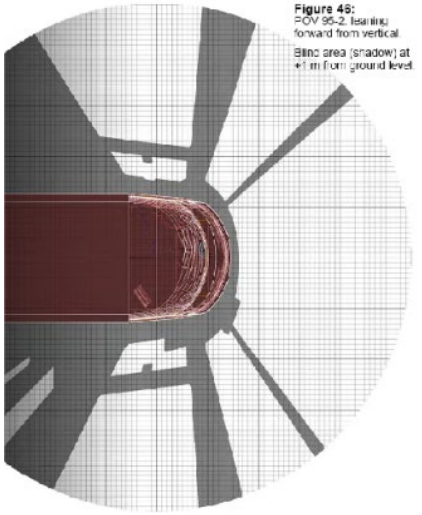
Energy Absorbing Bumpers

- **The need**
  - **Road vehicle and pedestrians are (by far) the vast majority of collision events**
  - **Need to reduce accident severity**
- **A solution**
  - **No exposed coupler / low ground clearance**
  - **Bumper with recoverable energy absorbing elements (self-restoring) for collision speeds below 5 mph**
- **Applied in four US projects:**
  - **Phoenix I (2008) KinkiSharyo**
  - **Phoenix II (2019) Siemens**
  - **OCTA (2019) Siemens**
  - **Purple Line (2019) CAF**

Other Industry Standards

- 2016 revision of STRMTG (France) Technical Guide *Safety in Tramway Driver's Cab*
  - Covers cab visibility and ergonomics
  - Quantifies testing for visibility / blind spots
- Driver Assistance
  - VDV 191 Fahrerassistenzsysteme ("FAST") standard under development
- Connected Vehicles
  - The Multi Modal Intelligent Transportation System (MMITSS)
- European Cooperation in Science and Technology (COST) TU1103
  - *Operation and Safety of Tramways in Interaction with Public Space*





Summary

Summary- How Do We Get There?

How might the safety technologies discussed here actually make it to a streetcar system near you?

- **Proactive-** ***Market Forces / Economic basis***
  - **Management process that is driven by life cycle cost**
  - **Process improvement / competitive differentiator**
  - **Customer request when ordering new vehicles or at overhaul**
- **Reactive-** ***Regulatory Forces***
  - **Comply with regulation or response to incident**
  - **Regulations aren't always "up to date", but regulators can also be innovative (e.g. FTA pilot program concepts, FRA alternative compliance)**

Summary- How Do We Get There?

- More new tools in the tool kit- assisted driving for trams is already here
- Standards; continuous development. Vehicle-to-vehicle collisions well understood, now the focus is on protecting other roadway users and interior safety improvements
- A US pilot project for streetcar driver assist or autonomous operation?
  - Agency perspective?
  - Carbuilder perspective?
  - Regulator perspective?
  - Public perspective?