SYSTRA

TRAM AUTOMATION: POSSIBILITIES AND CHALLENGES

Mathieu Melenchon, System Engineering Manager for international consultancy SYSTRA, considers the challenges and opportunities of removing the human element from tramway operation.

Dubai's tramway is currently the most 'automated' LRT system, using adapted CBTC technology. Jay Tornaquia

The fully autonomous self-driving car, something that sounded like science fiction only a decade ago, is now within our reach. As competing companies race to get ahead of their rivals, the technologies for autonomous driving have taken a huge leap forward. The latest developments in areas such as image analysis, machine learning and LIDAR – laser-based radar – mean that we could be looking at road-ready autonomous cars as early as 2030.

All of which raises an interesting question, one that SYSTRA has been thoroughly exploring in our latest white paper on *Automated and Autonomous Public Transport: Possibilities, Challenges and Technologies*. If such technology can be so transformative for cars, what can it do for public transport? In particular, what will it mean for trams?

The huge impact that mobile communication technologies are having on social organisation, the emergence of 'sharing economies', car pools and other virtual communities, is too significant for any transport provider to ignore. It is creating ever-increasing pressure for better connectivity and blurs the distinction between mass and private transport. Yet, technology offers great opportunities for fixed guideway providers to optimise the use of its networks and fleets, increase capacity, improve safety and system performance whilst reducing environmental impact. But can automated technologies be effectively deployed on tramways to enable us to make the most of these opportunities?

At first glance, the question might seem surprising. If a car can run autonomously in a modern urban environment, surely a tram, a vehicle that runs on rails and is therefore far more predictable in its movement, can be automated much more easily. And, in fact, driver-assistance technologies are already widely and successfully used in rail systems, including the 'advanced collision avoidance' technology that is currently being tested on Frankfurt's tramway system.

Yet, the position of trams in the urban transport ecology creates different challenges to those faced by other autonomous vehicles and will require legislative changes in advance of what we have seen so far.

A pressing priority is the security question. All autonomous vehicles are potentially at risk from cyber attack. Against this background, we have to consider every eventuality that could interfere with the smooth running of a 'driverless' tram, including unpredictable passenger behaviour and emergency braking, especially on busy standing room-only trams.

For rail modes that operate in a segregated environment, whether underground, elevated or at-grade, much of this is less challenging. An automated metro system only has to make 'decisions' about what is in front of it, a carefully controlled and monitored space. A tram, on the other hand, operates in an open environment with pedestrians and other city traffic on all sides, demanding a much higher level of awareness and a more dynamic interaction. The difference between automation and autonomy comes into play.

Defining the difference is not without controversy. We consider an autonomous system as one that is capable of making its own decisions without specific human-defined instructions, instantly analysing and reacting to changes in the environment in real-time. This is in contrast to automatic systems that perform task sequences based on pre-defined rules according to more or less predictable feedback from the outside environment. Understood in those terms, it is clear that the step from automatic to autonomous is not a small one.

The technical challenges in taking the step towards automation may be feasible, but we are faced with a legal void when it comes to regulatory approval for autonomous vehicles and, of course, that raises questions of liability and insurance too. A framework of regulatory approval, certification and safety standards will be needed to cover questions around collision avoidance, communication integrity, vehicle condition, situational management and onboard intelligence, before we can even get to the deeper philosophical questions off how autonomous systems will react to emergency situations.

Most of these issues are common to all forms of autonomous transport, and so there are real opportunities to take a lead in building intermodal technological and regulatory frameworks. We might look at adopting a global approach to risk, like the French security framework GAME[1] – whereby the total risk in any new system must not exceed the total risk in comparable existing standards, but allows for increases in risk in specific circumstances.

Such an approach to risk brings its own challenges and there would have to be clear boundaries that define a new system and the reference system it compares itself to, including a clear understanding of how to compensate for any differences.

Where liability should lie in the event of accident involving an autonomous vehicle is a murkier question, whether it is the operator, the transport authority, the mobile manufacturer or the software developer. Again, it is an issue that requires consensus and one that will ultimately help regulators keep pace with technological advances.

A new framework to qualify levels of autonomisation will be needed to help shape technological and regulatory innovations. We propose a series of steps from no automation to fully autonomous where the tram drives itself without any on-board agent which would be level LoA4.

- **LoA0:** No automation
- **LoA0 +:** The system controls the speed (with a gentle and progressive sanction mode)
- **LoA1:** The system helps the driver to drive better (speed setpoint, passive driving aids)
- **LoA2:** The driver assists the system to be driven (control and speed control by the system, initiated by the driver or by the system)
- **LoA3:** The driver becomes an attendant and intervenes when necessary
- **LoA4:** The tram drives itself, without the presence of any onboard agent

LoA1 and LoA2 have already been introduced in some tramways and tests within a controlled environment have also shown that LoA3 and LoA4 are possible, such as the trials undertaken by RATP and Alstom at the T7 depot in Vitry-sur-Seine, Paris.

At SYSTRA, we'd like to see advances in two areas: The first is autonomy within the depot, from simple automatic storage to other functions such as sandblasting, washing, preparation and taking vehicles out of service. The second is providing driver assistance to create a gradual increase in driver aids that address operator concerns such as: avoidance of collisions; over-speed protection; driving in low visibility weather conditions; and, support for training drivers and other operating staff.

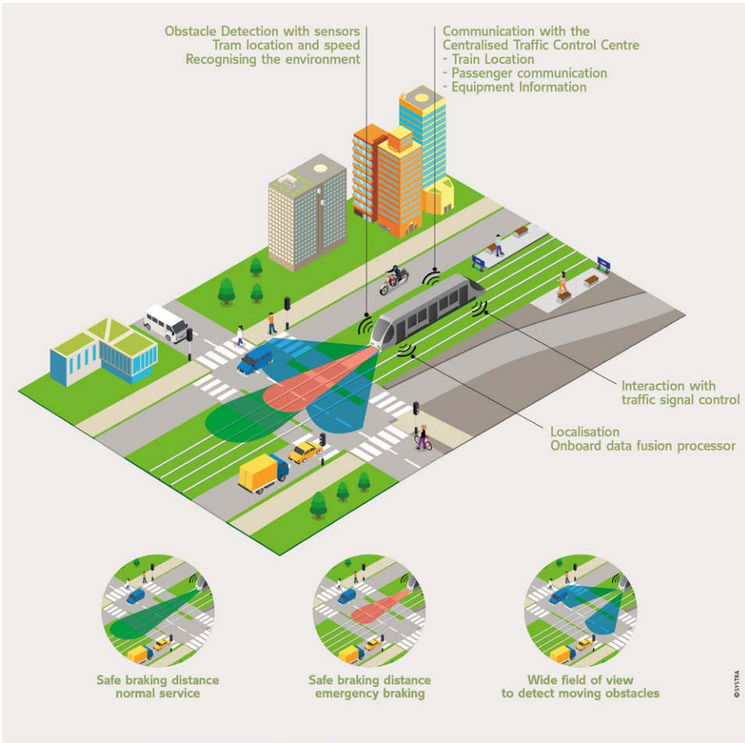
Our vision is thoroughly within the bounds of existing technology and practice. It would be a major step towards an autonomous-ready system with the potential of revolutionising our trams, not in competition with other modes, but in sync with them.

At SYSTRA, we believe fully autonomous trams are a realistic prospect by 2035-40. Of course there are major challenges ahead, but the advantages of autonomous tram are within our reach.

▲ READ THE WHITE PAPER

CHALLENGES OF AN AUTONOMOUS TRAM

- Additional complexity in security validation if Deep Learning is used (opacity of the algorithms, error rate, incompleteness of data, instability)
- Limited market size vs. R&D costs for the adaptation of autonomous vehicle technology
- Safety vs. availability of the service/overall performance of the system: an imperative for a tram which cannot leave its guideway and change itinerary to compensate for the loss of speed or regularity as an autonomous shuttle can do
- Stopping distance far superior than road vehicles (wheel rail contact and no belted passengers): - 50km/h, stopping distance: 100m – three times more than for a car departure of the train in the station with the presence of many pedestrians in front of the train



▲ **Parisian operator RATP carried out a pilot with 'driverless' tram stabling in conjunction with Alstom in 2017. A retrofitted *Citadis* manoeuvred itself around the T7 depot in Vitry-sur-Seine, following staff members around at safe distances and stopping at designated stabling positions.** RATP/Alstom

SPECIFIC ADVANTAGES OF AUTONOMOUS TRAMS

- Safety improvement? Depends on the accident rate and the level of professionalism of drivers. In France, there is a low accident rate: 1 victim (injured or killed) per million journeys – mainly related to collisions with third parties not complying with road signs (60% of events, but 80% of serious victims)
- Frequency and capacity improvements? The interval of the tram is limited by a crossing intersection (the duration of the green light for other roadway users)
- Improvement in journey time? The challenge is to avoid reducing commercial speed. A proven technology is needed to avoid unexpected stops. Stations should be designed in a way to dictate passenger flows and manage safe exchanges (closing doors, crossing passengers in front of the vehicle)
- Improvement in regularity? Risk management specific to the open road will remain a reality: less accidents mean fewer delays
- Improvement in flexibility? If there is no driver, supply can evolve in real-time according to changes in demand or specific events. The scope is not limited and service level can increase with only a marginal cost
- Improving the user experience? For (panoramic cab) and against (potential insecurity if the tram is without onboard personnel)
- Energy savings? A possible gain of 5-15% per user compared to private transport. There is a compromise to be achieved between travel time and energy consumption (eco-driving) which will be more difficult than for the metro because of the unpredictability of the open road. There are limited gains from braking energy recovery (hazard factor)
- A strong stake in operating savings if the autonomous tram can operate without a driver (drivers account for up to 50% of operating costs).