# sintropher

Innovative Technologies for Light Rail and Tram: A European reference resource

Briefing Paper 2 Ground-Level Power Supply -Alimentation par le Sol September 2015



# Sintropher

Sustainable transport for North-West Europe's periphery

Sintropher is a five-year €23m transnational cooperation project with the aim of enhancing local and regional transport provision to, from and withing five peripheral regions in North-West Europe.

#### **INTERREG IVB**



INTERREG IVB North-West Europe is a financial instrument of the European Union's Cohesion Policy. It funds projects which support transnational cooperation.







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# **Table of Contents**

Background	6
Innovative technologies for light rail and tram – developing opportunities	6
Alimentation Par le Sol (APS)	7
Technology	8
Attractiveness	9
Risks	9
Track Record	9
APS Case Study: Bordeaux Tram	9
System Specifications:	10
Why was the technology chosen in Bordeaux?	11
Benefits	11
Drawbacks	11
Assessment	11
Future Prospects and Transnational Relevance	11
Transnational relevance	12
Sources	13
References	13
Further information	13



# Background

This briefing paper is one of a series that together comprise a European reference resource for innovative technologies rail-based based systems, with particular reference to light rail and tram-based schemes in cities and regions. The approaches are also relevant, in many cases, to heavy rail and even other forms of public transport for example bus.

The resource is one of the Investments undertaken for the Sintropher project funded under the INTERREG IVB North West Europe Programme for transnational co-operation. The overall aim of Sintropher project is to develop sustainable, cost-effective solutions to improve connectivity to, from and within poorly connected regions in North-West Europe - to use innovative transport links to connect peripheral regions of NWE with the core European transport network of high-speed trains, via effective interchange hubs.

There has been a particular focus on tram-train systems which allow local trams to run on to national rail networks, pioneered in Germany, firstly in Karlsruhe and developed in Kassel, which allow urban tram systems to extend over national rail tracks to serve extensive city regions. The project has also looked at other innovative forms of tram systems such as single-track tramways, as well as high-quality transport interchanges that link such systems to major national or transnational rail or air hubs.

The project began in late 2009, with fourteen partner agencies in five EU Member States, and lead partner University College London (UCL): Valenciennes (France); the Fylde Coast (UK); West Flanders (Belgium); North Hesse (Germany); and Arnhem-Nijmegen (Netherlands).Participants included public transport operators, local authorities, regional transport agencies, and universities.

They have worked together on a series of feasibility evaluations, pilot investments and demonstration projects, as well as comparative analyses of EU best practice. The total budget is more than €23m, with funding part-financed by the EU's INTERREG IVB Programme.

A €1.5m project extension in 2014, covers follow-on work to capitalise on results from the initial project, and added a fifth objective: to test technologies for low cost transport links in different territorial contexts, plus integrated territorial corridor plans that help these links unlock wider economic and regeneration benefits; and better recognise these in business cases. This included two new partners (total now 16) and two extra demonstration regions (total now 7) in West Flanders Brugge-Zeebrugge (Belgium) and Saar-Moselle (a cross-border region France-Germany).

# Innovative technologies for light rail and tram – developing opportunities

Previous results from Sintropher show that low-cost systems, such as tram-train, tram-rail, and singletrack tram systems, have clear potential but there is no single "best" solution and these opportunities must be assessed and adapted to city/regional circumstances. (Sintropher Report *Connecting European regions using Innovative Transport. Investing in light rail and tram systems: technological and organisational dimensions.* See references at end.)

Additionally over the 5 years of Sintropher, there have been dramatic developments in relevant transport technologies. The most important are (a) very long-life batteries that allow electric trams and trains to operate over substantial distances "off the wire"; (b) charging devices that boost battery life by recharging at stops en route – e.g. the supercapacitator technology demonstrated at the 2010 Shanghai Expo, or the induction system employed by Bombardier in their Remove trams and buses; (c) discontinuous



electrification that allows electric trains and trams to "coast" under bridges and through short tunnels where it would be impossible or prohibitively expensive to install overhead catenary.

Also, a recent Report by UK Network Rail *"Network RUS: Alternative Solutions"* (July 2013) - an input to its Route Utilisation Strategy for long-term planning of the national rail network - has reviewed these developments. This work followed a remit to think imaginatively about cost effective solutions for accommodating growth in UK passenger demand, and operating services more efficiently. The solutions which are considered in the UK context are generally over and above the conventional solutions such as types of rolling stock and 25kV AC overhead line electrification. It looked at tram-train, tram systems, battery-powered vehicles, hybrid light rail, personal rapid transit, bus rapid transit and guided bus, and electrification solutions for lightly-used routes. Its main focus is existing rail lines in the UK network, but it can also be used to consider options for new transport corridors in urban areas.

The Report's overall comment is "Whilst some of the solutions are close to an appropriate stage of development (or adaption) for introduction onto the UK rail network, others will require more attention, for example on battery technology. It is important to be aware that, by definition, a process of innovation is a process of change and that some technologies that are not listed as appropriate at present may become appropriate after further development work. It is possible that over the next 30 years there may be some significant technological developments that could reshape the market for public transport and how it is powered."

So within the project's partner regions, there has been further feasibility work to test these kinds of innovative low-cost solutions in different city/regional contexts, including new developments in technical solutions.

The European reference resource informs project partners' work, and is also intended to be of relevance to much wider audiences especially. Particular target audiences are governmental authorities and transport agencies at city, regional, national and EU levels; and transport professionals and practitioners who may be involved in the initiation and implementation of new transport links

The reference resource is a snapshot in time (September 2015) and obviously the field of technologies is developing on an ongoing basis - it is hoped to update the briefing papers periodically as necessary.

# **Alimentation Par le Sol (APS)**

Literally meaning 'feeding via the ground', Alimentation Par le Sol (APS) is a modern third-rail electrical pick-up power supply mode pioneered in France in 2002 and used in selected urban tramways globally. APS systems boast high standards of safety and efficiency, and are minimally invasive aesthetically, which makes them especially suitable for urban settings.

Overall infrastructure costs relative to catenary installation remain higher and APS systems can experience problems when operating in extremely wet and rainy conditions. But despite this, many cities around the world are currently adopting APS and the system is experiencing a renaissance with recent improvements in reliability delivered through advances in technology.





Left: APS track sections showing third rails, powered segments, and neutral segments. Right: An Alstom Citadis train running on the Bordeaux APS network.

#### Technology

APS rail technology is distinct from most other methods of supplying power to trams. Instead of picking up power from a conventional overhead wire, the system uses a third rail placed centrally between riding rails to transfer power to the tram. The rail is broken into two types of segments: *neutral segments* (~3m) and *powered segments* (~10m).

The trams riding over these third rails utilise *power shoes* or *skates* to collect electricity from the powered rails, which are only activated when special radio antennae under the tram signal these rail segments to energise. Thus, only the segments directly under the moving tram which have been signalled by the undercar antennae will be electrified at any one time. This system is visualised below.



Above: APS track/tram interaction and visualisation of the electrified section of the rail.



#### Attractiveness

- APS is compatible with all types of road surfaces and can be extended relatively easily along existing rail, making it suitable for retrofitting.
- It offers safety benefits where other electrification processes would pose safety risks to pedestrians and road users.
- Advances in shoe collection technology allow greater line energy transfer efficiencies and reliability (up to 99%) relative to other catenary and non-catenary operations.

#### **Risks**

- APS tramways experience problems operating in extremely wet environments or on roads with poor drainage.
- Heavy rains on small urban streets with old stormwater systems have posed significant barriers to reliability in cities such as Bordeaux.
- Technology remains expensive and significant reductions in capital costs not anticipated with further development.

#### Track Record

Despite most historic ground level power supply systems being replaced by overhead wires or buses over the 20th century, a number of cities have announced new APS tramways over the past decade.

France was originally the largest adopter of this technology with three networks using APS in Bordeaux, Reims, Angers, and two more proposals under consideration in Marseille and Tours. In addition the UAE, Australia, China, Brazil, Spain, the USA, and Italy are all considering or have prepared proposals for APS tramways.

### **APS Case Study: Bordeaux Tram**





#### System Specifications:

Line	Length <sup>[1]</sup>	Stations <sup>[1][2]</sup>	Route	
A	20.6 km	41	Mérignac Centre - La Gardette Bassens Carbon Blanc and Floriac Dravemont	
В	15.2 km	32	Pessac Centre - Berges de la Garonne	
С	8.1 km	17	Terres Neuves - Berges du Lac	
-	-	-	14km total APS tramway between lines	

Rolling Stock: Alstom Citadis Trams with specifications shown below.

#### **Citadis for Bordeaux**

The standard-gauge, double-ended Citadis 100% low-floor trams are built by Alstom, at their factory at Aytré, near La Rochelle. The 5-section vehicle, type Citadis 302, has a length of 32 m and a capacity of 200 passengers. The 7-section vehicles for Bordeaux are of type Citadis 402, with a length of 44 m and a capacity of 300 passengers. Alstom has just decided to drop the numerical model designations for Citadis, but they are retained here for clarity.

	Citadis-302	Citadis-402
Length (m)	32.90	44.00
Width (m)	2.40	2.40
Height (m)	3.27	3.27
Entrance level (mm)	320	320
Passengers seated	48	70
Standees	170	230
Total capacity	213	300
Motors 9kW)	4x120	6 x 120
Axles	6	8
Max. Speed (km/h)	60	60



Status: Line B: extension under construction, completion summer 2015.

Line C: extension under construction, completion April 2015

New tram-train: 7.5km branch from line C, completion 2015

New Line D: 9.8km, under planning, expected delivery 2017

Line A completed 21 December 2003; extended Sept 2005, Feb 2007, and May 2008

Line C completed 24 April 2004

Line B completed 3 July 2004; extended May 2007, October 2008



#### Cost: EUR 1.2bn. Phase 1: €690m 2003-4; and phase 2: €560m 2006-8

Ridership: 117 million passenger journeys in 2012

#### Why was the technology chosen in Bordeaux?

*Urban aesthetics:* overhead wires were considered by the French Ministry of Culture and the public as invasive and irreconcilable with the urban form of the dense city centre.

*Safety*: Traditional conduit systems were deemed unsafe by government to use in the conditions of Bordeaux.

Solution 'of the times': Innorail (alongside Electricité de France) was commissioned to develop APS as a method to deliver a catenary-free, non-electrified third rail system.

#### **Benefits**

- The system has received acclaim for eliminating the need for overhead wires and preserving the aesthetic form of the dense urban centre.
- Safer alternative to conduit power systems as APS track electrification occurs only on track segments directly underneath each tram.

#### Drawbacks

- The system has faced difficulties on some streets with poor drainage where heavy rains can lead to short-term flooding and severe delays. This led the city to replace roughly 1km of APS tramway on streets with chronic flooding with overhead wires.
- Maintenance costs greatly exceeded initial estimates leading Bordeaux to initially spend more on the small portion of APS track than on the rest of the conventional tram network combined.

#### Assessment

Over the first two years of APS being rolled out in Bordeaux, tram ridership increased by roughly 25 per cent. While originally susceptible to cancellation due to heavy rain or flooding, improvements in drainage along tracks alongside better planning around extreme weather events has increased tram reliability along the APS to 99 per cent.

Additionally the implementation of APS has seen the removal of a number of overhead wire "webs" in the urban core allowing Bordeaux to preserve many of its historical sights and vistas. While it is difficult to argue whether the cost of APS justified its use, different judgements on the value of urban form and heritage preservation may make the system appear worthwhile. In general, France places significant emphasis on preserving urban "beauty" with often greater engineering costs. Thus, in contexts where such value is placed on urban form such as Bordeaux, the system can provide "return" on investment.

#### Future Prospects and Transnational Relevance

APS technology has demonstrated itself as a viable catenary-free alternative. While engineering costs are still high when compared to conventional trams the cost of implementation is expected to decrease somewhat with time as the technology becomes more popular. Indeed even if costs remain high many cities are placing a greater emphasis on preserving urban form and may benefit from APS systems.

Future improvements for APS technology include: increasing energy efficiency as it is still less efficient when compared to battery and super-capacitor trams; reducing engineering and maintenance costs; and increasing current capacity to allow longer trams on steeper gradients.



While APS technology has been pioneered by the French, the system has significant application in many other contexts. Indeed any city with a desire to explore third-rail systems can benefit from APS technology. In June 2013 Rio de Janeiro placed an order with Alstom for Citadis trams designed to run simultaneously with APS and super-capacitors demonstrating both a more global demand for the system alongside the potential for APS incorporate other catenary-free technologies.

# **Transnational relevance**

The technologies and approaches and city/region case examples on the reference resource are contextspecific and reflect:

- the geographical context: for example the extent of the urban or regional rail (and/or tram) network and degered of electrification or non-electrification; density of traffic; extent of urban and rural areas; and physical urban conditions such as street width, environmental conditions, historic areas.
- the technical context: the national regime of technical standards for rail or tram infrastructure, rolling-stock vehicles, rail electrification power supply.
- the regulatory context: the national regime for matters especially safety standards, CO2 emissions, environmental impact.

Some of the technical and regulatory matters are EU-wide. A Sintropher Report on the technological and organisational aspects of innovative tram-based systems looks at the desirability of greater harmonisation across Member States where different standards exist (see references).

These potential low-cost solutions now need to be tested in different regional cases in EU Member States. There are some distinct physical differences:

- rail systems in most Member States were built at lower cost than in the UK, with fewer overbridges and more at-grade road/rail crossings, which may reduce the benefits of some technological alternatives (e.g. discontinuous electrification).
- many areas have historic towns where conservation considerations make overhead catenary undesirable, increasing the advantage of battery-based solutions.
- in many European countries, in contrast to the UK, many urban tram systems have been maintained, or even constructed in the last 20 years, making tram-train solutions more relevant.

Even though the various approaches and case examples are context-specific, their transnational relevance is strong:

- the approaches offer a stimulus and possibilities for wider thinking by cities and regions in other European countries
- some or all of the various approaches might be potentially adaptable within the particular organisational and governance regime of another country, and technical and regulatory regime. For example the Governments' UK tram-train trial in Sheffield, Network Rail's UK trial with battery power for trains on a non-electrified heavy rail line in East Anglia, and (in Sintropher) Province Gelderland's feasibility studies for battery power to enable electric trains to operate on non-electrified routes in their regional network..

The reference resource should be seen from this perspective, as a means to promote knowledge transfer and learning across different NWE countries and regions.





### Sources

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# **Further information**

This paper was produced by UCL Bartlett School of Planning (Sintropher team members Charles King, Giacomo Vecia, Imogen Thompson) using desk research and expert comment. The paper reflects the views of the authors and should not be taken to be the formal view of UCL or Sintropher project

The European reference resource can be accessed on the following:

Sintropher project website

http://www.sintropher.eu/publications

POLIS website

http://www.polisnetwork.eu/sintropher or http://www.polisnetwork.eu/res/resources





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