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

Briefing Paper 3
Ground-Level Power Supply - Induction System
September 2015


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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.

Working in association with the POLIS European transport network, who are kindly hosting these briefing papers on their website.

Report produced by University College London

Lead Partner of Sintropher project

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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 single-track 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.

Induction (PRIMOVE) Trams

Coined commercially as “PRIMOVE”, induction powered trams are a novel hybrid technology developed by Bombardier through advances in other catenary-free technologies; namely Alimentation Par le Sol and battery-hybrid trams. The key distinctive of induction powered systems are the use of circuit coils imbedded underground to transfer electromagnetic energy to trams. This contact-free method boasts many of the benefits of APS systems such as wireless tramways, reduced maintenance costs, and safe third-rails.

While the technology is significantly more expensive to install and operate than overhead wires, potential advances in battery capacity and transfer efficiency coupled with a catenary-free network makes induction powered tramways an attractive option for heritage districts and city centres looking to minimise visible ‘wire pollution’.

Left: PRIMOVE-equipped rails. Right: Points of electrification during movement of an induction-powered tram.

Technology

Induction powered trams operate through a third-rail system that utilises electromagnetic waves to transfer power between circuit coils imbedded in the ground and pick-up coils on the underbody of the tram. The pick-up coils then convert this electromagnetic energy into electrical current which charges on-board batteries used to power the tram. Similar to APS technology, only the sections of track currently under the tram are magnetised in order to power the tram.

Induction powered tram tracks are capable of producing between 200 and 300 kilowatt hours (kWh) of continuous output, which is able to power a roughly 30 metre long light rail vehicle operating at up to 40km/h on a maximum 6% gradient. Commercial applications of up to 500kWh currents are being developed which are anticipated to be able to power carriages up to 42 metres long.

Attractiveness

- It offers safety benefits where other electrification processes would pose safety risks to pedestrians and road users.
- Induction powered trams have high reliability and low downtime under extreme weather conditions such as heavy snow, ice, rain, and sand.
- The induction loop power can also be extended to other modes of transport equipped with induction coils such as buses and cars.
- Stations can be converted to charging points for trams as needed.
- Induction loop systems are compatible with any road surface and almost any road topology.
- Little to no training required for drivers migration to induction loop system operation.
- Contactless system reduces maintenance and power system replacement costs.
- Older tram lines can upgrade to induction relatively easily.
- When used with super-capacitors, tram batteries, and regenerative braking, systems can provide up to 20-30% energy savings over conventional catenary systems.

Risks

- Electromagnetic interference not totally mitigated by magnetic shielding when active.
- Loops must be covered by 40mm layer of non-conductive material such as resin, asphalt base, or non-reinforced concrete and this layer is vulnerable to damage by heavy vehicle traffic.
- High initial capital costs.

Track Record

Despite most historic ground level power supply systems being replaced by overhead wires or buses over the 20th century there are a few cities exploring the implementation of induction loop systems. The first and most significant test for induction loop systems was attempted in Augsburg on an 800 metre long segment of Line 3. A major aim of this premier induction loop system project was “demonstrating reliable operation under the real conditions of daily operation in an urban environment”. This system is the only major induction loop system in place today and it is unclear whether other systems will be installed in the near future.

Induction (PRIMOVE) Case Study: Augsburg Tram

System Specifications

Line: 0.8km length, standard gauge

3	Regular line	Cross-city route	Stadtbergen – Haunstetten West	26 stops

Rolling Stock: Bidirectional Bombardier low-floor tram, model code unknown.

Status:

September 2010: Bombardier Transport installed PRIMOVE induction loop system on 800m segment.

Fall 2011: One bidirectional low-floor tram outfitted with PRIMOVE power receivers.

Fall 2011 – Summer 2012: Further tram and multimodal testing

May 2012: Larger rollout & press release of PRIMOVE induction loop system in Augsburg

Cost: Unknown

Ridership: 37,100,000 in 2010

Why was the technology chosen in Augsburg?

Urban aesthetics: Augsburg had a desire to preserve urban vistas and reduce the visual intrusion of overhead wires within its city centre.

Proof of concept test agreement: The introduction of induction loop technology in Augsburg can be attributed to both the city of Augsburg's interest in employing a catenary-free tram system through part of its urban core and Bombardier's desire to test its PRIMOVE system in an urban environment.

Proximity to Mannheim: Augsburg was chosen as an ideal candidate due to its proximity to Mannheim which was where Bombardier had begun developing its PRIMOVE technology on a test track since 2003.

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 induction loop track electrification occurs only on specific track segments directly underneath each tram.
- When combined with super-capacitors and regenerative braking, the system used 20-30% less energy than other conventional trams.

Drawbacks

- Whole track electrification was not possible due to lack of funds.
- Introduction was as a "proof of concept" rather than a bespoke solution.

Assessment

Critical reception of the Augsburg tram has been generally positive although information is limited. Some criticisms of costs and the time it took to complete construction are mentioned from some sources. Many rail critics agree that the use of PRIMOVE on this line was more of a "test" than a specifically-designed and -engineered solution.

Future Prospects and Transnational Relevance

Further development of induction loop trams are not being pursued by Augsburg due to the fact that it already "has a modern fleet of conventionally powered trams". Instead induction loop buses are being tested in the city on a 12km route to overlap with the 800 metres of induction track currently in use. Bombardier foresees the greatest development of induction loop systems not solely for tram networks but as a part of a greater transition to induction power across an entire public transportation network.

While induction loop technology on tram networks is still in the early stages of development implementation with other modes such as buses has become more popular, with many cities in China and Southeast Asia exploring induction charging for bus fleets. Thus while induction loop tram systems have not garnered the levels of interest shown in other catenary-free systems such as APS and super-capacitors, the multimodal integration of induction systems is predicted to generate more investment as technology costs decrease.

Transnational relevance

The technologies and approaches and city/region case examples on the reference resource are context-specific 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 over-bridges 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.

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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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