sintropher

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

Briefing Paper 4
Traction Battery - NiMH and PRIMOVE Systems
September 2015


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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

Investing in Opportunities

This project has received European Regional Development Funding through INTERREG IV B.

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.

Traction Battery Trams

Traction batteries (or electric vehicle batteries; EVBs) are batteries that are used for the primary or secondary propulsion of electric vehicles. While the majority of electric vehicles used in transport are cars and buses advances in traction battery storage capacities and recharge times have generated new potential for their entrance into light-rail systems. Costs of traction batteries have also dropped significantly over the last decade with some sources suggesting that engineering and replacement costs will continue to decline rapidly over the next fifty years. Used in junction with other technologies traction batteries demonstrate operational energy savings of up to 35%, making them extremely competitive with other catenary-free systems.

Above: SAFT traction battery-powered tram.

Technology

Traction battery trams cycle through a number of ‘modes of operation’ along its service route. Prior to use the traction battery must be sufficiently charged which is done either during off-service times in rail yards or while in service through catenary charging, induction, or any other method traditionally used to transfer electricity to the tram. Once the tram leaves the charging point and accelerate up to operational speed the traction batteries begin to discharge and bear the power loads of the car’s engines and any other auxiliary equipment such as HVAC systems or electric doors. Upon reaching operational speed battery efficiency is maximised by only drawing power when coasting speeds reduce. Upon deceleration of the tram into a stop or turn regenerative energy derived from excess heat and kinetic energy is released from the unit’s traction motors back into the battery units, recharging them and further increasing battery efficiency.

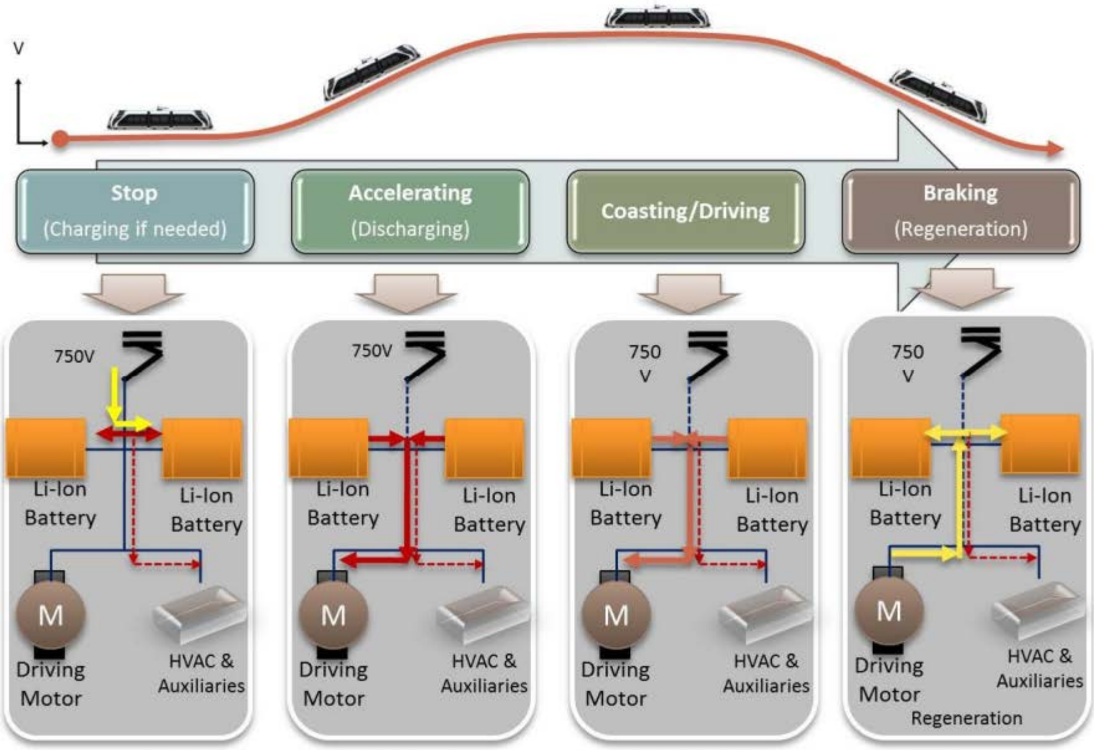


Figure 1 Operational steps of onboard battery-powered LRV

Attractiveness

- Offer greater operational range than super-capacitors.
- Significantly cheaper than super-capacitors.
- Do not use fossil fuels and improve air quality along lines.
- Do not require expensive third rail technologies such as electrified ground rails.
- Safer than third rail electric power transfer.
- With recent battery technology improvements, able to reduce long-term catenary maintenance costs significantly.

Risks

- Longer recharge times compared to other forms of on-board storage such as super-capacitors and fuels.
- Higher initial purchase price for rolling stock.
- Often require regular unit replacement due to short life cycles.
- Funding sources relatively poor for battery-only trams worldwide.

Track Record

While traction batteries have not had a successful history of operation recent technological advances in battery composition and efficiency have allowed these systems to become competitive both financially and energetically with other technologies. Currently there are at least three tram networks using traction battery trams in regular operation in France, Japan, and the US with another at least half dozen cities around the world conducting feasibility studies into their use.

NiMH Case Study Example: Nice, France

PRIMOVE Case Study Example: Nanjing, China

NiMH Battery Case Study: Nice Tram

System Specifications:

Line	Length[1]	Stations[1][2]	Route	Track Type	Status	Timescale
A	8.7 km	21 stops	Henri Sappia to Pont Michel	1,435 mm (4 ft 8 1⁄2 in) standard gauge	Completed	Opened 2007
B	11.3 km, with 3.2 km underground	20 stops	Connecting city centre with airport and Central Business District (CADAM, Arénas	1,435 mm (4 ft 8 1⁄2 in) standard gauge	Under construction	

Rolling Stock: 20 Alstom Citadis type 302 fully air-conditioned, 100% low-floor, modular five-unit double-ended trams.

Roof-mounted nickel metal batteries:

- an operational life of at least five years, supplied by Saft.
- range of up to 1km at a maximum speed of 30km/h with air-conditioning in operation.

Switching of power is activated by the driver, with pantograph fully lowered when running without OHLE, reducing training and upgrade costs.

Status: In service 2012.

Cost: The Nice tram system had a total cost of approximately €560m, of which just over 70% related to creating the tramway.

Ridership: 90,000 daily journeys as of January 2011.

Why was the technology chosen in Nice?

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

Carnival Processions: Nice's famous carnivals are a "substantial" part of the tourism industry. As such, it was necessary to avoid the installation of catenary wires in the town centre corridors these processions passed through.

Alimentation Par le Sol Alternative: While the Nice tramway was originally designed with APS ground-level power supply in mind the city eventually abandoned the idea for a combination of catenary and NiMH batteries due to the shorter length of catenary-free track required.

Benefits

- NiMH batteries are compact enough to add to tram roofs, minimizing engineering costs.

Drawbacks

- Batteries have relatively limited range (although only designed for 500m sections of catenary-free track).
- Newer battery technologies are being developed at an accelerated pace, making current NiMH systems appear inefficient in relative terms.
- Long recharge times relative to super-capacitors and other modern batteries previously considered for operation along the line.

Assessment

Following consideration of a light metro system and after substantial delays and controversy, and given the scale of the city's road traffic problems, Nice's modern tramway came relatively late in the resurgence of French light rail. Furthermore, the choice of a hybrid electric tram was not a natural one; Nice was highly influenced by its need to preserve the built environment of its famed plazas, and as such looked to Bordeaux for inspiration from the APS system. However, Nice ultimately chose the electric hybrid in order to cut costs, making it a financially-driven choice.

Future Prospects and Transnational Relevance

Battery powered trams provide an inexpensive alternative to more costly catenary-free systems such as APS and Induction Looping. However, the limited range of these batteries and the charging time required to fill them makes their application limited to short sections of catenary-free track. While they may excel in these conditions, the future of battery-powered trams more likely lies in energy-management systems that mix batteries and super-capacitors in a hybrid-style system.

As battery technology becomes cheaper, some experts believe that NiMH Battery-Powered trams could become an economically-feasible way for developing countries to preserve the heritage of their downtown cores and introduce shorter sections of catenary-free track.

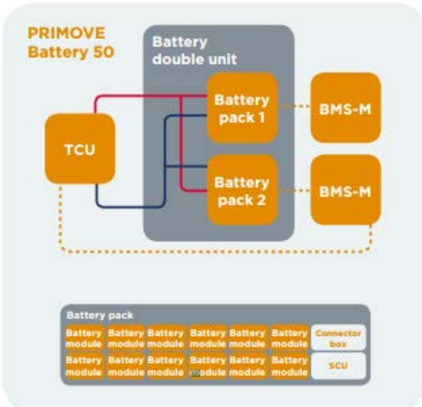
PRIMOVE Li-ion Battery Case Study: Nanjing Tram

System Specifications:

Lines: Hexi Line – 8km connecting Olympic Sports Centre, International Expo Centre, Youth Olympic Village, and Fishmount Wetlands Park.

Qilin Line – 9km

90% Catenary free lines, wires primarily overhead stations and steep gradient sections.



Rolling Stock:

- Based on Bombardier's FLEXITY 2 tech with MITAC propulsion and control, FLEXX Urban 3000 bogies, and PRIMOVE battery systems.
- 32.5m long and 2.65m wide
- Two 49kWh batteries per tram.

PRIMOVE battery 50:

- Li-ion
- Capacity: 49kWh: 2 systems per tram

- Voltage: 532V

Propulsion System MITRAC 500:

- Drive power 4x120kW
- Auxiliary supply voltage: 400 V AC
- 24 V DC supply
- Input voltage from catenary 750 V

Status: Hexi Line opened late 2014 after a 2 year tendering process and 2 years engineering.

Qilin Line opened early 2015 with similar timeframes.

Cost: Unknown.

Ridership: Unknown.

Why was the technology chosen in Nanjing?

Proof of Concept: Nanjing is the site of a CSR Puzhen factory (who along with Bombardier won the contract for engineering and building the low-floor, PRIMOVE-powered trams in Nanjing). Nanjing thus provided a convenient site to demonstrate Bombardier's new high-power PRIMOVE technology in China.

Prestige: The Nanjing Hexi and Qilin lines will be the first steel-wheel tram lines adopting catenary-free power supply technology in China. The added prestige was sought out to compliment Nanjing's hosting of the 2nd Summer Youth Olympics.

Benefits

- PRIMOVE batteries are able to recharge quickly via pantograph at tram stops and through some acceleration points, allowing for a 90% catenary-free system.

Drawbacks

- Technology is relatively new and has higher engineering costs than some other catenary-free systems.
- Battery lifespan not fully tested, could lead to regular replacement on high-traffic lines.

Assessment

The introduction of PRIMOVE batteries in Nanjing was given much press and generated excitement within the catenary-free discourse. While little information is available about current operation (the line only being opened in 2014) the introduction of a 90% catenary-free line with charging at station points could herald a new way to build tramways both in China and abroad.

Future Prospects and Transnational Relevance

Battery powered trams provide an inexpensive alternative to more costly catenary-free systems such as APS and Induction Looping. Traditionally, the limited range of these batteries and the charging time required to fill them makes their application limited to short sections of catenary-free track, however, PRIMOVE systems may offer a practical solution to the problem conventional battery-powered trams face. Application of PRIMOVE systems in other contexts, alongside more critical review of the system will help determine the next best steps for the technology.

PRIMOVE-battery enabled systems have been ordered in Braunschweig, Mannheim, and Berlin, Germany albeit for electric bus operation. While Bombardier currently holds the patent for PRIMOVE batteries, the sorts of applications this technology could be applied to are extensive in transport and tram systems could benefit greatly from further development of the technology. As battery/super-capacitor tramways become more popular in light rail discourse PRIMOVE systems could see their application widen significantly.

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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