sintropher

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

Briefing Paper 9
Kynetic Power - Flywheel System
September 2015


6
A
A
5.2

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.

nwe 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

Authors: Charles King, Giacomo Vecia, Imogen Thompson, Bartlett School of Planning, University College London. The paper reflects the views of the authors and should not be taken to be the formal view of UCL or Sintropher project.

Table of Contents

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.

Flywheel Trams

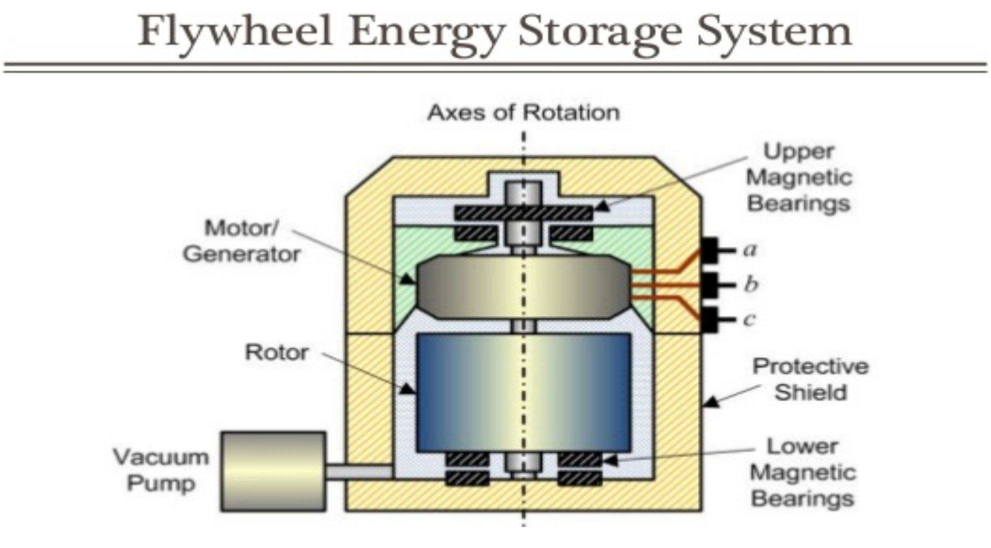
Flywheels are a rotating mechanical device that are used to store energy in the form of rotational technology. In transport the use of flywheels as a operating system dates back to the days of steam trains when large rotating disks were used to collect energy and help slow trains when braking down steep inclines. Modern flywheels are ‘charged’ by applying torque and increasing the rotational speed of the disc, while energy is drawn when applying that torque to a mechanical load. Advances in carbon fibre materials and magnetics are making flywheel technologies more viable than ever for use in large-scale and high-energy systems. Flywheel trams are also being explored in Formula One racing cars and for use in articulated buses.

Left: A Parry People Mover tram cab running on the Stourbridge line. Right: A flywheel-enabled tram light rail chassis.

Technology

Flywheels are essentially large discs that rotate at super-high rotation speeds of between 1,000 and 20,000 rotations per minute (rpm). This rotational energy can be drawn from the disc as either electrical or kinetic energy through the principle of the conservation of energy. Older flywheel technologies were developed with steel laminate disks whereas newer systems are being developed from high-strength carbon fibre composites suspended by magnetic bearings.

Flywheel trams exist in two primary forms: hybrid and zero-emissions. Hybrid flywheel trams draw on the kinetic energy stored in their flywheels to power the trains during acceleration and then recharge the flywheels when braking. Zero-emissions flywheel trams rely solely on the kinetic energy stored in their flywheels which is recharged at stations and stopping points. These stopping points must be relatively close together (<0.5miles in some cases) for this technology to be viable as a stand-alone system. External flywheel systems can also be used lineside on electrified railways to help regulate the voltage of the line through reducing power demands during acceleration.



Above: Diagram of a typical flywheel energy storage system.

Attractiveness

- Can release and absorb energy very efficiently and quickly;
- Wide temperature operating range;
- Can last 20 year or longer with minimal service requirements;
- Flexible sizing and installation into both new lines and retrofits;
- Can be installed in parallel operation and with other technologies for greater power conservation and regeneration;
- Provides significant energy savings and emissions reductions.

Risks

- Initial costs much higher than traditional power systems or batteries for energy storage (although lifetime costs lower);
- Flywheel failure from high speed rotation extremely dangerous (although most modern systems have safeguards in place);
- Must be engineered into most systems with bespoke production increasing costs;
- Large sizes and weights often negate energy savings in older systems.

Track Record

Flywheel systems have been used in a number of transport-related technologies, most of which on a trial basis. Some London buses now use flywheel technology to improve energy efficiency and the technology has made its way into Formula One racing cars as a way to capture braking energy. Flywheels have had limited success in rail, however, due to the incredible weight of rolling stock alongside a lack of commercial interest into the technology. This may be set to change as many recent studies have pointed to the potential for modern flywheels to save 10-15% of energy consumption when installed on traditional rolling stock.

Flywheel Case Study: Stourbridge Line Tram

System Specifications:

Line:
Branch line 0.8 mi long, single standard gauge track (shortest branch line in Europe).

Rolling Stock:

Class 139 PPM60, cap. 60
Flywheel energy storage: 1000-2600rpm
Max speed: 65km/h

Status: Difficulty initially receiving passenger certification but eventually accepted roughly 1 year late and entered service in March 2009.

Cost: “More than a bus but less than a train.” Actual cost unknown.

Ridership: 479,516 in 2012-2013

Why was the technology chosen in Stourbridge?

Test track: The Stourbridge branch line has a history as a test route for new types of small rail and light rail transport due to its short length and generally favourable operating conditions.

Proof of concept test agreement: Great Western Railway originally had tested its “autotrains” concept on the line and London Midlands had later turned to the line to test its “Parry People Movers” (PPM) flywheel tram concept.

Desire to “make news”: While the line had originally been threatened with closure, since the introduction of PPM trams line reliability and frequency has gone up leading to a revitalisation of the line “similar to the success of the Docklands Light Railway”.

Benefits

- The increased speed of the PPM60 vehicles allowed for an increase along the line from 4 to 6 services per hour.
- Flywheel technology has been promoted as a carbon-reducing option for light rail due to increased energy savings.
- The smaller automotive-like 2 litre engines used in the PPM60 trains are slightly quieter and easier to maintain.

Drawbacks

- The technology has been considered extremely “niche” and suitable due to the incredibly short nature of the single-track branch line.

Assessment

Reception of the PPM trams has been overwhelmingly positive due to their increased reliability (approaching 99%) and the positive press they have generated for the line. Ridership increased roughly 20% in the year they were introduced and has remained at significantly higher levels since 2009. This has led some to call for a route extension further into Stourbridge Town.

Future Prospects and Transnational Relevance

While flywheel technology is booming, the PPM model has gained relatively little traction due to its limited operating conditions. PPM advertises its vehicles as excellent alternatives to “supertrams” and rail on shorter branch lines due to their smaller engines and reduced energy demands. Thus flywheel technologies implemented as in the Parry People Movers may become more viable options on shorter branch lines with low to moderate passenger traffic.

Flywheels are becoming increasingly popular in rolling and riding stock. The usage of flywheels in trams and light rail is more commonly called “regenerative braking” and their ability to capture power while breaking is being explored in buses and cranes. Rail industry experts suggest they may become a commonplace method to reduce energy consumption on public transport within a generation.

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.

Sources

http://www.parrypeoplemovers.com/PPM50-60-spec.htm

http://www.parrypeoplemovers.com/technology.htm

https://en.wikipedia.org/wiki/Parry_People_Movers

http://www.stourbridgenews.co.uk/news/8362831.Revolutionary_tram_notches_up_500_000_passengers/

http://www.railwaygazette.com/news/business/single-view/view/alstom-to-test-onboard-flywheel-energy-storage.html

https://en.wikipedia.org/wiki/Stourbridge_Town_Branch_Line

https://en.wikipedia.org/wiki/British_Rail_Class_139

References

Network RUS - Alternative Solutions. (July 2013) Report by Network Rail, London. www.networkrail.co.uk

Connecting European regions using Innovative Transport. Investing in light rail and tram systems: technological and organisational dimensions. (September 2015) Sintropher Integration Report 1, University College London. www.sintropher.eu/publications

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

Contact details:

Colin Osborne

Project Manager

Tel: 0044 (0) 203 108 9544

Mob: 0044 (0) 7796 258078

colin.osborne@ucl.ac.uk

Dr. Robin Hickman

Project Director/Reader in Transport & City Planning

Tel: 0044 (0) 203 108 9531

Mob: 0044 (0) 7720 548849

r.hickman@ucl.ac.uk

University College London

Bartlett School of Planning

Central House, 5th Floor

14 Upper Woburn Place

London   WC1H 0NN

Partners

Sintropher is coordinated by

In partnership with

Co-funded by the INTERREG IVB programme for North-West Europe


5.2
RT 4 Wolfhagen

Sintropher

University College London
22 Gordon Street
London WC1H 0QB
United Kingdom

www.sintropher.eu