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

Briefing Paper 7
Additional Fuels -
Hybrid Diesel/Electric 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

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.

Dual-Mode Diesel Trams

Diesel-hybrid trams (conventionally known as dual-mode locomotives) are a unique hybrid technology allowing trams to run on both electrified and non-electrified rail. These trams have one set of combustion engines that can use diesel fuel to generate power and another electrical engine that can use the energy derived from an extended pantograph. The majority of diesel-hybrid trams operate on dual-mode networks providing continuous journeys across rail types and different levels of electrification, for example from urban tramway to regional railway.

Above: Dual-mode diesel tram in Kassel, Germany.

Technology

Diesel-hybrid trams use both conventional pantograph and diesel combustion engine systems for propulsion. The operational conditions and adaptation to these conditions are the main innovation associated with this typology. A brief comparison of a dual-voltage electric-only tram and a diesel-hybrid tram can be found below.

Comparison of diesel-hybrid and electric-only trams

	Diesel-hybrid tram	Dual-voltage electric-only tram
Number of vehicles	10	18
Power rating	600kW	600kW
Propulsion	diesel-electric: two roof-mounted six-cylinder MAN diesel engines, each delivering 375 kW tramway: 600 V DC	mainline: 15 kV AC tramway: 600 V DC
Number of traction motors	4	4
Acceleration from start	$1.1ms^2$	$1.1ms^2$
Maximum speed	100km/h	100km/h
Weight of a three-vehicle unit (when empty)	63.4t	59.8t
Weight of a three-vehicle unit (fully loaded)	85.2t	82.5t
Seating capacity	84 (plus 6 'tip-up')	84 (plus 6 'tip-up')
Standing capacity	139	139
Boarding height	360mm	360mm
Length over buffers / couplings	36.76m / 37.48m	36.76m / 37.48m
Width at maximum point	2.65m	2.65m
Minimum radius	22m	22m

Attractiveness

- Operational flexibility through capacity to extend routes beyond electrified rail to rural single-track branches and diesel-only freight lines
- Able to maximise use of existing infrastructure.
- Lower capital and engineering costs than other catenary-free alternatives.

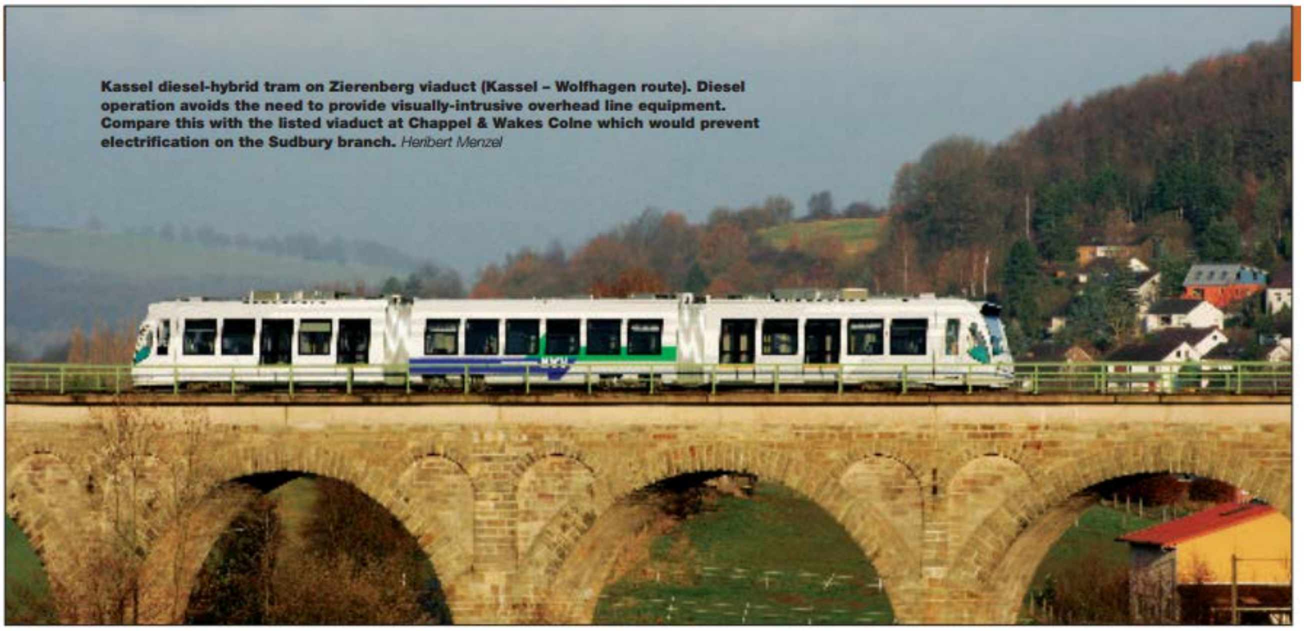
Risks

- Increased air pollution from diesel engine operation.
- Full electrification seen as superior for energy efficiency and reliability compared to diesel-hybrid option.
- Technology quickly becoming obsolete due to newer engineering solutions.

Track Record

There are currently at least two networks where dual mode diesel trams are in operation in Germany. Both systems have met with significant success, both during engineering and construction in the form of reduced capital costs and during operation through increasing ridership. Studies into the use of diesel-hybrid trams are being conducted in the United Kingdom for some lines extending out of Manchester.

Dual Mode Diesel Case Study: Kassel Tram-train



Line	Route
Line RT3	Hofgeismar-Hümme – Kassel
Line RT4	Wolfhagen – Kassel
Line RT5	Melsungen – Kassel
Line RT9	Schwalmstadt-Treysa – Kassel

System Specifications

Rolling Stock: Alstom RegioCitadis Trams with specially engineered carriages to accommodate different station geometries.

Status: 2000-2003: Feasibility studies.

2004-2006: Engineering and construction.

September 2007: Full operation.

Cost: £120 million, with £67 million in costs for new infrastructure and £53 million for new vehicles.

Ridership: From an opening year figure of 2.5 million passengers in 2008, this grew year on year to 3.7 million, an increase of 43%.

Technical Data and Main Dimensions

Vehicle type	bi-directional vehicle
Vehicle length	36,762 mm
Vehicle width	2,650 mm
Maximum vehicle height (above TOR)	3,650 mm
Track gauge	1,435 mm
Minimum negotiable radius	22 m
Floor height (above TOR)	
– low-floor area	413 mm
– high-floor area	663 mm
Low-floor portion	approx. 75 %
Entrance height (above TOR)	362 mm
Entrance doors per side	4
Seats	90
Standing facilities (4 pers. per m^2)	E-E variant: 139, E-DE variant: 127
Multipurpose areas	2
Power supply	750VDC + 15 kV AC 16 $^2/_3$ Hz and 750VDC + diesel-electric
Axle arrangement	Bo' 2' 2' Bo'
Maximum speed	100 km/h

Why was the technology chosen in Kassel?

Minimising the need for new rail infrastructure: Kassel sought to enable better transit between the city and its satellite communities. By engineering a tram that was capable of running on mainline tracks, the city was able to extend only 10km of newly laid rail into a network of over 122km in length through track sharing.

The Zierenberg tunnel problem: A tunnel on the non-electrified Wolfhagen route west of Kassel needed significant restructuring if it was to support electrification. Instead of rebuilding the tunnel, the diesel-hybrid trams were able to operate on the non-electrified portions of the line, saving capital costs upwards of £4.9m or roughly 55% of the total infrastructure cost to incorporate the line into the network.

Benefits

- Significant cost savings through minimizing rebuilding and new infrastructure requirements.
- Greater operational flexibility through ability to run on multiple electrified and non-electrified rail types which was required to connect to various parts of the region.
- Able to serve lines with fewer passengers without significant cost burdens.

Drawbacks

- Increased emissions and reduced air quality along non-electrified tram lines.
- System capitalised on initial infrastructure, which may not be possible in other newly-engineered networks.
- Newer technologies and engineering methods have emerged, making dual mode diesel seem a “solution of its time”.

Assessment

The diesel-hybrid tram-train network model worked extremely well for Kassel, increasing ridership and connecting satellite communities at a relatively low project cost. While there has been some difficulty in finding the transferability of the diesel-hybrid tram-train model, other networks that have the correct set of characteristics would benefit greatly from this technology. Additionally, many believe that developments in catenary technologies and other catenary-free systems could have provided a superior engineering solution to the use of dual-mode diesel trams.

Future Prospects and Transnational Relevance

As diesel engines have lessened in popularity for releasing more dangerous air pollutants than their petrol cousins (NOX gases, particulate matter, CO) concerns may arise from a resurgence of diesel rolling stock on rails. Thus for diesel-hybrid trams to remain competitive significant improvements in diesel combustion engines will be required to calm concerns over air pollution.

Diesel-hybrid trams could provide a most cost-effective alternative for nations looking to expand existing rail networks without incurring large infrastructure costs. Additionally, these trams could help other cities pick up the tram-train model when network conditions are favourable to its development. As such, some countries with specific electrified urban rail and non-electrified rural rail network conditions could benefit from this technology.

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.acorp.uk.com/Assets/mr_march_64_66_lo-res.pdf

http://www.railway-technology.com/projects/kasseltramtrains/

http://www.lrta.org/TramForward/TAUT_Jan_Tramtrain.pdf

http://www.railforthevalley.com/tag/diesel-hybrid-tram-train/

https://railforthevalley.wordpress.com/2010/04/04/diesel-trams-for-the-interurban-lessons-from-kassel-part-3/

http://connectedcities.eu/downloads/showcases/lrt_regio_citadis_kassel.pdf

https://en.wikipedia.org/wiki/Electro-diesel_locomotive

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

UCL

In partnership with

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

Investing in Opportunities

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

INTERREG IVB


5.2
RT 4 Wolfhagen

Sintropher

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

www.sintropher.eu