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LUND: LIGHT RAIL FOR A SMALL CITY

Sweden's newest tramway, where science meets sustainability

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LUND: A NEW MODEL

Per Gunnar Andersson describes in detail the background to the development of Sweden's newest tramway – a long-term investment in the city's future.

On 13 December 2020, the modern tramway in the Swedish city of Lund opened for passenger service on a 5.2km (3.2-mile) route from Lund C (the city's central railway station) to ESS (European Spallation Source). A large folk festival had been planned for the day before, however the ongoing COVID-19 pandemic brought an end to these plans. Instead, the inauguration was moved online and an event pre-recorded on 27 November was broadcast at 11.00 on 12 December (this is available online (in Swedish) at *www.youtube.com/watch?v=4HkK0vHPxTo*).

Sweden's last new tramway – in Karlskrona, approximately 185km (115 miles) to the east – opened almost exactly 110 years earlier, carrying its first passengers on 21 December 1910. This short 3.5km (2.2-mile) line closed on 15 May 1949, although two-axle car 13 survives in preservation at Sweden's local transport museum (Museispårvägen Malmköping).

Lund, with a population of 94 000, therefore becomes Sweden's fourth tramway city, following Stockholm (1877), Göteborg (1879), and Norrköping (1904). The first tram, car 03, departed from the northern ESS terminus at 06.13, carrying around 70 passengers on the inaugural service.

This exciting day marked the final chapter of a story that started in the late 1980s when the city's masterplan included an LRT corridor from the railway station passing the hospital, technical university, Ideon science park and a planned new town, ending in the village of Dalby around 10km (6.2 miles) to the east.

Although at that time the city was talking about light rail, regional public transport authority Malmöhus Trafik favoured BRT (bus rapid transit). To find a solution, a co-operative group was formed in 1995 and at the same time the city's Urban Planning Director Anders Tingvar came up with the name *Lundalänken* – the Lund link. This led to a 1996 pre-study which recommended the creation of a busway to a design that promoted enhancement to a future light rail service, from Lund C to the expanding north-eastern suburb of Brunnshög.

Based on this pre-study, an agreement was signed in January 1999 with both bus and light rail solutions forming part of a longer-term strategic plan. Building the busway brought a number of challenges, including the dismantling of the former hospital kitchen, construction of a new road underpass, relocation of sub-surface utility pipes and cables, and the installation of 4km (2.5 miles) of new busway itself. Four years later, on 23 January 2003, the service was inaugurated.

From BRT to LRT

Moving forward a decade, the main driver for conversion to light rail is the continued growth in the north-east of the city: the tramway was seen as a part of the urban

▲ **ABOVE LEFT: The Lundalänken bus route that was the precursor to tram service to ESS on 8 December 2016. The following day the Lundalänken closed as a busway in preparation for rebuilding as a tramway.**
▲ **ABOVE RIGHT: Four years later, CAF *Urbos* 02 (Åsa-Hanna) in the hospital area on 18 December 2020.**

FOR SUSTAINABILITY

▲ ABOVE: The first service tram, Blåtand (03), departs from the ESS terminus at 06.13 on 13 December 2020.

All images by the author, unless otherwise stated.

development and not a barrier to it. To this end, in 2006 the first Brunnshög masterplan was adopted and a year later the Swedish Government entered the competitive process to bring the prestigious European Spallation Source (ESS) research facility to Lund.

This unique materials evaluation facility is a Pan-European programme, with an estimated cost of EUR1.83bn (2013 figures). When the first study programmes begin in 2023, it is estimated that two to three thousand visiting scientists will arrive each year to perform experiments; full completion of the site is planned for 2025. Beating competing bids from other European cites, in May 2009 Lund was chosen as the future site of the ESS.

In addition to serving these key academic and research establishments, the new tramway is also envisaged as a regional investment in sustainable growth, creating the conditions for – and playing a key part of – a climate-smart and attractive urban development. Its implementation is therefore not in itself a goal, but rather a means to an end for a municipality focused on sustainable development based upon major infrastructure projects; this includes the provision of high-quality, environmentally-friendly public transport.

The tramway's route runs from Lund C via the hospital, university, the Ideon and Medicon Village area, Brunnshög – Lund's only major growth area – the research facilities

▲ ABOVE: The tramway passes through the former hospital kitchen, dismantled in 2002 for construction of the Lundalänken busway.

◀ LEFT: Car 03 (Blåtand) approaches the northern ESS terminus, with the research facility in the background to the left and the new tram depot to the upper right. In the coming years the green space on either side of the tramline will be occupied by further development.

TRAMS IN SKÅNE - SPIS

To enable prioritisation of the tramway plans in Skåne (both urban and regional), a 2007 study concluded that the proposed city lines in Malmö, Helsingborg and Lund should be given precedence. It was therefore natural to co-ordinate all three cities in 2012 under a common platform. The new body – 'SPIS – Spårvagnar i Skåne' (Trams in Skåne) received a SEK27m (EUR2.7m) contribution from the European Investment Bank for its studies.

SPIS subsequently created a knowledge bank and several reports concerning design and technical guidelines, arranging study trips to Germany, Switzerland, the UK, France, and Norway. The French tramway concept was identified as the main vision early on and several visits were made to Le Mans; a combination of quality design and high levels of safety was the main objective and Le Mans therefore served as the archetype for the future tramways in Skåne.

Sadly, no further progress on the tram project in Helsingborg has been made since 2015 and work paused in Malmö in spring 2017, leaving Lund to move forward alone from this point.

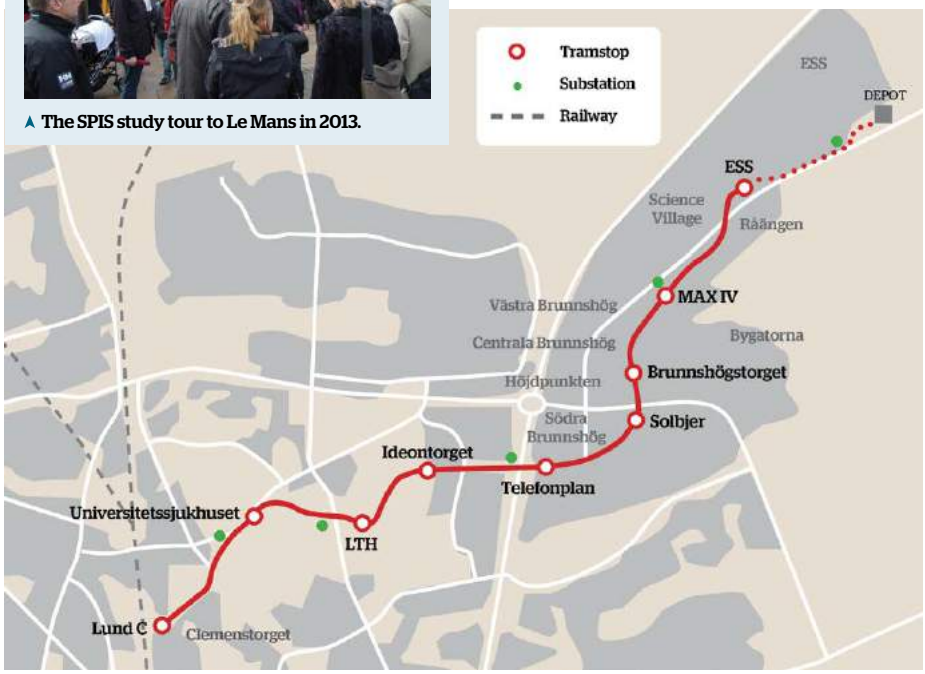
▲ The SPIS study tour to Le Mans in 2013.

MAX IV and ESS and the research-based Science Village. It incorporates the former Lundalänken busway with short extensions at each end.

Experience from modern tramway installations elsewhere is that they are suited to integration with well-designed spaces and the incorporation of around 40 000m² of grass track adds a valuable green element to the street space. The higher comfort levels and quality of the travel experience is also expected to attract more public transport users, importantly those who currently use a car as their primary mode of travel.

For the city, development along the tram corridor is also of great strategic importance: 30% of the expected growth over the next three decades is planned along the tramway, with a projected 40 000 new residents and workplaces. Positive effects have already been seen, in turn improving the conditions for further sustainable growth and becoming a virtuous circle.

Several developers have stated that without the tramway they would not have been interested in investing in Brunnshög. While it is difficult to put an exact monetary figure on this, it is proven elsewhere that fixed rail infrastructure creates a security that increases confidence in investing. Square metre prices along the route have risen by an average of 25% and while there is still a lot of land to be sold, a great deal of interest is being shown.



The first steps toward a tramway

Following a study in 2011, the city began the work required to create the six detailed legal plans required to make its tramway a reality in early 2012. These plans were ready for public consultation in May 2014, with the last approved in November 2015.

Concurrently, in 2015 the Swedish Government introduced a new form of financial support for the development of sustainable cities. Lund was one of the first to apply and on 17 December 2015 the city received confirmation of 40% (SEK298m/EUR30m) of the estimated tramway construction costs. The same day, the City Council authorised works to begin. This was a historic day, and the goal of starting operations in late 2018 or early 2019 was set. Pre-qualification tenders were published a week later, calling for bids to construct 5.5km (3.4 miles) of tracks and the supply of seven low-floor trams.

On 12 May 2016 it was announced that Swedish construction conglomerate Skanska was the winner of the contract to build the tramway, including electrification and associated road works. On 30 May, a further SEK74.5m package was agreed with the national Government under its *Sverigeförhandlingen* programme, increasing the state's contribution to co-financing of the project to 50%. Six months later the Regional Council began the procedure to produce the formal tender documentation for the required vehicles and depot construction.

The project's total outturn costs of SEK1.495bn (EUR148.4m) are divided as follows: SEK890m (EUR88.3m) for infrastructure, SEK310m (EUR30.8m) for the depot, and SEK295m (EUR29.3m) for rolling stock. The contribution from the national government totals SEK373m (EU37m).

Responsibility for tramway operations was given directly to local bus operator Nettbuss Stadsbussarna (now Vy Buss) in February 2018. Its contract is valid until 2023 and this integration has made it possible to involve the bus operator in the work to form the safety documents to get permission for the operation of the tramway from Transportstyrelsen (Sweden's Road and Rail Department).

Creating a sustainable depot

Designed by Tengbom architects, the three-track depot features space for six vehicles: one track features an inspection pit, another has lifting jacks, with the final track featuring an automated washing plant.

Early tenders were prepared to appoint a lead consultant to prepare all the construction

▲ ABOVE BOTH: A sign of the development along the tramway: Solbjer at the start of construction on 12 March 2017 and on the tramway's opening day, 13 December 2020.

documents for the new facility, however following budget reductions in June 2017 it was announced that the depot would be delayed as the plans were revised. This forced a further delay to the opening of the tramline, from September 2019 to spring 2020.

In January 2018 new plans were completed and a building permit given by the city. However, the first round of tenders saw no bidders – the lower budget, together with the construction demands, was not an attractive proposition to the market. The solution was to divide the tender into two parts, one for ground construction works, including track and electric installations, and one to build the depot itself. This time around Skanska was awarded the first contract, starting work in October 2018, while building of the depot was entrusted to NCC in December 2018 – with construction starting in early 2019.

The striking building also houses the operational control centre and has been designed with the highest environmental best practice in mind, featuring a sedum roof, rainwater collection and solar panelling.

In April 2019, a further inauguration date was given to provide more time to complete the depot –16 August 2020. In October that year, the political steering group was informed that the depot would be further delayed and on 7 February 2020 a new opening date was given – 13 December.

On 1 June last year, Skanska and NCC handed the depot over to Regionfastigheter, the administration responsible for Region Skåne's houses and buildings.

Seven individual trams

In July 2017 all pre-qualified companies received the final documents concerning the procurement of the system's seven trams – including the option for a further three vehicles. Regional transport authority Skånetrafiken (formed in 1999 to amalgamate the transport authorities in the counties of Kristianstads and Malmöhus) specified a standard-gauge 2.65m-wide double-ended vehicle with a length between 29m and 33.5m. At least 70% low-floor, but preferably 100%, the parameters for the passenger saloon included at least 40 seats and capacity for 240 standing passengers (at four passengers/m²).

After the evaluation of bids from both CAF and Stadler, the Spanish manufacturer was selected to deliver seven 100% low-floor, 33m five-section trams of the *Urbos 100* type.

In January 2019, the city announced a naming policy for its new trams, with the public invited to submit suggestions. A total of 484 proposals were received and following a review by a local jury at the end of March it was revealed which names had been chosen and their themes:

- **Knowledge – Sfinxen (01):** A female fairytale creature that adorns the city's university building.
- **Youth – Åsa-Hanna (02):** A book written by Lund-born author Elin Wägner.
- **Innovation – Blåtand (03):** Named after the Bluetooth technology invented in Lund in the late 1980s.
- **History – Brandklipparen (04):** King Charles XII's legendary horse. Charles XII ruled Sweden from Lund between 1716 and 1718.

ABOVE: Track construction underway at Allhelgonakyrkan in May 2018.

Lund's tram depot, pictured shortly after completion in September 2020.

- **Culture – Inferno (05):** A book written by novelist and playwright August Strindberg in Lund in 1897.
- **International – Saxo Grammaticus (06):** 13th Century Danish historian who worked in Lund on behalf of Archbishop Absalon.
- **Humour – Lindeman (07):** Lund student and comedian, Hasse Alfredson's legendary figure.

Vehicle construction had been progressing well, but as the global COVID-19 pandemic started to take its toll on Europe, the national lockdown in Spain forced a pause in the works underway at CAF's facility in Zaragoza in March 2020. This resumed a month later, on 21 April.

To accelerate operator tuition, five driver trainers were sent to Zaragoza in July, and ➤

during the spring drivers and traffic managers had been trained in Stockholm with the assistance of staff from Arriva, which operates the capital's Tvärbanan light rail line.

Shortly after 07.00 on 20 July 2020, tram 02 (Åsa-Hanna) arrived in Lund following just over a week of travel from CAF's manufacturing facility in Zaragoza. Transported by boat from Santander to Göteborg via the Belgian port of Zeebrugge, 02 reached the city by road under a special transport between Göteborg and Lund. Early in the morning of 7 August, the second tram, Sfinxen (01), arrived after completing 5000km (3100 miles) of tests in Spain. Following static tests at the depot, on 17 August Lund's first tram made its debut on the city's tracks. For this run Åsa-Hanna was fitted with foam side profiles, normal practice to test clearances.

Trials and route testing continued throughout September, becoming more frequent from the last week of the month, building up to commercial speed as Åsa-Hanna undertook endurance testing. Car 02 had to run 5000km (3100 miles) in Lund without error so the handover could take place according to the contract; this process had to be restarted a few times, but on 20 November 2020 it was passed ready for service.

The remaining trams were delivered during the autumn and by the December inauguration of the new line six were in the city, with Skånetrafiken taking four (02-05) for initial service.

The infrastructure works in detail

Main works began with an official ground-breaking ceremony on 17 February 2017. This wasn't the 'first excavation', but instead marked the first roll-out of grass as the future tramway would feature extensive green tracks in line with the overall urban environmental enhancement programme.

The real work started in March 2017 when a large number of trees alongside the new tramway corridor were either cut down or relocated; around 300 new trees of nine different types have been planted in their place. On Clemenstorget (Lund C) there was a need to move six established platans (plane) and two lindens to make space for the new terminus; these eight trees were moved to Brunnshög's Vindarnas park (Park of the Winds).

A year later a further three platans and five more lindens were moved from Clemenstorget as plans for the design of the square were modified. The new concept saw the square area raised by 200mm, resulting in more trees moving to Brunnshög.

At the beginning of May 2018, roadworks began with bus routes rerouted in the centre of the city to allow for the relocation of under-street utilities. The first rails arrived from Voestalpine in Linz, Austria, on 11 September; these were shipped to Lund via Berlin where they received rubber encapsulation before installation. Tracklaying began shortly afterwards, undertaken by Anker AB, based in Varberg.

Construction takes the form of U-shaped plastic baskets mounted directly on the superstructure. Since the tramway is double-track throughout, there are four parallel rows, with reinforcement placed in the mould. The baskets are tied together with a track bar to maintain the gauge. On 24 October, rail welding began and on 15 November the first casting of the concrete beams.

On 13 November, the first switches at Clemenstorget were installed. There are three sets of Vossloh switches along the line – at the two termini as well as a transition at Ideontorget – all located on a cast concrete slab.

The preferred trackform replicates that of Freiburg-im-Breisgau in Germany and is designed to sustain the green track during Lund's dry summers; the concrete beam construction also makes it easier to install a range of surfaces between the rails. Space outside the beams allows rainwater to drain slowly, decreasing the risk of flooding by heavy rain.

Although around 80% of the route is laid with grass track – not only absorbing noise and airborne pollutants, but also providing a clear delineation between the tramway and routes for other travel modes – other sections feature granite setts and even concrete at road junctions. All eight junctions are signal-controlled, offering full tram priority.

The grass track is mown during the day, subject to a strict safety regime, and cycle and pedestrian lanes run alongside the full length of the tramway (around 80% of these lanes

➤ **RIGHT: The first CAF *Urbos 100* tram, Åsa-Hanna (02), arrives in the city on 29 July 2020.**

➤ **FAR RIGHT: Blåtand (03) arrived on 12 October and was pushed into the depot using a 113-year-old tram borrowed from the museum tramway of Malmköping.**

"Around 80% of the route is laid with grass track – not only absorbing noise and airborne pollutants, but also providing a clear delineation between the tramway and routes for other modes of travel."

▼ **BELOW: Åsa-Hanna (02) undertakes a test run on 24 October 2020 during the 5000km proving period.**

▲ ABOVE: Tramway installation required a new bridge for the E22 motorway, moved into place on 9 April 2018. The E22 is used by 40 000 cars on a normal day.

◄ LEFT: The finished bridge on 9 January.

▲ ABOVE: The underpass at Tornavägen was built for the busway in 2002, featuring a nice brick wall design .

► RIGHT: A service bound for ESS at Telefonplan, the stylised tramstop's wooden benches and sedum roof are clearly visible.

are new), a further demonstration of the city's commitment to sustainable travel.

New landmark structures

A complicated construction challenge was the replacement of the bridge that carries the E22 highway over the tramway. This major road artery incorporates Sweden's first motorway, linking Malmö and Lund in 1953. The old structure was too low to allow safe passage of trams underneath and too narrow to allow the addition of two further lanes on the highway.

A new 5000-tonne structure was assembled 60m to the east and moved into place following demolition of the old bridge. The whole process required closure of the E22 for two weeks, although through efficient management the new bridge was hoisted into place on 9 April 2018 and the highway re-opened two days earlier than planned.

The unique tram shelter design is based around the theme of movement: one end is rounded to resemble the front of a tram and this end faces in the same direction of travel. Each shelter spans the full length of a tram and also features a sedum roof, sustainably-sourced wooden details on the ceilings and the benches, as well as digital passenger information screens.

Taking an innovative approach, in May 2018 the municipality decided that squares and tramstops should be heated using residual heat from the research facilities MAX IV and ESS; smart sensors determine which surfaces need to be heated and when, reacting to both temperature and precipitation. The platform height is 300mm and each is 45m in length, except for the 33m platforms at Lund C.

In January 2019, the municipality signed a contract with state-owned rail infrastructure manager Infranord for maintenance of the system. Exactly one year before the start of the operation, on 13 December 2019, the tramway was finally approved and handed over to the municipality.

Electrification and EM management

As the new tramline passes two sites which utilise delicate electronic equipment, the hospital and the university, detailed studies between 2014 and 2017 revealed electro-magnetic (EM) sensitivity in these two institutions that could be adversely affected by the new tramway. To address these issues, a system to reduce potential interference was developed by Dutch company Microsim.

Installed on two sections of the route – the intersection between Kävlingevägen and Getingevägen to Ideontorget, and from the roundabout at Odarslövsvägen to ESS – the solution feeds each pole, making the electrical loop as small as possible to reduce EM interference. The main feed is placed between the rails. In every pole there is a patented ➤

STECONFER: POWERING LUND'S TRAMWAY

Steconfer has carried out the complete overhead line installation of the Spårvägen Lund project, including earthing and bonding and the return current management.

This project was very exciting, mostly due to some particular and complex aspects. Along a considerable length of the route, there is sensitive research equipment that, together with the university hospital's X-ray departments, forced the construction of the overhead contact line to minimise the risk of EMF (Electric and Magnetic Fields) affecting those facilities.

This system, the second in the world, consisted of the assembly of section insulators on every console in order to interrupt the electrical continuity of the contact wire in between consecutive cantilevers. This also brought the need to inject current on both sides of all the insulators, section by section, to keep the system energised.

Besides this, inside the depot's workshop, a motorised rigid catenary was installed, improving the safety of tram maintenance. This retractable catenary is specially designed for Lund's rolling stock; its basic function is to physically remove the catenary to allow free access of personnel onto the roof of the vehicles or to lift bogies for maintenance.

The installed system is a 'trolley'-type catenary with mechanical compensation, composed of a hard-drawn electrolytic copper contact wire, supported on cantilevers or cross-spans, including under bridges or across viaducts.

divider, allowing the tram to pass with the current on. This award-winning concept has also been deployed on the new Uithoflijn in Utrecht and on the tramway in Delft.

Electrification works were undertaken by Steconfer, with the system's 107mm² overhead contact wires are suspended from poles 5.5m above the tracks; these are located either between or to the side of the running track. The first masts were erected in Brunnshög in February 2019, with overhead wire installed at Clemenstorget in July 2019 and continuing throughout the summer.

The 750V dc power supply is provided with five evenly distributed substations, built by Eitech in Prague using components from Secheron and ABB, in terms of load, converting 11kV to 750V dc; voltage is allowed to vary between 500V and 900V. The rectifier transformers used are of the dry type of 1100kVA with two secondary windings for a 12-pulse supply. The 12-pulse rectifier for 750V dc has a rated power of 1000kW.

Power is supplied to one of these substations, feeding a loop for the other four. As the sole user of electricity on the line, the tramway is not affected by others, thus minimising the risk of disruptions to service. The five substations can also act as back-ups for each other, with any malfunction in one allowing for power to be supplied from an adjacent installation without causing undue delays to the tram.

The first substation was installed on 4 October 2018, at the MAX IV tramstop. As each weighs 40 tonnes, they were delivered ready for connection and lifted into place with a crane truck. The last was installed between the ESS stop and the depot on 6 December 2018.

ABOVE: The tramway's second substation is lifted into place on 4 November 2018.

ABOVE: The EMC mitigation system uses feeder cables along the rail, feeding the overhead at each pole.

The long-awaited opening

At the start of service, not all trams had been delivered and not all drivers were trained. This meant the timetable until 31 January offered departures every 20 minutes on weekdays and every 30 minutes at weekends.

The seventh and final tram (07 – Lindeman) arrived on 4 January to complete the fleet, allowing the normal timetable to be assumed from 1 February, with trams running to ten-minute headways in the peak. End-to-end journey times are 15 minutes, offering a commercial speed of 21km/h (13mph).

The Skånetrafiken fare system is valid on the tramway, with a single journey priced at SEK27 (EUR2.60) and a 24-hour ticket costing SEK54 (EUR5.20).

Lund's new tramway is an important step in the city's ambition to be carbon neutral by 2030, beating by a full two decades the EU's 'Green Deal for Europe', which aims for the whole continent to reach net zero by 2050. TAUT

ABOVE: At 86m, Brunnshögstorget tramstop is one of the highest tramstops above sea level in Sweden.

ABOUT THE AUTHOR

Per Gunnar Andersson MSc (CE) Dr. Eng is a Founding Partner and Senior Consultant in public transport and urban planning for Trivector AB. Based in Lund, Trivector was founded in 1987 by three researchers, from the Department of Traffic Engineering at Lund University, and now has offices across Sweden.

Per Gunnar is also Chairman of the Museum tramway in Malmö.

"The seventh and final tram arrived on 4 January to complete the fleet, allowing the normal timetable to be assumed from 1 February."

ABOVE: Snow on the ground on 8 January in this view between Telefonplan and Solbjer.

MICROSIM®: MANAGING EM INTERFERENCE

Microsim® has been a consultant and engineer for many rail projects over more than 25 years, with many related to Electromagnetic Compatibility (EMC).

Tramways, like any other electrical system, cause electromagnetic fields in their surrounding environment. Though the power supply of trams and light rail systems are generally referred to as 'DC' (direct current), the reality is far from DC. The instantaneous power consumption of vehicles can and will change almost constantly, as will the magnetic fields caused by the currents. As vehicles move, the currents within the vehicles also move, causing changes in the environment.

The nature of those changes do not cause problems for humans, animals and most electric equipment, but some instruments – especially those used in universities and hospitals – will malfunction in the presence of magnetic fields. In these instances, shielding is no option so the 'conventional' power supply needs to be redesigned to lower the magnitude of the fields below the level of sensitivity of instruments.

For the Lund tramway, Microsim® calculated the magnetic emissions of both the infrastructure and vehicles using 3D modelling tools and designed the necessary modifications to the power supply system. Similar solutions have been designed for tramway systems in Utrecht, Jerusalem and Delft.

> For further details, contact *mark@microsim.nl*