METRO REPORT

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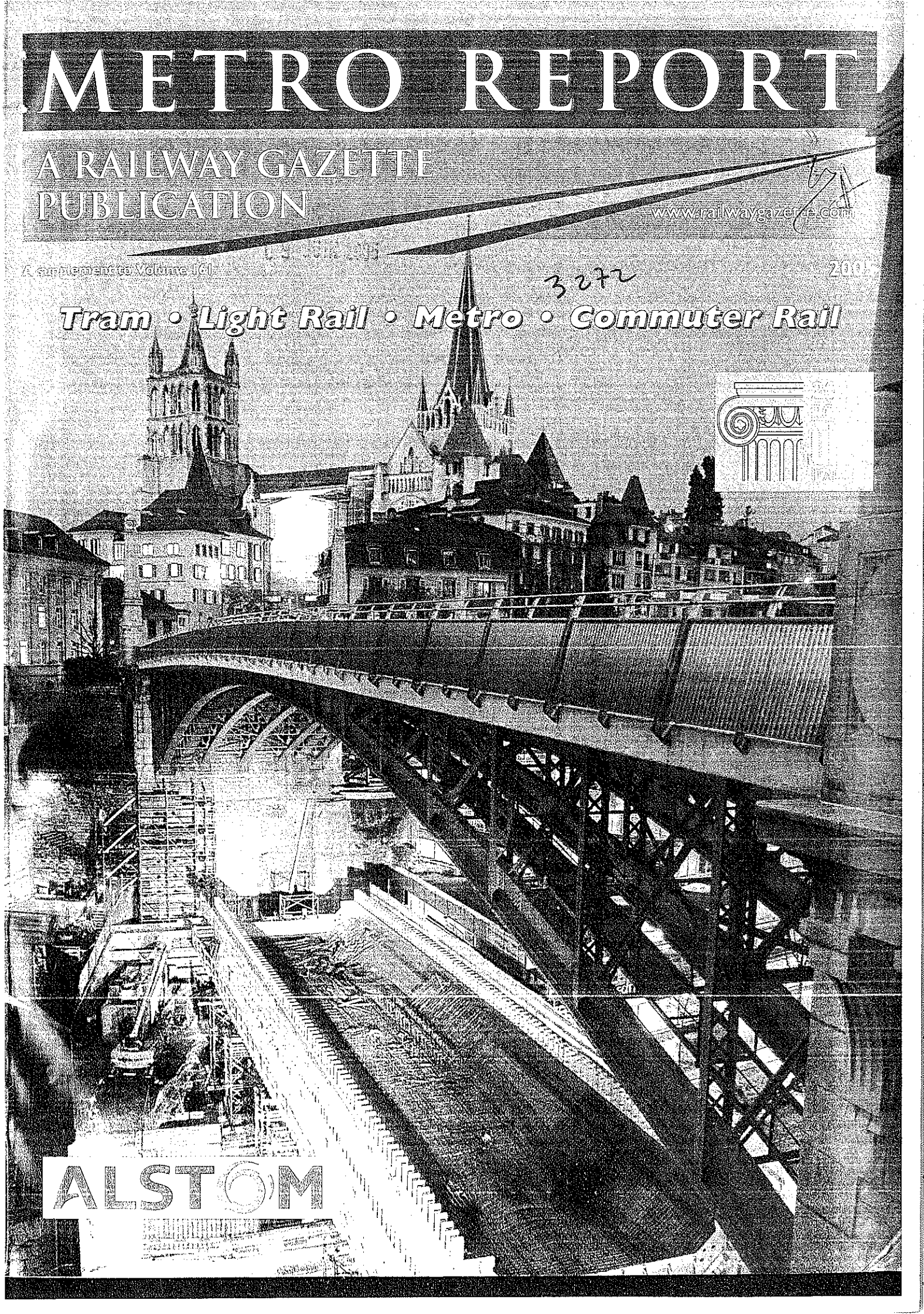
Tram • Light Rail • Metro • Commuter Rail



ALSTOM

Cities benefit from 20 years of urban rail development

THIS YEAR *Metro Report* marks its 20th anniversary, after two decades that have seen some momentous changes in the urban rail sector.

The launch issue of *Developing Metros* in 1985 marked the centenary of the International Union of Public Transport. UITP will be holding its 56th World Congress in Roma on June 5-9 (p5). With a theme of 'Making the Connection', the congress will examine public transport's role in social, economic and environmental policy.

Faced with economic globalisation, urban sprawl and other demographic and lifestyle changes, plus the advent of new technologies, UITP believes that public transport around the world stands at a crucial point in its development.

Many of the articles that have appeared in our pages have demonstrated that targeted investment in urban railways can help to stimulate personal, business and societal growth, as well as tackling environmental concerns.

For example, the cover of DM 85 featured a new train for Seoul, where Lines 3 and 4 opened that year. After two decades of growth, the South Korean capital now has one of the largest and busiest metros in the world. The burgeoning cities of the Far East have largely taken the lead in heavy metro construction, from Korea and Japan to the ASEAN countries and most notably China. Metros in Beijing, Shanghai and Guangzhou are growing rapidly, and further lines are under construction in smaller cities such as Nanjing, Shenzhen and Wuhan (p51).

Another city featured in DM 85 was Madrid, which has gone on to treble the size of its metro, developed an extensive suburban rail network, and is embarking on a third round of expansion. This includes four light rail lines, reflecting a mode that has become the major focus in many western cities today. More versatile and generally cheaper to build, light rail is capable of handling very substantial flows, as demonstrated in Montpellier (p35). Highly-visible surface routes, often allied to urban renewal, offer an enticing vision of modern, efficient and sustainable transport.

A major contributor to this trend has been the low-floor car, which made its first tentative appearance as recently as 1987. Since then we have seen a bewildering range of technical innovation, but with total orders approaching 5 000 vehicles the emphasis is on modularity and customised system cars (p55).

It is clear that the broad spectrum of urban rail – from commuter trains through metros and light rail to trams – has much to offer. But quality of life and environmental benefits are not always easy to quantify. Today, perhaps more than ever, there is a public and political awareness of value for money, which in many cases is enshrined in commercial operating contracts or concessions. Promoters, operators and suppliers need to ensure their products and services are economically attractive if rail is not to price itself out of the market, to the detriment of all. ■

METRO REPORT

A Railway Gazette yearbook

Railway Gazette International,
Quadrant House, Sutton,
SM2 5AS, Great Britain

Tel: +44 20 8652 8608
Fax: +44 20 8652 3738
e-mail: railway.gazette@rbi.co.uk

Editor-in-Chief: Murray Hughes BA

Editor: Chris Jackson BSc FCILT

Contributing Editors:
Robert Preston MA
Andrew Grantham MSci
Richard Hope OBE CEng MIEE MIMechE

Advertisement Manager: Sheena Rennie

Subscriptions Sales Executive: Franck Chardon

Journal Assistant: Sarah Jackson

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Tel: +44 1444 475630
Fax: +44 1444 445447
e-mail: railwaygazette.subs@qss-uk.com

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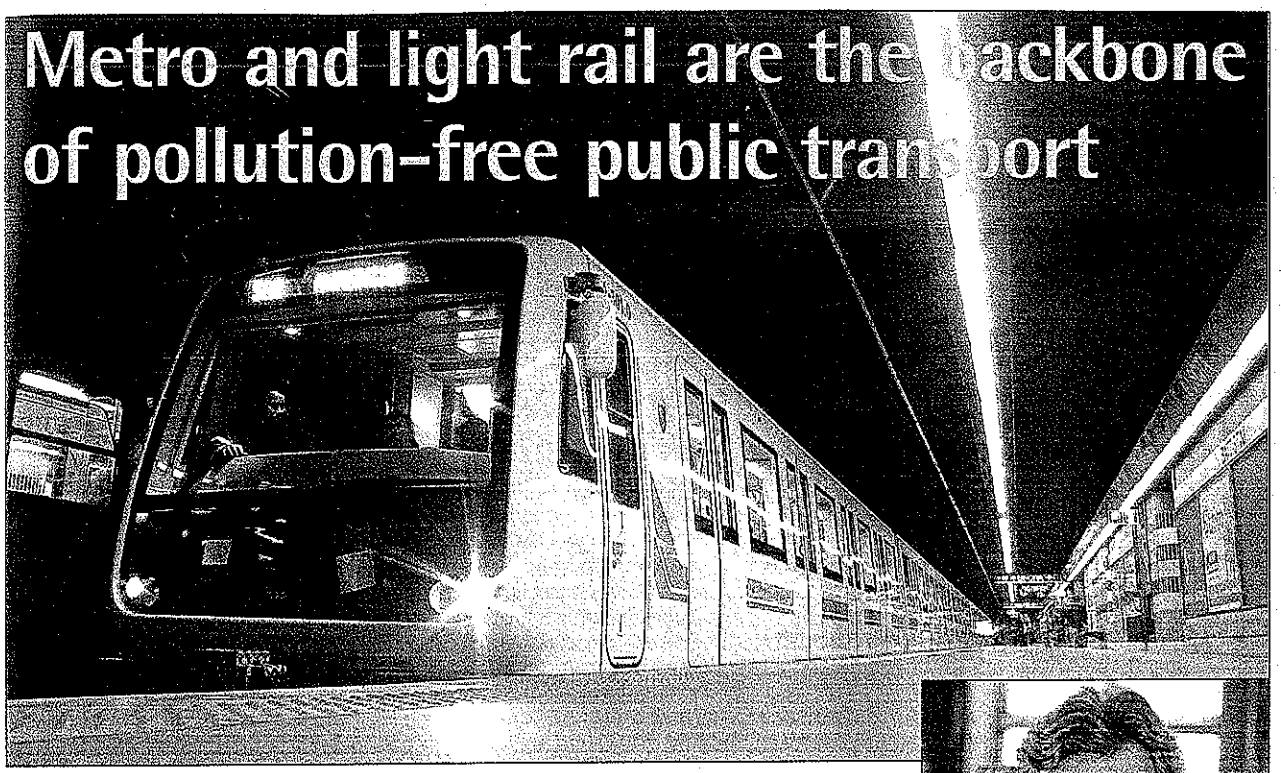
METRO REPORT

1985 - 2005

Front Cover:

Alstom is helping Lausanne to manage the four-year project to develop automated metro line M2, replacing existing infrastructure and building a 5 km extension. Alstom is supplying track, signalling, substations and engineering support, plus 15 two-car rubber-tyred trains. Commercial services are due to start in the second half of 2008

Metro and light rail are the backbone of pollution-free public transport



The host city for this year's UITP World Congress is expanding its rail networks, including construction of two automated metro lines

Roberto Cavalieri
Managing Director, Met.Ro SpA, and Chairman, UITP European Committee; formerly General Manager, ATAC SpA

SUSTAINABILITY is the theme which characterises nearly every action taken by Roma's public transport authority ATAC. It runs through all aspects of our business like the name in a stick of seaside rock.

Our vision is clear: a modern public transport infrastructure, with an innovative and clean fleet, offering new services to customers to meet all aspects of social responsibility. At the same time, we need to strengthen the relationship between public transport and private vehicles by linking urban transport and traffic regulation policies. In a nutshell, this is the future that ATAC is preparing for the citizens of Roma.

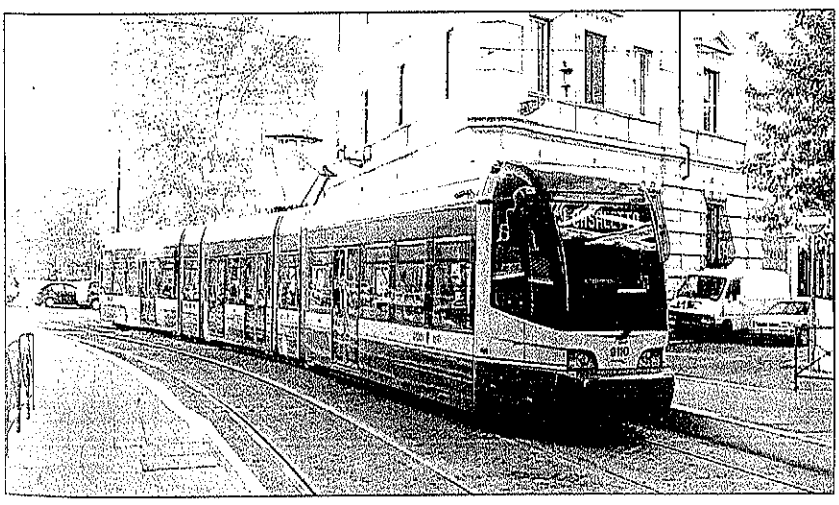
We are particularly delighted to be hosting the UITP World Congress and the Mobility & City Transport Exhibition in Roma this year, as we are sure that the delegates and visitors will find plenty of public transport innovations to see and discuss during the event.

Structural change

The Italian capital's public transport sector underwent a major restructuring at the end of the 1990s to meet the requirements of new European legislation. But ATAC SpA remains at the heart of the Eternal City's 'Mobility System'. In December 2000 the former unitary municipal authority was transformed into an agency, charged with planning and control of all public transport. This is structured as a joint-stock company, although it remains wholly owned by the municipality.

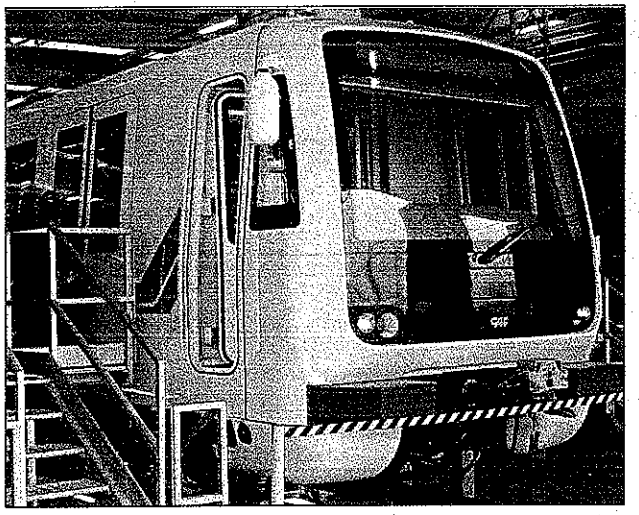
ATAC is about to undergo another major change, as it will soon be merged with STA, the municipal body responsible for congestion monitoring, traffic signals and on-street parking charges throughout the city. Putting together the planning of public and private transport will bring better traffic co-ordination, allowing us to implement a strong integrated policy to reduce pollution, traffic congestion and noise.

The change has the full co-operation of the other municipal-owned companies which share in the operation of Roma's public transport. The largest of these are



TOP: *The first of 33 six-car trainsets being built by CAF entered service on Line A earlier this year* Photo: David Campione

LEFT: *After years of decline, Roma's tram network is undergoing a renaissance, with two generations of Cityway low-floor cars acquired to work new and reopened routes*



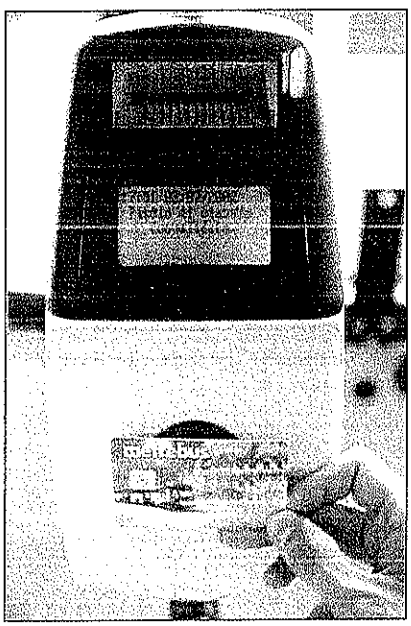
Met.Ro expects to concentrate the new CAF trainsets on Line A, cascading older stock to Line B and the Roma – Lido railway

Trambus SpA, which runs the tram network and most bus routes, operating 112·5 million vehicle-km last year, and Met.Ro SpA, which manages metro lines A and B plus the local railways to the coast at Ostia (Roma – Lido), towns north of the capital (Roma – Viterbo) and the Castelli Romani area (Roma – Pantano).

The group of municipally-owned companies is completed by Roma Metropolitane srl, which is responsible for the planning of new metro lines, appointing contractors and negotiating project finance, as well as managing construction work. In addition, private bus operator Ati Sita won several contracts during the tendering process. Ati has only a minor stake in the Roma network, but with 26·7 million vehicle-km per year its activities are on the same scale as the entire public transport network in Firenze, for example.

Legal ownership of all municipal infrastructure and rolling stock is vested in ATAC, giving the agency clear responsibility for long-term policies and a strong role in ensuring that the network functions reliably. This role became even stronger earlier this year, when the municipal Transport Department signed 'single service' contracts with each agency and operator, assigning the public transport operations to Trambus and Met.Ro for the next seven years.

As owner of the bus and tram fleets, depots and metro stations, ATAC can decide what innovations are needed. As it is also responsible for the municipal mobility management and car-sharing policies, the company is well aware of the needs of Roma citizens. Faced, too, with constant cutting of public finance for local transport, ATAC has developed a series of innovative funding activities. In 2003 we issued a tranche of Eurobonds, now given a long-term rating of A+ and an A- short-term rating by Standard & Poor's. In 2004 ATAC SpA became the first Italian operator to participate in a US cross-border leasing agreement.



The Metrobus smart card ticketing system has enabled ATAC to develop a range of social and market-led ticketing promotions to encourage greater use of public transport

Sustainable mobility

The forthcoming merger of ATAC and STA will bring a new impetus to the important task of developing sustainable mobility in Roma, creating an effective instrument to regulate all aspects of mobility around the city.

The merger will help to reinforce the municipality's policy of discouraging people from using private cars to travel to work in the centre, shifting them onto a public transport network that is set to grow steadily over the next few years with new metro lines and pollution-free surface transport in the heart of the city. The merger will also build on the principle that higher charges for highly-polluting private vehicles should help to pay for public transport, creating an interdependence for the sake of the city and its residents.

Nevertheless, ATAC is still primarily a public transport agency. After a strong effort over the past five years to lower the average age of Roman buses from 12 to six years, what has been called in the past 'ATAC's dream' is now close to becoming a reality: pollution-free public transport in the historic city centre. This environmental commitment is also linked with a social one, in that 60% of the buses can now be accessed by people in wheelchairs; a much higher percentage than is required by law.

But the concept of fully-accessible transport takes on another meaning when applied to fares and ticketing. Despite the backdrop of decreasing public funding for local transport, Roma municipality and ATAC have been able to establish a 'social' fares structure with special rates for unemployed people and low-income families as well as the more usual concesions for students and senior citizens. There are also special cut-price rates for a second annual season ticket purchased by members of the same family. These innovative principles have also been adopted by the Province of Roma for student and long-distance commuter fares which it supports.

Underground revolution

The next few years will see a silent revolution on the Roma metro. At long last, after many years of debate, work is about to get underway on a third line. This will break away from the present X-shaped system, with only one interchange at Termini, and start to create a genuine network.

For historical reasons, both in terms of politics and the need to preserve the archaeology of the city, Roma has only been able to develop two metro lines. Ironically, Line B is the older, with the 11 km Termini – Laurentina section dating back to the World Expo in 1955 and the northeastern section to Rebibbia following in 1990. The 14·5 km first stage of Line A between Anagnina in the south and Ottaviano in the northwest began running in 1980, and a 4·5 km extension west to Battistini was completed in 1999-2000.

A financing package has now been put in place for Line C. The Italian government agreed at the end of December 2004 to fund 70% of the anticipated €3bn cost, with Roma municipality contributing 18% and Regione Lazio the remaining 12%. The newly-formed project management company Roma Metropolitane is tendering for a general contractor to build the line, and we hope that work will start by mid-2006, so that the first section will be ready to open for revenue service in 2011.

Line C will be 25·8 km long with 30 stations, with 17·9 km underground and 7·9 km on the surface. It will provide a direct connection between the existing metro lines and the populous areas east of the centre as far as the Grande Raccordo Anulare – Roma's motorway ring. At the other end it will serve the business district of Prati/Mazzini west of the Tiber. But most important of all, it will serve the historic city centre, which today can only be reached from the Line A station at Piazza di Spagna or from Line B at Colosseo.

The new line is being designed for driverless operation. The stations are planned as archaeological museums, similar to the strategy adopted for the new metro stations in Athens. Line C will interchange with Line A at San Giovanni, just inside the second ring of the ancient Roman city walls, and at Ottaviano-San Pietro which is the station serving

Vatican City. Interchange with Line B will be provided at Colosseo, right beneath the city's well-known monument.

Line C will intersect with tram Route 8 at the archaeological site of Largo di Torre Argentina, with Route 19 at Piazza Risorgimento, and with Route 3 near Colosseo. Another important surface connection will be with two battery-electric bus routes: 116 on Corso Vittorio Emanuele II and 119 at Argentina.

The first stage of Line C will run underground from Colosseo through San Giovanni and Malatesta to Torre Spaccata in the eastern suburbs. Here it will surface and take over the alignment of the 950 mm gauge Roma – Pantano line, which is now being upgraded. The second stage – to be completed after 2011 – will run northwest from Colosseo through Ottaviano to Clodio/Mazzini and Vigna Clara. In the longer term, there are also plans for a branch from Teano to Colli Aniene, designated Line C1.

With traffic on Line C projected at 600 000 passengers/day, a fleet of 43 six-car trainsets is to be ordered at an estimated cost of €280m. Operating at up to 80 km/h, each train will have seats for 300 passengers and standing space for a further 900. The long-term plan is to build a new depot and workshop complex at Tor Vergata, reached by a short branch from Torre Angela. In the initial stage, the Line C trains would be kept in stabling sidings at Pantano, and use a connecting curve at San Giovanni to reach the Line A depot at Osteria del Curato for maintenance.

Northeast and southwest

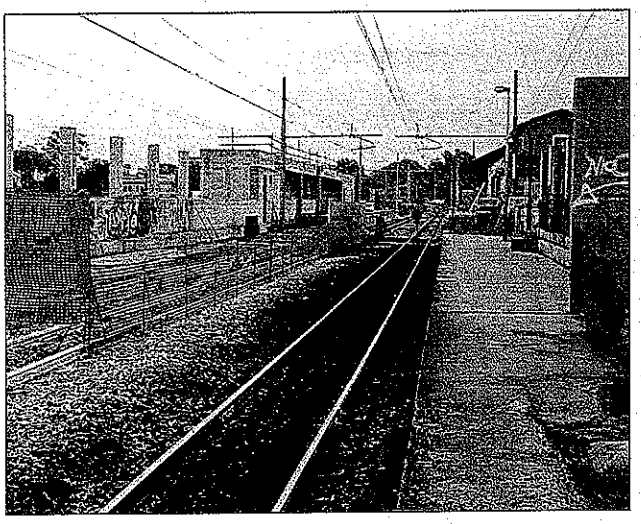
The metro web is also set to spread in the northern part of the city, where work is expected to start in October on the construction of Line B1. This 3·8 km branch from the Line B station at Bologna to Conca d'Oro will have three intermediate stations at Nomentana, Annibaliano and Gondar.

Planned to start operation in 2010, Line B1 will serve the boroughs north of the Aniene river, which together have around half a million residents. Cost of the project is put at €453m, of which 60% will be covered by the Italian government and 40% by Roma municipality.

In the longer term, Line B1 would be extended north from Conca d'Oro to meet the motorway ring. There would be stations at Viale Jonio, Val Melaina, Via Cervialto, Serpentara and Buffalota.

Planning is also getting underway for an extension of Line B south from Laurentina to Tor Pagnotta, with four stations to serve the Divisione Torino and Cecchignola areas, after this was approved by the city government in January. These extensions to lines B and B1 would add a further 24 route-km.

At the same time, the government authorised the start of planning for two extensions to Line A. One would run southeast from Anagnina to Romanine, near the University Campus at Tor Vergata, with intermediate stations at Tor di Mezzavia and Ponte Linari. The other would run northwest from Battistini to Casal Selce, with stops to serve the suburbs of Bembo, Torrevecchia and Casalotti.



Stations along the outer section of the 950 mm gauge line to Pantano are being rebuilt with high platforms and wider track spacing ready for conversion to standard gauge when the route becomes part of metro Line C

Along the Tiber

Roma Metropolitane is also working on plans for Line D, and recently published the results of a feasibility study for a 18·9 km line with 24 stations. The city administration hopes to push ahead with this scheme to a much shorter timescale than is being achieved with Line C.

The fourth line is intended to knit together new parts of the web, offering a second north-south metro connection across the city centre. It would also be fully automated, and would run entirely underground.

Planning of Line D is being undertaken in three sections. At the southern end, the first 2·8 km will start from Piazzale dell'Agricoltura and run to Lungotevere Dante, connecting with Line B at Eur-Magliana and passing under the Tiber twice to serve the southwestern suburbs. This section would have four stations.

The 10·8 km central section with 13 stations would pass under the Tiber again to interchange with Trenitalia at Trastavere, and then parallel tram Route 8 north to Argentina, where it will interchange with Line C. It would continue under the city centre to connect with Line A at Barberini and pass under the Villa Borghese park to reach Verbano and Villa Chigi.

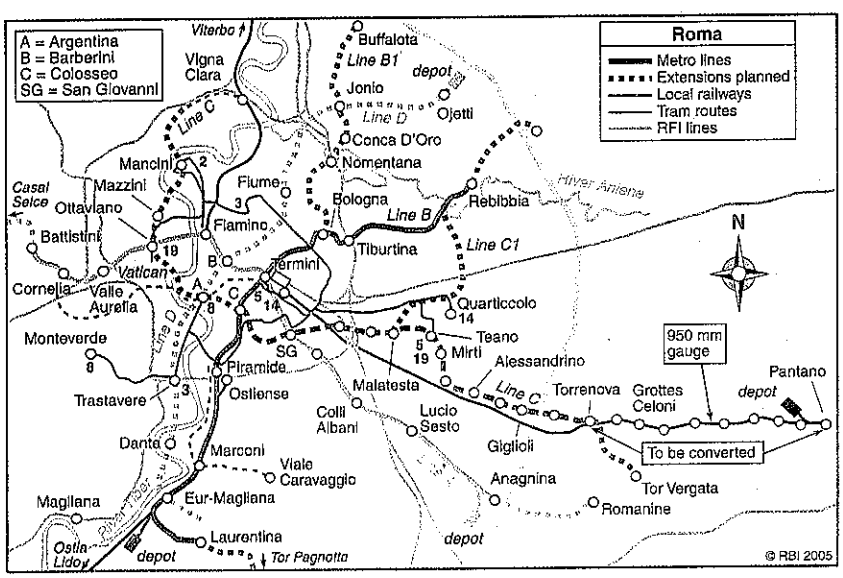
The final 5·5 km with seven stations would continue northeast to interchange with the proposed Line B1 extension at Jonio and then turn east to terminate at Via Ojetti in Montesacro, where the depot would be located.

Line A gets a facelift

Meanwhile, metro Line A is undergoing a major upgrading which is expected to take three years. Every night the services stop running at 21.00, and the late evening trains are replaced by shuttle buses so that the track can be renewed. The stations are also being refurbished, which we hope will eliminate the extensive graffiti that has plagued the network in the past few years.

In April passengers on Line A were able to sample the first of 33 new six-car trainsets being supplied by CAF of Spain under a €230m contract awarded in 1999. The first train arrived in January 2005, with deliveries continuing at one train a month until June and then stepping up to two per month until the final unit arrives in August 2006. Met.Ro expects to have all 33 sets in service by October next year.

The current rolling stock strategy envisages that the new trains will take over all services on Line A, cascading the existing fleet onto Line B. This in turn will release the present Line B stock to



Inaugurated in 1998, Route 8 currently terminates next to the archeological remains at Largo do Torre Argentina, but ATAC plans to extend the line through the city centre to Termini

operate the Roma – Lido interurban railway, which is currently being worked by the 1955 trainsets ordered for the original Termini – Laurentia metro line.

Tram revival

Augmenting the metro are six tram routes operated by Trambus SpA. Only four run-down and under-used routes survived after the bulk of the traditional network was closed in the 1950s, but since then two more lines have been opened and the tram network has seen a revival as a high-capacity and environmentally-friendly mode.

In 1990 tracks were reinstated along Via Flaminia, and a new Route 2 introduced between Porta Flaminia and the football stadium at Piazza Mancini. This was the first route in Roma with tram priority at the traffic lights and a fully-segregated right of way laid out to light rail standards.

The same year saw the purchase of 30 new low-floor cars from Socimi to operate on Route 3. The remaining half of a former circle line, this busy orbital route connects Trenitalia's Trastevere station in the south to the art museum at Valle Giulia in the northeast via Colosseo, the eastern suburbs, the university and the main hospital.

The northeastern part of Route 3 is shared with Route 19, which starts at Via Porta Togliatti in the eastern suburbs and continues past Valle Giulia to connect with Route 2 near Porta Flaminia. Route 19 terminates outside the north wall of Vatican City. Serving a very busy neighbourhood, full of offices and shops, it carries a heavy flow of commuters and tourists, and is worked by Cityway Roma I low-floor cars supplied by Fiat Ferroviaria in 1998-99.

Sharing tracks with the eastern end of Route 19 is Route 5 from the main station at Roma Termini to Viale Palmiro Togliatti. The busy Route 14 from Termini also shares these tracks for about 80% of its length, before diverging to serve Piazza dei Gerani.

The newest tram line is Route 8, which was inaugurated in March 1998, once again built to light rail standards and fully segregated from road traffic. Route 8 runs from the residential neighbourhood of Gianicolense in the southwest to Largo di Torre Argentina in the city centre, serving several hospitals, ministries and schools. Route 8 is also operated by Cityway cars, primarily the Roma II version built by Fiat Ferroviaria and Alstom in 1999-2003.

Top priority is an extension of Route 8 from Largo di Torre Argentina to Termini. This will transform today's bus corridor along Via Nazionale into a modern light rail reservation. There are some concerns over visual intrusion, so ATAC has suggested to the city government that the extension should not have overhead cables, but introduce to Roma the concept of ground-level power supply. Meanwhile, plans are taking shape for a new tram-metro interchange at Termini bringing together lines A and B with routes 5, 8 and 14.

Another new route would share the planned tracks from Termini along Via Nazionale, but would continue north-west beyond Largo di Torre Argentina to St Peter's Basilica and Vatican City. In the longer term this route would be extended beyond San Pietro to Piazza Giureconsulti in the densely-populated northwestern suburbs, using the existing segregated bus lanes in Via Gregorio VII and Circonvallazione Cornelia.

Planning is also continuing for the so-called Caravaggio Line from Piramide on Route 8 to the Viale Caravaggio. Connecting Ostiense and Marconi, this would serve the western suburbs of Garbatella, Tor Marancio and Montagnola, partly following the former Route 11 abandoned in 1972. Building of this line is linked to the construction of a planned new tram depot near the Tiber at Ponte Marconi.

Electric innovation

Other forms of electric surface transport are also set to expand, as part of ATAC's environmental strategy. Following our positive experience with 20-seat electric minibuses in Roma's narrow streets the battery-electric bus fleet – already the biggest in Europe – is to be nearly doubled. The new vehicles will have twice the capacity and more power to climb up and down the seven hills.

March 23 saw the return to Roma of trolleybuses, after an absence of more than 30 years. The new-generation vehicles will operate Line 90 Express, using conventional overhead wires outside the central area but running on batteries in the historic streets of the city, where they pass the ancient monuments and archaeological sites.

By the end of the year, another clean bus family will make its debut, when methane-fuelled vehicles are added to the electric network, operating on routes relieving the main orbital traffic corridors.

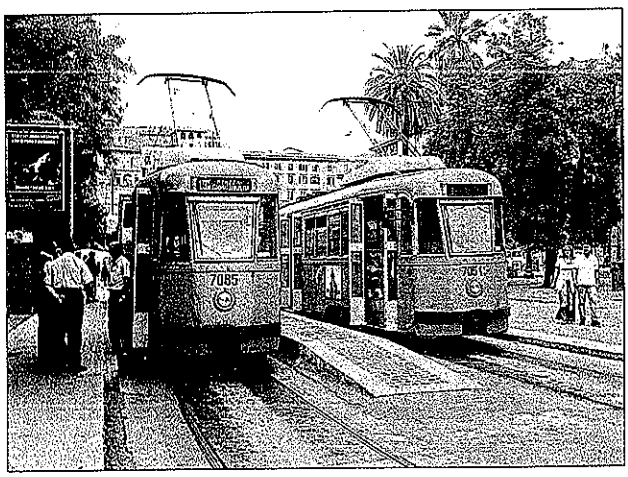
These innovations will enable ATAC to provide environmentally-friendly surface transport throughout Roma without conflicting with the interests of those who protect the unique nature of our historic city. By 2008, around 60% of ATAC's tram and bus fleet will be 'clean' vehicles, and most of the rest will meet Euro 4 emissions standards.

Communications platform

Ambitious plans need to be communicated. Therefore, ATAC SpA has transformed its Press Office into an innovative, multimedia communications platform. As well as the usual communications tasks, Roma's Mobility Agency now provides a daily *Trasporti & Mobilità* page in the Roma edition of the *Metro* newspaper.

In the metro stations on both lines A and B, and in the Forum Termini shopping centre below the Trenitalia terminus, we also broadcast news for commuters seven days a week as RomaRadio – The Tube Station. We will soon extend its reach using displays in the newest buses and at the interactive stops which are now being tested across the city. Another innovation is 'InfoAtac', which provides news and information to handheld PDAs and on the internet.

The Italian word 'trasportare' is not translated simply as 'to transport'. It also means 'to carry along with enthusiasm', and that is certainly what we mean to do for the citizens of Roma! ■



The Route 19 terminus at Piazza Risorgimento lies close to the northern side of Vatican City, a few minutes walk from St Peter's Square

Funding law drives urban expansion

Restructuring of Italy's public transport sector has focused attention on the need for increased capital investment. Since new funding legislation was approved in 1992, many metro and light rail lines have opened, and more projects are taking shape around the country

Dr Marco Puiri
President, Railway Section
Italian Public Transport Association (ASSTRA)

THE ITALIAN public transport sector is currently undergoing far-reaching changes, with deregulation and the introduction of competition. Today, more than ever, traffic congestion and pollution demand that bold choices are made to improve the quality of life in our cities.

In the urban sector, the most notable change is the requirement to put transport production – that is operation of services – onto a contract basis. To achieve the long-term objectives behind this restructuring, it is proving essential to optimise the relationships between the many players in the process.

Many companies are undergoing radical internal reorganisation to be ready for the advent of competition. This is mirroring the changes in other European Union member states which are separating the social, political and planning functions of public transport from the commercial operations through a contract structure.

As the changes start to work through, it has become increasingly apparent that considerable investment is needed to modernise the urban transport infrastructure, including for example reallocation of road capacity between public and private transport. The bulk of capital investment in transport over many years has been dominated by the road sector, and it is now widely recognised that it is essential to redress the balance.

Financing unblocked

A major step towards increasing the level of investment in urban public transport came in 1992 with the passing of Law 211, 'Interventions in the field of mass rapid transit systems'. In fact, this followed, and built on, earlier legislation – in particular Law 910 of 1986. These measures were accompanied by other legislation covering the construction of strategic public infrastructure and providing finance for the various projects.

Law 211 has focused on tackling urban congestion by boosting the construction of express tramways, light rail lines, metros and local railways, both within cities and to link them with nearby traffic generators such as airports, universities and hospitals.

Most schemes are authorised on the basis of co-funding by the national and local governments. The municipal administrations are then responsible for awarding contracts to private companies for the construction and operation of the various new lines.

To qualify under Law 211, a project must first be approved by the national fund allocating body CIPE. Once the initial planning has been completed, the project is presented to an inter-departmental commission for technical and economic evaluation. Only after the final drafting of the project plan and its approval by the Ministry of Infrastructure & Transport are the funds allocated and the tendering process started.

This can be a lengthy process, but it is intended to ensure sound project engineering before the commitment to go ahead is given. Another benefit is that once approval has been given by the various institutions, this strengthens the applicant city's ability to seek matching support from the European Union and international funding bodies.

A great many projects have already been approved within this investment framework, and others are currently under study. They are all expected to contribute to a radical change in the mobility of our country. The variety of projects now underway is considerable, and this article can only provide a few examples as a snapshot. It is also worth pointing out that the situation can change in the short term, and frequently does, because of the high degree of ferment within the transport sector.

Capital leads the way

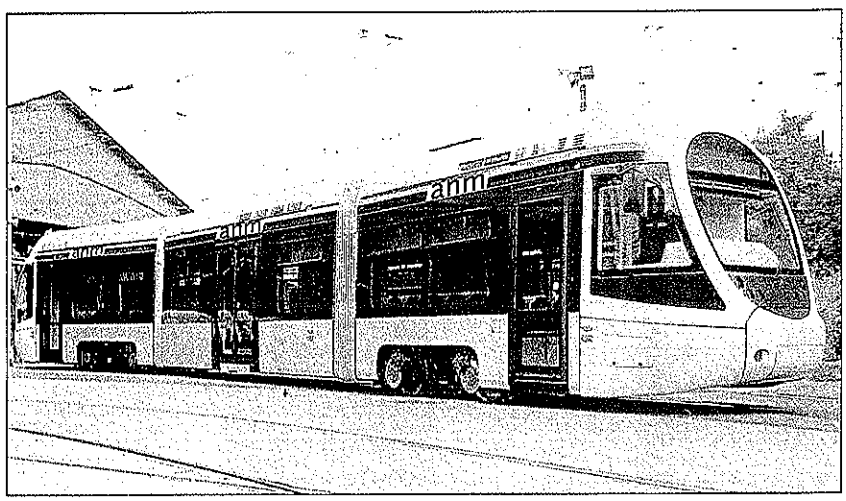
Epitomising the changes now sweeping through Italy's public transport sector is the renewed emphasis on urban rail expansion in the capital (p5). It has been said that the future of Roma's road network lies in the tunnels of its metro network. The ambitious goal is to expand the metro from 36 km to 87·3 km, and double the average daily ridership from 860 000 to 1·7 million.

Work is already in progress on a major upgrading of Line A, which will culminate in July 2006 with the entry into service of the last of 30 new six-car trainsets.

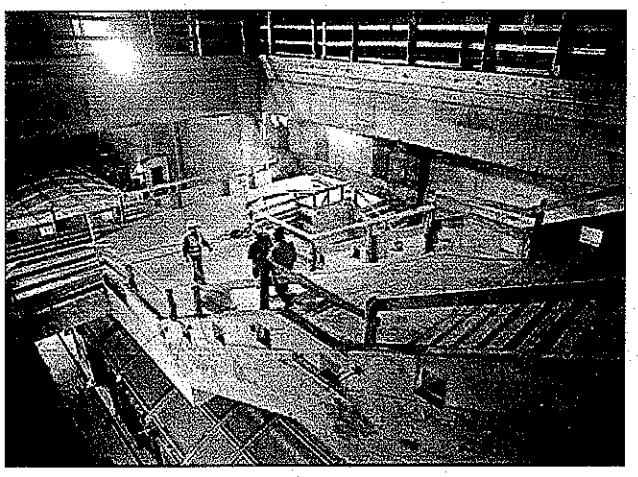
On Line B, a new branch is under construction which is designed to carry up to 24 000 passengers/h in each direction. The superbly-engineered infrastructure has been designed to minimise urban intrusion during the construction phase, when both car and bus traffic will have to be rerouted. The spacious stations will be fully-accessible, and designed to the latest functional specifications to serve the greatest number of residents, as well as providing convenient interchange to other modes.

The latest station designs will also feature on the long-planned Line C, which will eventually run for 42 km from northwest to southeast across the capital. After many years of debate, tenders were called on February 14 this year for the so-called 'main trunk' section of Line C, which will run for 25·8 km serving 30 stations.

The line will run underground for 17·9 km, at a depth of 25 to 30 m



To renew its tram fleet, ANM of Napoli is putting into service 22 Sirio 3C2 cars being supplied by AnsaldoBreda. The shortest Sirio cars yet built, these 21·6 tonne Bo 2 cars are 19·4 m long and 2 300 mm wide, with seats for 31 and room for 83 standing passengers
Photo: Harry Hondius



Fitting out work is well advanced at stations on the first section of Torino's automated metro line, which is scheduled to open by the end of this year, ready for the city to host the Winter Olympic Games early in 2006

below street level. To minimise construction risks, proven excavation techniques have been specified. Work on the project is being phased for practical engineering reasons as well as the innovative financing procedures. The 7·9 km surface section at the eastern end of the line will follow the alignment of the narrow-gauge Roma – Pantano line, where conversion to metro standards is to be completed by the end of this year.

Line C will be the first in Roma to adopt fully-automated operation, with platform screen doors at 30 of the planned 42 stations. Automation has already been adopted for metro lines now under construction in Milano, Torino and Brescia, having proved cost-effective and flexible in other cities such as København, Singapore, Paris and Lille. Thanks to automation, operator Met.Ro expects to run the whole of Line C with just 20 people on each shift.

Automation is also envisaged for Line D, which will run for 22 km serving 24 stations. Planning for this line is being accelerated, and Roma's transport agency Atac envisages that the project financing notice for the 14 km first section with 14 stations will be published in the spring of 2006.

VAL in Piemonte

Italy's first driverless metro is on course to open at the end of this year, with the inauguration of the first section of the Torino light metro. The 8·4 km underground line from Porta Nuova to Collegno is part of a programme of improvements to public transport in the Piemonte region ahead of the 2006 Winter Olympic Games. Other projects include completion of the Lingotto – Dora cross-city railway tunnel, extension of tram Route 4 (MR 02 p51), upgrading of the local railway serving Caselle Airport and creation of a new transport interchange at Porta Susa station.

The last section of running tunnel was holed through at Porta Nuova on March 18, and many of the cut-and-cover station boxes are already being fitted out. The first part of Line 1 between Collegno and the city centre is on schedule to open by the end of this year, and the remainder will be operational by December 2006.

After a thorough review of existing metros around the world, the city of Torino opted for VAL automatic light metro technology using 2·08 m wide cars. This was ideally suited for fitting into the existing urban environment and offered a design capacity of 15 000 passengers/h in each direction.

The initial line will serve 15 stations, of which 12 will be built to a standard design. Throughout Line 1 there has been an attempt to achieve aesthetic consistency with a uniform spatial design for the stations. Wide open spaces offering good accessibility have been laid out to minimise walking distances in the stations and access passages. All internal walkways and waiting areas are equipped with CCTV to ensure personal security. Platforms will be 60 m long and 19 m wide, typically 15 m below street level. The entire operation, including start-up and shut-down each day, will be supervised by staff in the Operations Control Centre, using remote control technology. They will also have video surveillance equipment to monitor passenger movements and announcement systems to provide information and assistance. Other safety measures incorporated into the metro design include platform screen doors at all stations, emergency walkways in the tunnels and easily-accessible evacuation ramps. Stations and trains will also be fitted with fire detection and suppression systems.

Suburban expansion

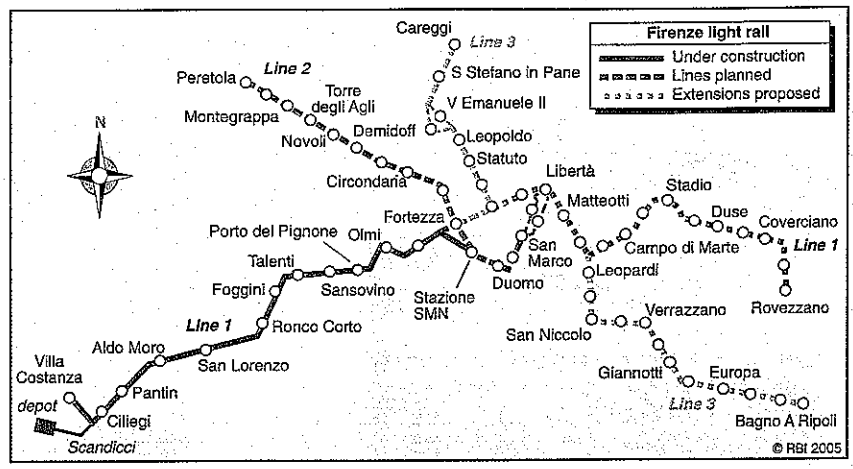
Independent and regional railways are also benefiting from investment in urban mobility. For example, in Bari 10 new stations are being built along the Ferrovie Appulo Lucane, which will be served by a metro-frequency service between Bari and Matera. Trains will continue through a new tunnel under the city centre to stations at Policlinico and Bari Centrale, where the line will interchange with Trenitalia.

In Napoli, Ferrovia Circumvesuviana has completed a number of renovation and expansion projects since 2000. New trains have been put into service, and the signalling renewed. A new line from S Giorgio a Cremano to Vollo connects with the Napoli – Nola – Baiano line to create Line 3 of the regional metro network, forming a ring around the eastern side of the city. A new line from Alfalancia to Acerra links the administrative and business districts in central Napoli with the densely populated

Ferrovie Appulo Lucane is upgrading its line between Bari and Matera, where 10 new stations will be served by a metro-frequency suburban service; this will connect with Trenitalia via a new tunnel to Bari Centrale

Photo: David Campione

Construction has started on the initial 7·5 km light rail line between Firenze and Scandicci, which will be expanded to form a three-line network over the next decade



suburbs around Acerra, where many industrial plants are located.

Light rail revival

Another innovation resulting from Law 211 funding has been the implementation of modern light rail networks, mirroring developments in other European countries. Light rail is starting to make a major contribution to mobility in urban areas. As well as providing fast and reliable public transport that offers a real alternative to the private car, it is helping to reduce the isolation of specific areas and revitalise run-down districts.

A good example is the city of Bergamo, where the long-term plan is to develop a dense network across the whole city, as part of a strategy to change the balance between public and private transport modes. The project is based on the concept of interoperability of trains, trams and light rail, creating an interconnected network where each system retains its own peculiarities. In particular, the introduction of tram-train vehicles will allow existing railway services to penetrate better into the city centre and reduce the need for passengers to change modes.

Tramvie Elettriche Bergmasche has selected the construction consortium CCC to build 12·6 km of new line, which will form the basis of two routes.

Proposals to introduce light rail in Firenze reached a critical point in May 1999 when the municipal government signed an agreement to provide funding to local transport operator ATAF for construction of a network that will eventually cover most of the urban area and several adjoining municipalities.

After a false start, a consortium led by Paris Transport Authority's international subsidiary RATP Développement was awarded a 30-year concession in December 2004 to design, build and operate a three-line standard-gauge network which will eventually total 29·5 km (RG 1.05 p10). Other partners include civil engineering groups CC, Baldassini and Tognozzi, plus Ansaldo and Alstom who will be responsible for the vehicles and E&M systems.

Construction of the first 7·5 km is now underway, after a start-of-work ceremony on December 1. The route from Santa Maria Novella station to Scandicci is expected to open in 2007, serving 15 stops. Line 2 from Peretola Airport to Piazza della Libertà and the first section of Line 3 from Careggi Hospital to Viale Strozzi will open the following year. In the longer term, Line 1 will be extended to Rovezzano.

Tram-train in Sardinia

Meanwhile, Gestione Ferrovie della Sardegna is pushing ahead with two tram-train projects to improve the penetration of existing railway lines into the centres of Sassari and Cagliari.

Sassari has already started a provisional passenger service on its first 3·3 km route linking the FS station in the west of the city with Emiciclo Garibaldi in the east, running around the south side of the central area. The line has 2·5 km of new grooved-rail track laid in the city streets and uses 0·8 km of existing 950 mm gauge FdeS line.

Built at a cost of €19m, the route is single-track, with passing places at each of the seven stops. It is worked by four Sirio low-floor cars from AnsaldoBreda, which were delivered in 2002. Each car can carry 51 seated and 150 standing passengers.

In due course, work is expected to get underway on a second line, which is expected to be completed by 2010 at a total cost of €78·2m. This 9·2 km route will also start from Sassari FS station, and will run to Li Punti and Bandica, serving 12 stops.

Meanwhile, Skoda has been awarded a contract to supply six bi-directional five-section Astra 06T cars for use in Cagliari, with an option for a further seven. These dual-mode cars will be able to carry up to 220 passengers in total, of which 44 will be seated. Work is already underway on the first of Cagliari's two planned lines. This 6·4 km route with seven stops makes use of an existing railway alignment, and is scheduled for completion in 2006, so that a provisional passenger service can begin in 2007. The Gottardo – Policlinico line is expected to follow by the end of 2008. This 1·75 km double-track line serving three stops is projected to cost €24·3m.

Light rail is now envisaged in Bologna, replacing earlier proposals for an 11 km automated metro. The newly-elected city administration that took office last year announced in August 2004 its plans for a three-stage development. The initial 3·3 km section between Trenitalia's main station and the trade fair would still be built as an underground line, with six stations. Total cost of this section is put at €187m, of which the government has already pledged to contribute €90m.

The 2·3 km second phase to Porta San Felice with five stations will also run underground, but the final 5·5 km serving Borgo Panigale would run on segregated surface tracks, with 13 stops. A fleet of 32 m long LRVs able to carry around 200 passengers would give a design capacity of 6 500 passengers/h in each direction, compared to the 10 000 envisaged for the metro. In the longer term, Bologna is also looking at further extensions to serve the airport in the west and the new university district. ■

Four 950 mm gauge Sirio tram-train cars are now operating in Sassari, where through services will link the existing FdS suburban line to the city centre

Light rail operators face power supply conundrum

Joseph Scheerens
Senior Consultant
Tractebel Development Engineering SA

Upgrading existing tramways to light rail standards is a cost-effective way to raise capacity, speed and quality of service. However, the introduction of heavier power-hungry light rail vehicles can have significant implications for the traction supply

POLITICAL PRESSURE and year-on-year passenger traffic growth, coupled with growing calls for higher operating speeds, comfortable vehicles and a better quality of service, combine to present significant challenges to the operators of conventional city tram networks.

One way to cope with these challenges is to introduce larger and more powerful vehicles, and move to light-rail style operation with new extensions and rebuilt lines on segregated tracks. This upgrading strategy is not new in itself, as many cities have embarked on such conversions over the past 40 years. However, the introduction of new vehicles on conventional tramway networks can also have a big impact on the existing infrastructure.

As an example of the kind of issues involved, the Flemish transport operator VVM De Lijn is currently embarking on a programme to renew completely the Gent traction power supply network and control systems. There were many electrical, mechanical and operational issues to be addressed in developing the project, which is expected to bring long-term benefits in reducing the cost of energy whilst improving service quality.

De Lijn now uses two car types on its Gent network: upgraded PCC-type trams and Siemens low-floor articulated cars introduced gradually since 2000. Able to accommodate up to 250 passengers, these new vehicles are formed of five sections able to fit through the narrow streets in the historic city centre.

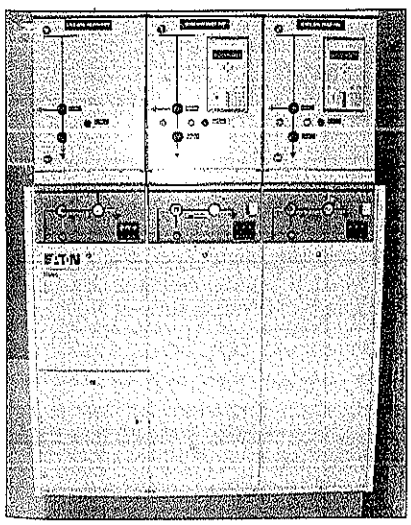
As the first step in a phased fleet expansion and renewal programme, De Lijn is putting into service as many Siemens trams as there were PCC-type trams in 2000, doubling the size of its fleet. In the subsequent phases, further articulated cars will replace the PCC trams over the next 20 years.

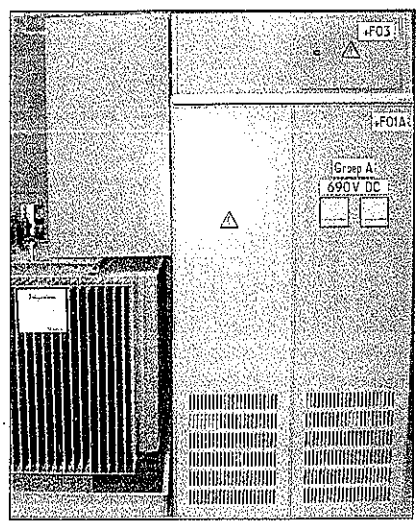
Introduction of the bigger articulated cars has placed a considerably higher load on the overhead lines and substations. At present, the Siemens cars can only be used in a reduced-power mode. To allow the modern vehicles to operate on full power and to permit the introduction of a full low-floor fleet in the future, De Lijn recognised that upgrading of the entire Gent tramway power supply network would be necessary.

After a public call for tenders, Tractebel and Technum were chosen to carry out a study of the entire infrastructure, and identify how to optimise and strengthen the network. For this study, Technum drew on the resources of its rail infrastructure team, which specialises in railway and tramway engineering.

Technum was responsible for the complete design and for calculations of the mechanical stability of the overhead lines, including the suspension of the catenary and the continued use of wall-mounted support fixings with heavier wiring. It also undertook a concept study of the electrical infrastructure, covering dimensioning, design and implementation of improvements to substations, feeder cables and control systems.

The study showed that partial upgrading and patching would not suffice. A complete renewal of the overhead line equipment, substations, feeders and the power control network would be necessary. Before the final decision was taken, De Lijn and Technum discussed the advantages and disadvantages of various propositions, in





TOP: *VVM De Lijn has started taking delivery of a second build of articulated low-floor cars from Siemens and Bombardier for use in Gent, seen here on the recently-opened extension of Line 1 to Flanders Expo*

LEFT and RIGHT: *The complete renewal of Gent's traction supply network will require the upgrading of eight existing substations and construction of 11 new ones*

order to develop a consensus on the best solution for each specific situation across the network.

To ensure consistency in the materials and equipment used, De Lijn decided to organise the renovation and modernisation of the whole traction supply network as a single major project. The renewal is expected to bring more reliable operation, simpler maintenance and a reduction in the number of equipment failures and breakdowns in service.

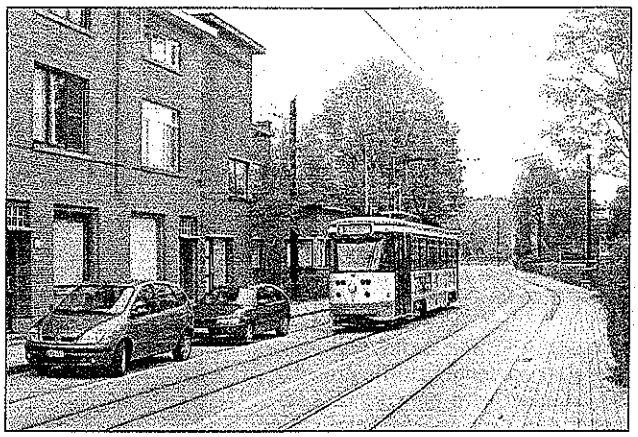
Substations and overhead line

Reinforcement of the power supply will require the construction of 11 new substations and the reconstruction of eight existing facilities. Three of the present substations will be abolished, giving a net increase from 11 to 19 supply points.

The optimum number and location of the substations was calculated as a function of the voltage drop in the wires and the short-circuit current in the event of an electrical failure. Instead of dry transformers, the new substations will use oil-cooled transformers of the hermetically-closed type with limited electric losses. These are largely resistant against overload and peak load, require less maintenance and produce less noise. However, they are no more expensive than the older type.

Upgrading or renewal of the contact wires formed a major issue in its own right, as the cross-section of the existing contact wires is too small for future power requirements. Technum looked at the pros and cons of various alternatives, such as a single new contact wire with a bigger cross-section, a double contact wire, or using a catenary suspension to give two overhead lines but only one contact wire.

In the end, two different solutions were chosen. Outside the city centre, a catenary suspension will be adopted. With this arrangement, both the suspension and contact wires are used as current conductors, replacing the bulk of the underground feeder cable network, which is very expensive to install and maintain.



De Lijn has refurbished half of its original fleet of PCC-type tram cars, but plans to phase these out as further low-floor vehicles are ordered over the next 20 years

For aesthetic reasons, a single contact wire will be used for street tracks in the urban area and the city centre. This will have a cross-section of 150 mm², which is the maximum possible in the circumstances. However, such a heavy wire needs specialised installation equipment to ensure that it is positioned and adjusted accurately, and this is obviously a disadvantage. A copper-silver wire will be used because of its excellent mechanical and electrical properties.

Technum also opted to minimise the overall length of underground feeder cabling, in order to reduce the impact or damage caused by excavations in the public roads. The cables being adopted have a reinforced external cover, and the return connections from the rails are connected by splicing into the cross-section for good conductivity. In this situation, two smaller parallel cables are preferred over one cable with a bigger cross-section. The feeder cables are connected to the overhead lines using motorised switches which will permit the remote isolation of different feeder sections.

Interconnected network

To maximise the efficiency of the new power supply network, the existing section isolators will be bypassed, so that in normal operation the whole of the overhead line will form a single interconnected network. The various substations will each supply current to a part of the network, and the loading will balance between them automatically.

This is expected to bring significant advantages in energy efficiency, as there will be fewer peaks in power consumption. Such 'peak shaving' can reduce the electricity bill considerably (Fig 1).

Another advantage of bypassing the section breakers is the ability to re-use a higher proportion of regenerative brake energy. At present, regenerated energy is limited to one single section and one substation, and cannot be shared by cars drawing current in an adjacent section. Coupling the sections together will allow the energy to be recovered more easily, and should bring a further reduction in the overall energy bill.

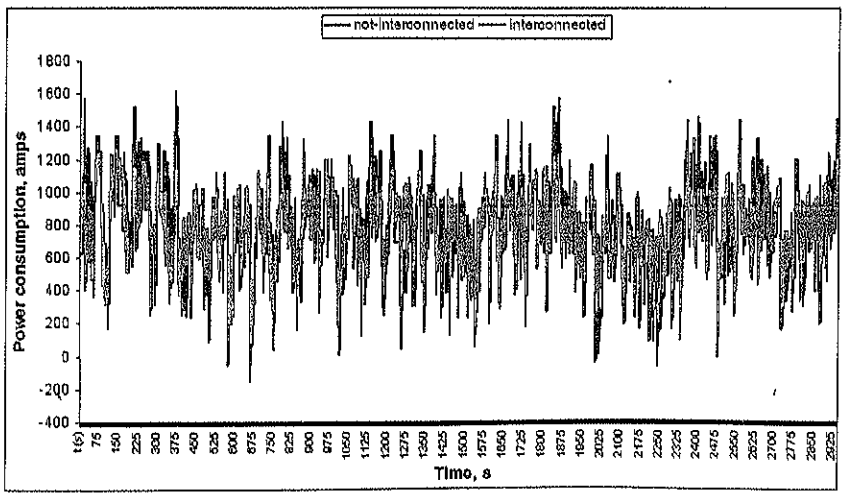
A new SCADA control system will be installed to oversee the entire power network. It was recognised that interconnecting the various sections could trigger intertripping between the different substations, requiring a rapid response from the control centre for both safety and operational reasons.

De Lijn has therefore decided to install its own optic fibre network linking the control centre and all of the substations. In the future this control network will also be available for communications functions, such as providing real-time information to passengers, integration and automation of ticket vending equipment, and video surveillance or other security systems.

Another issue is that of stray currents and insulation, where standards and regulations are getting stricter in the same way as those concerning the level of noise and vibration. Stray currents making their way back to the substation can cause corrosion to underground metal pipes and other utility lines, or the metal earth points of lineside buildings. Because of vibration issues, relaid tracks have the rails isolated from the concrete bedding slabs – increasingly adopted so that trams and buses can use the same dedicated alignments.

However, it is important to provide a good contact between the rail and underground return cable to enhance the lifespan of the various underground metals. It is very difficult to verify the quality of the contact between rail and cable when the track is buried in a concrete slab, so special rail contact boxes will be provided to give maintenance access in the future. ■

Fig 1. Interconnecting the feeder sections on the power supply network will permit more effective use of regenerated power and bring down the peak demand, helping to cut the overall cost of electricity



Tokyo Metro prepares for privatisation

Construction of Line 13 in 2007 will complete the publicly-funded metro network in Japan's capital, paving the way for shares in the restructured operating company to be floated on the stock market. Chris Jackson discussed developments with Tokyo Metro's Director, Corporate Planning & Administration, Toshikazu Saito and Director of International Affairs Hidemi Someya

APRIL 1 2004 was a milestone in the history of Tokyo's metropolitan railways. The former Teito Rapid Transit Authority was replaced by a new company, Tokyo Metro Co Ltd, as the first step in the process of returning the metro network to private ownership.

Tokyo Metro is structured as a 'special corporation', with a registered share capital of ¥58·1bn, but at present all the shares are still owned by public-sector bodies. The company is owned 53·4% by the Japanese government and 46·6% by Tokyo Metropolitan Government – the same proportions as their respective stakes in TRTA.

The company is the larger of the two metro operators in the Japanese capital, running eight lines compared to Toei's four. Tokyo Metro runs a network of 183·2 km and handles around 75% of all metro passengers in the capital.

Over the next few years, the government and TMG expect to transfer ownership of Tokyo Metro to the private sector by floating tranches of shares on the Tokyo Stock Exchange, in a similar process to that adopted for JR East, JR West and JR Central. This privatisation will, in fact, complete a circle in terms of ownership, as the TRTA network has its origins in the private sector.

The privatisation strategy was drawn up by the Doko Committee, formed in 1986 to consider the long-term development of the TRTA network, and enshrined in legislation passed in 2002.

Under the old structure, TRTA had to comply with the 'law on rapid transport' which meant that it could only invest in projects approved by government, and carried heavy responsibilities reflecting the high levels of state funding.

The new regulations and changed status give Tokyo Metro the freedom to manage its own business and powers to develop related activities where this is considered appropriate. In addition, the private corporation structure is more focused on the needs of customers and on the operation of the network – measured by factors such as safety, reliability and comfort.

In return for this freedom to manage, the government expects to see the value of its capital increase as the price of Tokyo Metro shares starts to rise in line with improved management performance. Both the national government and Tokyo Metropolitan Government will be able to realise a capital gain by selling their stakes at a good price, when the market conditions are right.

The timing of the sale is a matter for the owners, but will depend on stable management performance at Tokyo Metro and prevailing stock market conditions. However, the board does not expect to see any shares sold before the opening of Line 13 in 2007. This is an expensive project, and the level of patronage after it opens will have a major impact on the metro's profitability and commercial results.

Toshikazu Saito (left) is Tokyo Metro's Director, Corporate Planning & Administration. Hidemi Someya (right) is Director of International Affairs

Steady growth continues

The capital's oldest metro line, the 2·2 km section of the Ginza Line between Asakusa and Ueno, was opened

TOP: *Carrying a commemorative headboard to mark the first anniversary of Tokyo Metro, this Series 06 trainset on the Chiyoda Line is typical of the more recent generations of stock operated by the company.*

LEFT: *Series 08 cars are used on the Hanzomon Line*

by the private-sector Tokyo Underground Railway in 1927. The rate of construction was slow, and a second company, the Tokyo Rapid Railway, was formed before the whole 14·3 km line could be completed in 1939.

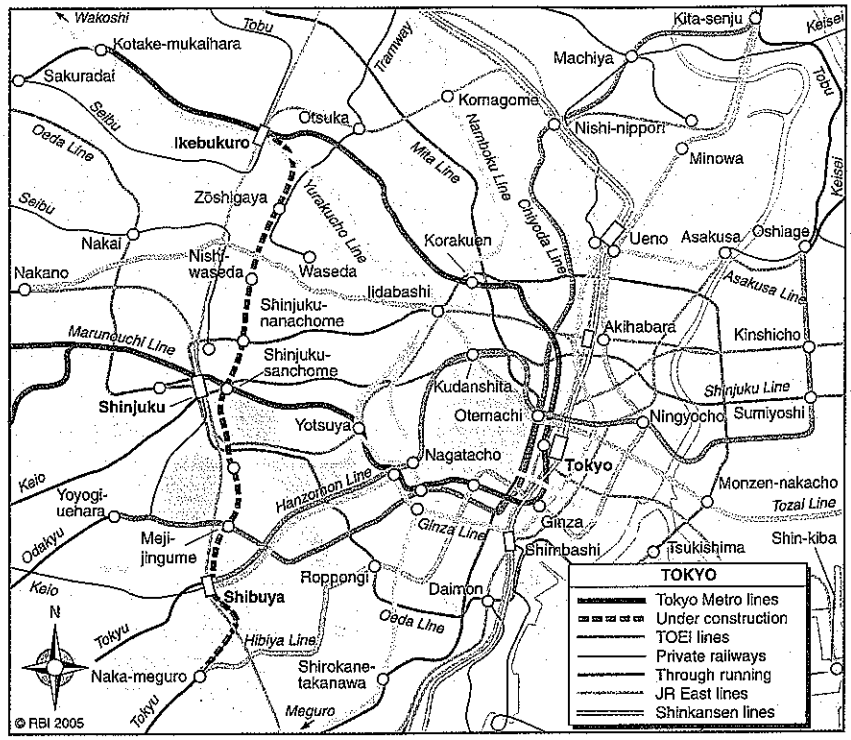
However, the cost of building new lines proved too great for the private sector to carry, which is why the network ended up in public ownership. In 1941 the city government decided that it would have to take the lead. The two companies were taken over and merged to form TRTA, which was given a remit to build and operate the growing metro network.

Over the next 63 years, TRTA completed a further seven lines totalling 168 km, funded by a mix of grants and loans from the national government. Of the total ¥1 883bn invested in new line construction between 1950 and 2002, 43·2% came in government funds and 12% in interest-free loans. Another 33·7% was raised from the private sector, including ¥535·9bn in public subscriptions to transport bonds.

The expansion process concluded with the opening of the last section of the Hanzomon Line in 2003, and today the network's 2 515 vehicles handle an average of 5·7 million passengers per day.

The newest route in the Tokyo Metro network is the Namboku Line, which was completed through to Meguro in September 2000. Fitted with platform screen doors throughout, this line is worked by Series 9000 trainsets equipped for Automatic Train Operation, although an attendant is still carried on each train. All the other lines are fitted with ATC, and cab signalling is provided on all lines except the Tozai Line.

The government now believes that only one more route remains to be completed before the network reaches a natural maturity. Once the construction phase ends, there will be no further need for capital grants. The operating business should be able to cover its day-to-day running costs from revenue, making it fit for transfer to private ownership.



Line 13 takes shape

Expected to cost around ¥251bn, the 8·9 km Line 13 due to open in 2007 will provide a north-south link between Ikebukuro and Shibuya. It is primarily intended to relieve the western side of JR East's Yamanote Loop, which today is the busiest railway in the capital.

Running under the busy thoroughfare of Meiji-Dori, Line 13 will also help to relieve traffic congestion on the roads around Shinjuku. In the longer term, through-running agreements with the private suburban railways at both ends of the line are expected to drive the development of cross-regional commuting between Saitama prefecture and Yokohama.

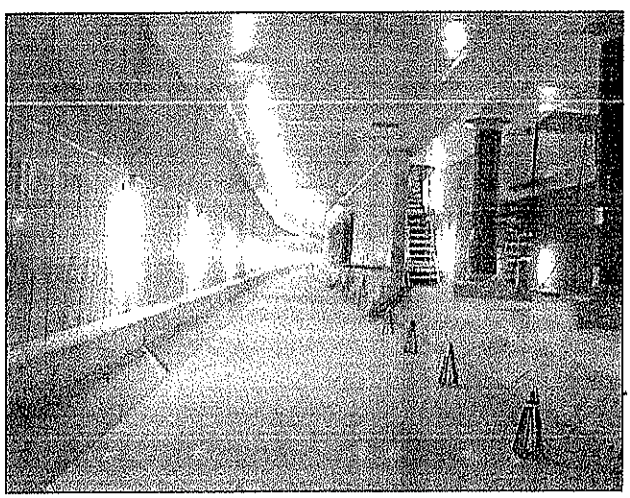
The basic concept for Line 13 was agreed by the Transportation Policy Council in 1985 and proposals for through running were endorsed in 2000. Responsibility for project planning, development and construction management of Line 13 was initially awarded to the TRTA Construction Bureau, although this was abolished and replaced by Tokyo Metro's Construction Department as part of the restructuring.

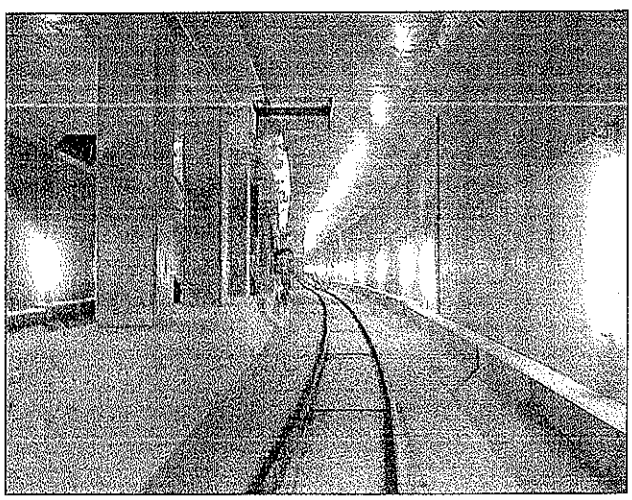
Five of the eight new stations are being built using cut-and-cover, with 15 m wide station boxes. At Zoshigaya and Nishi-Waseda, twin-bore station caverns are being dug using shield tunnelling methods, which are also being used for the running tunnels. At Shinjuku-nanachome there will be separate island platforms for each direction, located one above the other. At this point the lower running tunnel will be 25 m below ground level. The Shibuya station box is 36 m wide to accommodate four platform tracks on the lower level, 21 m below ground.

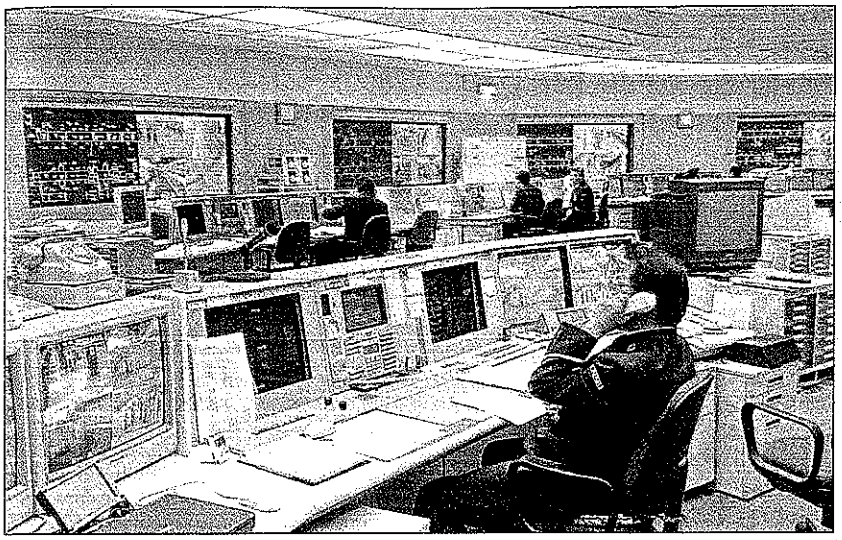
Through-running strategy

Tokyo Metro has extensive through-running arrangements with JR East and various private railways (Table I), except for the Ginza and Marunouchi lines where the gauge and third-rail power supply are incompatible. Through running will also play a fundamental part in the Line 13 operating strategy.

Civil engineering work is well advanced on the 8·9 km first phase of Line 13 between Ikebukuro and Shibuya, which is expected to open in 2007







Tokyo Metro's integrated control centre brings together the teams responsible for train operations, passenger movements, power control, rolling stock and engineering facilities

Several railways feed into Ikebukuro, from where passengers transfer to the Yamanote Loop, or to the Marunouchi and Yurakucho lines. There are existing through services onto the metro's Yurakucho Line from Tobu Railway's Tojo Line at Wakoshi and from Seibu's Yurakucho Line at Kotake-mukaihara.

Between Kotake-mukaihara and Ikebukuro the metro's capacity has been doubled by the construction of two express tracks, the so-called Yurakucho New Line. These tracks will be transferred to Line 13 from 2007, after which the Tobu trains will run through to Shibuya and the Seibu trains will continue to serve the Yurakucho Line.

At the southern end of Line 13, a connection from Shibuya to meet Tokyu Railway's Toyoko Line at Daikanyama is due to be completed in 2012. Trains will continue over the Toyoko Line to Yokohama, where they will run through onto the recently-opened Minato-Mirai 21 metro line.

A special committee has been formed to draw up the specifications for the through services by the five railways involved – Tokyo Metro, Tokyu, Tobu, Seibu, and Minato-Mirai 21. A co-operation agreement has already been signed covering the basic specifications such as the 1 067 mm track gauge, tunnel profile, kinematic envelope and signalling system. To a large extent these specifications mirror those for the through services on the Yurakucho Line, because Line 13 will inherit some of the existing through services.

There are some difference between the trains used on the other routes, but all will meet the Line 13 tunnel standards. The biggest technical issues reflect the five different signalling systems now in use, which means that the through-running trainsets will have to be fitted with multiple sets of on-board equipment. Some other upgrading work will be needed on the Tokyu Toyoko Line, and this is due to be completed by the time that the Shibuya link opens in 2012.

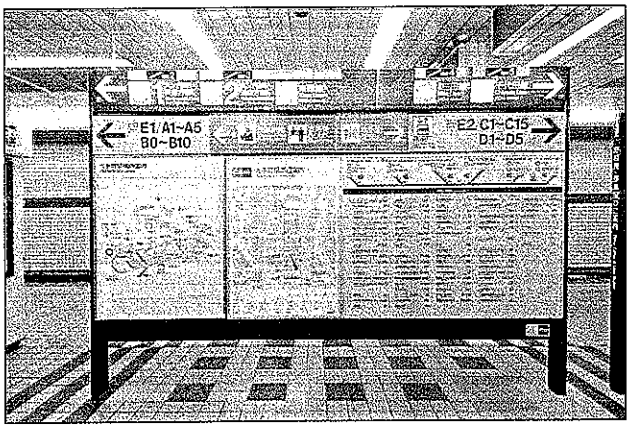
The through service committee is still discussing the details of the Line 13 operating plan, which have not yet been finalised. The intention is to equalise the train mileage operated by each partner. A more intensive service is expected to operate over the central section to augment the through trains, but it has not yet been decided where the extra services will start and finish at each end.

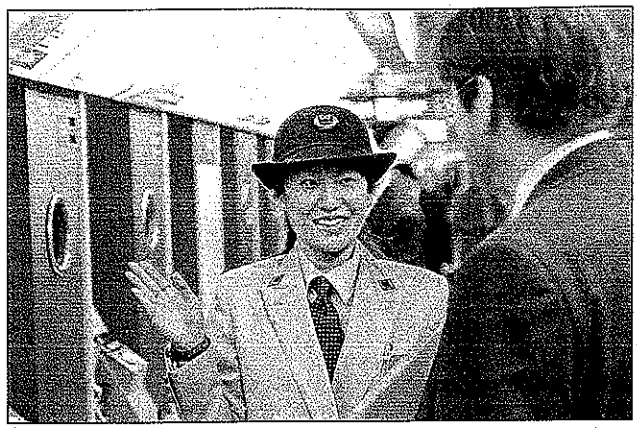
Tokyo Metro is planning to buy new rolling stock for its share of the operation, and unofficial discussions have started on the topic of design. At present the metro, Tobu and Seibu have standardised on 10-car formations, whilst Tokyu uses eight-car trains. The stations on Line 13 are all being built to accommodate 10-car formations,

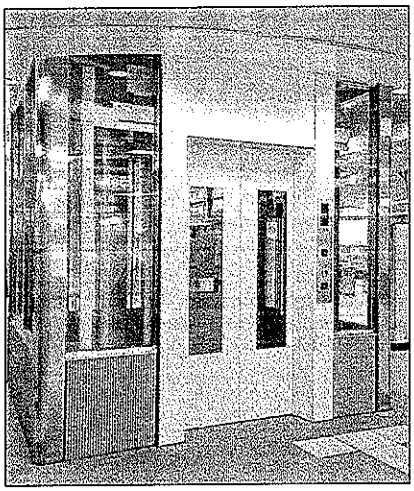
Table I. Tokyo's metro network in figures

Line	Name	Route	Length *km*	Gauge *mm*	Power supply	Opened	Through services
Tokyo Metro lines							
3	Ginza	Asakusa – Shibuya	14·3	1 435	600 V DC *	1927-39	–
4	Marunouchi	Ikebukuro – Ogikubo	24·2	1 435	600 V DC *	1954-62	–
		Nakano-sakaue – Honancho	3·2				–
2	Hibiya	Kita-senju – Naka-meguro	20·3	1 067	1·5 kV DC †	1961-64	Tobu, Kita-senju – Tobu-dobutsukoen, 33·9 km; Tokyu, Naka-meguru – Kikuna, 16·6 km
5	Tozai	Nakano – Nishi-funabashi	30·8	1 067	1·5 kV DC †	1964-69	JR East, Nakano – Mitaka 9·4 km; JR East, Nishi-funabashi – Tsudanuma, 6·1 km; Toyokosoku, Nishi-funabashi – Toyo-katsutadai, 16·2 km
9	Chiyoda	Kita-ayase – Yoyogi-uehara	24·0	1 067	1·5 kV DC †	1969-79	Odakyu, Yoyogi-uehara – Hon-atsugi, Karakida, 52·5 km; JR East, Ayase – Tonde, 20·9 km
8	Yurakucho	Wakoshi – Shin-kiba	28·3	1 067	1·5 kV DC †	1974-88	Seibu, Kotake-mukaihara – Hanno, 40·3 km; Tobu, Wakashita – Shinrin-koen, 18·9 km (to Line 13 in 2007)
Yurakucho New		Kotake-mukaihara – Ikebukuro	3·2	1 067	1·5 kV DC †		(will be connected to Line 13 from 2007)
11	Hanzomon	Shibuya – Oshiage	16·8	1 067	1·5 kV DC †	1978-2003	Tokyu, Shibuya – Chuo-rinkan, 31·5 km; Tobu, Oshihage – Minami-kunhashi, 50·2 km
7	Namboku	Meguro – Akabane-iwabuchi	21·3	1 067	1·5 kV DC †	1991-2000	Tokyu, Meguro – Musashi-kosugi, 9·1 km Saitama Railway, Akabane-iwabushi – Urawa-Misono, 14·6 km
13	Line 13	Ikebukuro – Shibuya	8·9	1 067	1·5 kV DC †	2007	Tokyu, Shibuya – Yokohama (from 2012)
Toei lines							
1	Asakusa	Oshiage – Nishi-magome	18·3	1 435	1·5 kV DC †	1960-68	Keisei, Oshigae – Narota-kuko, Higashi-narita, 70·6 km; Hokuso, Kodan – Oshiage – Inba-nihon-ida, 32·3 km; Keikyu – Senhakuji – Misakiguchi, Shin-zushi, 73·4 km
6	Mita	Nishi-takashimadaira – Meguro	26·5	1 067	1·5 kV DC †	1968-2000	Tokyu, Meguro – Musashi-kosugi, 9·1 km
10	Shinjuku	Shinjuku – Motoyawata	23·5	1 372	1·5 kV DC †	1978-89	Keio, Shinjuku – Hashimoto, Takaosen-guchi, 67·3 km
12	Oedo	Hikarigaoka – Kiyosumi-shirakawa	40·7	1 435	1·5 kV DC †	1991-2000	(small-profile loop line)

* Third rail † Overhead bar conductor ‡ Overhead catenary







A programme of station enhancements is underway to make the complex network easier to use. This includes lifts giving disabled access to the platforms (left), new colour-coded signs and standardised station numbers (above left) and service managers to assist passengers at principal stations (above right)

although it has not yet been decided whether to use eight or 10-car trains or a mix of both.

Freedom to invest

The restructuring of Tokyo Metro has allowed the company to expand its business activities, and to branch out into commercial investment ventures beyond the metro network. The driving philosophy behind this strategy is 'efficient use of capital'.

Nevertheless, there are four major projects underway across the network to enhance the quality of services provided. The first of these is to provide barrier-free disabled access at all stations, including the installation of escalators, lifts and disabled toilets. The 'Restroom Clean-up Campaign' launched in February 2004 will see the cleaning and modernisation of 187 toilet facilities at 143 out of the 168 metro stations.

A related project launched in the light of the Taegu metro fire in South Korea is to improve fire prevention and suppression measures across the network.

A third programme covers the upgrading of ticket vending machines and gates at a cost of ¥15m. At present Tokyo Metro is part of the Passnet group, which operates a magnetic stored-value ticket valid on 27 railways across the Tokyo region. There is another grouping offering a magnetic stored value card for a similar number of bus companies, and both organisations have agreed that the two systems will be replaced by a common smart card.

JR East's Suica IC card is already being used by around six million commuters, so the other operators have reached agreement to share the technology. From the financial year beginning on April 1 2007, passengers will be able to use a single smart card on 57 rail and bus companies across the greater Tokyo region.

The fourth network-wide investment project is designed to improve passenger information facilities. With its very high-density network proving complicated for occasional users, Tokyo Metro is looking to simplify and clarify the information provided. As part of a city government initiative to boost tourism and sightseeing, Tokyo Metro and Toei have adopted a common policy to give all lines an identifying letter and each station an identifying number.

The letters and numbers shown on a new network map form the basis of colour-coded signs at all stations, together with international-standard pictograms for basic facilities. During 2004, the new signage was being evaluated at Ginza and Otemachi stations. By the end of the 2005 financial year, 83 stations will have been re-equipped at a cost of ¥17·7bn.

A related initiative is the introduction of roving 'service managers' at the busiest and most complex stations, able to assist unfamiliar passengers with questions about fares, interchanges and which exit to use to reach key places in the local neighbourhood. As of April 2005, 55 managers had been dispatched at 11 stations. Tokyo Metro is also introducing pre-recorded English-language announcements on its trains.

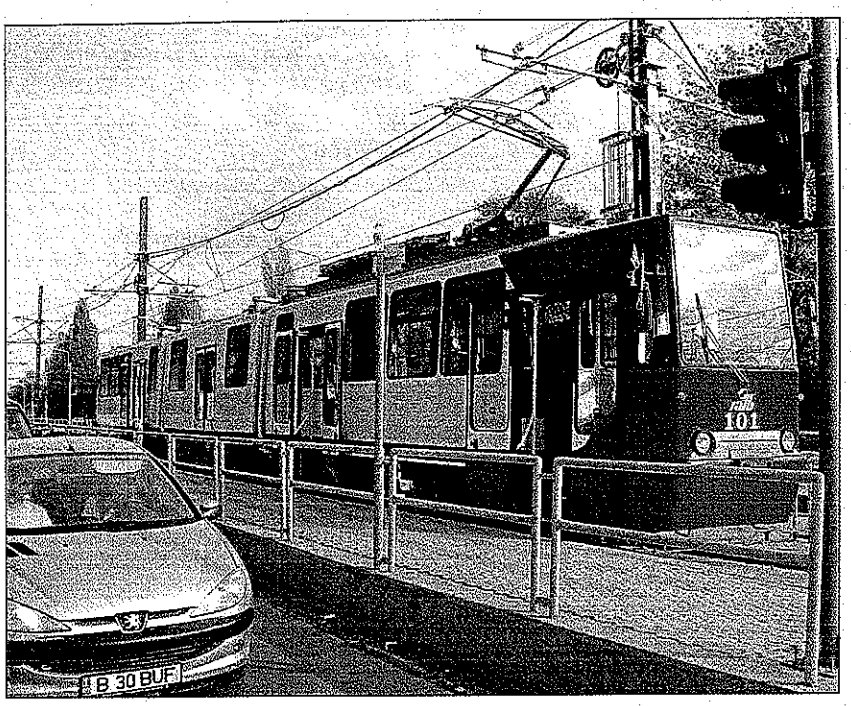
Combining passenger benefits with commercial investment is a programme to enhance station services through the provision of space for third-party retailers. By the end of February 2005, Tokyo Metro had opened 61 stores at 23 stations, with tenants ranging from convenience stores to coffee shops, café-restaurants, florists, and other services.

Another profitable venture is the construction of business hotels, offering economically-priced accommodation in the heart of the capital. In 2004 Tokyo Metro started work on the first of two pilot projects where it owned convenient plots of land. The first at Kiyosumi-shirakawa opened in March 2005, built on a former construction site for Line 11. The second will be at Toyocho on the Tozai Line, where land has been released by the demolition of a former substation which has been relocated underground. ■

Full platform screen doors were fitted on the ATO-equipped Namboku Line opened in 2000, and Tokyo Metro is testing half-height barriers and gates to improve platform safety on the Marunouchi Line

Light rail helps solve capacity crisis

Dr-Eng Ion Dedu
Infrastructure Manager
Regia Autonoma de Transport Bucuresti



The busy orbital Route 41 was used as the testbed for upgrading much of RATB's tram network to light rail standards

OVER THE next decade, the demand for public transport in the Romanian capital is forecast to grow by 20% as the metropolitan area continues to expand. To handle the business, we are upgrading many of our tram routes to light rail standards, building on the success of the first line since its conversion in 2002.

Bucuresti has a population of about 2 million in an urban area of 228 km². RATB is the largest urban transport operator in Romania, handling 83% of all public transport trips on a 700 route-km network. We have a market share of around 52% of motorised trips in the capital, although the capacity of our fleet of nearly 2 000 trams and buses is about 20% less than we need to cope with current levels of demand.

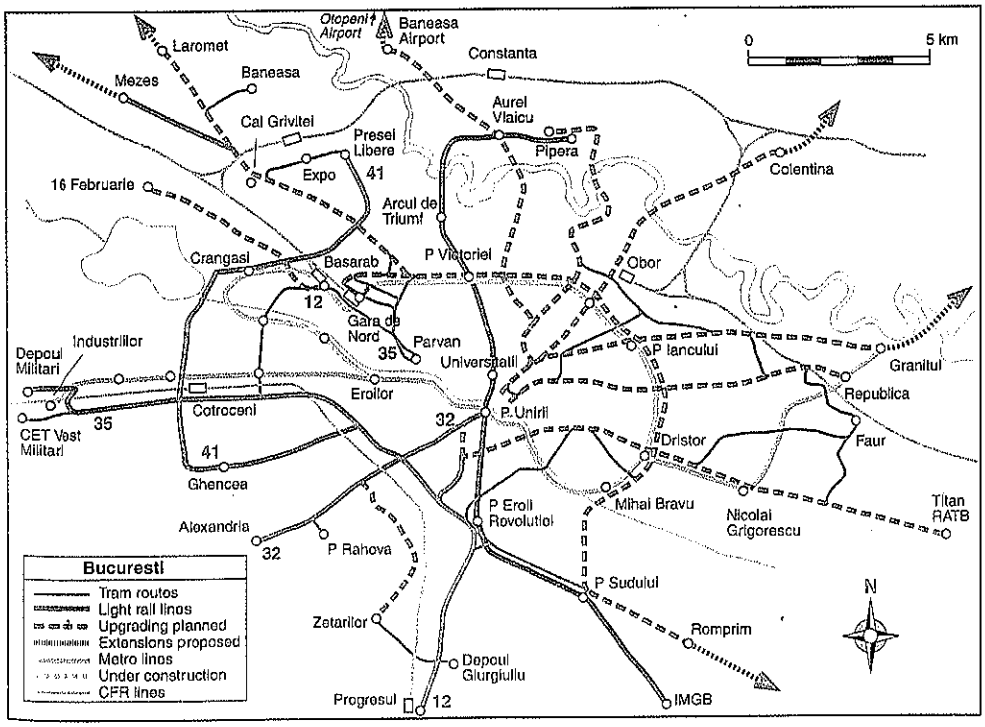
To tackle this shortfall, RATB's management is concentrating investment on high-capacity modes such as trams and light rail. Bucuresti is fortunate that it still has an extensive and well-distributed tram network which has considerable potential for development.

The tram network was extensively modernised in the 1980s, but the prefabricated slab track technology available at the time has not proved adequate to cope with the increasing demand. Poor reliability, coupled with the traffic growth, led to higher levels of wear to the infrastructure. As the rate of repairs could not keep pace, we saw a steady deterioration in track quality.

At the same time, the number of operational incidents increased and the reliability and availability of the rolling stock fleet fell, leading to higher operating and maintenance expenses.

To restore normal standards and optimise the operation of the tram network, we recognised in the late 1990s that radical measures would have to be taken. These included a programme of infrastructure rehabilitation using new construction methods and rebuilding of the rolling stock. At the same time, the introduction of an integrated ticketing system covering the bus, tram and metro networks helped to redistribute the busiest flows and reduce the worst levels of overcrowding.

After evaluating the opportunities for financial support, RATB drew up short, medium and long-term strategies for development of the capital's surface public transport network. One short-term target has been infrastructure renewal on the tram routes in the southwest of Bucuresti, amounting in total to 110 track-km. This programme started with Route 41, which became the first light rail line in Romania.



Orbital pioneer

Route 41 was originally introduced in 1982 to give a direct connection between Piata Presei Libere in the north of Bucuresti and Crangasi – one of the most populated districts on the city's western side. Three years later it was extended to the busy Steaua sporting complex in the southwest suburb of Ghencea. The 19·7 km route now serves five heavily-populated districts with a density of between 150 and 350 inhabitants/ha.

Over the past 20 years demand on this orbital corridor has increased steadily, and today Route 41 is one of the most important in the capital. Thus it was an ideal

LEFT: *Overhead line equipment on Route 41 was upgraded from simple trolley wire to a double-balanced catenary suitable for higher speeds*

RIGHT: *Tram signals at 11 key junctions have been integrated with the city's traffic management system to ensure tram priority*

candidate to serve as the prototype for light rail upgrading in 2002.

There were a wide variety of infrastructure conditions along the route, including the Grand Passageway over the approaches to the main railway station, the Ciurel Bridge and the Lujerul Tunnel under the Iuliu Maniu Boulevard and Cotroceni station. Taking these into account, together with the interfaces with other utilities networks, we felt that Route 41 was an ideal testbed for developing many constructive solutions during the light rail upgrading.

For the majority of the line, we adopted classic ballasted track on a segregated reservation. Elsewhere we have used various types of track structure embedded in concrete. For straight alignments and curves greater than 200 m radius we used S49 flat-bottomed rail; NP4AS grooved rails are used for tighter curves and special trackwork. Steel quality is S900A for the flat-bottomed rail and S900V for the grooved rail.

The overhead line equipment was upgraded from a single trolley wire to a double-balanced longitudinal catenary, making it more suited to higher speeds and increasing the cross-section to boost the power transmission capacity. To improve the power supply, extra sub-stations were installed to keep the length of the DC feeder cables down to less than 500 m. The line is now fed from seven substations – five new containerised units rated at 2·3 MVA and two existing 1·2 MVA installations. All of these will eventually be controlled remotely using a SCADA system.

The two termini have been rebuilt as multimodal interchanges to facilitate the transfer of passengers. Platforms at the intermediate stops were rebuilt to accommodate higher passenger flows, in accordance with European standards on passenger safety, and redesigned to fit in with the local urban landscape. Architectural considerations also influenced the design of the real-time passenger information displays at the stops, which include provision for showing advertisements.

To optimise the commercial speed of the service, a new traffic management system was installed which also provides real-time vehicle location and timetable supervision. At present there are 11 road intersections with traffic lights where the traffic management system is integrated with the city's SPOT/UTOPIA control network to give priority to the light rail vehicles. At these intersections, the traffic light cycles are adjusted to anticipate the heaviest traffic flows and optimise overall performance. This has helped to raise the commercial speed to 21 km/h.

Rehabilitated vehicles

With no finance available for new vehicles, rolling stock for Route 41 was rebuilt from existing V3A eight-axle trams which had been built in RATB's own workshops from 1973 onwards.

The rebuilt three-section articulated cars each have a capacity of 300 passengers at 5/m². The work included increasing the capacity of vehicles, installing modernised traction equipment to upgrade performance and maximum speed, and fitting visual and audio passenger information systems.

Reconstruction of the route increased its nominal capacity from 4 000 to 6 000 passengers/h in each direction. However, the upgrading attracted more riders, and traffic rapidly exceeded the level forecast in the feasibility study. In order to satisfy this increased demand we had to raise the number of vehicles in use from 28 to 32, reducing the average peak-hour headway from 260 to 225 sec.

During the reconstruction, considerable thought was given to future maintenance, and the track elements were designed for both a longer life and easier renewal. At the same time, specialised infrastructure maintenance equipment was procured. Together with changes to the maintenance and renewals schedules, this has helped to reduce the overall costs for track and rolling stock maintenance by about 80%.

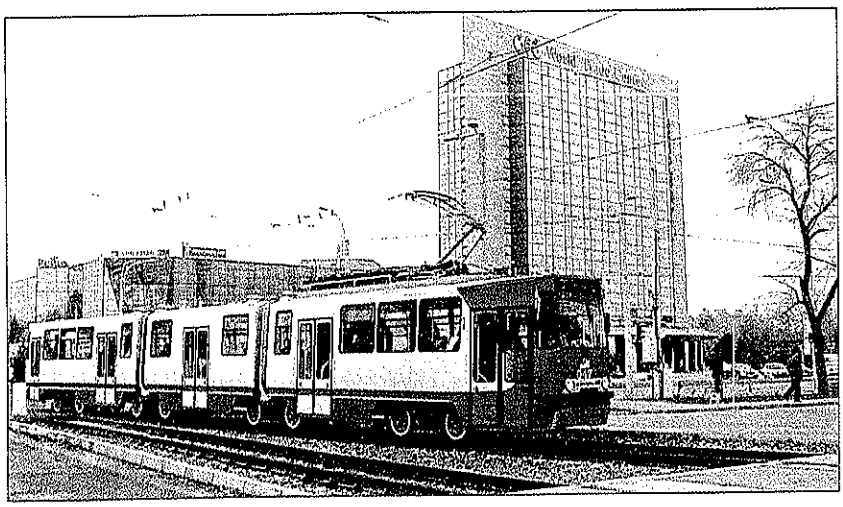
Following the success of Route 41, RATB decided in 2003 to roll out the infrastructure modernisation to further routes on the western side of the network. In the past year we have completed the upgrading of Routes 12, 32 and 35, and have nearly completed the modernisation of Alexandria and Militari depots.

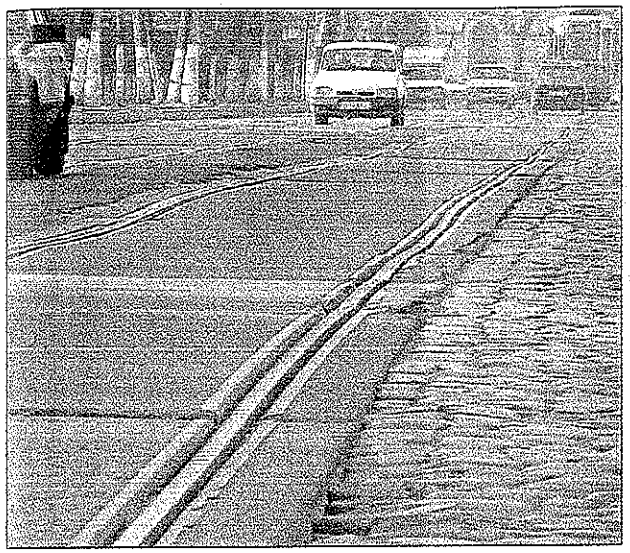
Work on the other two tram depots has started, and we are now embarking on a programme to upgrade all the remaining tram routes over the next decade. The layouts vary because of local alignments, road conditions and demand, but in all cases we are following the principles established on Route 41.

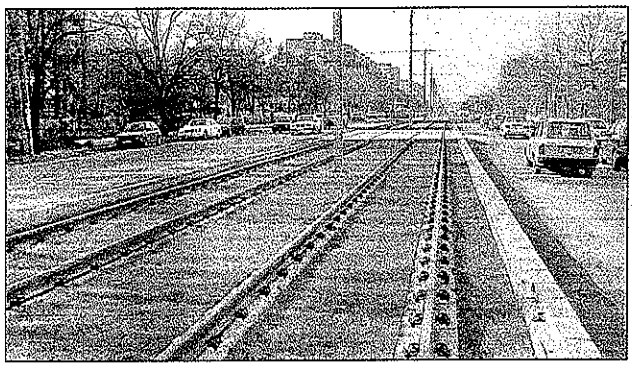
Long-term strategy

Our citizens' demand for mobility is continuing to rise, and as the number of private cars keeps growing, so do the traffic jams and air pollution. As its contribution to solving the city's long-term mobility problems, RATB has adopted an environmentally-responsible strategy to invest in high-capacity vehicles with minimum emissions, notably light rail, trams and

Eight-axle V3M articulated trams have been rebuilt at RATB's own workshops with modernised traction equipment to upgrade their performance on the light rail routes







Track structures adopted in the 1980s have not proved long-lasting (above), and RATB has rebuilt Route 41 and Route 32 with ballasted track on segregated alignments wherever possible (above right). Grassed track has been installed on a section of Route 35 (right)

trolleybuses. To improve the city's visual appearance we have been experimenting with grassed tracks on the tramway reservations. This has proved very popular, and will be used extensively in future infrastructure rehabilitation projects.

Meanwhile, work has started on the first phase of the substation control system, which will eventually see all 20 tramway substations managed remotely from a single control centre. Four smaller area control offices will be provided for emergency backup.

At the same time, as part of the ongoing fares integration process, RATB and metro operator Metrorex have started implementing a contactless smart card ticketing system. The winning bidder for this contract is a consortium of UTI Italy SRL, AP Trans SA, APB Prodata Ltda and UTI Retail Solutions SRL.

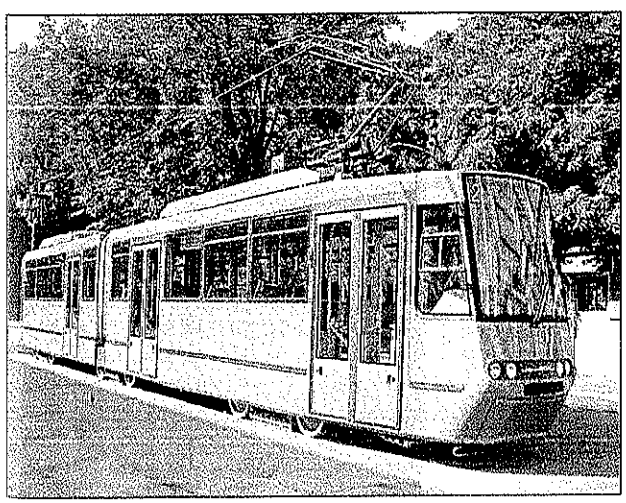
Integrated ticketing stands as a symbol for a closer working relationship between the city-owned tramway and state-owned metro networks, which will allow us to co-ordinate future development for the greater benefit of Bucuresti's citizens.

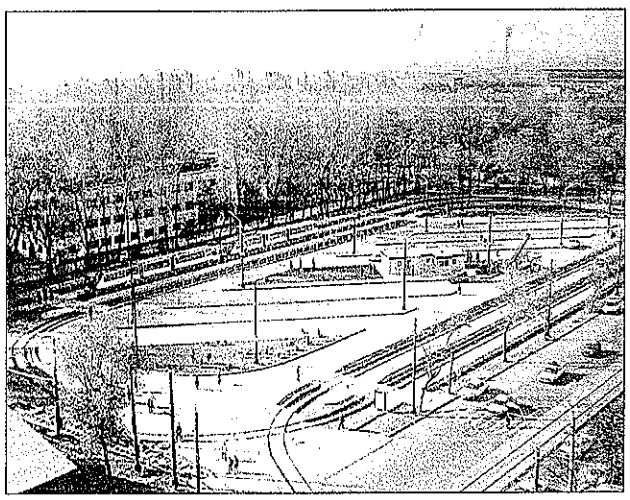
A feasibility study is now in progress to set the priorities for modernisation of the tramway infrastructure in the north-to-southeast quadrant of the city, which forms part of RATB's medium-term strategy. The programme covers the rehabilitation of approximately 150 track-km, of which the great majority will be reconstructed to light rail standards, paving the way for expansion of the network in the longer term.

The rolling stock rehabilitation programme is continuing, and around 100 Tatra trams out of the present fleet of 520 cars will be rebuilt. The remainder will be replaced by new low-floor vehicles. We are currently working on the development of a prototype car with a partial low floor and modern traction equipment, which has been completely developed and built in RATB's own workshops.

In view of the continuing growth of the Bucuresti metropolitan area, we anticipate that expansion of electric rail services will be needed after 2012, investing in both metro and light rail to suit the various requirements. Extensions to the northwest, north, northeast and southeast are being studied.

Bucuresti City Government has recognised that investment in attractive high-quality, high-capacity public transport is the only way to tackle the city's mobility problems. This is RATB's top priority, and we are rising to the challenge. ■





BELOW LEFT: *RATB is developing its own LRV prototype with a partial low floor, and hopes to replace up to 80% of its present fleet of Tatra tram cars*

BELOW: *The Route 41 terminus at Ghencea includes high-capacity turning loops, able to hold extra cars ready to carry heavy flows of passengers from the adjacent sports stadium*

Three extensions set to open in 2006

CONTRACTORS are poised to start installing electrical and mechanical equipment on the first section of Caracas metro Line 4 between Capuchinos and Plaza Venezuela. The work will get underway as soon as the civil engineering teams grant access for the E&M contractors.

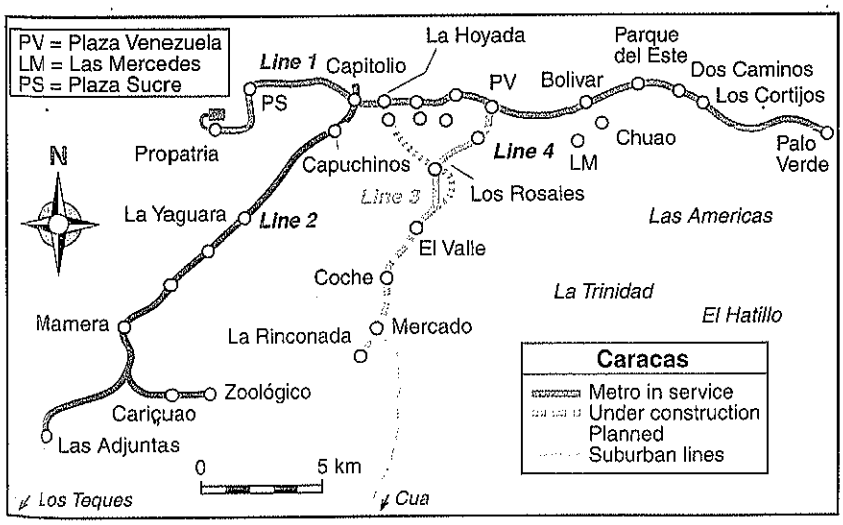
If all goes well, the 5·8 km line could be ready for testing and commissioning by mid-2006, allowing Metro de Caracas to carry the first passengers by an autumn 2006 deadline – the aim is to have it in service ahead of the presidential election scheduled for December 2006.

Line 4 has been much delayed because of problems with funding the civil engineering work, which is being handled by Brazilian company Odebrecht. Metro de Caracas insisted on some of the lost ground being made up. Odebrecht then brought in a new tunnel boring machine, and the current position is that access for E&M installation will be possible along the whole of the Line 4 alignment by the end of 2005.

As with all other E&M work on the Caracas metro, the Line 4 contract is in the hands of the Frameca consortium, with the deal inked in 1998. Frameca was established in 1986, with the work shared between the members as follows:

- Track: AMEC Spie, Vossloh and Alstom;
- Traction power supply and electrification: Alstom, AMEC Spie;
- Train control and communications: Thales, Siemens Transportation Systems, Alstom, CSEE Transport;
- Rolling stock: Alstom, Bombardier;
- Project co-ordination and engineering consultancy: SGTE (an AMEC Spie subsidiary), Alstom.

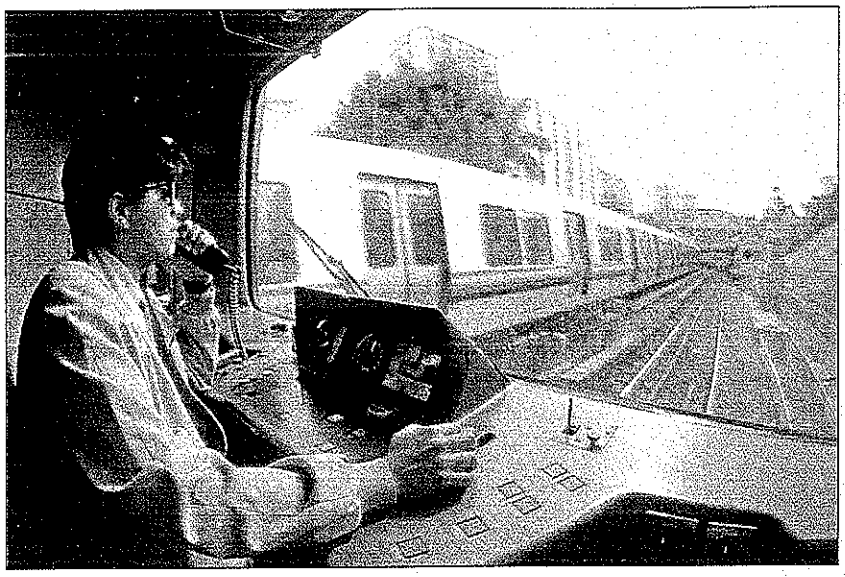
The citizens of Caracas are proud of their metro. Visitors are surprised at the cleanliness of the stations and trains, while there is a complete absence of graffiti. A Line 2 train arrives at Zoológico terminus



Relief for Line 1

Line 4 is of major significance for the Caracas metro as it parallels a section of Line 1, which suffers from severe overcrowding – more than one million passengers a day ride the trains on the 22·5 km route. The western terminus of Line 4 at Capuchinos will offer direct interchange with Line 2, while in the east it will connect with Line 1 at Plaza Venezuela.

This will have two advantages. Not only will Line 4 provide an alternative route for some Line 1 traffic, but it will



The most recent builds of car for the Caracas metro are visually identical to the earlier fleet, but numerous technical improvements have been made

also divert passengers who currently use Line 2 and then change to Line 1 at El Silencio-Capitolio. Estimates suggest that the new line will carry between 150 000 and 200 000 passengers a day.

The existing network handles around 1·4 million passengers every day, with traffic growing steadily as the network expands. The first 6·7 km section of Line 1 was opened between Propatria and La Hoyada in January 1983, and the next section running east from La Hoyada to Chacaíto followed in March that year.

The initial section of Line 2 from La Paz to Zoológico, with a branch to Las Adjuntas, was opened in October 1987, and this was extended north to meet Line 1 at El Silencio in November 1988. By that time Line 1 had been extended further east to Dos Caminos, and the final section of Line 1 to Palo Verde followed in November 1989.

Line 3 progress

Construction is also in hand on an extension to Line 3. The first part of this route opened in 1994 over the 4·5 km from Plaza Venezuela to El Valle. A contract to build the 6·7 km south from El Valle to La Rinconada with intermediate stations at Los Jardines, Coche and Mercado was signed with Odebrecht as long ago as 2001, but funding delays also held up this project.

Not until 2002 was a contract for E&M equipment signed with Frameca (RG 11.02 p672). This covers 42 cars, which will also feature an up-to-date traction equipment package. Alstom and its partners have commenced production of the equipment, and the aim is to have the extension ready for inauguration in autumn 2006, although full commercial service may not be possible until a later date.

The Line 3 extension is expected to generate between 30 000 and 50 000 additional passengers a day, but many more are anticipated when the 43 km Tuy Medio suburban line (RG 9.04 p544) opens. This line will tap traffic in the development area between southern Caracas and Cua and feed it into Line 3 at Mercado; opening of the line is also expected during 2006.

All civil engineering on the Tuy Medio line has been finished, and E&M work is around 80% complete. The job includes electrification at 25 kV 50 Hz by Balfour Beatty Rail SpA of Italy; a fleet of 52 stainless steel EMU cars is being supplied by Nippon Sharyo of Japan, with fitting out by Costaferroviaria of Italy.

Los Teques next

There is clearly a case to extend Line 4 eastward from Plaza Venezuela, but for the moment Metro de Caracas is heavily committed with the first part of Line 4 and the Line 3 extension. It is also awaiting completion of a third project.

This is the long-standing Los Teques scheme for an independent feeder line running 9·5 km from Las Adjuntas at the south end of Line 2 to El Tambor in the centre of Los Teques. Management of this scheme is in the hands of a separate organisation, CA Metro Los Teques, which was set up in October 1998. The company was charged with building along the San Pedro valley to serve the residential and dormitory zones in the Altos Miranda area. Some delay occurred while the company pondered how best to finance the US$450m project, and a concession arrangement was rejected in favour of more conventional funding.

The civil engineering contract was awarded to a consortium of Brazilian and Italian companies led by Odebrecht, and about 75% of the work is finished. Major tunnels are being built at La Linea and Rio Cristal. All civil work is due to be completed by September this year, although some delay is anticipated.

A tender for the E&M equipment, which includes the supply of 24 cars, is due to be issued shortly. The cars are likely to be the same as those supplied for Lines 3 and 4 as the line is being built to full metro standards. This will ensure standardisation and allow the Los Teques fleet to be maintained at the Line 2 workshop at Las Adjuntas.

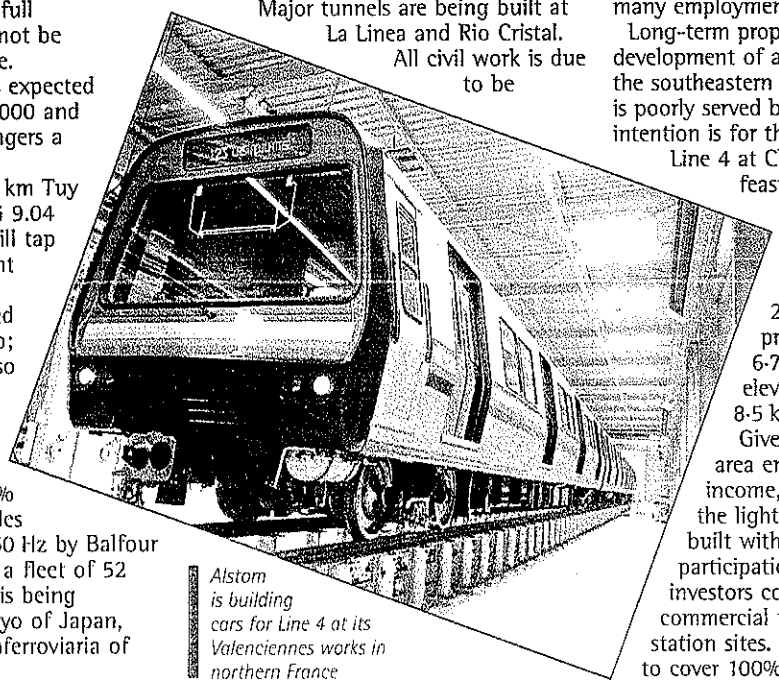
However, there will be no through service, and passengers between Los Teques and Caracas will need to change at Las Adjuntas, where provision was made for interchange when the Line 2 station was built.

Long-term plans

In the long term Line 4 is likely to be extended from Plaza Venezuela to Parque del Este, taking the length of the line to 12·3 km with 10 stations. This extension would run entirely in tunnel, with two crossings of the River Guaire. It would serve a large part of the city's central area with a dense population and many employment opportunities.

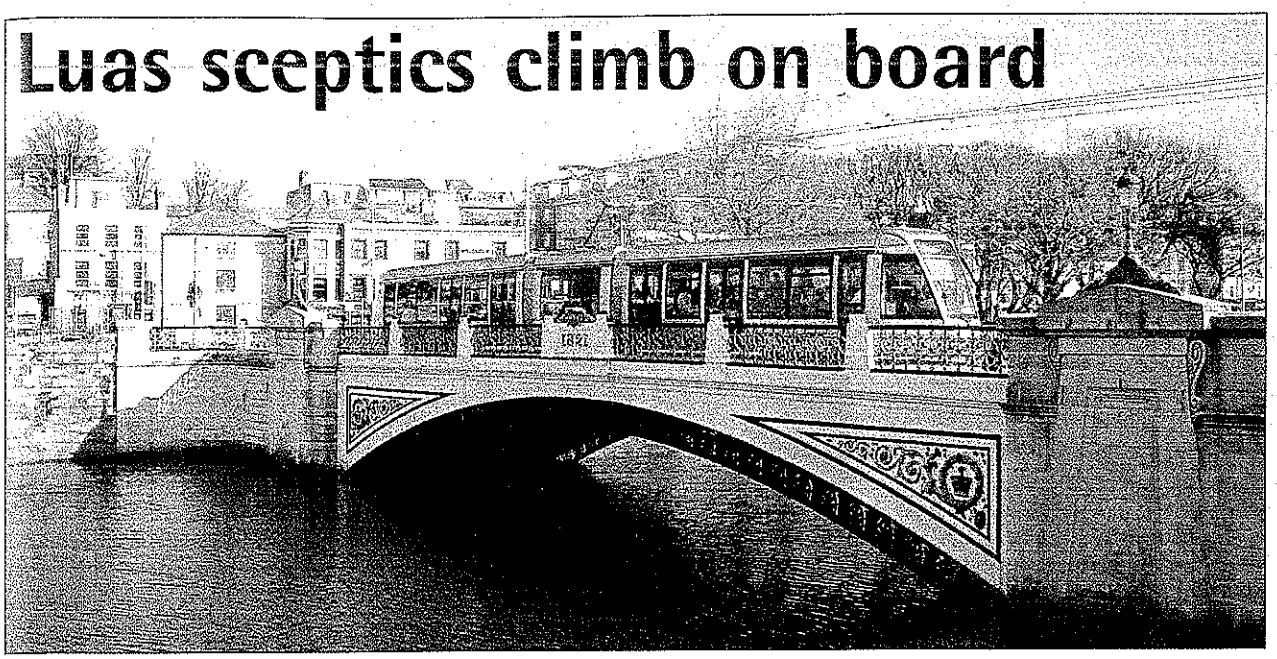
Long-term proposals also envisage the development of a light rail network in the southeastern sector of the city, which is poorly served by public transport. The intention is for this to feed into metro Line 4 at Chuao or Tamanaco. Pre-feasibility studies suggest that the light rail service could be carrying 340 000 passengers a day by 2010. A 15 km route is proposed, of which 6·7 km would run on elevated alignment and 8·5 km in tunnel.

Given that people in this area enjoy relatively high income, proposals envisage that the light rail project could be built with private-sector participation; one idea is that investors could be attracted to commercial property development at station sites. Fares would be pitched to cover 100% of operating costs. ■



Alstom is building cars for Line 4 at its Valenciennes works in northern France

Luas sceptics climb on board

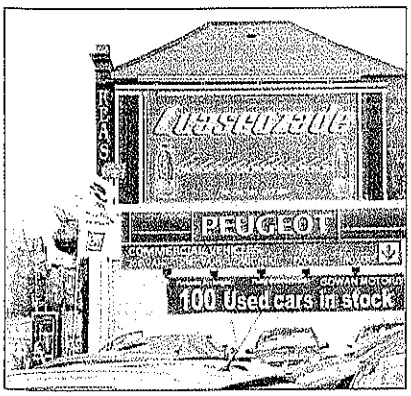


Michael Sheedy
Director, Light Rail
Railway Procurement Agency

OVER 1·8 million passengers rode the two light rail lines in Dublin during March, bringing the total ridership since the first section of line was opened in June 2004 to more than 11 million.

Our target patronage for the first year of full operation is 20 million. In fact, the build-up is running well ahead of projections, confirming our long-held belief that light rail has a valuable role to play in Dublin's transport mix. Thanks to strong economic growth over the past decade, the Irish capital has expanded rapidly, and housing developments are continuing to spring up on both sides of the new orbital motorway.

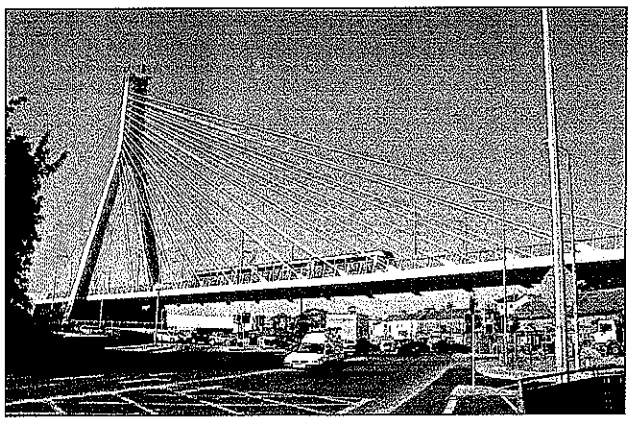
When the idea of light rail for Dublin was first floated in 1984, there were many sceptics who doubted the viability of the concept. Criticism continued as successive plans were unveiled and the route network kept changing, even after the Dublin Light Rail Act was passed in 1996. Throughout the planning and construction process, the protests grew louder with every minor problem. But within a couple of months of the first trams running, doubt turned to acceptance and then delight.



Luas imagery is already being used for a wide range of unrelated advertising, symbolising the modern face of today's Dublin

TOP: *The Red Line makes use of the historic 1821 bridge across the Liffey at Heuston station*

RIGHT: *Replacing a demolished bridge on the old Harcourt Street alignment, this dramatic cable-stayed viaduct at Dundrum on the Green Line is one of the architectural signatures of the Luas project*



Today Dubliners have taken Luas to their hearts. The trams are seen as a symbol of modernity and renewal, of vision for the future. It is notable how many advertisements for a whole range of products are already featuring Luas in some way or another. And it is clear from the growing ridership that this support is not just being expressed in words.

A further vote of confidence has come from the many development projects taking shape along the routes, some of which started before the lines were ready to open. Particularly worthy of note are the new Jervis shopping complex on the Red Line near Abbey Street and a luxury residential block over the park-and-ride car park at Balally, where the flats are attracting premium prices because of the good transport links.

Phased opening

The background to Luas and details of the construction were explained in a previous article (MR 01 p31). At that time we were still in the early days of civil engineering on the Red Line, and the Green Line had only just been authorised.

Over the next two years civil works pushed ahead, followed by tracklaying and electrification, and the construction of the depots for the two independent lines. The Red Cow depot on the Red Line is the larger, housing the control centre and offices for the operating concessionaire, but Sandyford is fully equipped for servicing and maintenance.

A major advance came in May 2002, when after competitive tendering the operating franchise was awarded to Connex Transport Ireland. The contract runs for five years, with an option to extend for a further five years. Ridership risk remains with RPA, but the payment structure means that Connex is incentivised to increase ridership where possible.

Apart from ridership, the performance-related contract gives Connex total responsibility for all aspects of the operation. RPA had already awarded maintenance contracts to Alstom, Dalkia and Scheidt & Bachmann, but these were subsequently novated to Connex so that the concessionaire has single-point responsibility (RG 3.05 p158).

Awarding the operating concession before the line was completed, and giving the rolling stock maintenance contract to the supplier, meant that both parties were on board during the final commissioning process, and they provided valuable input in the run-up to opening.

Because the 9 km Green Line is shorter,

and mostly follows the alignment of the former Harcourt Street railway closed in 1958, construction was much simpler and quicker. Despite the later start, this route was ready to open first.

After a simple ceremony on June 30 2004, we threw the line open for five days of free travel, which attracted over 350 000 people – more than a third of the city's entire population! There were long queues snaking around St Stephen's Green as people waited happily to sample the new trams.

This burst of enthusiasm was repeated when the 15 km Red Line was formally inaugurated by the Taoiseach, Bertie Ahern on September 28. Again Dubliners turned out in their hundreds of thousands, with 225 000 sampling the line in the six days before the start of revenue operation on October 4.

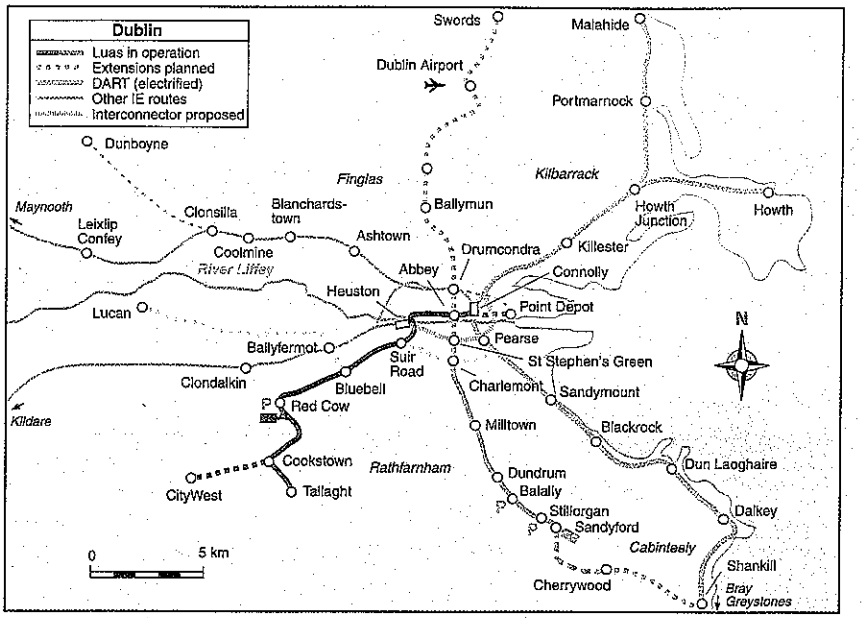
Within two months of opening, average daily ridership on the Red Line reached 23 250, overtaking the 21 350 being recorded on the Green Line. By the end of 2004 Luas had carried over 6 million passengers – 4 million on the Green Line in six months and 2 million on the Red Line in three.

Contrasting lines

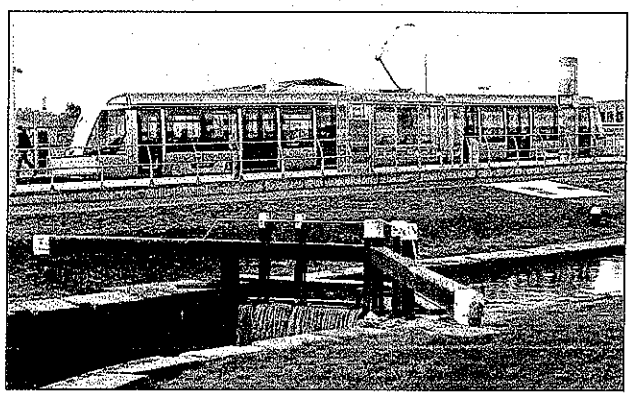
The Red Line provides the long-awaited cross-city link between Iarnród Éireann's principal stations at Connolly and Heuston, continuing through the south-west suburbs to Red Cow and Tallaght. The line is operated by a fleet of 26 Citadis 301 cars, 30 m long, running typically at 5 to 6 min intervals. The scheduled service requires 24 cars, giving a typical capacity of 2 800 passengers/h in each direction.

By contrast, the shorter Green Line to the southeast has a smaller fleet of 14 cars, but these are the 40 m long Citadis 401 version, so the capacity with 13 cars in service is higher at 3 650 passengers/h despite a less frequent off-peak service running at 10 or 11 min intervals.

Both Luas routes serve park-and ride interchanges, with four sites offering 2 200 spaces. The biggest of these is at Red Cow, with others at Stillorgan and Balally on the Green Line. Red Cow lies close to a key junction on the orbital motorway, and is proving popular with commuters from the western suburbs. Next year we expect to complete a flyover allowing cars to reach the park-and-ride without getting caught in the traffic jams that build up around the junction, which should boost usage even further.



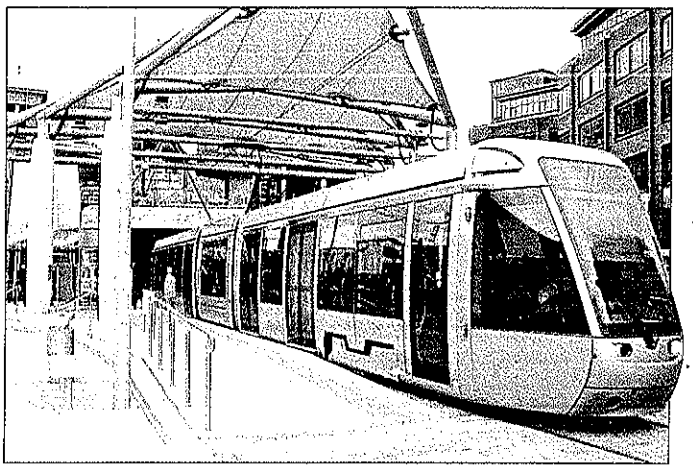
ABOVE: *The Dublin Transport Strategy published in 2002 envisages the addition of several extensions to the light rail network by 2014*



RIGHT: *A 30 m Red Line car runs alongside the Grand Canal through Dublin's southwest suburbs inbound from Tallaght*

In the months following the opening of the Red Line, various improvements have been instituted to cut the running time and increase the service frequency. At the start the end-to-end journey time was 48 min and the basic headway 10 min. By the end of 2004 these had been cut to 45 and 7½ min respectively, and in April they were reduced further to 43 and 5 min.

If the Red Line patronage continues to rise at current rates, we are looking to cut the peak headways to 4 min by the end of 2006, and we may also be looking at lengthening the trams to 40 m by inserting an extra section. This is one of the advantages of Alstom's modular Citadis design – cars have already been lengthened in this way for Montpellier.



The Red Line terminus at Connolly lies adjacent to the station entrance

Some interesting ridership trends have started to emerge over the first six months, with clear weekday daily and hourly patterns emerging. The morning peak has been very steady since the start of service, followed by a mid-morning slump and stronger ridership around lunchtime. The afternoon dip is less noticeable, with the afternoon peak spread well into the evening by late-night shopping traffic.

In fact, the busiest single day of the week is Saturday, as Luas has proved particularly attractive for shopping and leisure travel in and out of the city centre. The busiest periods on Saturday see more transactions at the ticket vending machines than the weekday morning peaks. Sunday is the quietest day, but nevertheless there has been a noticeable impact from 'Luas Tourists' taking family days out.

Because leisure and off-peak occasional riders are the dominant sectors, basic singles and returns represent around 80% of all ticket purchases, and season ticket sales have not been as high as we expected. In conjunction with IE and Dublin Bus, we have launched combined bus/tram and rail/tram passes, and on March 21 we introduced smart cards on the trams. RPA is currently leading the procurement process for an integrated

smart card ticketing system that will be introduced across all three modes over the next 18 months or so.

Future expansion

The Dublin Transport Strategy published in 2002 sets out a number of rail expansion projects to be carried forward over the next decade. This includes the first stage of the capital's planned Metro network, improvements to IÉ suburban services (RG 5.05 p275) and extensions to the Luas light rail network.

At the southern end of the Green Line, planning is well advanced for a 7·5 km extension from Sandyford to Cherrywood, which would diverge from the old railway alignment to serve new suburbs further west. RPA is about to lodge a formal application for powers to build this line. A subsequent extension would rejoin the old trackbed and follow it to Shankill, where the trams would interchange with the electrified DART suburban railway to Bray and Greystones.

A 1·8 km eastern extension of the Red Line from Connolly to Point Depot is at an advanced planning stage; with four stops this would serve the docklands development zone on the north bank of the River Liffey. We hope to start work in 2006 for opening in 2008. Still under discussion is the possibility of raising finance from the private sector, perhaps through some sort of property development levy.

Another challenge will be to close the gap between the two lines, eliminating the 10 min walk from St Stephen's Green to Abbey Street. With Grafton Street now pedestrianised, we have commissioned studies into alternative surface routes. Achieving a surface connection would require surrendering some road space now used by buses and cars, so getting public opinion behind Luas will be essential.

The distinctive metallic lilac and purple livery adopted for the Luas cars has proved very popular

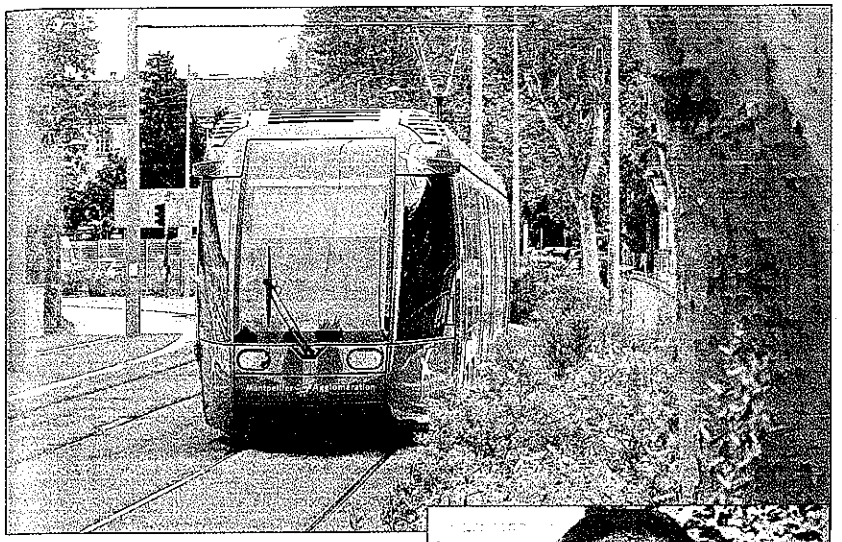
An underground extension of the Green Line northwards from St Stephens Green is envisaged by the government as the first stage of the Metro network, and the line has been designed for upgrading to metro standards if required. After connecting with the Red Line near Abbey Street, the route would continue north through Ballymun to the airport and the growing suburbs around Swords.

Two further lines to serve the western suburbs are currently being examined. The first is a 4·0 km branch off the Red Line, which would diverge at Cookstown and run to CityWest, adding four stops.

The Yellow Line would start from Lucan and run eastwards to Ballyfermot, where there would be an interchange with IÉ's Heuston – Kildare line, and then turn south to join the Red Line at Bluebell. Yellow Line services would share the existing track towards the city centre as far as Suir Road, after which the Yellow Line would continue alongside the Grand Canal around the south side of the city centre to meet DART in the southeast of the city, interchanging with the Green Line at Charlemont en route.

Further interchanges between Luas and the suburban network would be provided if IÉ's proposals for its Interconnector cross-city rail tunnel go ahead (RG 5.04 p276). This would run east from Heuston to a station at St Stephen's Green and then loop northwards under the Liffey to a Docklands station near Point Depot. After this the route would surface again and connect with the routes leading north and west from Connolly. ■

Trams at the heart of a model integrated public transport network



Marc Le Tourneur
General Manager
Transports de l'Agglomération de Montpellier

AT THE END of January 2005 the Montpellier light rail network reached an important milestone when it carried its 100 millionth passenger. Line 1 is now carrying almost 50% more passengers each day than anticipated, and traffic is still rising.

The Montpellier system is a model of how modern urban tram networks should be run. It is safe, reliable, comfortable, accessible, environmentally-friendly and well-used.

Opened in July 2000, Line 1 runs for 15·2 km from Mosson in the northwest of the city to Odysseum in the southeast. Its benefits are felt by the whole population of the urban area, thanks to excellent connections with local bus services. Four park-and-ride interchanges with a total capacity of 1 400 cars also allow the residents of 31 outlying villages to make use of the line. Parking costs €3·20 per day, including travel on the tram for all the car passengers.

Operation of the park-and-ride facilities is simplified by a management structure that is unique in France. TaM was set up in 1978 as a company owned jointly by the *Communauté Urbaine de l'Agglomération de Montpellier* (CAM) and transport operator Transdev. As well as running the bus and tram networks, TaM's remit extends to planning tram expansion and managing more than 16 000 parking places throughout the conurbation. With a total of 860 staff, TaM is the only French public transport agency which is also responsible for parking management.

When Line 1 opened in July 2000, the predicted daily patronage was 75 000 passengers/day. This forecast was thought by many people to be optimistic, but in fact the figure was quickly exceeded. Average daily ridership had passed 100 000 by March 2003 and reached 110 000 in April 2004.

To handle this growth, two additional trams were ordered to augment the original fleet of 28 Citadis 301 part-low-floor cars. At the same time, all 30 cars were extended from 30 m to 40 m by the insertion of an extra bogie module and another saloon section; this work was achieved without any interruption to services.

Line 2 takes shape

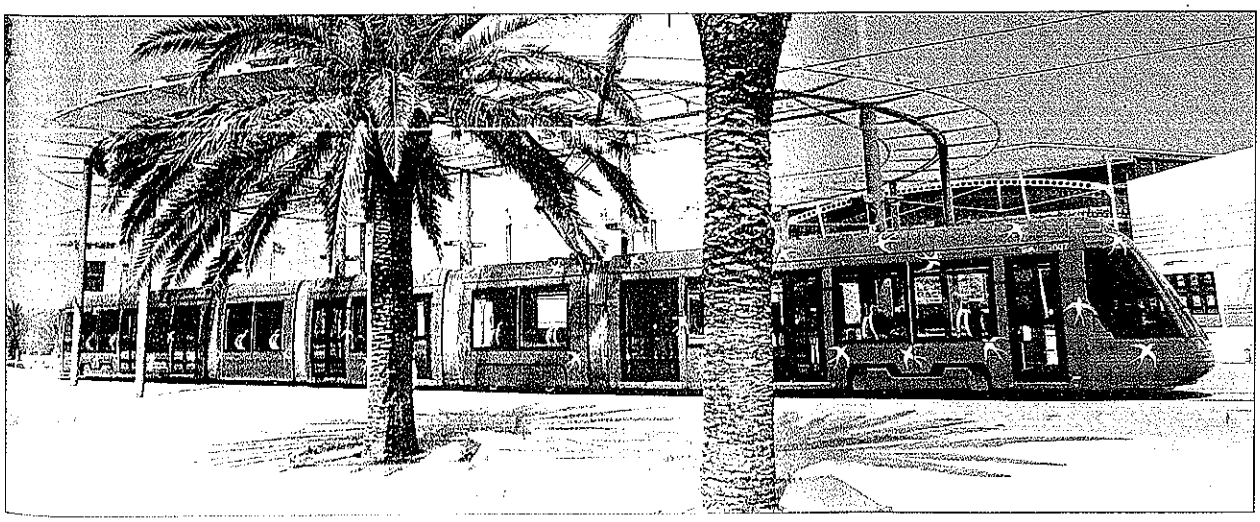
As Line 1 goes from strength to strength, the city is already looking forward to the opening of a second route at the end of 2006. In fact, the CAM urban transport plan which initiated the light rail project envisages the construction of a three-line network by 2012. The three routes are expected to carry more than 80% of the population of the Greater Montpellier area each day.

Line 2 will run for 19·5 km, linking Saint-Jean-de-Védas in the southwest to Jacou in the northeast; interchange with Line 1 will be provided at Gares, Place de l'Europe and Corum in the city centre.

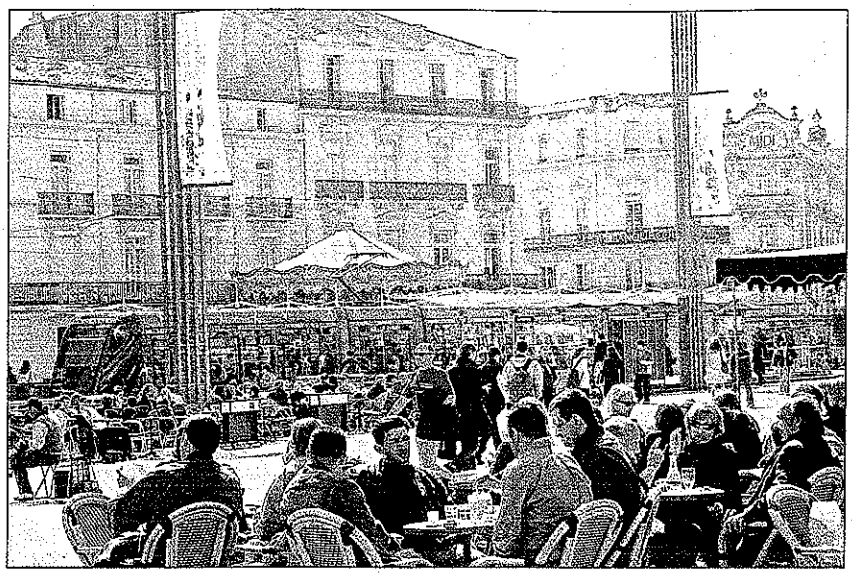
The preferred route for this line was agreed by local officials in September

TOP: *Some sections of Line 1 incorporate a grassed reservation which helps the tramway to blend into the urban landscape*

BELOW: *Innovative architecture on Line 1 has encouraged urban renewal, as exemplified by this tram-bus interchange*



Good penetration of the city centre, together with convenient park-and-ride facilities and easy interchange with local bus routes, has helped Montpellier's first light rail line beat all its patronage projections



2001, and endorsed by the Ministry of Transport in April 2002. Following a lengthy public consultation process, Line 2 finally received its Declaration of Public Utility on May 11 2004, enabling construction work to get underway.

Earlier this year the main road between Montpellier and Castelnau-le-Lez was closed for 17 months to permit the reconstruction of the bridge over the River Lez. The old bridge, known locally as the 'Pont Submersible' for its propensity to flood, will be replaced by a new structure, 6 m higher above the water, carrying two road lanes, two tram tracks and a segregated cycleway.

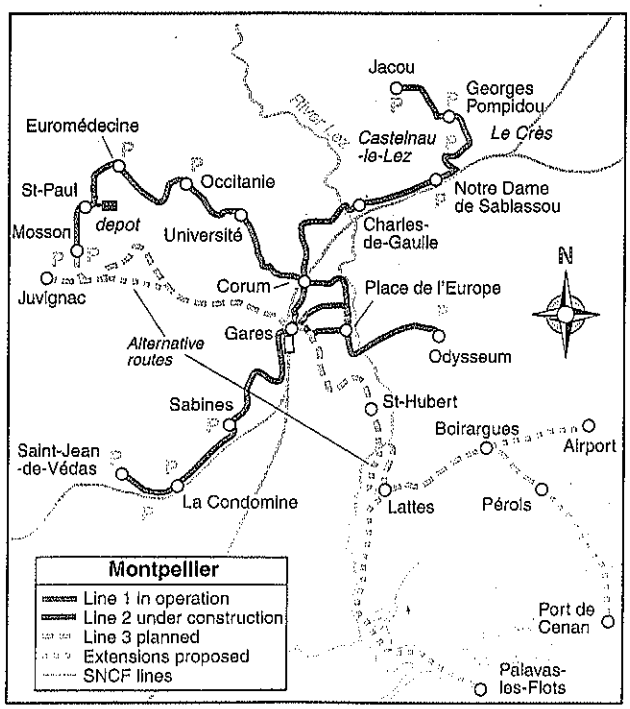
Total cost of the project is put at €424m (at 2000 prices). Of this the government agreed to contribute €100m, and the *région* and *département* would each provide €23m, leaving CAM to raise the balance of €278m. In practice the government cancelled part of its support, so that CAM and the region had to make up the difference.

Connecting five outlying towns and suburbs with the city centre, Line 2 is forecast to carry around 52 000 passengers/day. Services will operate from 05.00 to 01.00 each day, with headways of 5 to 7 min on the central section between Sabines and Sablassou and 10 to 15 min on the extremities. The route will serve nine park-and-ride facilities: four in the south and five in the northeast. Initially there will be 1 930 parking spaces, with provision to increase this to 3 980 in the long term.

To operate the new line, TaM has ordered a further 24 Citadis cars from Alstom at a cost of €54m. Unlike the original vehicles, they will be all-low-floor, but they will share many common parts and will also be designed for subsequent extension from 30 to 40 m if required. Both fleets will be able to operate on either line if necessary, but they will normally keep to their own tracks.

Alstom engineers have been working with the city's interior and external design consultants Garouste and Bonetti and with local passenger representatives to develop the new vehicles. The designers have given the Line 2 cars their own identity, with more rounded car ends, ergonomic improvements to the cabs, and modified headlight clusters. The cars will carry a green livery featuring flowers instead of the blue livery and seagulls used on the Line 1 vehicles.

Capacity of the Line 2 cars will be 64 seated and 146 standing passengers, compared to the 76 seated and 213 standing on the lengthened Line 1 vehicles. Maximum speed in service will remain 70 km/h, and the target is to offer an end-to-end commercial speed of 20 km/h including 32 intermediate stops.



The Line 2 Citadis cars will carry a floral motif to differentiate them from the blue Line 1 fleet sporting their distinctive seagull symbols

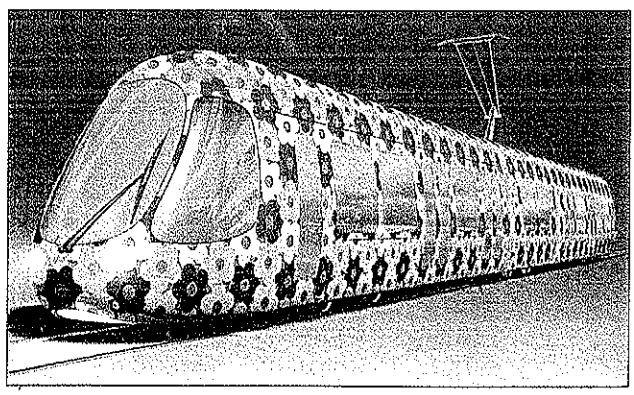
Line 3 to follow

Planning for a third route has been underway for almost five years, and in April 2002 CAM voted to adopt a preferred route with one or two alternatives for further study. In May 2005 a consortium led by Semaly was appointed to manage the €450m project, with the target of putting the line into operation in 2010.

Line 3 is intended to serve four park-and-ride sites. It will start from Juvignac, to where Line 1 will also be extended from Mosson. Line 3 will run to the south of the existing route to reach the city centre, and then continue southeast to Pérols. The preferred route is 21 km long, and it is forecast to carry around 55 000 passengers/h when it opens.

When all three lines are operational, they will form the main axes of a complete public transport 'grid' across the entire TaM service area, offering high-quality interchange between train, tram, bus and interurban bus services. There will also be improved facilities for pedestrians and cyclists, offering every resident of Montpellier and the surrounding communities an effective alternative to using their cars.

Reflecting this ambition and anchoring the network will be a transport hub in the city centre. A new interchange to be served by all three tram routes is taking shape in front of the railway station, at the heart of a truly integrated, high-quality public transport network. ■



Takt 10 creates Germany's busiest cross-city link

COMMUTERS in München have enjoyed greatly enhanced levels of service since December 13 2004. Service frequency has been doubled on the S-Bahn routes from Maisach, Zorneding, Germering-Unterpfaffenhofen and Deisenhofen, with trains running every 10 min during the morning and afternoon peak hours.

The new face of S-Bahn München. A Class 423 EMU calls at Pasing on a test run before entering service

From 06.30 to 09.00 on Mondays to Fridays and from 15.30 to 19.00 on Mondays to Thursdays the 10 min interval service on these routes has given passengers more flexibility in planning their journeys, while loads have been spread more evenly. Passengers know that they will never have to wait longer than a few minutes for the next train.

Heinrich Beckmann
Chairman of the Managing Board S-Bahn München GmbH

Introducing the 10 min interval service was not a simple matter. Planning for the 'Takt 10' service remodelling started back in the 1990s, but only in December 1998 was an agreement covering finance and implementation of this major investment programme signed by the *Land* of Bayern and German Railway.

The €266m programme covered double-tracking of an 11 km section of the line to Deisenhofen, a 4 km bypass round Berg am Laim, reconstruction of München Ostbahnhof and complete modernisation of the S-Bahn cross-city underground link. Other work included modernisation of numerous stations and remodelling of the service pattern with some routes renumbered.

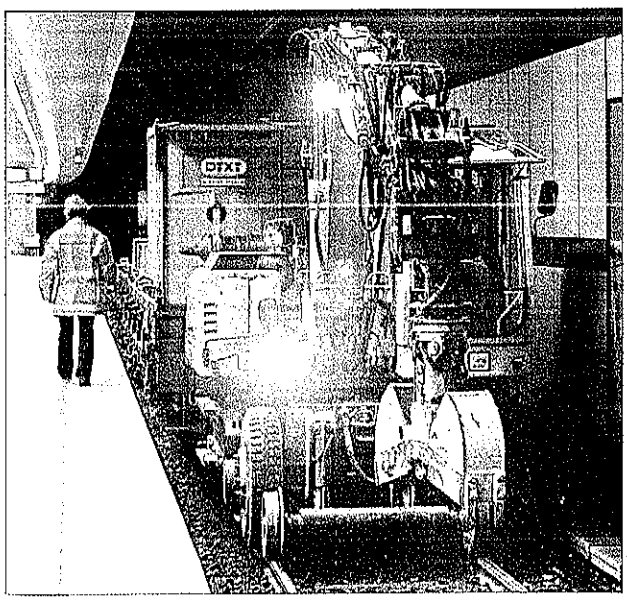
Beyond the core sections where 10 min interval services operate, trains normally run every 20 min, with 40 min intervals on the sections furthest from the city centre. Our future plans envisage extension of the 10 min interval service to Dachau by December 2005.

Cross-city core

Running between Pasing in the west and Ostbahnhof on the eastern fringe of the city centre, the cross-city tunnel was opened in time for the 1972 Olympic Games. Introduction of 10 min interval services means that many more trains have to be funnelled through the link.

All S-Bahn lines converge on the 11·4 km section from Pasing to Ostbahnhof – around 1 000 trains every weekday. This means that it is now the busiest main line railway in Europe in terms of the number of services operated, with trains running at 2 min intervals.

Normally there are 27 trains per hour in each direction, but it is possible to increase this to 30 trains an hour. Elsewhere in Europe this frequency has only been achieved on metro lines, although the Paris RER provides a comparable frequency.



A key component in the capacity enhancement was the installation of LZB inductive train control and cab signalling

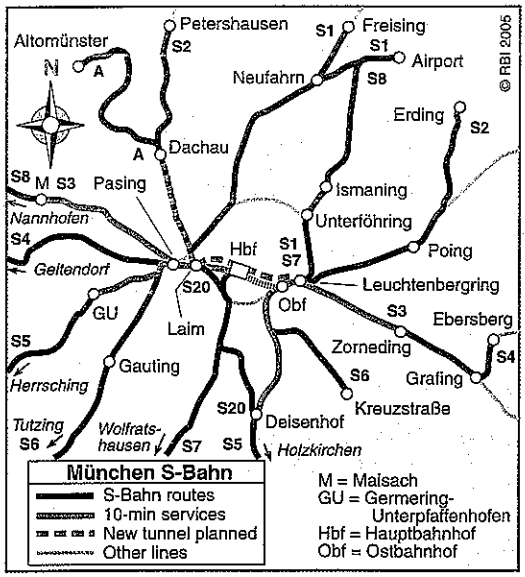
To accommodate this level of service required extensive modernisation of the 30-year-old tunnel. Only by careful planning and rigorous adherence to a tightly-timed work schedule were the contractors able to complete this demanding and comprehensive programme in the time window available.

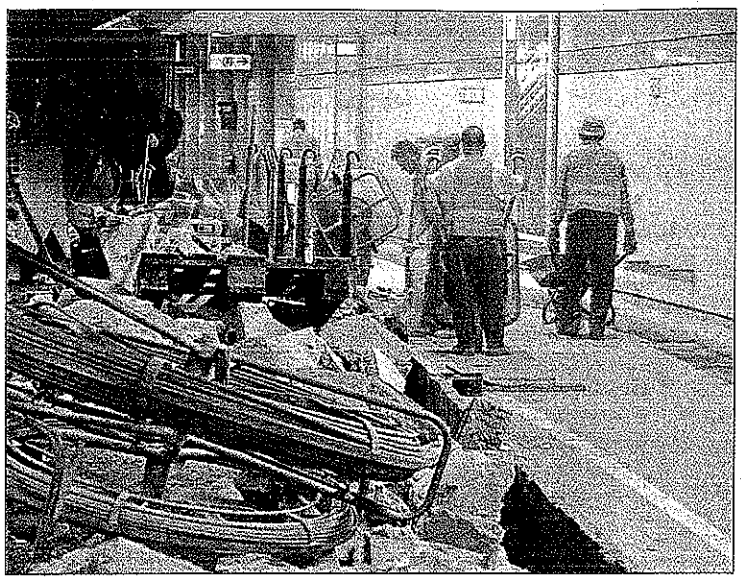
The work required 49 weekends and more than 200 weekdays when the line was completely closed or operated with single-line working. Between January 2003 and August 2004 around 200 km of signalling cables were laid, 349 signals erected, and a new modular control centre built and commissioned.

Achieving the increase in line capacity would not have been possible without resignalling. LZB inductive train control was installed, and this went live in November 2004 – the first time that LZB has been used on a S-Bahn route in Germany. LZB provides continuous speed supervision, with a screen in the driver's cab displaying the maximum permissible speed and the distance to the next stop signal or location where the line speed changes. The information is updated every second.

Rolling stock fleet replaced

Modernisation of the rolling stock fleet was also essential. The entire fleet of ET420 three-car trains dating from the 1970s was replaced by 234 Class ET423





Reconstruction work to increase the capacity of the cross-city tunnel required extensive daytime and weekend closures between January 2003 and August 2004

trainsets by mid-2003. The whole process took four years and absorbed around €790m, of which Bayern provided €180m.

The ET423 is an articulated lightweight design with regenerative braking and a maximum speed of 140 km/h. Each air-conditioned set seats 192 passengers with room for 352 standees; visual and audio passenger information is provided, with some messages given in English.

An essential part of the job was a comprehensive staff training programme so that everyone was thoroughly familiar with the new equipment and the new trains. No fewer than 551 drivers had to be trained on the ET423, and considerable use was made of a driving simulator so that drivers were truly familiar with the function and operation of LZB.

Another 120 station and platform staff had to be trained too. The role of these employees is to provide passengers with information about services, but their most important task is to ensure that the 30 sec station dwell time on the cross-city link between Pasing and Ostbahnhof is strictly adhered to. They ensure that trains are dispatched on time, as failure to do so would jeopardise the very tightly programmed timetable.

Extensive trials were staged during the night in November 2004 to check the feasibility of the 10 min interval service, involving train control staff, station staff and train drivers. The trials covered a wide range of situations that the staff may encounter, giving them real practice at keeping to the station dwell times in sometimes adverse circumstances.

Responsibility for operating the intensive service is shared by the train control staff. At the beginning of 2004, the dispatchers, crew managers and rolling stock managers were brought together in a single control centre. Having all the decision makers together in this way enables them to work together closely, so that they can rapidly agree on any action to be taken in the event of disruption.

The individual cogs in this new organisation have proved to be well-oiled, and we have seen how the staff have reacted quickly and effectively when required, by organising bus replacement services for example. So-called red telephones have been installed to provide immediate links to the control centres for the city's U-Bahn, tram and bus operations, so that all the controllers can keep their colleagues informed of developments. This also ensures that passengers making their way to and from the S-Bahn are kept informed of potential problems around the network.

Around 20 standard emergency action programmes were worked out for use when the cross-city link is disrupted. The aim was to develop an ability to react quickly and flexibly, to ensure that all staff are kept informed and familiar with the altered routines, and to ensure that passengers are kept informed of developments and alternative travel options.

The S-Bahn control centre employs 29 staff, who are responsible for overseeing the operation of 1 100 trains a day on the largest S-Bahn network in Germany.

Second tunnel planned

The München S-Bahn now operates over 442 route-km, with a network of 10 routes serving 147 stations. A typical weekday sees 720 000 trips, with 350 000 on a Saturday and 240 000 on Sundays.

All forecasts suggest that demand will grow in the future, which is why a second cross-city S-Bahn tunnel is being planned parallel to the existing route. Work on the 10 km line with stations at Laim, Hauptbahnhof, Marienhof, Ostbahnhof and Leuchtenbergring is scheduled to start next year, with completion anticipated in 2010. This would offer a Laim – Ostbahnhof trip time of 9 min 30 sec.

The second tunnel will be dug at a depth of 40 m below the surface, and the steepest grade will be 4%. The cost is put at around €1bn, of which 60% would be funded by the federal government and 40% by the *Land* of Bayern.

The project is currrently working its way through the formal approval process, which is expected to take between one and two years. Allowing time for tendering and awarding contracts, we hope to see the start of construction in the autumn of 2006. ■

Introduction of 10 min interval services required the purchase of additional EMUs on top of the fleet renewal programme; the extra sets were funded by the Land of Bayern

Completing Japan's first subway loop

OCTOBER 6 2004 was a very special day for the Nagoya metro. To coincide with the 50th anniversary of the start of construction on the first route, the city inaugurated its latest extension, completing Japan's first true metro ring line.

Nagoya's six metro lines carry an average of around 1·1 million passengers on a typical weekday, on a network of 89·1 km

When the City of Nagoya began work on its first metro in 1954, the initial section of Line 1, the Higashiyama Line, ran for just 2·4 km from Nagoya station to Sakae-machi (now simply known as Sakae). Over the next 50 years, the network has grown steadily, so that by the end of 2004 there were six lines totalling 89·1 route-km.

Today, the metro carries an average of 1·1 million passengers a day. This is equivalent to approximately half of the total population of Nagoya City.

Nobuo Yoshii
Director-General
Nagoya City
Transportation Bureau

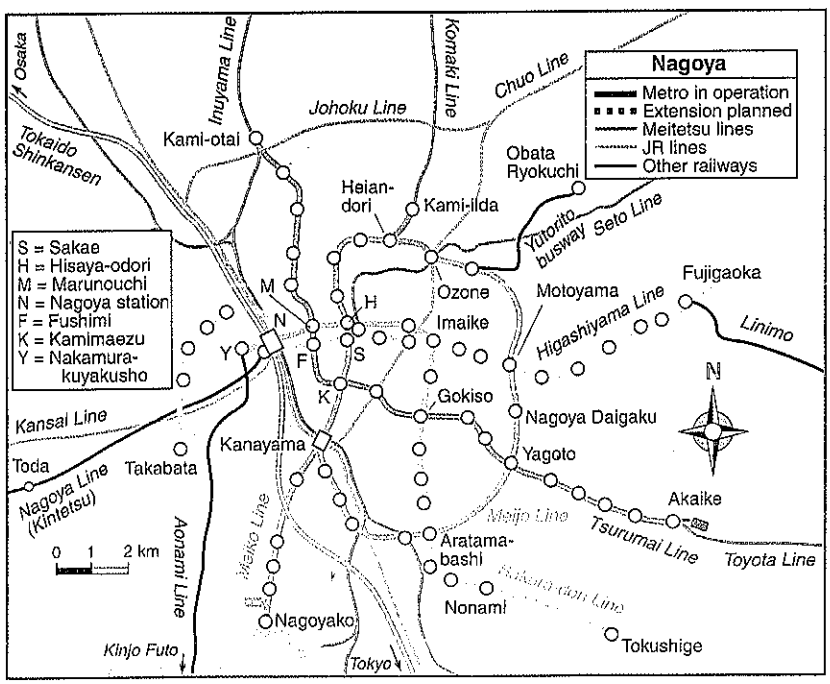
The Higashiyama Line is 1 435 mm gauge and electrified using a 600 V DC third rail supply, as are the later Meijo and Meiko lines. The first line grew slowly through the 1960s, reaching 8·5 km in 1963. Two years later we opened the first 1·3 km section of line 2, then known as the Meijo Line, between Sakae and Shiyakusho (City Hall). Both routes were extended in phases until the network reached 32·4 km in December 1971.

The 5·7 km Line 4 from Kanayama to Aratama-bashi in the south of the city opened in March 1974, followed three years later by the 8·0 km Line 3 from Fushimi to Yagoto. Line 3, the Tsurumai Line, was built to 1 067 mm gauge and electrified at 1·5 kV DC overhead to permit through running from the private-sector Nagoya Railway, Meitetsu.

Through running began in 1978, following the extension of Line 3 from Yagoto to Akaike, where it makes an end-on connection with Meitetsu's Toyota Line. The other end of Line 3 was also extended in stages until the opening of the 1·4 km from Shonai Ryokuchi-koen to Kami-otai in August 1993 permitted through running onto Meitetsu's Inuyama Line.

Today Nagoya Metro and Meitetsu share the operation of the Tsurumai Line under a reciprocal rights agreement. A similar agreement also applies to the 0·8 km Kami-Iida Line, which was opened in January 2003 so that Meitetsu's Komaki Line trains can reach an interchange with the Meijo Line at Heian-dori.

Meanwhile, the 6·3 km first section of Line 6 between Nakamura-kuyakusho and Imaike opened in September 1989. Known as the Sakura-dori Line, this was also built to 1 067 mm gauge, so that the trains can share the Tsurumai Line workshop, which is reached via a short connection at Marunouchi. The 8·6 km second section from Imaike to Nonami was opened in 1994.



Completing the ring

In 1992 Nagoya City Government adopted a 'Basic Policy' setting out its objectives for development of the metro network to 2008 and beyond.

This led to the significant decision to extend lines 2 and 4 around the eastern side of the city to create a metro loop, mirroring underground the busy elevated motorway ring that encircles the city centre. The ring was intended to improve the connectivity and convenience of the metro network, providing good connections with all five of the other lines.

The eastern side of the ring was completed in three phases over the next decade. First to be completed was a short extension at the northern end from Ozone to Sunada-bashi, which opened in January 2000, serving the new Nagoya Stadium. In December 2003 the line was extended southwards from Sunada-bashi to Nagoya Daigaku, serving the university, via a new interchange with Line 1 at Motoyama.

The ring line project was finally completed on October 6 2004, when the

5·6 km section between Nagoya Daigaku and Aratama-bashi was opened for traffic. With the completion of the loop, the service pattern on Lines 2 and 4 was restructured.

Officially, Line 2 runs from Nagoyako to Ozone and Line 4 from Ozone to Kanayama via Aratama-bashi. Both lines were originally known as the Meijo Line, but now this is taken to refer to the ring, whilst the southern part of Line 2 from Kanayama to Nagoyako (Nagoya Port) was renamed the Meiko Line.

The new section runs entirely underground, and serves four new stations at Yagoto Nisseki, Yagoto, Sogo Rihabiri Center and Mizuho Undojo Higashi. The stations were built using an open box technique, but the running tunnels between them were excavated using a shield tunnelling method. The 50 kg/m rails are laid on a concrete slab substructure incorporating vibration-reduction measures.

With the opening of the final section, the completed loop is 26·4 km long, serving 28 stations in total. The loop is smaller than JR East's Yamanote Line in Tokyo, but larger than JR West's Osaka Loop. It is similar in length to the 'frying pan' section of Toei's Oedo Line in Tokyo.

Meijo Line trains operate in both directions around the ring, with a running time of 48 min. This service is overlaid by the Meiko Line trains from Nagoyako which run through over the northwestern part of the ring as far as Ozone, providing a more intensive service through the city centre. Between Ozone and Kanayama, trains run at headways of between 150 and 210 sec during the morning and evening peak periods. Before 07.00 and after 20.00 the Meiko Line operates as a 10min interval shuttle from Kanayama to Nagoyako.

Expansion continues

Opening of the loop line is not the end of expansion for the Nagoya metro. The Basic Policy strategy set out in 1992 identified a number of potential projects, although it is not definitive and other proposals can also be considered.

Future metro extensions are grouped into three categories. Class A projects will go ahead under agreed timescales, Class B projects are subject to detailed development and planning work, whilst Class C schemes are to be considered for possible development in the future.

The next major project to go ahead is a 4·1 km all-underground extension of the Sakura-dori Line from Nonami to Tokushige. This will serve the southeastern part of the city, which has seen a remarkable increase in population over recent years. The project was classified as Class A, and the City of Nagoya received permission to build and operate the line in September 2003. Civil engineering construction is expected to get underway in the financial year beginning on April 1 2005, with the line due to open in fiscal 2014.

Other projects were included in the Basic Policy, although we do not have any plans to build them at present.

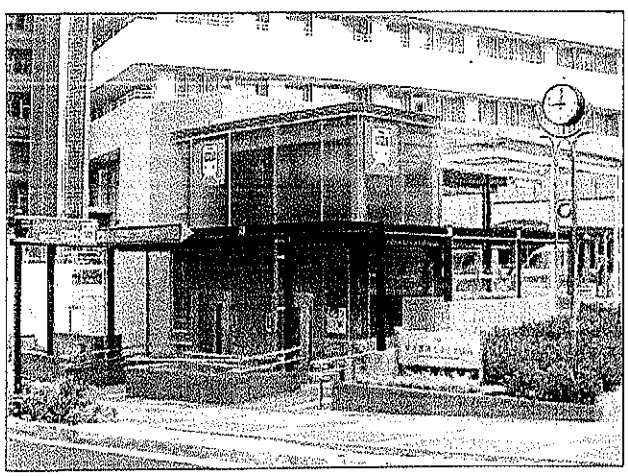
A special year

2005 is a significant year for the city, as Nagoya is hosting the World Exposition which runs from March 25 to September 25. The Transportation Bureau is responsible for providing access to the Expo site, which is connected to the Higashiyama Line terminus at Fujigaoka station on by the Linimo maglev peoplemover (RG 9.04 p539). Now known as the Tobukyuryo Line, this 8·9 km route was opened for revenue service at the beginning of March.

Stations on the newly-completed section of the ring match the architectural style of the older parts of the Meijo Line

Another development which came on-stream in time for the expo is the Central Japan International Airport which opened on February 17. This is connected to the centre of Nagoya by Meitetsu's μSKY airport express service which was launched at the end of January (RG 3.05 p220).

With many more international visitors expected in Nagoya this year, the Transportation Bureau took the opportunity of the opening of the ring line to introduce a new multi-lingual metro network map with standardised numbering for all the stations. We expect that this will make the metro much easier to use, both for the visitors from across Japan and from other countries. ■



Prominent markings at the station entrances (below left) make the metro easy to find. Multi-lingual signage is being introduced to cater for an expected flood of visitors to this year's World Exposition

Step by step to a three-line network

Krasimir Krastanov*

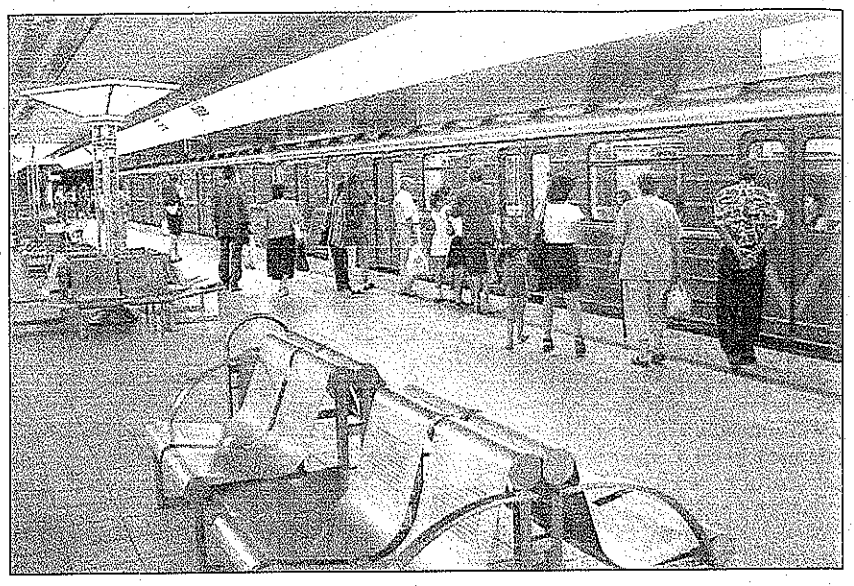
AT THE MOMENT Sofia has only one metro line, but plans call for a three-line network to be built, stretching to a total length of 52 km. When this is eventually completed, the network will have 47 stations, and traffic will amount to more than 1 million trips a day.

The Bulgarian capital has a population of about 1·25 million, living in an area of slightly more than 190 km². Studies deemed it essential for the capital to have a metro network, and the municipality plans to complete this in stages based on a development plan drawn up for the period to 2020. This envisages that the metro will become the backbone of the capital's transport network, meshing with bus and tram services.

A technical and economic feasibility report published in May 1974 concluded that the first line should run for 21 km and have 17 stations. The second line is to be 18 km long with 15 stations, and the third line will be 15·8 km long with 15 stations. All three will meet in the central area, where they will form a triangle.

The report recommended an average distance between stations of 1 100 m, with trains running at up to 90 km/h. Capacity in each direction will be 50 000 passengers/h, the shortest headway being 90 sec thanks to the use of automation. Gauge is 1 435 mm and power is supplied by a bottom-contact third rail at 825 V DC.

*Krasimir Krastanov is a PhD student holding an MSc in Engineering from the University of Transport in Sofia. He can be contacted at: krasi_krastanov@yahoo.com

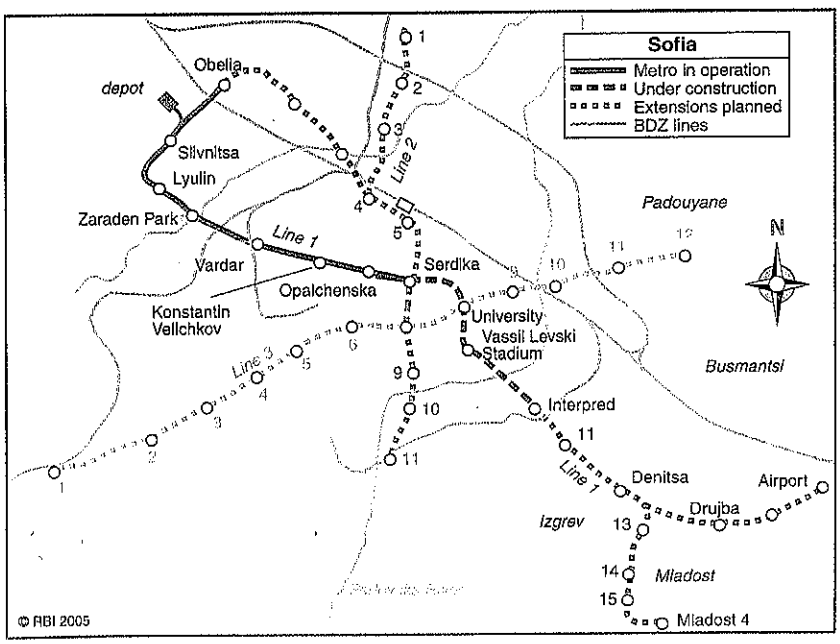


Trains on the Sofia metro are built to a standard Russian design

Although planning began as long ago as the early 1970s, construction of the first line is relatively recent. The first two stations and the tunnel between them formed part of the same project that saw the National Palace of Culture built in the city centre in 1992. Construction continued, and the first 6·4 km section with five stations opened in January 1998. Another station at Opalchenska was added in September 1999, taking the length of the line to 8·1 km with seven stations. Work on the most recent 1·8 km extension to Serdika began in October 2000, and the station was opened in early 2003. Construction of this section demanded special precautions because of the historic buildings in the central area. Most construction was undertaken using cut-and-cover techniques.

Design and construction of the first metro line was carried out entirely by Bulgarian companies. Control and operational equipment was sourced from other countries, although Bulgarian software was used. Rolling stock was supplied from Russia, and ATO equipment was supplied by Bulgarian companies using Russian-made components matching the equipment installed on the cars.

Functional control systems include train radio and dispatching, information and fire alarm systems, ventilation, ticketing and visual information displays.



Station design

The architectural design of the stations emerged as a major element in the urban environment, and in Sofia planners were conscious that station design on other metro networks generally represents the type of architecture that is popular during the period of construction – or is chosen to match specific features of the area through which the line passes.

Despite the fact that the architecture of the stations absorbs a mere 3% of the total cost, it has a major aesthetic impact on passengers, with the potential to create a feeling of comfort and to encapsulate the overall image of the metro. In Sofia design and implementation was developed in joint efforts by the design staff for each metro station and the investor, and in most cases the final version was selected from a range of alternatives.

Line 1 extensions

Work is already getting underway on the next extension of Line 1, which will add a further 2·4 km and three stations. In 2002 Bulgaria signed a loan agreement with Japan to fund this extension. The Japan Bank for International Co-operation has agreed a credit worth US$104m with a term of 30 years

before repayments are due.

Japanese contractors were awarded a contract for construction of the 2·4 km extension from Serdika to Interpred, which is scheduled to open in October 2007. The contract includes the construction of two stations serving Sofia University and the Bulgarian National Radio building; a third is being funded separately by the municipality. When this extension is completed, Line 1 will run for 15 km with 11 stations, and will carry an estimated 35 million passengers a year.

The extension will run in two parallel single-track bores. The new station under construction at the University of Sofia will be one of the busiest on the network, as it will provide interchange with several of the principal surface routes. The second new station lies at a considerable depth below the surface, because the extension must pass under the Perlovska river and the adjacent sewers. There will be three underground levels between the surface and the station tunnels, and here an underground car park with 300 spaces is envisaged.

After this station, the line will run beneath one of the city's main boulevards, climbing at a relatively steep 3·7% gradient up from the river crossing. Interpred station will also be underground, but after this the route will run onto the surface, where the reversing crossovers will be located.

Engineering design is now in hand for another 6 km extension with six stations that will take the line to the business park and residential suburb of Mladost on the outskirts of Sofia. The municipality is currently looking for funding in parallel with the design work, which is expected to be completed by the end of this year.

Construction will start in 2007 and should be completed in 2009, although Mayor Stefan Soflanski said recently that it is possible that the metro could open in 2008. The work is likely to be split into two sections, with Interpred – Denitsa opening in 2008 and the final section to Mladost the following year. This would bring Line 1 to a total length of 21 km with 17 stations. End-to-end journey time will be 30 min compared with the present trip by tram and bus which takes 1 h 20 min because of the severe traffic congestion in the city centre.

Line 2 under construction

Work has also started on the second line, although the initial section is just 1·2 km long. The first station will provide an interchange to Line 1 immediately in front of the National Palace of Culture, and the single-track tunnel taking the line to a station in front of the Hotel Hemus will be completed by the end of 2005.

The municipality is also planning to extend the metro to the airport, where a new terminal is now under construction. The intention is to apply for accession funding after Bulgaria joins the European Union in 2007.

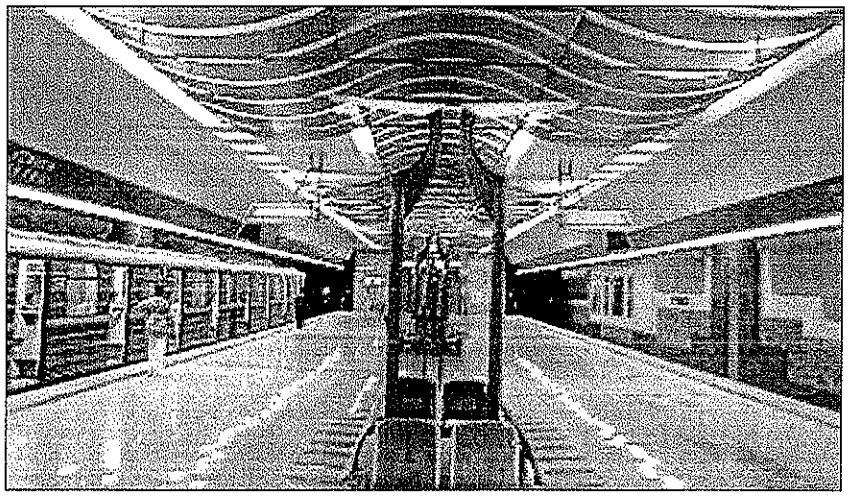
The airport branch would diverge from Line 1 at Denitsa and run via Drujba. It would be around 9 km long, with construction expected to take five or six years. This accords with the timescale envisaged in Sofia's recently-adopted general town planning strategy, which assumes as a worst case that the metro will open to the airport by 2020.

Although implementation of the Sofia metro plan in stages has been approved by the municipality, the funds needed to continue construction of the second line and to start the third have not yet been secured. Despite this, plans are being prepared to continue work during the period from 2010 to 2020. Once the three lines are complete, most important parts of the city will be served, in particular those which currently suffer from heavy traffic. The municipality expects the length of the metro to reach 25 km by 2012 and 42 km by 2020.

For the moment the metro has a 3% share of the trips taken within the city. Despite heavy investment, this is not much to show for the cost and the effort, and the traffic of about 90 000 passengers per day or 29 million a year is a long way from the forecast of 52 million passengers a year anticipated when the first line is complete. However, with construction of the final section in prospect, the perspectives are excellent, and current figures suggest that the number of passengers carried will quadruple by the end of 2007.

Daily patronage is expected to increase to 600 000 by 2020. According to the municipality, after completion of the first two routes the metro will be carrying about 25% of all rush-hour trips.

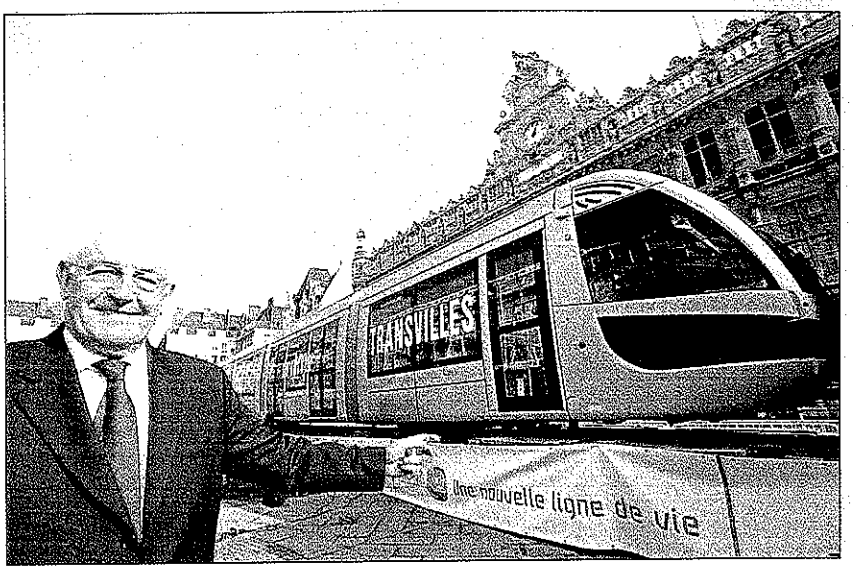
A flat fare equivalent to €0·25 is charged, generating about €7·2m a year. Additional revenue is generated by advertising sales and rental of numerous cafes and shops at the stations. Operating costs amount to around €10·1m a year, with the difference being covered by the municipality. ■



Serdika station serves the city centre, adjacent to the National Palace of Culture; it will provide interchange with Line 2 from 2007

All aboard the tram!

Francis Decourrière
President, Syndicat Intercommunal pour les Transports Urbains de la Région de Valenciennes (SITURV)



THE ARRIVAL in January of the first low-floor light rail vehicle for the Valenciennes tram network marked a significant milestone in a lengthy process of planning, construction and commissioning. Now we are looking forward to the inauguration of the first route on June 16 next year.

The opening will bring to fruition a dream that dates back to 1992. As has been demonstrated elsewhere in France, we are confident that the trams will bring an immediate improvement in the quality of life in our region. The project has already started to encourage urban regeneration in line with the regional planning strategy.

With 350 000 inhabitants in 75 *communes*, the Valenciennes region is now the 12th largest urban area in France. Valenciennes itself is home to 41 000 people, and Denain to over 20 000. In 2001 these 75 *communes* were grouped into two *Communautés d'Agglomération*, Valenciennes Métropole and Porte du Hainaut.

The region has changed a great deal over the last 20 years. The built-up area has grown, with inhabitants living further and further from the town centre and from each other. However, development has not progressed at the same pace throughout the region. The Town Planning Strategy, as drawn up in 1992 and revised in December 2002, places an emphasis on restructuring the area and restoring cohesion between the urban centres and the suburban communities.

The area's industrial past has left its mark and the strategy includes the restoration of green space, with specific actions to rehabilitate industrial wasteland.

Transport and urban planning

It was also recognised that the town planning strategy must be accompanied by an improvement in public transport provision, and the tram network being sponsored by SITURV has been an integral part of the strategy since it was adopted in May 1992.

With urban growth increasing average journey lengths, travelling times became longer, and the number of journeys needed multiplied. The number of motor vehicles in the Valenciennes area increased from 49 000 cars in 1975 to 121 155 in 1997. But even after this growth, we found that 60% of the region's residents were reliant on public transport at certain times of the day.

This increase in the use of cars caused more congestion in the town centre. As almost everywhere, cars are omnipresent, bringing noise and pollution. At the beginning of the 1990s, SITURV broached the idea of improving public transport. In June 1996 it agreed to draw up a Local Traffic Plan for the Greater Valenciennes region within the framework of the 1982 Law on Town Planning for Transport.

This process was accelerated by the Law on the Quality of Air and Rational Use of Energy (LAURE) passed on December 30 1996. All urban areas with more than 100.000 inhabitants are required to draw up a Local Traffic Plan, limiting the use of cars and encouraging the use of other modes, including public transport, bicycles and walking. The finished plan for Valenciennes was officially approved on February 21 2001.

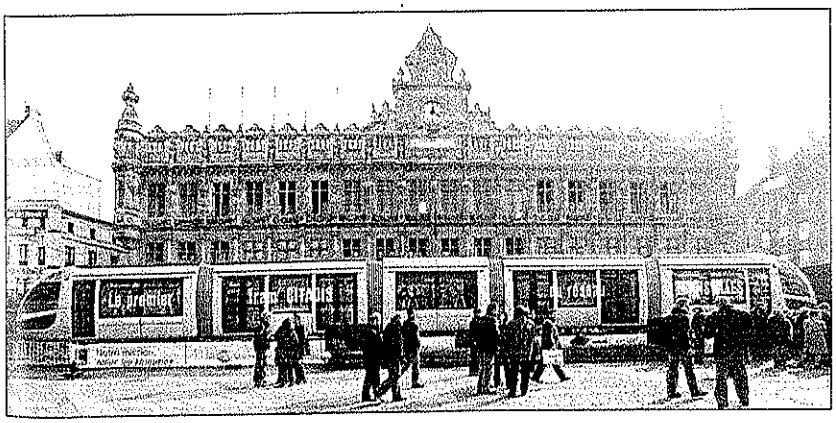
Driving force for change

The decision to invest in a new tram network has enabled Valenciennes to redesign its entire public transport network. The long-term plan envisages construction of a two-line H-shaped network connecting the four major economic centres: Valenciennes, Denain, Condé-sur-Escaut and St-Amand-les-Eaux.

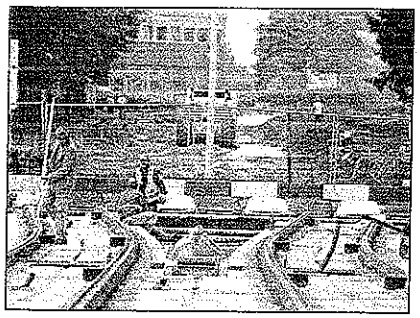
The final go-ahead for the tramway came in August 2001, when the Préfet of Nord Pas-de-Calais signed the formal Declaration of Public Utility, so that work on Phase 1 could get underway at the beginning of 2002. Preparatory works and utilities diversion occupied most of 2003, and it was not until May 2004 that civil engineering work could begin. Rapid progress at this stage led to a ceremony on September 7 to mark the start of tracklaying (RG 10.04 p663).

Civil engineering on the western and southern sections of Phase 1 is being undertaken by a consortium of Beugnet Hainaut and Colas Nord Picardie for €31·4m. Jean Lefebvre and SCREG Ramery are responsible for work in the central area valued at €33·7m. Major structures including three bridges have been contracted to Norpac and Quillery for €23m.

Track and signalling are being supplied by Vossloh under a €33·6m contract, with the 41GPU section grooved rails coming from Corus. The 750 V DC overhead electrification package worth €2·3m is the responsibility of a consortium of AMEC Spie Rail, Forclum



The first of 17 Citadis 302 low-floor trams being supplied by Alstom for Valenciennes Line 1 was officially unveiled to the town's citizens in a ceremony outside the town hall on February 25

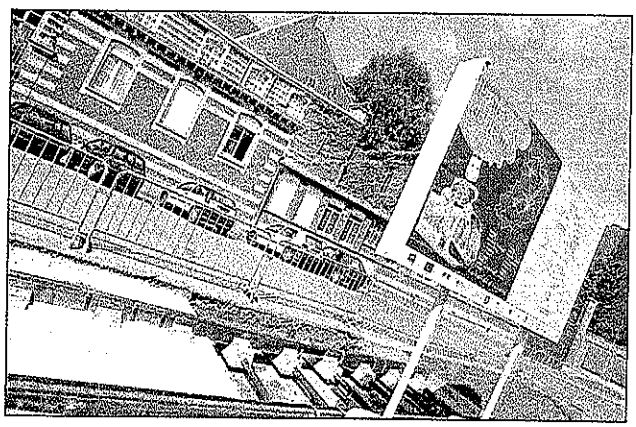


Tracklaying work is well underway in the town centre, where bus routes and car traffic have been re-routed to free up road space for segregated tram tracks wherever possible

Ingénierie and Norelec Industrie. Thanks to competitive tendering, the total cost for all these contracts came in at €10·4m under budget.

The first section of Line 1 will be 9·5 km long with 19 stops. It will start from Dutemple in the southwest of Valenciennes and run north to Anzin along the alignment of the disused Somain – Péruwelz industrial railway, which was acquired by SITURV in 1999. From Anzin it turns east past the main railway station to the centre of Valenciennes.

The line will then continue south through Marly, Aulnoy, Famars and Hainaut-Cambrésis to terminate on the Université de Mont Houry campus at Aulnoy. The main depot and workshops

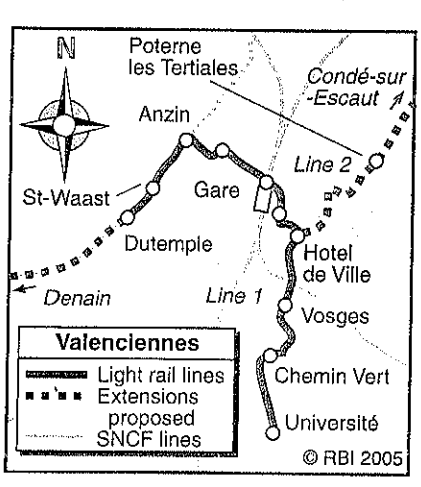


are located on the site of the former mineral railway yard at Saint-Waast, which will also house the operations control centre, electrical distribution feeder and a bus stabling area.

Total cost of the first phase is put at €243m at 2001 prices, of which €41·5m is coming from the French Ministry of Public Works & Transport, under a grant agreement signed on November 27 2002. The European Investment Bank is contributing €110·5m through loans to SITURV, and the rest will come from a consortium of banks. Operating costs will be covered by an increase in the local *versement de transport* workplace tax from 1% to 1·75%.

Line 1 will be worked by a fleet of 17 Citadis 302 all-low-floor LRVs ordered from Alstom at a cost of €48·5m; the contract includes options for up to 11 more vehicles to work various extensions. To maximise local content, the cars are being assembled at Petit-Forêt by Bombardier's former ANF Industrie plant, which is also building the bodyshells and bogies. The 33 m long, 2 400 mm wide cars each carry 48 seated and 147 standing passengers. The bidirectional cars have four double and two single doorways on each side, and the floor height at the doorways is just 280 mm above rail level.

Dutemple – Université services on Line 1 will run every 12 min off-peak and every 8 min at peak times, overlaid with a shuttle between Anzin and Valenciennes halving the headway in the central area. End-to-end journey time is estimated at 25 min, requiring a commercial speed of 20 to 25 km/h including stops.



An expanding network

The opening of Line 1 in June 2006 will not be the end of the story. Construction work is already underway on the €49m second phase, which has been accelerated by a year to give a target completion date of 2007.

This phase covers an 8·5 km extension of Line 1 running southwest from Dutemple to Denain, designated Line 1bis. The route uses a further section of the old industrial railway alignment. There will be seven stations to serve the communities of Denain, Oisy, Hérin and La Sentinelle. There will also be a major park-and-ride facility close to the A23 Lille – Valenciennes motorway.

The new terminus at rue Villars in Denain is being designed as a major transport hub, in conjunction with a retail and office development, L'Espace Villars. The second most important hub on the tram network, it will have 4 m wide platforms offering convenient interchange between tram and bus services.

With trams serving Valenciennes and Denain by 2007, SITURV will then turn its attention to extending the network to the third of the four towns in the region, Condé-sur-Escaut. This 12 km branch will diverge from Line 1 at Anzin and run north through Poterne and Les Tertiales. Line 2 trams from Condé will continue over the Line 1 tracks to reach the centre of Valenciennes.

St-Amand-les-Eaux will benefit from an improved TER service on SNCF's Lille – Valenciennes route. To accommodate the anticipated traffic, the station has been rebuilt with park-and-ride facilities, providing spaces for 200 cars and 75 bicycles.

Restructuring the network

To ensure close co-ordination between tram and bus services, SITURV has contracted the operation of tram services to the existing bus operator, a Transdev subsidiary. SEMURVAL currently runs 18 urban and 14 regional bus routes, operating more than 8·6 million bus-km each year.

The opening of the tram route will be marked by a profound change to the entire public transport network serving the Valenciennes area. The first phase of Line 1 will serve five major interchanges, of which four will have park-and-ride facilities, where motorists will be able to leave their vehicle and continue their journey by tram without having to worry about traffic, pollution or parking.

Introduction of the tram to the town centre has already required reorganisation of certain bus routes to free up road space. To ensure that the two modes compliment each other, some bus routes will be altered, and others extended or modified to improve connections with the trams. The stations at Université, Anzin and Place du Hainault in the town centre are being designed as specific bus-tram interchanges.

Cyclists and motorcyclists will also be able to use the car parks, and bicycles will be permitted on some trams outside peak hours. We expect the restructured network to improve the quality of public transport right across the region, in terms of both speed and availability to all. ▩

Richard A White
CEO & General Manager
Washington Metropolitan Area Transit Authority

Coping with ridership growth on an ageing network

OVER THE PAST eight years, ridership on the metro and bus services operated by Washington Metropolitan Area Transit Authority has risen by a third. We are operating more services on more routes and setting new ridership records, yet at the same time we have to come to terms with maintaining, upgrading and renewing our ageing assets despite ongoing issues of under-investment.

WMATA was established by Congress in 1967 to serve the transportation needs of the federal government, the nation's capital and the Greater Washington region. Our leadership has embraced this mission, and today Metro (as the authority is known locally) is recognised as a leader in the transit industry and a national security asset.

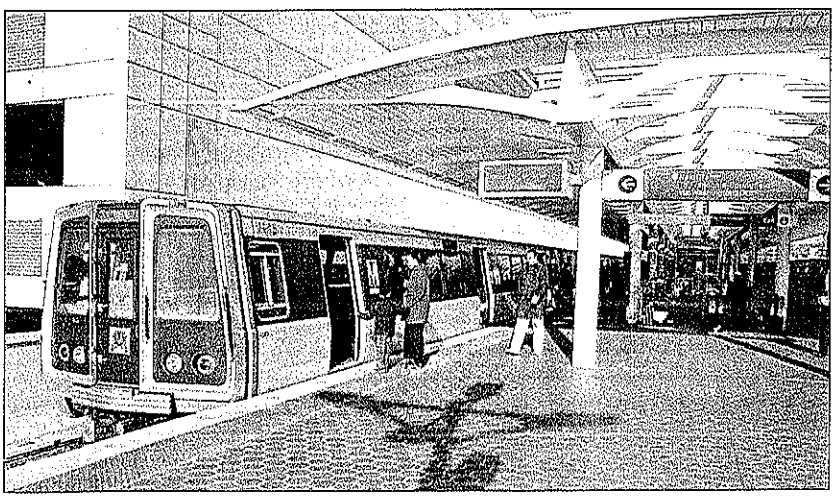
Over the past eight years, we have successfully fulfilled the promise made more than 30 years ago – to build and operate a world-class transit system, opening doors of opportunity and accessibility across the diverse communities that are served by Metrorail, Metrobus and Metroaccess.

Metro serves an area of 3 885 km², with 4·2 million residents, which is visited by 20 million people a year. Each weekday, Metrorail operates more than 1 500 trains making 33 000 station stops, with 758 metro cars scheduled to be in operation.

In the financial year to September 30 2004, Metro handled 336 million passenger-journeys – 190 million on rail and 146 million on bus. Ridership has grown by 33% since 1996, and severe overcrowding exists on both the rail and bus networks. On an average weekday, 670 000 passenger trips are made on Metrorail. In June 2004, on the day of the funeral of former President Ronald Reagan, the rail network handled an unprecedented 850 636 passenger trips, smashing the previous single-day ridership of 811 257 which had stood for more than a decade since President Clinton's Inauguration Day in 1993.

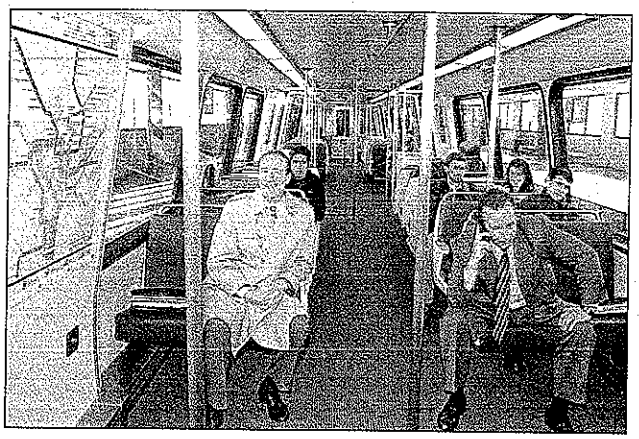
Despite – or perhaps exacerbated by – the rapid growth in ridership, our transit infrastructure is ageing. Over 60% of the rail network is at least 20 years old, and investment has not kept pace with need. A key issue that needs to be faced by our regional and national governments is WMATA's lack of a reliable dedicated funding source.

Construction of the 163 km initial network was funded through specific



TOP: *A mixed trainset including CAF-built Series 5000 cars calls at Archives-Navy Memorial station on the Green Line*

LEFT: *WMATA's new Blue Line terminus at Largo Town Center in Maryland was opened on December 18 2004*



The interior of the CAF-built Series 5000 cars is brighter than earlier vehicles. More radical changes to the interior layout are planned for the Series 6000 cars on order from Alstom

federal grants, and but no mechanism was put in place to fund ongoing operating subsidies or maintenance and renewal of the assets.

Improvement initiatives

Over the last few years, we have undertaken several initiatives to improve our network, and introduced a range of service enhancements to make Metrorail even more convenient for local residents and visitors.

In the last decade, Metrorail has added 12 stations and extended its hours of service four times. Since 1996 we have added 20 000 parking spaces at suburban stations across the region, increasing our park-and-ride capacity by 40%.

To handle growing traffic and increased service levels, Metro ordered 192 Series 5000 cars from CAF of Spain in April 1998, bringing the total fleet to 950 vehicles. The first of these new cars entered service on the Green Line in 2001, and the final vehicles began running on the Red Line in April 2004.

The Series 5000 cars feature new colourful interiors and station stop displays which enhance the comfort and convenience of our customers' riding experience. The state-of-the-art cars have many other features that are not readily apparent to the passenger, including computerised traction and braking controls and more advanced air-conditioning systems.

Later this year we will start to take delivery of the next generation of cars, designated Series 6000. An initial batch of 62 cars was ordered from Alstom Transportation Inc in 2002, and an option for a further 122 cars was exercised in October 2004, bringing the total order to 184 vehicles at a cost of $229·1m. When these extra cars arrive, we will be able to extend one-third of our peak-hour services from the present six-car formation to eight-car trains.

The Series 6000 cars will feature a remodelled interior layout designed to increase seating and standing capacity. The changes include the elimination of draught screens at the doorway vestibules and mounting the metal pole hand-holds on the seat backs instead of running them from floor to ceiling.

As well as procuring new cars, we are rehabilitating our existing fleet. This proactive approach improves the performance of older cars and extends their life, reducing operating costs and saving the capital cost of replacing them by new vehicles.

Work is now underway on an extensive refurbishment of the 364 Breda-built cars which date from the 1980s. This work is being undertaken by Alstom at Hornell, and 106 cars have been refurbished so far; the programme is expected to be completed by early 2007.

The mid-life rehabilitation includes replacing the braking, propulsion and lighting systems. Other mechanical, electrical, electronic and interior components are being renewed, refurbished or replaced at the same time.

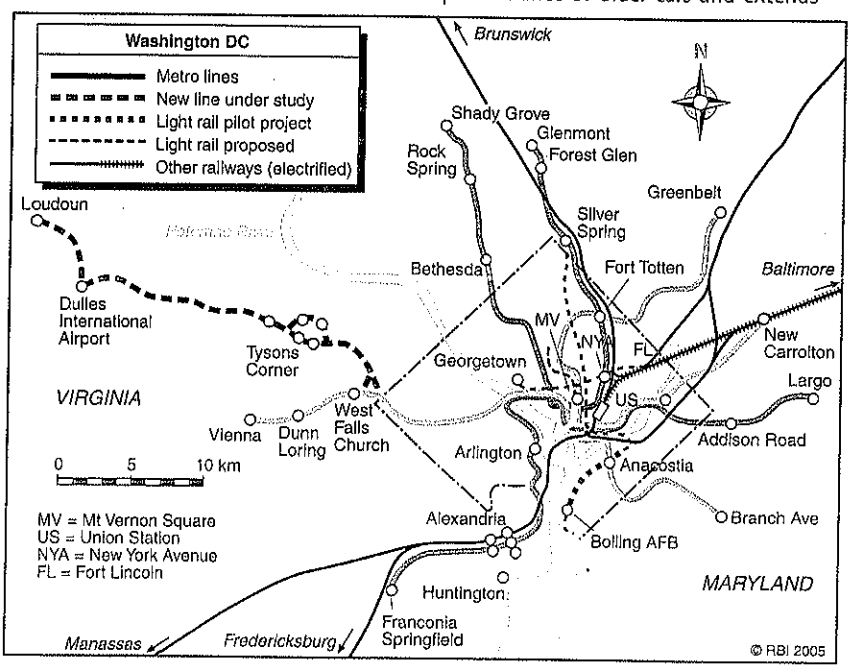
Expansion continues

WMATA's original federally-designated 163 km rail network was completed with the opening of the final section of the Green Line to Branch Avenue in January 2001. Since then, our attention has largely been focused on the maintenance of the system and increasing capacity to accommodate growing demand. Nevertheless, we are still progressing a number of network expansion projects.

Last November we opened a new station at New York Avenue-Florida Avenue-Gallaudet University in the District of Columbia. Located on the Red Line northwest of Union Station, this was our first infill station to be built on an operational route between two existing stations. It was also Metrorail's first public-private partnership project; the $104m cost was shared by the federal government, the District of Columbia and private-sector businesses. The station is expected to be handling around 1 500 passengers a day by the end of its first year in service.

On December 18 2004 we opened the first Metrorail extension beyond the core network, authorised by the Metro board in 1997 and built at a cost of $456m. Continuing the Blue Line to the east, the extension runs for 4·5 km from Addison Road to Largo Town Center, located just beyond the Capital Beltway in Prince George's County, Maryland.

The extension includes one intermediate station at Morgan Boulevard. The two stations are already being used by 9 300 passengers on a typical weekday. Daily boardings are projected to increase to 28 500 in 2020, with the two stations attracting around



16 400 new daily riders to the network.

Although there is currently no metro construction work underway, planning is in hand for a major expansion project in northern Virginia, where Metro has been working with Virginia's Department of Rail & Public Transportation to study a range of public transport improvements in the Dulles Corridor through Fairfax and Loudoun counties.

The preferred option is a 37·8 km branch from the Orange Line at West Falls Church to Dulles International Airport and a park-and-ride terminal at Route 772. Expected to cost around $4bn, the line is being sponsored by the Commonwealth of Virginia and will probably be built in two phases.

Last year the Federal Transit Administration awarded a $58·9m grant to cover 50% of the cost of preliminary engineering on the initial 18·9 km as far as Wiehle Avenue, via the regional retail and office hub at Tysons Corner. DRPT has awarded a $45·5m contract to the Dulles Transit Partners consortium of Bechtel and Washington Group for the engineering design work. We hope to inaugurate revenue services on the first phase in 2009 and complete the line to Dulles by 2015.

Light rail pilot project

Another innovation in the Metro service area is the introduction of light rail feeder routes. Serving neighbourhoods that are not currently accessible from our heavy rail network, the light rail lines will make an important contribution to our community service remit.

Construction work is now getting underway on a 4·3 km pilot line in Anacostia, at an estimated cost of $55m. The line is expected to open in the autumn of 2006, no less than 44 years after the closure of the last classic trolley lines in the national capital area.

The light rail route will follow the alignment of the CSX Shepard Branch industrial spur between Pennsylvania Avenue, south of the John Phillip Sousa Bridge, and Bolling Air Force Base. There will be six stations, including an interchange with the Green Line at Anacostia. The line will also serve the residential district at Barry Farms. The route could be extended to serve a proposed baseball stadium on the Anacostia River waterfront, and in the longer term it may also be continued across the river, bringing the total length to 11·6 km.

Groundbreaking ceremonies were held at Anacostia station on November 13 last year, with Metro Board Member Gladys W Mack, Mayor Anthony A Williams and the Director of the District of Columbia Department of Transportation Dan Tangherlini participating.

Tangherlini said during the ceremony that he hoped workers at the Bolling base would use the line to commute, and to go shopping in the surrounding area. 'The way to revitalise a community is to give them access to opportunity – opportunity for jobs, opportunity for recreation, opportunity [to attend] cultural and religious events', he emphasised. Projected ridership is around 3 000 passengers per day.

Metro has provided an initial $16·1m contribution to fund land acquisition, site preparation and the purchase of three Astra low-floor cars, similar to those supplied to Portland and Tacoma, by Skoda Transportation. Trackwork and stations, the maintenance facility and two substations are expected to cost between $30m and $40m. The District will meet the rest of the investment from funds generated by economic development projects and other capital funds. Tangherlini said that the city envisaged that WMATA would run the line, but no formal agreement has yet been reached.

> **'Metro Matters is a major step forward, but it is only a stop-gap ... we estimate that the total capital spending required over the next decade is around $12bn.'**
>
> Richard A White

Four other light rail routes in the greater Washington region totalling 54 km were identified as priority projects in an 18-month study by DC DoT and Metro completed last year. The Anacostia Corridor would run from Minnesota Avenue to National Harbor, incorporating the pilot project. A second route would run north-south from the Red Line station at Silver Spring to Anacostia, and another would link the Metrorail station at Stadium-Amory with the suburb of Woodley Park. The fourth route would serve the historic district of Georgetown on the Potomac waterfront. DC DoT's intention is to apply for federal funding for these schemes from the FTA New Starts programme.

Metro Matters

Nevertheless, the issue of under-investment remains, and needs to be addressed urgently. Over the past 30 years a total of $9·4bn has been invested in the region's transit networks, equivalent to $24bn at today's prices. This investment must be protected through prudent and timely expenditure.

WMATA is an anomaly, given the unique way it is structured, governed and funded. Although it is one of the area's largest employers, with more than 10 000 full-time employees, and an annual capital and operating budget of $1·3bn, we are forced to go cap in hand to our local jurisdictional funding partners at budget time every year.

Although our partners in Washington DC, Maryland and Virginia contribute significantly to our operating and capital budgets, the local politicians must juggle the same competing priorities that all modern communities face: how to fund education, security, public health and safety, and a host of other critical regional requirements.

In the autumn of 2004, we launched a programme called 'Metro Matters', which led to the adoption of an historic $3·3bn six-year capital programme. This will fund our most urgent infrastructure renewal priorities as well as the extra 120 cars needed for the eight-car service. It will also provide relief to the most overcrowded bus routes, and will allow us to continue investment in security measures against the threat of terrorism.

Metro Matters is a major step forward, but it is only a stop-gap that will merely keep the wolf from the door for the next six years. We estimate that the total capital spending required over the next decade is around $12bn. A recent report by the Brookings Institution, *Washington's Metro: Deficits by Design*, clearly articulates WMATA's need for a dedicated source of revenue to finance its operations, maintenance and renewal. Our future will be dependent upon putting in place an adequate, reliable and dedicated source of funds.

Metro remains committed to providing the safest, most convenient and reliable public transport services for our region, through upgrading our rolling stock, acquisition of new vehicles and continuing expansion of our rail network. While we are faced with budgetary challenges at the moment, we are continuing to search aggressively for creative ways in which we can enhance our services for our customers today and in the future. ■

Groundbreaking ceremonies were held in November 2004 for the Anacostia light rail pilot project; a 4·3 km line linking the WMATA station with Bolling Air Force Base

China's first driverless metro enters service

SEPTEMBER 28 2004 marked a milestone in the history of China's metro development, with the formal inauguration of the country's first driverless light metro. Wuhan is the seventh city in mainland China to open a metro.

The capital of Hubei province is a large industrial and trading city, with over eight million inhabitants. Located at the confluence of the Chang Jiang (Yangtze) with its major tributary the Han Shui, Wuhan is actually divided into three parts – Wuchang where the government departments are located, Hankou, the commercial hub, and the industrial district of Hanyang.

Like many growing cities throughout the country, Wuhan has been suffering from growing problems of air pollution and road congestion, with over 600 000 motor vehicles in use on its roads today. Road congestion is exacerbated by the river crossings. To optimise land use and meet the increasing demands of citizens and tourists for improved mobility, the city decided to start the development of a seven-line metro network.

According to the General Manager of Wuhan Rail Transit Co Ltd, Zhang Songxin, the Chinese government's State Planning Committee gave the formal go-ahead at the end of 2000 for work to start on an initial 10·2 km section of Line 1, at a capital cost of 2·2bn yuan. With 10 stations, the elevated line would be worked by a fleet of 48 cars.

The first line

The first phase of Line 1 links Huangpu Lu and Zongguan along Jinghang Dado, in the central part of Hankou. It follows the former alignment of Chinese Railways' Beijing - Guangzhou main line, that had been relocated during the remodelling of the city's heavy rail network. Civil engineering work on the double-track viaduct got underway in April 2001.

Changchun Car Co has supplied a fleet of 12 four-car trainsets for the first phase of Wuhan Line 1. Wide inter-car gangways allow for easy movement inside the train, and there is ample space for standing passengers

The initial section of Line 1 also includes a depot between Chongren Lu and Qiaokou Lu stations, with capacity to stable 12 trainsets. The operations control centre is also located here.

In April 2002, the fleet of 12 four-car trainsets was ordered from Changchun Car Co, and the following month saw a €15m contract awarded to Alcatel for the supply and installation of SelTrac S40 communications-based train control and 24 interlockings (RG 6.02 p287).

Following delivery of the first trainset, test running began on November 26 2003. After six months all of the trainsets and lineside interlockings had been commissioned, enabling the operator to start full testing of the automated train control system on July 28. After two months of ghost running, the line was approved for test service.

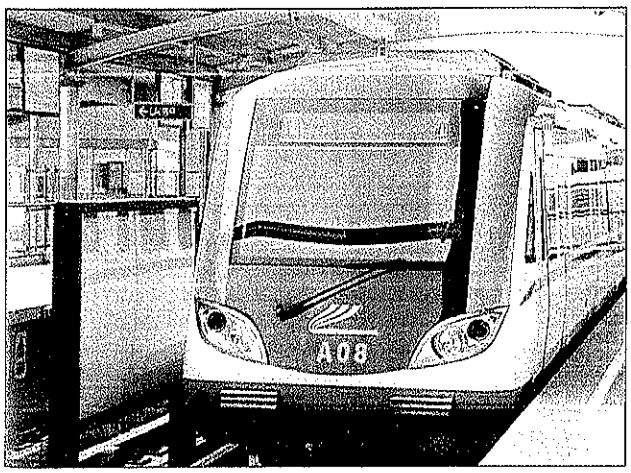
Design capacity of the elevated Line 1 is 18 000 passengers/h in each direction, using four-car trainsets running at 120 sec intervals at peak times

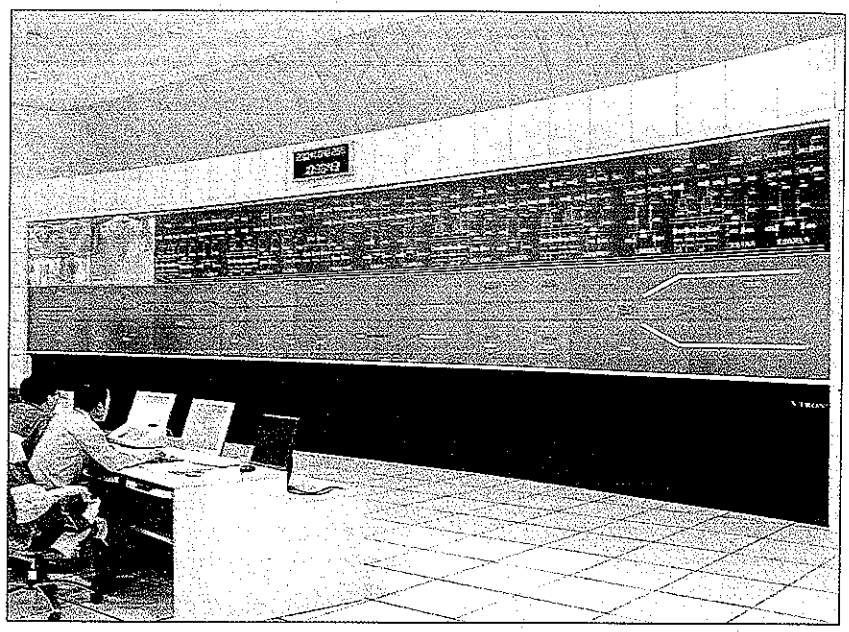
Design capacity of the line is 18 000 passengers/h in each direction. Trains operate at a maximum speed of 80 km/h at a peak headway of 120 sec, although the signalling is designed to permit 90 sec headways in future to accommodate growth. A flat fare of 3 yuan is charged for any single journey.

Flexible controls

One of the most eye-catching features of the Wuhan metro is that the trains are basically driverless, although under normal operating conditions there is an attendant on board to assist the passengers.

During the speeches on inauguration day, WRTC Vice-President Yao Chunqiao





The Wuhan metro Line 1 control centre at Chongren Lu depot uses Alcatel's NetTrac MT modular central control system with automatic conflict resolution. The graphical display makes provision for the planned extensions at both ends of the initial route

said the company had selected SelTrac S40 train control technology 'for its advantages in maximising operational flexibility, expandability, and minimising maintenance costs. We are very happy to be the first metro in northern China to use the technology', he added.

Working with its consortium partners Alcatel Transport Automation Control Systems and China Railway Signalling & Communications Design Institute of Beijing, Alcatel Transport Automation Solutions' Canadian-based urban rail business unit was responsible for design and supply of the driverless lineside signalling and depot interlockings, together with supervision of the installation work, testing and commissioning.

Alcatel's Senior Vice-President Walter Friesen said the company had been able to install and commission the equipment 'in an unprecedented time of 26 months by maintaining excellent supplier-customer teamwork and by employing a proven system'. The commissioning process ahead of opening included many on-site tests and simulations, which were successfully completed, including an attempt to run two trains towards each other on the same track.

The Wuhan installation combines SelTrac S40 CBTC and Alcatel's NetTrac MT modular central control system with automatic conflict resolution facilities. SelTrac ATO technology is in use in 20 other cities around the world. S40 incorporates moving-block technology to permit very short headways and optimise service frequency. Wuhan uses an inductive loop cable to transfer data messages between the trains, lineside equipment and the control centre. Alcatel is now offering SelTrac S40 with open-standard radio-based communications links.

The heart of the automatic train supervision function is the Vehicle Control Centre, which ensures safe train separation and movement in conjunction with the route setting module and the 24 lineside interlockings. The on-board VOBC uses a redundant microprocessor-based system to drive the train within speed and distance limits authorised by the VCC. Station Controllers manage the lineside devices, including axle counters to provide a separate train location function interlocked with the turnouts.

Each morning, the central control operator initiates the process by uploading timetable information to the trains, which then perform their scheduled trips automatically, controlled by the supervisory system. An operator moves the trains out of the depot using manual driving, after which the ATO takes over and automatically dispatches the trains according to the overall schedule. ■

Seven-line network planned

WUHAN'S INITIAL 10·2 km elevated light metro line is seen as the first step in an ambitious programme to develop a seven-line network totalling 222·8 km serving 182 stations. There will be one elevated and six underground lines.

Work is expected to get underway on the second phase of Line 1 by the end of this year, for completion in 2010. WRTC plans to extend Line 1 at both ends, adding a further 16 stations and bringing the total length to 28·8 km. There will be six stations on the northern extension from Huangpu Lu to Gutian Yi Lu and 10 on the western section from Zongguan to Fujiapo.

The next priorities are Lines 2 and 4, which are now in the detailed design stage and are expected to be built over the next five years.

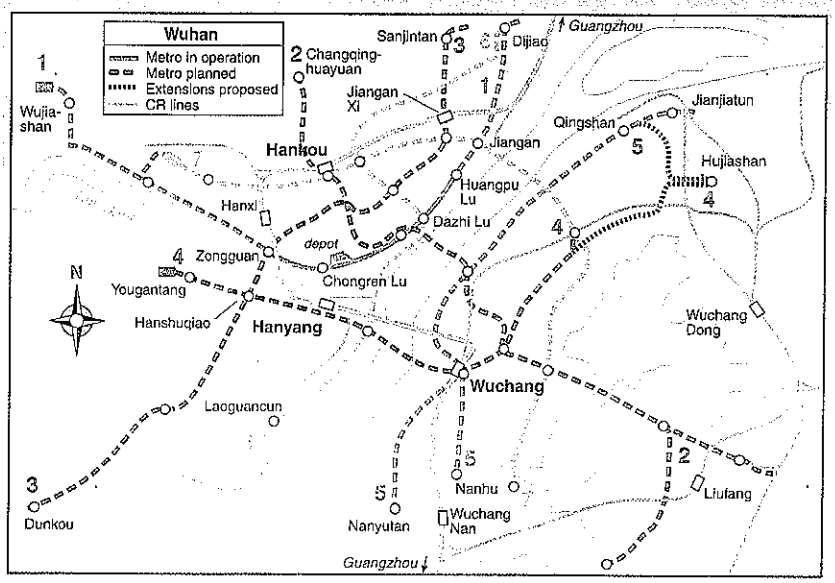
Line 2 will connect Hankou and Wuchang, using a 3·6 km long road and rail tunnel under the Yangtze which is now under construction. Authorised by the State Development Planning Commission in April 2002, the toll tunnel from Huangshilu in Hankou to Sancenglou in Wuchang is expected to take four years to build as a BOT project. It is designed to accommodate four road lanes and the double-track metro.

Line 4 will also run underground, connecting Wuchang and Hanyang beneath the Yangtze.

The city's current master plan envisages the construction of four more underground metro lines. Lines 3 and 6 will connect Hankou and Hanyang across the Han Shui, and Line 5 will parallel the Yangtze through the heart of Wuchang. Line 7 will run from the southern part of Wuchang to Hanxi to give a third crossing of the Yangtze.

Once all seven routes are in operation, the city government hopes that it will be possible to rationalise further the main line network, and concentrate all inter-city services at one station – at present there are three principal railway stations in Wuchang and three more in Hankou.

WRTC Board Chairman Liu Yuhua estimated last year that the total cost of building the seven-line network would be around 100bn yuan, which would have to be met using commercial funding as well as city and government grants. His ambition is that by 2050 the metro will be handling around 50% of all public transport trips in the Wuhan region. ■



Orders grow and capacity falls, but new entrants UPSET the market

Harry Hondius reviews developments in the tram and LRV sector in the western world for the past 12 months

THE PAST YEAR has been one of marked contrasts in the tram-building industry. On the one hand rationalisation and staff reductions continue to be the main focus for the major players as they seek profitability. On the other, two newcomers have joined CAF at the smaller end of the market, further diluting the potential for consolidating orders.

Order volumes have risen, but not as much as the numbers would suggest at first glance. And prices are continuing to rise, which is good for the suppliers, but not the operators, as there is a growing risk that rail will again price itself out of the market in comparison with bus.

In the 12 months to April 15 2005, orders were placed in the western market for a total of 697 vehicles – 518 trams and 179 LRVs. Table I shows that Alstom is the market leader in the tram field this year, but has shared the LRV market almost equally with Bombardier and Siemens. Of the 697 cars, 265 trams and 69 LRVs are destined for new networks, extensions and new lines, with the remainder replacing older cars.

Table I. Overview of low-floor tram and LRV orders in the year to April 15 2005

Trams	Total	Low floor 100%	Low floor 70%	System cars
Alstom	210	210		210
Siemens	127	150	9	-32
Bombardier	116	63	53	93
Stadler	30	30		
AnsaldoBreda	22	22		22
LFB	12		12	
CAF	1		1	
Total	**518**	**475**	**75**	**293**

LRVs	Total	70% LF	High floor	System cars
Bombardier	52	52		
Alstom	50	50		50
Siemens	49	16	33	49
Kinki Sharyo	20	20		
Stadler	8	2	6	
Total	**179**	**140**	**39**	**99**

Unfortunately, the jump in the annual total from around 500 to 697 cars does not mean a breakthrough in terms of order volumes. The biggest single order is for 150 ULF cars from Siemens for Wien, with an option for another 150. Deliveries will start next year, at a rate of 25 cars/year. This gives a nice steady load for the SGP plant, but in reality only adds 25 cars to the annual throughput. Another big order that came out of the blue is for 70 cars from Alstom for four new lines in Madrid, with options for 100 more. LRV order levels remain fairly constant.

In the high-floor market, Calgary has ordered a further 33 SD160 cars from Siemens. Stadler has won an order from Bochum for six 'Tango' cars, a standard-gauge three-section LRV comparable with the Stadtbahnwagen B. These 28·2 m long x 2 650 mm wide cars have 64 seats and weigh 34 tonnes; they will run on bogies derived from Stadler's Forchbahn cars.

Tables II to IV break down the accumulated low-floor car orders in more detail. Tables V and VI show the growing numbers of system cars in the LRV and tram sectors respectively.

Prices keep rising

Table VII shows the published prices for cars ordered in the last 12 months, which continue the steady rise apparent since 2000. The dream that modular system cars could ensure low costs for all operators with large or small order volumes has evaporated completely. Prestigious large operators can still get low prices for large orders, as exemplified by Madrid and Paris. A newcomer to the market like Stadler must also offer low prices to buy into the market, as with the Bochum order. And cities such as Mannheim can profit from low prices when exercising options in their original orders.

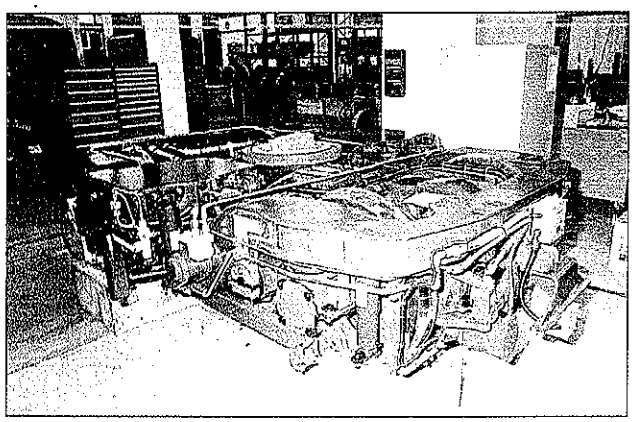
Looking at orders for 2 650 mm wide cars, the smaller numbers and high specific engineering costs, like battery traction, have raised the price of the Nice cars by 30% compared with Paris. Montpellier, an existing customer with no specific requirements, is only paying 15% more.

In the 2 400 mm bracket, Budapest is obviously a shrewd negotiator and is paying 10% less for a completely new Siemens GTX-N design compared with the original order for Combinos. Valencia, Marseille, Le Mans, Tunis, Tenerife and Wien are all in the same price range. Although Adelaide has ordered an identical car to Frankfurt, it is a long way away and the quantity is very small, so the price is the highest for this type.

Prices in the LRV field are quite similar, as the US prices have come down to European levels with the fall in the dollar to euro exchange rate. Trams were never cheap, which is the main reason why they almost disappeared. But now,

TOP: *The Stadler/Bombardier LRV for Switzerland's Trogener Bahn has a powered centre section*

BELOW: *Stadler's metre-gauge power bogie for the Trogener Bahn car, showing the air springs and stabiliser*

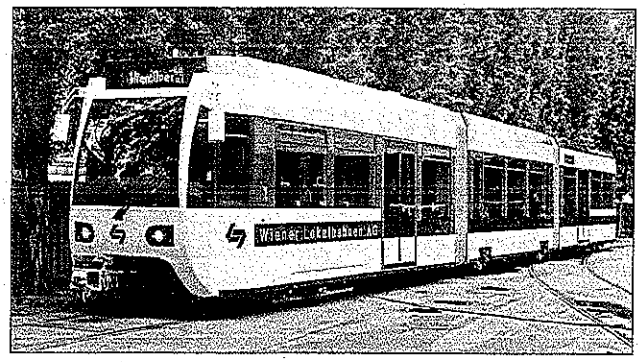


price per seat for even the cheapest cars is more than six times that for a comparable low-floor bus.

Industry developments

Under intense supervision from the European Commission and facing a restriction on future state aid, Alstom is committed to improving its performance and has made arrangements with its bankers to reduce its debts. The company's target is to achieve a 7% operating margin in 2006. Alstom Transport is reducing its staffing by 4 300, with seven sites across Europe and Canada affected.

Alstom is concentrating its traction equipment manufacture at Tarbes in France and Sesto San Giovanni in Italy, whilst bogies and trucks will be fabricated at Le Creusot (France) and Salzgitter (Germany). Bogies will no longer be made at Savigliano in Italy or Neuhausen in Switzerland. Trams are being produced at Aytré, and at Barcelona for the Spanish market; RegioCitadis LRVs will be concentrated at Salzgitter. The sole exception is the cars for Strasbourg which are being assembled at the former De Dietrich plant in Reichshoffen. The Alacant tram-train order formed an integral part of the sale of Alstom's Valencia plant to Vossloh.



Bombardier medium-floor LRV for Wiener Lokalbahn

This consolidation is seeing the disappearance of some famous plants with their long heritage. In the UK, the Preston site where traction equipment has been produced since 1897 under the Dick Kerr, English Electric and GEC names has now closed. Five years after its acquisition, the Ridderkerk site in the Netherlands has been reduced to a sales and service centre, with engineering and production transferred to Tarbes. As successively Smit, Holec and Traxis it has supplied traction equipment since 1914, and developed the Onix 850 inverters used in the Citadis 302B cars for Rotterdam, Strasbourg, Tenerife and the RegioCitadis. But orders from the Netherlands have largely dried up.

Bombardier has also launched a programme to cut 6 600 staff. This involves changes to the balance of tram and LRV work between Bautzen and the Bombardier Transportation Austria (formerly BWS) plant in Wien. In general, engineering will be done at both sites, but Bautzen will lead the production process.

Bautzen will produce all vehicles with welded steel bodyshells, both high and low-floor. Starting with the Marseille and Valencia contracts, Bautzen will also supply the bodyshell components for modular vehicles such as Cityrunner and tram-train cars, which will mostly be assembled by BTA, although Bautzen may do some assembly to smooth any peaks in the workload. BTA will remain responsible for all aspects of the Wien U6 cars. Meanwhile, the Talbot plant in Aachen has been fully integrated into Bombardier Germany.

Siemens Transportation is well on its way to establishing and organising the major Combino rectification programme (MR 04 p60), but final approval of its strategy by independent experts is not likely to be ready before the end of July. The future of the light rail division will not be decided until the full impact of the affair has been digested. Meanwhile, the STS factory in Sacramento is reported to have an order backlog of around 18 months; this plant employs 350 and has a turnover of US$100m per year.

There are questions about the future of Wien-based Elin EBG, and TractionSysteme Austria, if Siemens goes ahead with its planned purchase of their parent company, the Austrian engineering conglomorate Via Tech. Similarly, Siemens' planned €1·2bn purchase of Flender Holding GmbH and its integration in Siemens Automation & Drives may have some impact on Bombardier's use of Flender drives.

Stadler is expanding rapidly, with 113 Flirt EMUs now on order, and it has leased the PFA plant in Germany as Stadler Weiden. Stadler is putting a huge effort into selling Variotrams, and its ambition is to make Pankow its centre for tram manufacture. This presumes that it is possible to make money in the tram market with so many other builders in competition!

Another new entrant is Leoliner-Fahrzeug-Bau-Leipzig GmbH, set up by Leipzig operator LVB with the transfer of 50 staff after Siemens declined to market Leoliner and left the Leipziger Fahrzeugservice Betrieb partnership. The newcomer has an order from LVB, and negotiations are underway for Vossloh Electrical Systems (formerly Kiepe) to become a shareholder.

Part low-floor cars

Using the vehicle categories defined in DM95, Category A2 covers cars carried on two driven and two non-driven bogies. AVG and VBK of Karlsruhe have bought another seven GT8-100S/2SM cars, carried on articulation bogies from Bombardier/Siemens, bringing the total to 86 cars. Added to the original 35 high-floor cars, they will bring the tram-train fleet to 121 cars serving more than 500 route-km of tram-train lines.

Table II. Market share of low-floor trams supplied or ordered from western suppliers up to April 15 2005

Mechanical parts	Orders	Options
Siemens	1 533	242
ex Duewag (various)	*696*	*19*
Combino	*425*	*12*
NF8-12	*66*	*61*
SGP ULF	*302*	*150*
GT8N-12N	*64*	–
Bombardier Transportation[1,2]	1 510	284
GTNX	*473*	*2*
Eurotram	*151*	–
Variotram	*136*	*81*
Incentro	*48*	*6*
Cobra	*74*	*22*
Vevey	*73*[1]	–
BN Brugge	*45*	–
DWA Bautzen	*142*	*43*
Classic (Bautzen)	*173*	*49*
Cityrunner I (BWS Wien)	*18*	–
Cityrunner II (Outlook)	*177*	*81*
Alstom[3]	1 245	297
TSF 1 (Nantes)	*46*	–
TSF 2 (Grenoble)	*116*	
Citadis	*711*	*249*
T 2000 (Brussels)	*51*	–
Vevey	*20*	–
LHB	*126*[2]	*48*
ex Fiat, various	*105*	–
ex Fiat, Cityway	*70*	*45*
AnsaldoBreda+Firema	296	65
Sirio	*248*	*65*
Breda	*24*	–
Firema	*24*	–
Socimi	42	–
Stadler	30	–
CAF	25	–
LFB	14	18
Total	4 715	890

1. Includes 46 middle-floor cars
2. Plus 60 trailers
3. Plus 30 trailers

Table III. Electrical equipment for low-floor trams supplied or ordered up to April 15 2005

Supplier	Total
Bombardier	1 699
Bombardier	*389*
ex-Adtranz	*358*
ex ABB[1]	*577*
ex AEG (Germany)	*351*
ex AEG (USA)	*24*
Alstom	1 149
France + UK	*838*
Parizzi (Italy)	*145*
Netherlands	*166*
Siemens	839
Elin	355
Kiepe Elektrik[2]	333
AnsaldoBreda	302
Ingelectric	8
Stadler[3]	30
Total[1]	4 715

1. Includes 46 middle-floor cars.
2. 127 cars with Alstom motors, 126 with Skoda, 66 with Siemens and 32 with VEM
3. Electrical supplier not known

Table IV. Market share for low- and medium-floor LRVs ordered up to April 15 2005

Mechanical parts	Orders	Options
Bombardier	567	66
Kinki Sharyo	266	70
Siemens Transportation	234	65
AnsaldoBreda (Firema)	148	–
Alstom	87	–
Stadler (Forchbahn, TB)	15	–
Total	**1 317**	**201**
Electrical equipment		
Bombardier[1]	384	
Vossloh Kiepe	361	
Elin/TSA motors	*116*	
Alstom motors	*176*	
Skoda motors	*69*	
Alstom	266	
Siemens	164	
Elin EBG	67	
AnsaldoBreda	48	
Toshiba	27	
Total	**1 317**	

1. 83 cars with Alstom motors

After trials with a prototype last year, Dallas Area Rapid Transit has ordered from Kinki Sharyo and Bombardier 20 cars 38·8 m long, which have similar articulation bogies and a new steel-framed glass fibre-bodied low-floor centre section.

Stadler has delivered to Switzerland's Trogener Bahn two 2'Bo'Bo'2' cars of a completely new design. These 2 400 mm wide vehicles have a central section 11·9 m long carried on a pair of motored bogies. The two non-driven end sections are each 12·7 m long, giving a total length of 37·3 m.

All four bogies have a wheelbase of 1 860 mm and the centres of the two motored bogies are 7 456 mm apart. The wheel diameter is 680 mm, and each car is powered by four 100 kW motors. The low-floor sections are 360 mm above rail, with two steps leading up to the high-floor sections above each bogie at 860 mm. The car shares modular parts with the 13 Forchbahn cars which are now all in service.

All-motored variations of this type have existed in Freiburg since 1971, but the idea of driving only the central section is new. The aluminium body is part welded and part bolted, and has been constructed to withstand a 400 kN buffing load.

The bogies have a primary suspension consisting of swing links with coil springs and vertical dampers. The body rests on an air-sprung bi-partite circular bolster, which is connected to the bogie frame by linkages placed on the outside. Vertical shock absorbers support the air springs. The 1 kV DC traction system comes from Bombardier Sweden, feeding three-point-suspended force-ventilated asynchronous motors which drive the axles through a two-stage helical ZF-gearbox, quill shaft and cardan couplings. Pneumatic spring-loaded disc brakes are mounted on all axles.

Category B1 covers cars on non-driven bogies with axles and small wheels. The two prototype Leoliners from LFB (MR 04 p54) have been in revenue service in Leipzig since June 1 2004 and ride well. Running at 70 km/h on flat-bottomed rails, the interior noise level is around 75 dB(A). The Kiepe choppers are silent. LVB has ordered 12 Leoliners for delivery in 2007, with options for 12 and six.

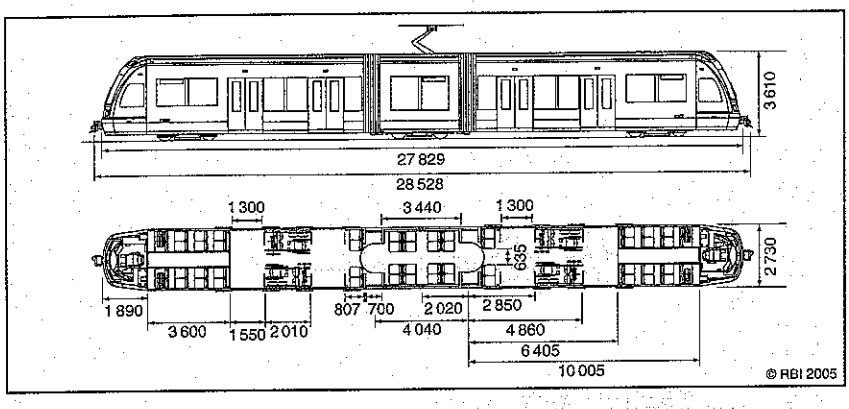


Fig 1. Siemens Avanto LRV for Charlotte, North Carolina

Category B2 covers cars with driven bogies and one or more articulated sections running on trucks with individual wheels. The first of 15 Avanto tram-trains ordered by SNCF is running at Siemens' Wildenrath test centre (p64), and is expected to be delivered by the end of this year. Siemens has received an order for 16 Avantos to operate a new line in Charlotte, North Carolina. These 2 650 mm wide cars are 27·8 m long (Fig 1), and will have 68 seats, 660 mm wheels and four 140 kW motors. Buffing load is 810 kN and the weight 44 tonnes (597 kg/m²). Bombardier received an order for three more Swift cars for Minneapolis.

Another US city is having problems, however. The 100 Type 8 LRVs being built for MBTA of Boston by Breda and Adtranz were assembled in Littleton, Massachussets. These were described in MR 00 (p17); in 1999 the ride was satisfactory, but the cars were noisy.

In December, the *Boston Globe* reported that this delivery had turned into a real drama. First the cars derailed, which was put down to track condition although other cars did not have problems. As a result the wheel profiles were changed and 21 km of track relaid. After the Type 8s returned to service in 2003, limited to 40 km/h, MBTA was still experiencing too many daily problems with various components and suspended the contract.

After four years MBTA had paid US$140m out of the US$225m contract price, and US$9·5m on modifications. MBTA said it would modify the 37 operational cars using subcontractors without any assistance from Breda. It refused to accept further deliveries, and threatened to sue Breda for damages, although more recent reports suggest that a compromise may be reached.

Meanwhile, CAF and Ingelec have supplied an eighth car to Bilbao. This 24·4 m long 2 400 mm wide vehicle has a motored centre truck and Bo' Bo Bo' configuration, to test the formula selected for use in Sevilla (MR 04 p58).

Independent wheels

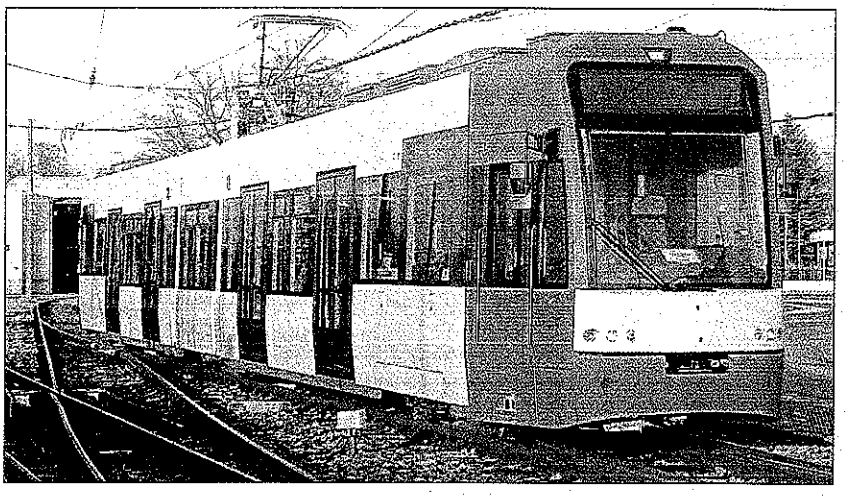
Category B2A covers multi-articulated cars which use conventional motored trucks and non-driven trucks with independent wheels.

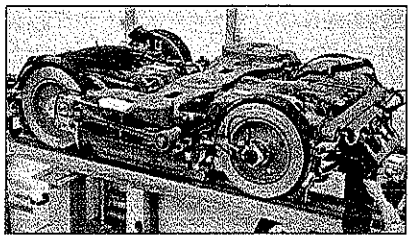
Belgium's VVM De Lijn is expected to order shortly the final nine MGT6 'Hermelijn' cars from Siemens and Bombardier, bringing deliveries of the Bo 2 Bo design to 102 between 1999 and 2006, with options for a further 10. Of these, 71 uni-directional cars will be

Table V. System middle and low-floor LRVs ordered up to April 15 2005

City	Type	Orders	Gauge mm	Length m	Width mm	% low floor	Power kW	Delivery date
Bombardier	**Swift LF**	**83**						
Stockholm	A 32	22	1 435	29·7[1]	2 650	65	4 x 120	1999-2003
Gouda	A 32	6	1 435	29·7[1]	2 650	65	4 x 120	2003
Istanbul		55	1 435	29·7[1]	2 650	65	4 x 110	2003-04
Siemens	**Avanto**	**60**						
Houston	S70	18	1 435	29·37[1]	2 650	60	4 x 140	2003
San Diego	S70	11	1 435	26·4[1]	2 650	60	4 x 140	2004
SNCF	25 kV/750 V	15	1 435	36·37[1]	2 650	70	4 x 160	2004
Charlotte	S70	16	1 435	27·74[1]	2 650	70	4 x 140	2006
Alstom	**RegioCitadis**	**87**						
Kassel	15 kV/600 V	18	1 435	36·76[1]	2 650	67	4 x 150	2004-05
Kassel	600 V/DE	10	1 435	36·76[1]	2 650	67	4 x 150	2004-05
RandstadRail	750/600 V	50	1 435	36·76[1]	2 650	67	4 x 150	2006
Alacant	Tram-train	9	1 000	37·0[1]	2 550	32	6 x 140	2005
Total		**230**						

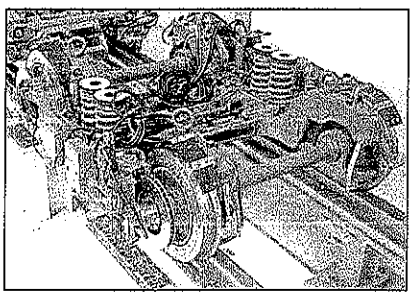
1. Bi-directional cars DE. supplementary diesel-electric drive





ABOVE: *On test in Wien earlier this year is the first Bombardier K4500 car for KVB, Köln; it has Vossloh electrical equipment. Four pre-series cars are now running in Köln*

LEFT: *The K4500 motor bogie is similar to the design used for the earlier K4000 and K5000 cars, but the unpowered central truck (below left) is very different, with conventional axles*



running in Antwerpen and 31 bi-directional cars in Gent. As a result of union pressure, the last 57 cars have an enclosed cab and the front door is no longer open to passengers. The intention is to cease selling tickets on the trams and rely on vending machines at the stops.

Because Germany's *Land* of Baden-Württemberg is still subsidising tram purchases, MVV of Mannheim has been able to exercise part of its option for 2 400 mm wide Variotrams from Bombardier Bautzen. This will add 10 bi-directional cars 30·5 m long and three uni-directional cars of 42·8 m. However, neighbouring Ludwigshafen is across the river in Rheinland-Pfalz and will not get any more subsidies, so VBL could not follow suit.

This year sees the introduction of a new Category B3 covering similar cars to B2 but with a central truck running on conventional axles. The first example of this type are the 69 K4500 cars ordered by KVB from Bombardier and Vossloh Electrical Systems, which will be delivered over the next year. Four Wien-built pre-series cars are already in Köln, after testing on WLB between Wien and Baden. The first car completed 10 000 km and the other three 2 000 km each. Car 4501 arrived in Köln on March 22, and was officially presented to the public on April 18.

The four cars will be thoroughly tested in passenger service to detect any bugs before assembly of the series versions in Aachen begins in the autumn. The car was briefly described in MR 04. It uses the same hybrid construction as more than 300 Swift cars – K4000 and K5000 in Köln, A32 in Stockholm, the CR4000 for Croydon and cars for Istanbul.

The innovation is the use of conventional axles in the central truck, like Cityrunner. As with other manufacturers, Bombardier has found that independent wheels, with their higher unsprung mass, can tend to louder running and the development of wheel flats. Braking is also more difficult. The air-conditioned K4500 is 28·5 m long and 2 650 mm wide, and weighs 39·3 tonnes (520 kg/m²). The bogies and truck are all of 1 800 mm wheelbase, with wheel diameters of 660 and 580 mm. Each Bo' 2 Bo' car has four 120 kW fully-suspended Skoda motors.

The articulated centre section is 2 550 mm long with a floor height of 520 mm over the central truck. Ramps lead down to the main floor sections which are 420 mm above rail, from

Table VI. System trams ordered up to April 15 2005

City	Type	Orders	Options	Gauge mm	Length m	Width mm	% low floor	Power kW	Delivery date
Alstom	Citadis	711	249						
Montpellier	401	30	–	1 435	40·9[1]	2 650	70	4 x 140 +2 x 120	1999-2002
Orléans	301	22		1 435	29·9[1]	2 320	70	4 x 140	2000-01
Dublin	301	26		1 435	29·7[1]	2 400	70	4 x 140	2001-02
Dublin	401	14		1 435	40·9[1]	2 400	70	4 x 140 +2 x 120	2003
Lyon	302	57	13	1 435	32·4[1]	2 400	100	4 x 120	2000-07
Melbourne	202A	36		1 435	22·7[1]	2 650	100	4 x 100	2001-02
Bordeaux	402	56		1 435	43·9[1]	2 400	100	6 x 120	2002-06
Bordeaux	302	14		1 435	32·8[1]	2 400	100	4 x 120	2002-06
Rotterdam	302B	60		1 435	31·2	2 400	100	4 x 100	2002-04
Barcelona	302	37		1 435	32·5[1]	2 650	100	4 x 120	2002-04
Paris	302	26	34	1 435	32·2[1]	2 400	100	4 x 120	2002-04
La Rochelle	302	1		1 435	32·4[1]	2 400	100	4 x 120	2001
Grenoble	402	35	10	1 435	43·7[1]	2 400	100	6 x 120	2005-06
Mulhouse	302	27		1 435	32·5[1]	2 650	100	4 x 120	2005
Valenciennes	302	21	7	1 435	33·2[1]	2 400	100	4 x 120	2005
Strasbourg	403	41	6	1 435	45·0	2 400	100	6 x 120	2005-06
Paris	402	21	49	1 435	40·0[1]	2 650	100	6 x 120	2006
Nice	302	20	8	1 435	33·0[1]	2 650	100	4 x 120	2006-07
Tenerife	302	20	13	1 435	32·2[1]	2 400	100	6 x 120	2006-07
Tunis[2]	302	30		1 435	32·0[1]	2 400	100	4 x 120	2006-07
Le Mans	302	23	6	1 435	30·0[1]	2 400	100	4 x 120	2006-07
Montpellier	302	24	3	1 435	32·3[1]	2 650	100	4 x 120	2006-07
Madrid	302	70	100	1 435	32·2[1]	2 400	100	4 x 120	2006-07
Alstom Italy	Cityway	70							
Torino	–	49		1 445	34·0[1]	2 400	100	12 x 41	2002-03
Torino	–	6		1 445	34·0	2 400	100	12 x 41	2001
Messina	–	15		1 435	22·5[1]	2 400	100	8 x 41	2002
Siemens	Combino	425	12						
Potsdam	Prototype	1		1 435	26·5[1]	2 300	100	4 x 100	1996
Potsdam	Basic	16		1 435	30·5	2 300	100	4 x 100	1998-2001
Augsburg	Basic	41		1 000	41·9	2 300	100	6 x 100	2000-04
Freiburg	Basic	8		1 000	42·0[1]	2 300	100	6 x 100	1999-03
Freiburg	Advanced	10		1 000	42·9[1]	2 300	100	6 x 100	2005
Basel	Basic	28		1 000	42·9	2 300	100	6 x 100	2000-02
Hiroshima	Basic	12		1 435	30·5[1]	2 450	100	4 x 100	1999-02
Erfurt	Basic	7		1 000	30·5	2 300	100	4 x 100	2000
Erfurt	Advanced	29		1 000	31·5	2 300	100	4 x 100	2002-05
Erfurt	Advanced	12		1 000	20·0	2 300	100	2 x 100	2002-04
Nordhausen	Basic	2		1 000	19·1	2 300	100	4 x 100	2000-01
Nordhausen	Advanced	2		1 000	20·0	2 300	100	4 x 100	2002-03
Nordhausen	Advanced	3		1 000	20·0[1]	2 300	100	4 x 100	2002

which there is a step up to 625 mm high sections over the motored bogies. The outer sections rest on the centre module via a flat bearing that allows movements in the transverse and vertical axes. A Watts linkage on the roof connects the three sections, allowing movement on the same two axes whilst damping any rolling movements.

The central car body descends into the truck, and the traction forces are transmitted by rubber/steel gliding surfaces, echoing the PCC and Tatra models. The truck has a cast steel frame derived from the Incentro design. Rubber springs act as primary suspensions and axle guides, and the steel secondary springs are backed up with two vertical shock absorbers per side. The disc brakes are still placed on the outer side of the truck, making them easily accessible for maintenance – a truly interesting innovation! The driven bogies are largely identical with those used on the 124 K4000 cars and the 74 K5000 variants.

Category B4 groups cars with floating articulations which steer 'single axles' consisting of independent wheels. In this category, Düsseldorf's Rheinbahn received 48 NF6 cars from Siemens in 1995-98. Rheinbahn is now suing its supplier for €6·7m, citing excessive maintenance costs for these radial 'single-axle bogies', which run well through curves but exhibit considerable wheel wear on straight track.

Category B7 covers cars with a central section running on single-axle bogies and end sections with motored bogies resting on the central section, giving a Bo' 1' 1' Bo' arrangement. The single-axle bogies under the central part are steered from the articulation, which results in a very long wheel life. Over 600 000 km has been recorded.

The design is used exclusively by WVB in Wien, where 78 cars 26·8 m long and 2 650 mm wide are used on Line U6. Bombardier Austria and Vossloh Electrical Systems have now received an order for 38 further cars for U6. Wiener Lokalbahnen, which operates six similar cars only 2 500 mm wide (p56), has ordered a further four, but these will have Bombardier electrical equipment. All cars will have motors from TSA.

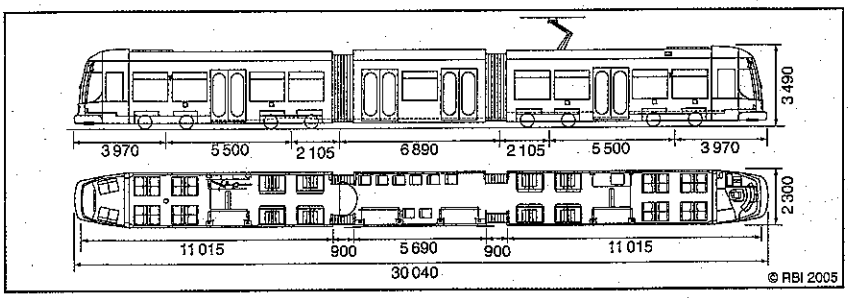


Fig 2. Bombardier's Classic NGT8DD car for Dresden is a shorter version of the successful NGT12DD design.

Category B8 covers cars running on bogies, but where the unpowered ones have independently-turning wheels. Dresden and Bombardier Bautzen have developed a new Classic variant, known as NGT8DD (Fig 2). This 30 m long Bo' Bo' 2' Bo' car is effectively two four-axle cars with a wheel-less centre section hung between them. The 2 300 mm wide car is powered by six 85 kW motors and has 56 seats. Low-floor areas are provided in all three car modules. Weight is 39·5 tonnes, or 572 kg/m². DVB has ordered 20 cars and a further eight of the similar NGT12DD design, bringing the total of these 45 m long cars to 32. Adelaide has ordered nine Classic cars, identical to the 60 ordered by Frankfurt.

Tram-train operations from Kassel to Warburg are now expected to start around six months later than anticipated. Six of the Alstom RegioCitadis cars (RG 9.04 p585) have received conditional certification from EBA to run on DB tracks, and full certification was expected at the end of May.

Testing on the 6 km long main ring at Wildenrath in August 2004 showed excellent riding qualities at 110 km/h using the 15 kV 16⅔ Hz supply. Given ideal track and weather conditions the interior noise level was superb, at 73 dB(A) above the motored bogies and in the articulation, and just 68·5 dB(A) at 1·6 m above rail in the low-floor central saloon. This is significantly better than existing tram-train vehicles.

However, the EBA certification procedure has taken nine months, and the associated cost is estimated at around €2m. Unhappily the car is not a Euro-RegioCitadis, so if Mulhouse wanted to purchase the car for example, the certification process would have to start all over again in France. Other cost factors include crashworthiness and the energy absorption capacity of the nose, plus the use of fire-resistant materials. In contrast, the bus manufacturers need only certification in one EU member

Nordhausen	Adv DE	3		1 000	20·0	2 300	100	4 x 100	2003
Amsterdam	Advanced	151		1 435	29·2	2 400	100	4 x 100	2001-03
Amsterdam	Advanced	4		1 435	29·2[1]	2 400	100	4 x 100	2002
Melbourne	Advanced	21		1 435	29·9[1]	2 650	100	4 x 100	2002-04
Melbourne	Advanced	38		1 435	20·0[1]	2 650	100	4 x 100	2002-03
Bern	Advanced	15		1 000	30·5	2 300	100	4 x 100	2002-03
Ulm	Advanced	8	2	1 000	30·8	2 400	100	4 x 100	2002
Poznan	Advanced	14	10	1 435	29·2	2 400	100	4 x 100	2004
Siemens	**GTXN**	**64**							
Almeda	GT8N	24		1 435	36·4[1]	2 650	100	6 x 100	2005-06
Budapest	GT12N	40		1 435	54·0[1]	2 400	100	8 x 100	2006
AnsaldoBreda	**Sirio**	**248**	**60**						
Prototype	3C2	1		1 445	17·5[1]	2 400	100	2 x 106	2002
Sassari	5C3	4		950	27·0[1]	2 400	100	4 x 106	2002
Milano	7C4	58		1 445	35·0	2 400	100	4 x 106	2002-04
Napoli	3C2	22		1 445	18·5[1]	2 400	100	4 x 106	2004
Milano	5C3	35		1 445	25·0	2 400	100	4 x 106	2004-05
Göteborg	5C3	40	60	1 435	29·4	2 650	100	4 x 106	2004-05
Athens	5C3	35		1 435	32·0[1]	2 400	100	4 x 106	2004
Bergamo	5C3	14		1 435	29·8[1]	2 400	100	4 x 106	2004
Firenze	5C3	17		1 435	31·7[1]	2 400	100	4 x 106	2005
Kayseri	5C3	22		1 435	32·0[1]	2 650	100	4 x 106	2008
Bombardier	**Incentro**	**48**	**6**						
Nantes	AT5/6L	33	6	1 435	36·4[1]	2 400	100	8 x 45	2000-06
Nottingham	AT5/6	15		1 435	33·0[1]	2 400	100	8 x 45	2003
Bombardier	**Classic**	**173**	**49**						
Dessau	NGT6	10		1 435	21·0	2 300	45	4 x 85	2000-01
Dresden	NGT12DD	32	17	1 450	44·6	2 300	56	8 x 85	2003
Halle	NGT6[2]	30		1 000	21·0	2 300	45	4 x 85	2003-05
Frankfurt	NGT8 'S'	60		1 435	30·0[1]	2 400	62	4 x 95	2003-04
Leipzig	NGTXXL	12	12	1 458	44·6	2 300	56	8 x 85	2005
Dresden	NGT8DD	20	20	1 450	30·0	2 300	62	6 x 85	2006
Adelaide	NGT8	9		1 435	30·0[1]	2 400	62	4 x 95	2006
Bombardier	**Cityrunner**	**177**	**81**						
Linz	(Outlook)	21	18	900	40·0	2 300	62*	6 x 100	2001-04
Lodz		15		1 000	29·5	2 300	62*	4 x 100	2001-02
Eskisehir		18		1 000	29·5	2 300	62*	4 x 100	2004
Genève		21	17	1 000	42·0[1]	2 300	62*	6 x 100	2004-05
Brussels		27		1 435	31·9[1]	2 300	62*	4 x 100	2005-06
Brussels		19		1 435	43·2[1]	2 300	62*	6 x 100	2006
Marseille		26	36	1 435	32·5[1]	2 400	62*	4 x 100	2007
Valencia		30	10	1 000	32·5[1]	2 400	62*	4 x 100	2007
Total		**1 948**	**467**						

* Ramps lead up to slightly higher floor above the intermediate trucks

1. Bi-directional car.

2. No rear cab; cars run coupled back-to-back

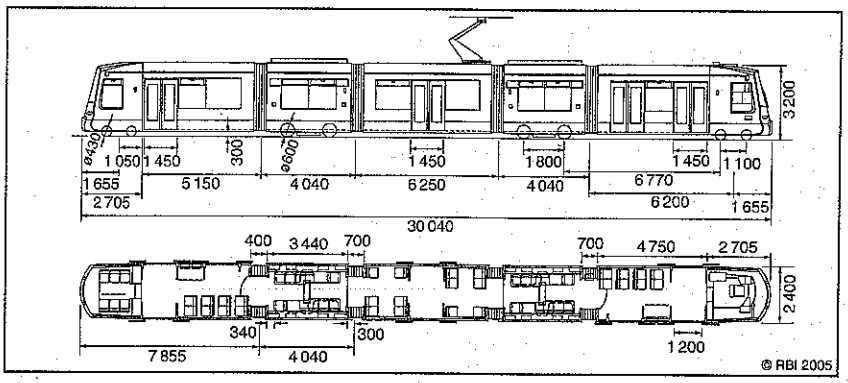


Fig 3. Siemens NF8U car for Rheinbahn, Düsseldorf, with electrical equipment from Vossloh Electrical Systems

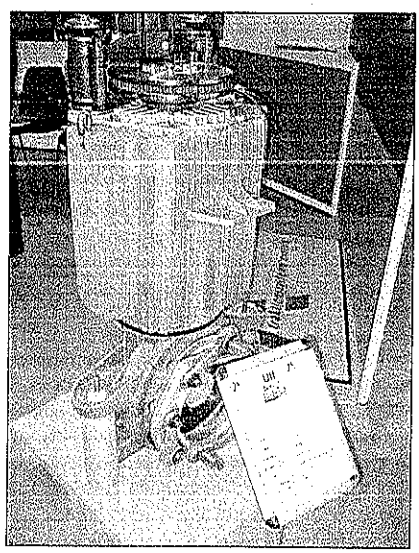
state to run freely in all the others!

In July 2004 HTM Personenvervoer of Den Haag ordered 50 RegioCitadis cars for RandstadRail, largely identical to the Kassel design but equipped for 750 and 600 V DC (RG 4.05 p209). These cars will have a central door in the centre section. They are LRVs with a top speed of 80 km/h, and not a tram-train, so they will not have to undergo yet another difficult and costly certification process.

All-low-floor cars

Although system cars are starting to dominate the 100% low-floor sector, many cities are still placing orders for non-system vehicles. Japanese cities continue to show interest in Bombardier's GT4K design, with Toyama ordering seven cars from Niigata Engineering. This brings the total for the ex-AEG family to 473. The cars will be similar to the Takaoka vehicles illustrated in MR 04 (p57).

The Combino problems with Alugrip bolted bodyshells have affected the Cobra design for Zürich, which has been redesigned for the third time. The bolted aluminium construction is being replaced by a welded design and the roof girders strengthened. The articulation is now welded from stainless steel, and bolted to the welded aluminium chassis. The series cars are being fabricated in Bautzen and assembled at the Bombardier plant in Villeneuve; the first vehicle is expected to be ready at the end of this year.



The latest batch of ULF cars will be fitted with this TSA vertical motor with convection air-cooling, brake disc and ZF gearbox to drive the adjacent wheel. The entire assembly is hung from the portal frame of the articulation

Photo: TSA

The six Cobra prototypes are now operating in service; after attention to noise issues, they are running well. The cars are being monitored regularly to check the bolted bodyshells, and they will be modified if necessary.

Similarly, Siemens has reached an agreement with Düsseldorf's Rheinbahn about the changes to 15 bi-directional NF8U trams, which are on order as part a contract for 76 cars. Again, the Alugrip bolted structure has been dropped and the 30 m long 2' Bo Bo 2'cars will now have an all-welded aluminium bodyshell (Fig 3). This brings the weight of the 2 400 mm wide cars to 35·5 tonnes (492 kg/m²). Wheel diameters are 600 mm for the powered trucks and 430 mm for the small-wheeled end bogies. Each car will have 50 seats and space for 120 standees. Electrical equipment is coming from Vossloh Electrical Systems, with the exception of the four 100 kW Siemens motors.

Siemens' order for a further 80 Type A and 70 Type B ULF cars to be delivered to Wien by 2012 will provide an important baseload for the SGP factory in the Austrian capital, as well as Elin and TSA. Although Bombardier supplied the steel car frames for the earlier vehicles, this will no longer be the case.

The ULF fleet in operation now stands at 152 cars, and intensive collaboration between Siemens, SGP and WVB[1] has seen a substantial improvement in wheel wear. The main wheels are now replaced at 150 000 km intervals, although the leading wheelsets are changed after 100 000 km.

The main changes in the new series will be use of a new convection air-cooled motor developed by TSA, coupled to a ZF gearbox. Whereas Elin IGBT inverters used to feed three or four motors per side, each motor will now have its own air-cooled inverter. In a Type B car, two converter packs with four inverters each will feed two pairs of motors per side in the four articulation portals. These changes save 920 kg in weight.

The motors can still be 'steered' to produce a sinusoidal hunting movement. The car 'kneeling' function to lower the entrance height has been dropped and the retractable wheelchair ramp is now hand-operated instead of powered by an electric motor.

WVB Type A car 50 was tested by BVG in Berlin after the InnoTrans exhibition last September, and it will be interesting to see whether this leads to an order.

Thanks to the licence awarded under EU pressure when Bombardier took over Adtranz, Stadler is continuing to market the Variotram design. Bochum-Gelsenkirchen operator Bogestra has ordered 30 metre-gauge cars from Stadler for delivery in 2007. These cars will be 29·6 m long and 2 300 mm wide, weighing 35·5 tonnes (521 kg/m²); each will carry 68 seats and 120 standing passengers. ABB Schweiz, Elin and Vossloh Electrical Systems are bidding for the electrical contract, and the gearless motors will come from TSA.

The Bogestra cars are directly derived from the 40 cars with gearless drives, which were ordered from Adtranz and Talgo Transtech by Helsinki's HKL. In May 2004, the *Helsingin Sanomat* reported that all was not well with these 24·3 m long cars, which are 2 300 mm wide and powered by 12 motors rated at 45 kW (35·5 tonnes, 635 kg/m²). The newspaper said that at the time only 16 cars had been accepted and paid for, citing problems with the stability of the trucks, which have all wheels driven. There were also extensive complaints about noise and vibration due to the high unsprung weight.

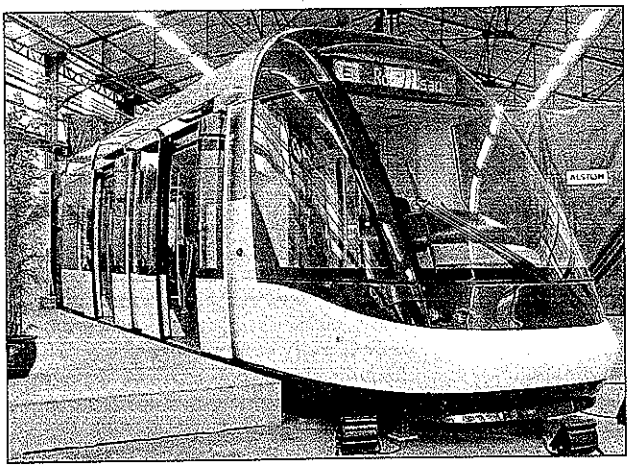
In contrast, the 30 Bombardier Variotrams operating in the wide streets of Chemnitz, largely on railway-style tracks, are running to the full satisfaction of CVAG, although the swing links of the individual wheels had to be reinforced. Some of these cars also run at up to 80 km/h on the local railway to the neighbouring town of Stollberg.

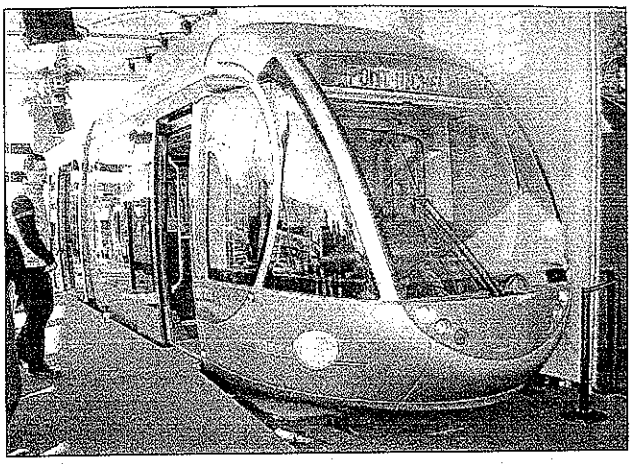
Citadis heads the system cars

With new orders for 210 bi-directional Citadis cars, bringing the total to 711, Alstom firmly rules the system car sector. The past 12 months have seen orders for 204 Type 302 cars with Arpège trucks without primary suspension, from Nice (20), Montpellier (24), Madrid (70), Le Mans (23), Tunis (30), Tenerife (20), Lyon (10) and Mulhouse (7). Strasbourg has ordered six more Type 403 cars.

With the exception of the Montpellier and Mulhouse vehicles (RG 12.04 p816), which are 2 650 mm wide, all the other cars have a width of 2 400 mm. The Tunis cars will have only one cab and a flat rear end, as the vehicles will be permanently coupled back-to-back. The Tenerife version will have all wheels driven because of the network's long, steep gradients.

Around 350 Citadis cars have been delivered so far. The 711 car total is made up from 92 cars of Type 301/401,





Mock-ups of the Alstom Citadis 403 car for Strasbourg (left), which has a small-wheeled bogie below the cab, and the 2 650 mm wide Citadis 302 for Nice (above) Nice photo: F Giana

370 of Type 302 and 112 of Type 402, plus 60 Type 302B cars for Rotterdam, 36 short Type 202A for Melbourne and 41 of Type 403 for Strasbourg. The clear leader is the Citadis 302/402, which has benefited from the adaptability of its exterior styling to reflect the desires of local politicians, with some particularly radical variations to the noses and interiors, whilst keeping intact the high degree of modularity[2].

All 60 of the one-off Type 302 B cars for Rotterdam are now in service (RG 1.05 p14), and seem to be wearing well. Noise levels remain low, but the wheels squeal badly in curves. In the early days this showed up in terms of high flange wear, which was addressed by fitting wheels with greater hardness and flange lubrification.

The 45 m long Type 403 cars for Strasbourg are basically the 402 design with small-wheeled bogies under the cabs to give a 2' Bo Bo Bo 2' wheel arrangement. These bogies are derived from the Magdeburg design.

Most Citadis cars have Onix 808 inverters from Tarbes, which are rather heavy and not very quiet. The exceptions are those for Rotterdam, Tenerife and Strasbourg, which use the silent Onix 850 design.

After three years of operation in Lyon, the Citadis 302 cars on Line T2 are running very well. The wheels are reprofiled every 20 000 km, and 20% of the rails on the network have also been ground. However, the rubber elements in the Valdunes and Bochum super-resilient wheels are not yet achieving the anticipated life expectancy. These wheels are essential to soften the ride of the Arpège bogies without any primary suspension. The wheels themselves have an expected life of 180 000 km.

Noise levels inside the Lyon cars are 54 dB(A) when the car is stationary with the air-conditioning running, increasing to 70 dB(A) at the end of the cars and 73·5 dB(A) in the centre section when running at the maximum speed of 50 km/h. The Barcelona cars (RG 5.04 p 253) have similar noise levels.

The Bordeaux cars are particularly silent. A pedestrian walking in the empty Rue Vital Charles at night when a 43 m Citadis 402 car glides past hears only the click-click from the APS third rail pick-up shoe. Interior noise level when running at the limited 35 km/h permitted in the town centre is typically 62 to 64 dB(A), and 69 dB(A) when standing above the contact shoe. Running over the right-angle crossings at 30 km/h produces no detectable vibrations. Every effort seems to have been made to create a silent and vibration-free operation.

Technical innovation

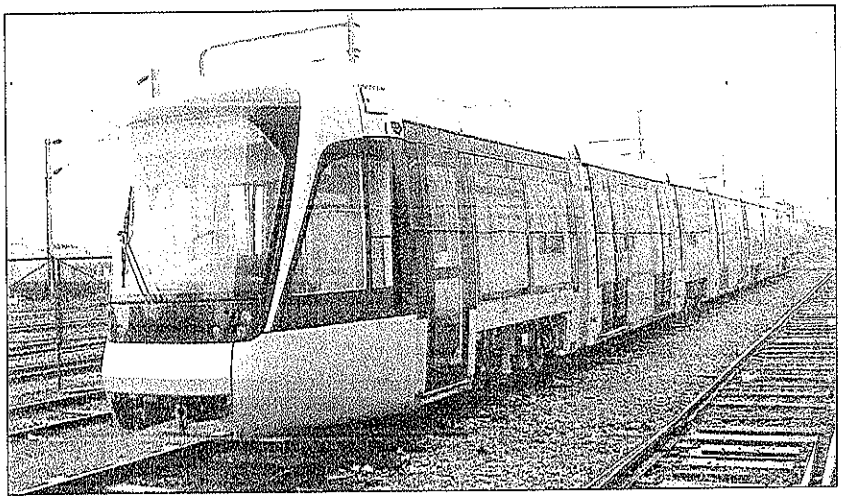
Meanwhile, Alstom is continuing with some interesting technical developments. Rotterdam car 2001 has been equipped with a flywheel storage system from CCM of Nuenen, turning at 22 000 rev/min. Weighing 1 200 kg complete with the control equipment, it can supply 320 kW from an energy reserve of 4 kWh, and can accelerate a tram from a stand at one end of the Erasmus bridge to 30 km/h and continue at this speed to the other end, 1·3 km away. Extensive tests will be needed to show how much energy is saved.

Car 2050 has been equipped with permanent-magnet motors. These enclosed, forced-ventilated, eight-pole machines turn at up to 3 600 rev/min. Continuous rating is 100 kW, and the short-term rating is 120 kW when accelerating and 240 kW when braking. The efficiency of the motors is reported to be 96%. With dimensions of 380 x 420 x 525 mm, they weigh only 285 kg compared to 485 kg for a similarly-rated asynchronous motor. Noise levels should also be reduced.

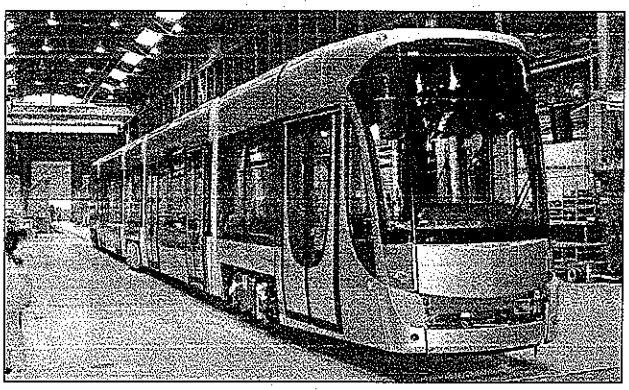
Nice needs its new trams to cross Place Masséna and Place Garibaldi without any overhead wires, leaving the cars to cover two sections of 450 m without an external power supply. The Citadis cars will therefore be equipped with 540 V nickel-hydride batteries rated at 80 Ah. Each car will have 45 x 12-cell batteries, addding 1 450 kg to the weight.

The APS surface-contact power supply should have been the showpiece of the Bordeaux tram network, with 10·7 km of the 22·5 km operating without overhead wires, but it has turned into a very costly experiment, despite early tests in Marseille, at the factory and over 3 000 km of running on the demonstration line in La Rochelle. From day one – the opening of the first line by President Chirac on December 21 2003 – APS has caused long service interruptions and has cost Alstom very dearly.

Alain Juppé, the then Mayor of Bordeaux and driving force behind the tram project, finally announced that if 99% availability was not achieved by the end of 2004, APS would be abandoned



Alstom Citadis 402 car for Grenoble on test in La Rochelle



The first Bombardier bi-directional Cityrunner for Brussels was mounted on its own wheels during April

and replaced by overhead wires. The Alstom-led development group replaced 966 of the radio-operated switch boxes which feed the 8 m third-rail sections and worked systematically to improve reliability. Alstom Chairman Patrick Kron personally assured Juppé that things would come right.

The city commissioned Veritas to carry out an audit, which seems to have had a positive result. It looks as if APS will remain in place, and will be fitted as planned to the 2·5 km anticipated for Phase II. However, if the system is subject to so many problems in a mild climate, what are the prospects for parts of the world where there is often snow and salt on the roads? Perhaps the real lesson is not to respond too eagerly to the wishes of politicians.

Sirio in full swing

Production of AnsaldoBreda's Sirio family continues apace. The new Athens tram network worked well during the Olympic Games (RG 7.04 p423), but after that the city's enchantment seems to have fallen away. In December the *Frankfurter Rundschau* reported that average daily traffic had dropped to only 35 000 passengers. One issue is the lack of priority at traffic lights, which gives a low commercial speed of around 18 km/h. There are also complaints about the cars squealing in curves.

Delivery has started of the shorter Sirio cars for Milano (RG 2.05 p68) and the 19·5 m cars for Napoli which are only 2 300 mm wide (MR 04 p61). Trial operations have started with the 950 mm gauge tramway in Sassari.

Meanwhile, two pre-series cars for Göteborg have also started test running, around eight months behind schedule. The end modules of this 29·6 m long, 2 650 mm wide car differ from the other Sirios in that they have double doors. The sidewalls are of Dibond aluminium composite panels and the roof is aluminium. Weighing 39 tonnes (497 kg/m²), the cars are powered by four 106 kW motors and run on 660 mm diameter wheels. Each uni-directional car has four 1 350 mm wide doorways on one side, 82 seats and space for 104 standing passengers at 4/m².

AnsaldoBreda's latest order is for 22 cars to operate the new 17·1 km network in Kayseri, Turkey. These 32 m long 2 650 mm wide cars bring the total number of Sirios ordered to 248.

Cityrunner runs ahead

Deliveries are also in full swing of the Cityrunner design, now designated the Outlook C-Series by Bombardier. Delivery of the 21 cars for Linz has been completed, and supply of the 18 cars for Genève is also well in hand, allowing the borrowed Lodz cars to return to Poland.

The first of 46 cars for Brussels (MR 04 p60) was unveiled to local politicians on March 21, and it was announced that STIB might be looking to purchase between 25 and 35 additional vehicles. There was a shock in the German tram market when Bochum decided not to order 30 Cityrunners after testing the Eskisehir car, but to choose the Variotram, which had not had the opportunity of a test run. Compensation for Bombardier came with an order for 26 trams for Marseille and another for 30 near-identical cars to be supplied to Valencia; these two orders bring the current total of Cityrunners to 177.

The Marseille order is interesting, as it is the first time that a customer has paid €7·5m for a full-size design mock-up. MBD of Paris has produced a special design based around maritime themes.

Whereas the Cityrunners for Linz, Lodz and Eskisehir had all modules identical, this is not the case with the Genève and Brussels cars, nor the Marseille design[3]. These 32·5 m long cars, 2 400 mm wide, are expected to weigh 40 tonnes (517

Fig 4. MBD of Paris has been responsible for the design and styling of the Marseille Cityrunner cars; Bombardier is to build 26 vehicles for delivery in 2007

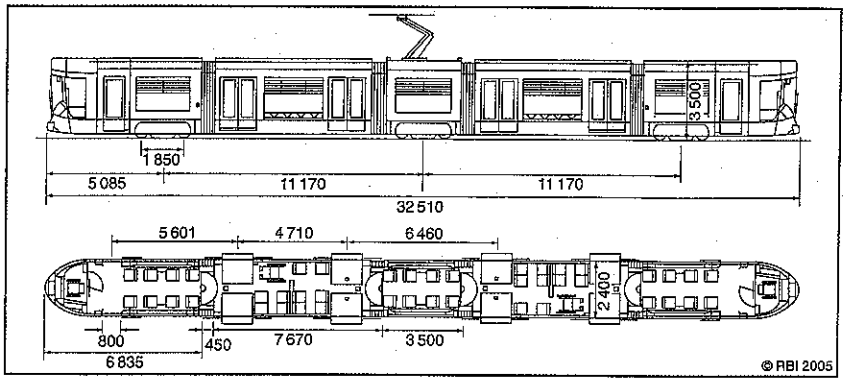
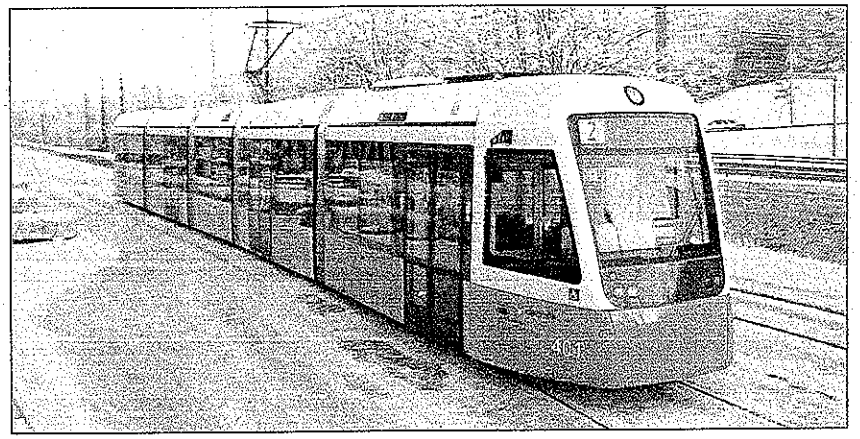


Table VII. Published prices of tram and LRV orders placed in 2004–05

City	Type	Orders	Options	Length m	Width mm	Price €m/car	Price €/m²
Trams							
Paris TMS	Citadis 402	21	49	40·0[1]	2 650	2·58	24 393
Nice	Citadis 302	20	8	32·0[1]	2 650	2·85	33 608
Montpellier	Citadis 302	24	3	32·3[1]	2 650	2·42	28 218
Budapest	GT12N	40		54·0	2 400	3·4	26 238
Valencia	Cityrunner	30		32·5[1]	2 400	2·7	34 615
Marseille	Cityrunner	26		32·5[1]	2 400	2·63	33 700
Madrid	Citadis 302	70	100	32·2[1]	2 400	2·065	20 657
Le Mans	Citadis 302	23	6	30·0[1]	2 400	2·39	33 194
Tunis	Citadis 302	30		32·0[1]	2 400	2·67	34 764
Tenerife	Citadis 302[5]	20	13	32·2[1]	2 400	2·5	32 400
Lyon LEA	Citadis 302	10	13	32·4[1]	2 400	2·4	31 055
Adelaide	Classic	9		30·0[1]	2 400	3·0	41 700
Mannheim	Variotram	13	3	30·5[1]	2 400	2·13[3]	26 976[3]
Mannheim	Variotram	3		42·8	2 400		
Wien	ULF A	80	150[2]	23·6	2 340	2·38[3]	34 897[3]
Wien	ULF B	70		35·5	2 340		
Dresden	Classic DD8	20	20	30·0	2 300	2·15	31 160
Bochum	Variotram	30		29·6[1]	2 300	2·19[4]	26 976[4]
LRVs							
Den Haag	RegioCitadis	50		36·8[1]	2 650	3·1	32 000
Wien	T	38		26·8[1]	2 650	2·7	34 615
Minneapolis	Swift	3		28·0[1]	2 650	2·5	33 692
Charlotte	Avanto S70	16	25	27·7[1]	2 650	US$3·28	$44 619
Calgary	SD160	33		24·4[1]	2 650	US$3·0	$46 226

1. Bi-directional car
2. Option for ULFs not specified whether type A or B.
3. Total price divided by number of cars in firm order
4. Order is for 30 trams + 6 LRVs. Total order price averaged by m²
5. All wheels driven



AnsaldoBreda's five-section Sirio 5C3 car 401 has been undertaking winter weather testing in Göteborg ahead of series construction of the remaining vehicles. The order for 40 cars includes an option for another 60

kg/m²), and will have 44 seats. Each car will be powered by four 115 kW motors (Fig 4).

The continuous axles and low unsprung weight for the non-driven truck contribute to Cityrunner's excellent riding qualities and low noise levels, which are also helped by the Hübner double-corrugated bellows. In my view, the metre-gauge Cityrunner is one of the best multi-articulated cars on the market.

Production of the former Adtranz Incentro design continues. The first of 10 additional cars for Nantes was dispatched from Bautzen on March 31 for testing in Berlin ahead of delivery. Bombardier also has a contract to supply 360 Incentro pattern trucks to China for use under locally-built cars, but work on the order has apparently still not started.

Combino crisis continues

The ongoing structural problems with Siemens' Combino design were explained in MR04 p60. The issue revolves around incorrect calculations of the car's strength. What seemed in 2002 to be a harmless case of some broken Alugrip bolts developed into one of the biggest technical problems in the rolling stock industry, and as a consequence Alcan Mass Transportation is being rationalised and the car body design business wound up.

Discounting the prototype, Siemens had taken orders for 424 Combino cars before the problems emerged – 114 of the original 'Basic' design and 320 of the later 'Advanced' type. Of these, the contracts to supply 22 cars for Verona and 10 for Alacant have been cancelled. The 24 cars for the MTS network in Almeida have been changed to GT8N cars with stainless-steel bodies, as have the NF12s for Budapest, which will be built as GT12Ns instead.

Meanwhile, four of the Erfurt three-module cars will be fitted with modified bodyshells before delivery. Another 12 five-module cars for Erfurt and five seven-module cars for Freiburg have yet to be built. As a result of all these changes, Siemens is left with 403 Combinos that need to be modified, together with 36 NF10 and 15 NF8 for Rheinbahn, bringing the grand total to 454 cars or 2 418 modules. Siemens has allocated €476m for this work, which works out at more than €1m per car.

Over the past years, many studies and measurements have been undertaken on revamped GVB car 2091 in Amsterdam, and on a three-module Erfurt car. Other component tests have been done by outside agencies, together with scientific calculations and discussions between Siemens, its customers and consultants. This research has produced a package of three remedial measures:

1. relieve the car modules from torsional forces in the upper part of the articulations;
2. relieve the modules from forces resulting from the truck/car connections;
3. reinforce the modules to withstand the remaining forces, in such a way that an overall life span of 25 to 30 years can be achieved without further cracking.

At present four cars are being rebuilt as a test for this process: one from Bern, one from Poznan and two from Amsterdam. In addition, Erfurt 709-712 will be reconstructed before delivery. At a best estimate, calculations to assess whether Siemens' proposals will give the guaranteed life expectancy will not be ready until the end of August. All the Combinos have been put back into service, with provisional modifications to keep them operational until they are reconstructed. The rectification programme will be a lengthy one, and will not see all the cars rebuilt before mid-2007 at the earliest.

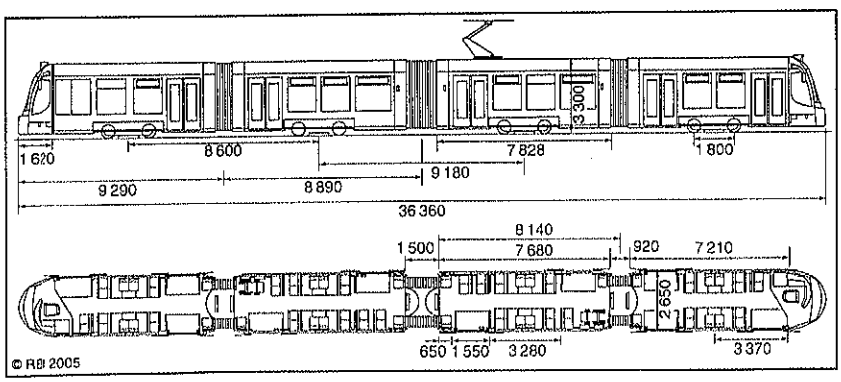
Meanwhile, the three Combino Duo electro-diesel units for Nordhausen entered service in May 2004 (RG 5.04 p258). These operate a through service from the Nordhausen tram system to Ilfeld using 11 km of the non-electrified HSB line. Combino Duo is a 20 m long three-module car, 2 300 m wide, powered by four 100 kW motors and weighing 27·5 tonnes (596 kg/m²). The supplementary 3·9 litre V8 BMW diesel engine rated at 190 kW at 4 000 rev/min is coupled to a 170 kW synchronous generator to feed the 700 V DC traction equipment.

Steel-bodied cars

Before the Combino problems emerged, Budapest had ordered 40 cars and Almeida in Portugal a further 24. Siemens has now developed a new stainless-steel bodied low-floor tram for these orders, which is basically a variant of the GTXN design, for which Bombardier's patents have lapsed, but with standard Combino electrical equipment. Kiepe Elektrik will no longer have any involvement with these orders.

Budapest will get a 2 400 mm wide GT12N version with six modules, no less than 54 m long. Almeida's four-module GT8N will be shorter, but 2 650 mm wide. The Combino trucks become 'quasi bogies' with up to 4·2° of movement. Three of the Hübner articulations, between sections 1+2, 3+4 and 5+6, will be steered, using the same design as the Type R cars for Frankfurt. The other two will in principle be the same as those used on the Bombardier/Siemens GT8N2

Fig 5. Siemens has developed a family of steel-bodied GTXN cars for Budapest and MTS in Almeida, Portgal. The MTS GT8N cars for MTS in Almeida will be shorter than the Budapest GT12N, but 2 650 mm wide



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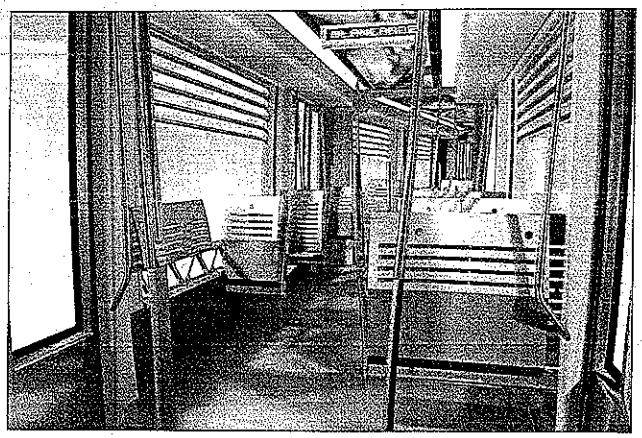
4. Trams in the Balkans – Perspectives for the future. *Tramnews*, Hanning & Kahl, March 2005.

cars for München and Nürnberg.

The GT12N will have four motored and two unpowered bogies, arranged Bo' 2' Bo' Bo' 2' Bo', with eight 100 kW motors; total weight will be 66 tonnes (509 kg/m²). Interior floor height is 350 mm above rail, with the entrances at 320 mm. Mechanically the car is arranged as three GT4Ns, and electrically it is six GT6Ns. The Almeida GT8N is a bi-directional Bo' Bo' 2' Bo' car, 36·4 m long, powered by six 100 kW motors, Weight is 49·8 tonnes or 519 kg/m².



ABOVE: *MBD has been responsible for the interior design and styling of the Bombardier Cityrunner cars for Marseille*

RIGHT: *The Bombardier bi-directional Cityrunner delivered to TPG in Genève has a spacious interior given its 2 300 mm width*

Outlook still uncertain

We have to ask again how long the three big systems integrators will remain active in the tram and light rail sector. Their results are generally reported to be mediocre at best. Despite their efforts to persuade customers to adopt standardised designs and order in large batches, volumes remain low, whilst the engineering design input and after-sales service require considerable effort, and the risks are high.

It seems clear that it will be increasingly difficult for manufacturers to maintain a steady flow of orders at a high enough level to sustain their existing capacity. And the fact that total newcomers like Stadler can find easy acceptance in the German market, and customers even take pride in the increased competition, will do nothing to inspire confidence in the existing suppliers.

Prospects for orders in the next few years are mixed, to say the least. In France, it looks as if tram projects in Angers, Brest, Reims and Toulouse are set to go ahead, although Strasbourg has abandoned its tram-train plans. Liverpool's Merseytram and Edinburgh are close to taking off, and despite the recent criticism of the UK Department for Transport, the Leeds Supertram and Manchester Metrolink 'Big Bang' projects are not dead yet. Jerusalem's order for 46 Citadis 302 cars is expected to be confirmed shortly.

Several cities are now planning large orders to replace existing fleets that are approaching life-expiry. In Frankfurt, VGF plans to order 170 LRVs to replace its fleet of U2 and U3 cars dating from 1968 onwards at a rate of 17 vehicles per year, but this has been affected by the decisions of Hessen and Rheinland-Pfalz to stop subsidising investment.

Dortmund intends to replace its Stadtbahn N8C cars, which only date from 1978-83, by 47 low-floor trams, and Berlin is preparing to purchase a few hundred cars to replace its modernised T6 and KT4D trams by the end of this decade. Darmstadt wants to replace 18 cars and Potsdam 19.

In Switzerland, the two Basel operators BVB and BLT are teaming up for a joint purchase of 65 cars over the next decade. Innsbruck wants to replace its existing Duewag trams and trolleybuses with 45 low-floor cars, and Graz has called tenders for 30 cars of around 27 m in length. Belgium's VVM De Lijn plans to purchase 108 cars by 2012 to replace its remaining PCC-derived trams in Gent and Antwerpen.

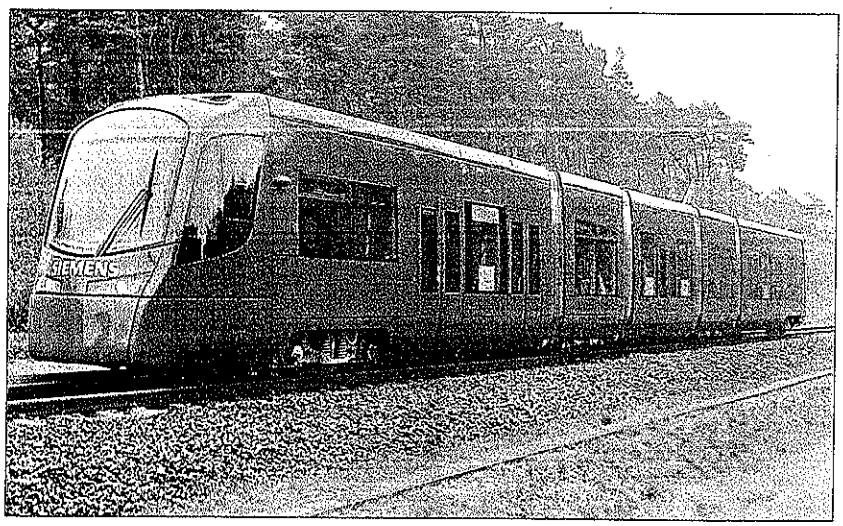
On the LRV front, Luxembourg, Saarbrücken and Porto are still talking about ordering tram-train cars. RET of Rotterdam is about to order 21 three-car LRVs for RandstadRail (RG 4.05 p209). Still unclear are the prospects for orders from Toulon, Hanoi and Tel Aviv.

Another unknown is the possible impact on the market of Croatian and Czech producers such as Koncar and Skoda.

Koncar and local Croatian firms are working on an order to supply 70 unidirectional 100% low-floor cars for Zagreb, designated series TMK 2200. These 31·5 m long, 2 300 mm wide cars have 660 mm diameter wheels and are powered by six 65 kW motors. Offering 43 seats and space for 159 standing passengers, they are reported to weigh 36 tonnes (497 kg/m²). Pictures show three powered modules like the GT6N, each with two end doors and a central truck, connected by two small wheel-less sections[4].

Skoda and the Ostrava tram company Inekon have exported 13 three-section Astra low-floor cars to the USA, for Portland, Tacoma and now Washington DC. Skoda is also supplying six five-module versions to Cagliari.

Japanese builders Mitsubishi, Kinki Sharyo and Toyo Electric have teamed up to build the experimental Green Mover low-floor car for Hiroshima (RG 1.05 p10). Will this be the beginning of a similar export drive for the low-floor tram sector as we have seen in the US LRV market, where Kinki Sharyo is currently working on orders from Dallas, Phoenix and Seattle? ■



On test at Wildenrath at the end of April was the first Siemens Avanto car for SNCF's Bondy – Aulnay line in the eastern suburbs of Paris. This is the first tram-train vehicle to be equipped for 25 kV 50 Hz operation