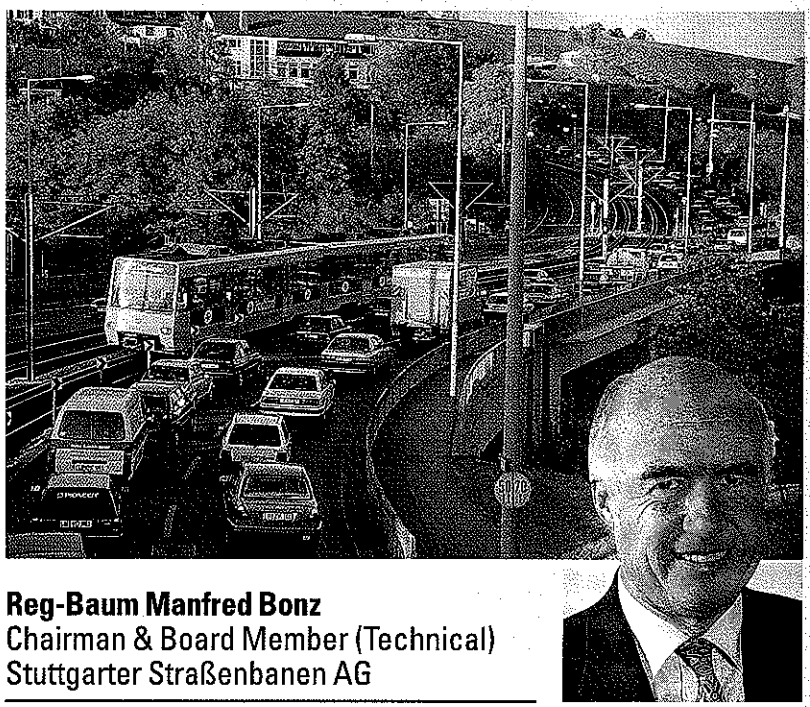
SSB hosts the 1997 UITP Congress

From June 1 to 6, Stuttgarter Straßenbanen AG is hosting the 52nd Congress of the International Union of Public Transport, and the City Transport '97 exhibition. Massive investment in the city's local transport means there is much for delegates to see



Reg-Baum Manfred Bonz
Chairman & Board Member (Technical)
Stuttgarter Straßenbanen AG

WITH AROUND 570 000 inhabitants, Stuttgart is the state capital of Baden-Württemberg and lies at the centre of a busy economic region. Various local transport companies, of which Stuttgarter Straßenbanen AG is the biggest, handle 1·2 million passengers a day on an interconnecting network with a common fares structure.

Although Stuttgart is the home of the German car industry, public transport still has a 33% market share – higher than many other European cities. This result is not unconnected to the massive scale of public transport investment over the past two decades, notably in the S-Bahn commuter rail and the Stadtbahn light rail networks.

For public transport to offer a real alternative to the private car, it has to distinguish itself with a very high quality of service, of which fast journey times and a high degree of punctuality are important features. One of the first measures we took in Stuttgart was to give light rail priority at all intersections controlled by traffic lights, and on sections of road still shared with cars and lorries. This reduced the time spent waiting at traffic lights to just 2% of the trip time, and increased the average journey speed for light rail to 26 km/h.

At the same time, we found that giving priority to public transport did not seriously obstruct car movements, particularly where modern techniques such as the 'green wave' principle allowed us to optimise the green light periods for both public and private transport.

Trams into Stadtbahn

Top priority at SSB for several years has been the extension of the Stadtbahn through replacement of classic metre-gauge tram routes by a high-quality standard-gauge light rail network. This programme is set to continue for several more years. The first lines to be converted were U1, U3, U5, U6, U9 and U14, which were finished by 1991.

In 1992 SSB opened a completely new line (U11) to serve the Gottlieb Daimler stadium. This was followed in 1993 by Line U7 from Degerloch to the exhibition and congress centre at Killesberg, and in 1994 by Line U4 from Botnang to Untertürkheim. At present the Stadtbahn network extends to 84·2 route-km.

Another policy of continuous improvement is the construction of high platforms to provide level boarding into the vehicles. Accessed by ramps or elevators, these high platforms ensure comfortable and convenient access to the vehicles for mobility impaired riders, children, elderly people, passengers with heavy luggage, and mothers with prams. Level access also reduces the time needed for boarding and alighting, and therefore contributes to a further reduction of journey times.

Line U6 was the first line to be operated regularly by trains of two articulated LRVs running in multiple. Double sets also run at certain times on U7, which is heavily used during trade fairs at the exhibition centre. For this reason the high platforms on these two routes are 80 m long, compared to 40 m on other lines.

SSB has recently invested heavily in modern traffic management systems to improve the quality of service on the Stadtbahn network. A computer-based command and control centre helps to minimise the consequences of any traffic delays. Passengers at stations or on the vehicles can be informed immediately of any problems, and a dynamic schedule synchronisation process helps to get the services back to normal as quickly as possible.

SSB's segregated Stadtbahn routes offer an alternative to congestion for commuters

In parallel with the computerised control system, SSB has modernised its passenger information provision. The traditional 'static' display boards and timetables have been augmented by dynamic displays which provide extensive information to the passengers including real-time details of train running.

LCD boards at the stations show when the next train will arrive, its length, and the route it will be taking. In addition to the standard messages, a free-form automated message system enables special announcements to be made about significant events – even in different languages.

Network extension

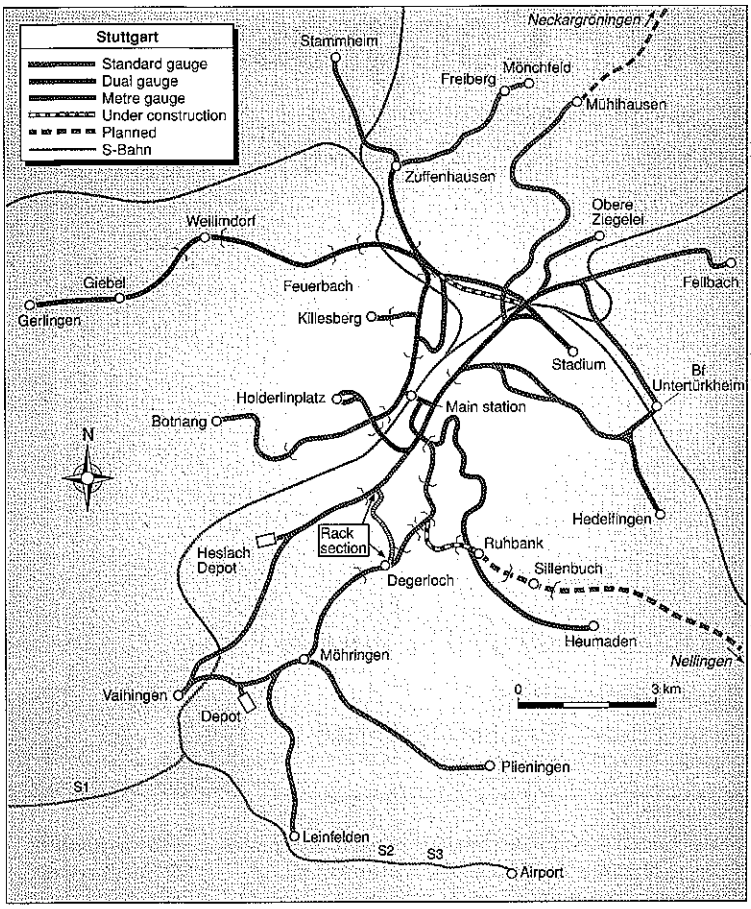
Expansion of the Stadtbahn network is set to continue at a rapid pace for the next few years. Just a few days before the UITP congress, on May 31, SSB opened its latest extension taking Line U6 to its final terminus at Gerlingen.

Construction work has already started on converting tram route 13 to light rail standards; Stadtbahn Line U13 from Hedelfingen to Pfostenwaldle is expected to start operation in May 1998. A new southern branch of Line U7 from Bopser to Ruhbank is also due to open in May 1998. This is being tunnelled using deep mining techniques, and delegates will have the opportunity to see some of the construction works during the congress. Line U7 is due to be extended to Nellingen by September 2000.

Providing highly accessible transport for all is an important objective for SSB

Mühlhaus

Two new Stadtbahn routes in the north of



Stuttgart are scheduled to open in 1999. May of that year will see the extension of Line U14 to Neckargröningen, whilst in the autumn Line U5 will be extended northwards to the current U14 terminus at Mühlhausen. The new link between U5 and U14 is expected to give us much greater flexibility in diagramming light rail vehicles between the different routes.

The last of the current wave of extensions is expected to come on stream in the autumn of 2000. This will see the opening of a completely new Line U8 from Heumaden to Vaihingen in the southeast.

A major challenge to SSB's light rail development strategy has emerged with the launch of the 'Stuttgart 21' project to replace the city's main line railway station. The existing terminus will be replaced by an underground through station leading to a cross-city tunnel, speeding journey times on DB's Frankfurt – München intercity corridor. This will release an area of about 100 ha northeast of the city centre for residential development. We are planning to serve the area by a new light rail branch from the main station to Hallschlag, which would be served by an extension of Line U12 from Degerloch.

Vehicle advances

The present Stadtbahn network is operated by a standard series of LRVs which were specially designed for Stuttgart by Lindinger & Partners, and built at Duewag in Düsseldorf at the beginning of the 1980s. This design is now being further developed and modernised to create a new DT8.10 series, which is intended to go into operation by the end of 1998.

The new vehicle has been designed to take account of the changing needs of passengers and other road users, as well as our own staff – drivers, driver training instructors, and the maintenance workers.

In order to give better 'social control' within the vehicle, and to improve the passengers' perception of safety, a gangway has been added between the two halves of the original twin-section vehicles.

This also has a useful side-effect in helping passengers to spread more evenly through the vehicle and optimise use of available seating. Green-tinted windows will reduce the radiation intensity of the sun. Internally, visual displays at both ends of the vehicle will give the name of the next stop.

To reduce the risk of damage in the event of a collision with road vehicles, the original couplings which protrude from the car ends will be replaced by a retractable version. This will also provide better protection for pedestrians, and will enhance the smooth design of the vehicle ends.

An enlarged cab and an ergonomically constructed seat will contribute to a higher level of comfort for the drivers. In addition, the bottom edge of the windscreen is being lowered to improve visibility.

In technical terms, the biggest changes come in the drive technology. The classic DC traction drive is being replaced by three-phase AC motors, which are virtually maintenance-free. The motor construction means they cannot be strained or damaged, and they are much lighter than a comparable DC motor. The longitudinal transmission layout has been changed to transverse, raising the performance of the transmission and enabling more economical exploitation of the tyre profile.

Further technical improvements include a change from relays to microprocessors in the traction control system, the use of a vehicle databus to reduce wiring, and installation of a fault diagnosis system which can be used by the drivers and maintenance department. The power conditioning will be air-cooled to eliminate the use of environmentally damaging refrigerants.

During the conception of the DT8.10, much attention was paid to keeping life-cycle costs as low as possible. Several factors have contributed to this goal:

- use of components with low maintenance costs (AC drives and databus);
- extended servicing periods;
- high reliability and availability;
- reduced vehicle weight.

Simulation boosts training

Despite the extensive segregation of light rail routes from other traffic wherever possible, using railway alignments and exclusive rights-of-way, light rail drivers will still have to cope with driving in open streets on some sections for the foreseeable future. Steady increases in the level of car and lorry use, and occasionally irrational or impulsive behaviour of other road-users, require the driver's full attention and rapid reaction abilities.

To reinforce these skills, all SSB driving staff need to obtain a high level of theoretical knowledge and extensive practical experience. But when conducting practical training out on the network in a service vehicle, the instructor must occasionally intervene to avoid an imminent accident or offer assistance after a malfunction occurred, so as to avoid delaying the following traffic. If this intervention comes too early, it can take away the opportunity for the trainee to experience the practical effects of an incident. Now, the use of a training simulator enables an instructor to demonstrate typical situations impressively and without danger.

SSB will soon install a driving simulator consisting of a complete reproduction of an LRV cab, right down to all the controls, services and displays, a functioning door with drop-down steps, an emergency braking unit with emergency call and passenger intercom. The simulator can imitate external visibility both in the direction of travel and in the rear-view mirrors, and is designed to reproduce acceleration movements and vibrations as well as environmental influences and the function or malfunction logistics of all the technical elements.

Use of the simulator enables trainee drivers to get used to the vehicle away from real traffic, and decreases the risk of training runs interfering with regular services. By releasing track capacity occupied by training vehicles, it also leads to a lower risk of delays to scheduled operations. It also gives a much higher quality of emergency training.

We plan to use the simulator for all initial training, and for re-training of experienced drivers at regular intervals. Some 'live' training out on the track will still be needed to ensure adequate knowledge of the various routes. The simulator is initially being programmed with a representation of Line U1, but in the longer term we hope to set up a library of all the other lines, increasing the flexibility of the training programmes.

The driving simulator will be on show at the 'City Transport 97' exhibition accompanying the UITP congress, and visitors will be invited to sample our latest training methods themselves. We are sure they will find it impressive. ❑

Central sections of Stuttgart's U-Bahn are designed to full metro standards

Stuttgart congress explores hot topics

The International Union of Public Transport is holding its 52nd International Congress and City Transport exhibition in Stuttgart's Messe- und Kongresszentrum on June 1-6. Technical visits to the city's light rail network and innovative regional operations round off a programme exploring financial, technical and management options for the future.

The congress and accompanying City Transport exhibition will be opened on June 2 in the presence of German Transport Minister Matthias Wissman and EU Transport Commissioner Neil Kinnock. A plenary session in the afternoon for members of the UITP and the Association of German Transport Companies considers new horizons for public transport; papers from France, Germany and Brazil will examine new challenges in a changing urban environment, major interchange projects, the vehicle revolution in regional transport and public/private investment partnerships.

The congress divides into two strands on June 3. In the morning session, papers on measuring and raising passenger satisfaction and a workshop presenting the first phase of UITP's world statistics project vie for delegates' attention with urban light rail and a European plenary session examining the threats and challenges of public transport finance. The afternoon session considers, amongst other topics, urban railways and customer satisfaction.

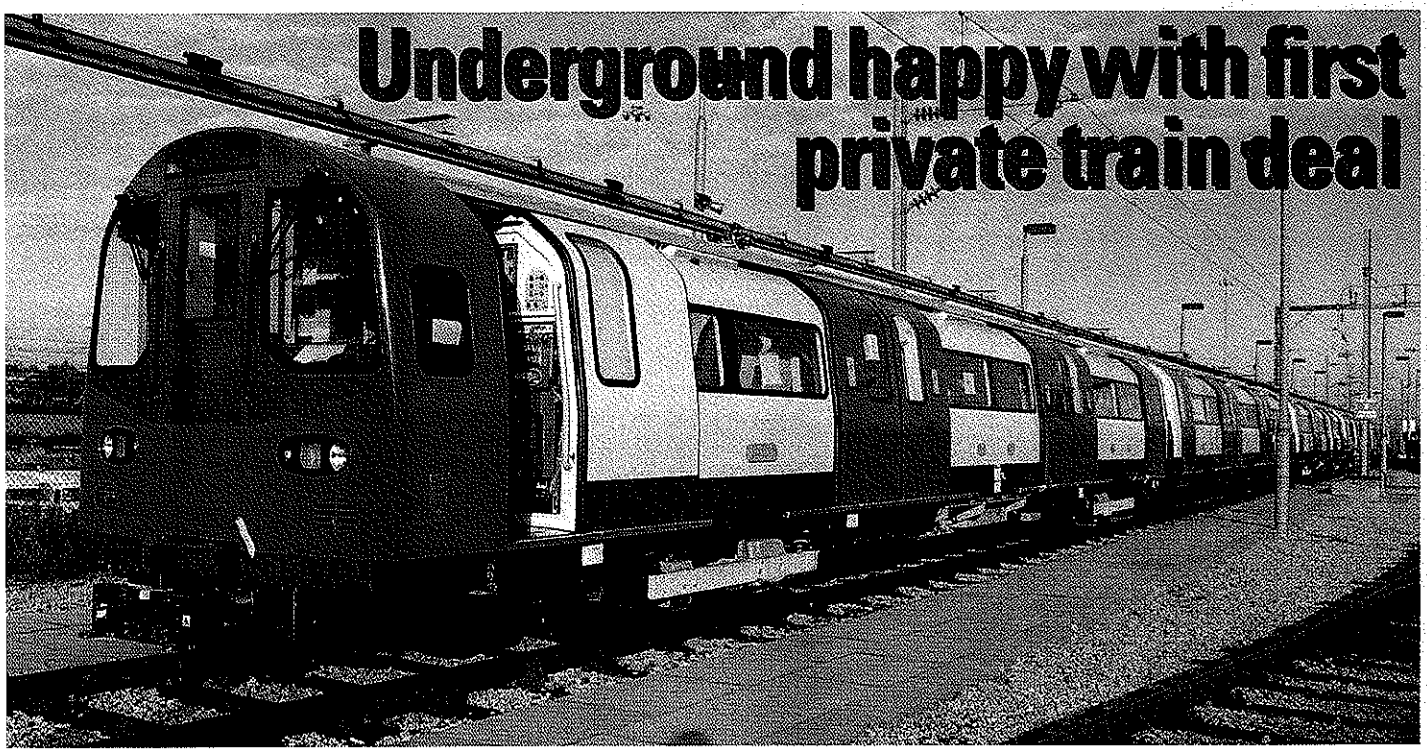
'Hot topics in public transport', such as cashless payment and life-cycle costs of rolling stock and fixed installations, form the subject of a plenary session in the morning of June 4. In the afternoon, UITP's Asia/Pacific Committee considers quality of service best practice in the region; a North American case study examines land use regulation in successful transit investment with reference to Atlanta. The other strand of the congress considers a paper from Sweden on making regional services more attractive and cost-effective, and the first results in München of an international campaign to encourage car users to switch to public transport.

The final day of the congress begins with a presentation from the UITP Industry Committee on partnerships between suppliers and operators. Following the closing session, which includes the presentation of the new UITP President, the afternoon is taken up by a programme of technical visits. These include the control centre and vehicle workshops of congress host Stuttgarter Straßenbanen AG, and a visit to the Altenbergstaffel – Ruhbank light rail route currently under construction. One visit combines Karlsruher Verkehrsbetriebe's hybrid light/heavy rail operations with the Böblingen – Dettenhausen route reopened to passenger traffic in December by Württembergische Eisenbahn Gesellschaft (RG11.96 p710) using low-floor diesel railcars. ❑

STUTTGART

Further information on the congress programme and registration details from: UITP, Avenue de l'Uruguay 19, B-1000 Brussels, Belgium
Tel: +32 2 673 61 05 Fax: +32 2 660 10 72
e-mail: events@uitp.com

Underground happy with first private train deal



Two years into the £400m lease-and-maintain agreement under which GEC Alsthom is building 106 trains for the Northern line, Richard Hope explains why London Underground expects a growing proportion of investment to be privately financed

WITH LABOUR replacing the Conservatives in the May 1 general election, plans to privatise the London Underground (RG 4.97 p197) have been aborted. This does not mean, however, that deep cuts in capital grant funding for London Transport imposed last November will be restored, as Labour is committed to respecting limits on public spending set in the November 1996 budget statement.

Setting aside the Jubilee Line Extension, which is partly funded by property developer Canary Wharf Ltd, LU's first major deal under the government's 1992 Private Finance Initiative was signed on April 7 1995. This provided for the complete replacement of trains on the Northern line by 106 six-car trains offering higher capacity and performance.

In fact, GEC Alsthom agreed to build and maintain sufficient new trains to provide a 25% increase in capacity on parts of the Northern line – once new signalling had been installed allowing 36 trains/h to operate reliably on the busiest section between Kennington and Morden. Payments, linked to performance measured primarily in terms of train availability, are spread over 36 years – if an option to extend the contract beyond 20 years is taken up.

A remarkable feature of the deal was that GEC Alsthom agreed to assume responsibility for the two depots at Morden and Golders Green where Northern line trains are stabled and maintained. Depot staff were transferred in November 1995 to GEC Alsthom Railway Maintenance Services Ltd, a subsidiary company set up with this project in view.

Since then, RMS has been responsible for maintaining and cleaning the 1959 and 1972 stock used on the Northern line, and making the specified number of trains available for traffic each day. LU makes a baseline payment for train provision, and RMS pays compensation in the event of train failure in service.

As John Harker, LU's Train Service Contracts Manager, explains, 'we did market testing for Bakerloo line train maintenance and cleaning in 1992 but the in-house team won it, so prior to the Northern line PFI we had experience of tendering but not of actually transferring a depot to outside management.' The new Stratford depot for the extended Jubilee line will also be managed by train manufacturer GEC Alsthom, through RMS, but this was agreed after the Northern line deal was closed.

LU has three more service-provision PFI deals in the pipeline covering traction power, revenue collection and communications (panel, p12). The first, known as *Power*, is in the final stages of negotiation with the Seeboard Powerlink Consortium comprising Seeboard (a privatised regional electricity supplier), BICC and ABB. Valued at £200m to £300m, it would cover the supply of power to the Underground for 30 years, and require the consortium to take over LU's two power stations and distribution network.

Four consortia were shortlisted for the *Prestige* PFI deal, which involves the replacement of tickets coded with a magnetic stripe by contactless smart cards. Three withdrew last year leaving LU to negotiate with the TranSys consortium comprising Westinghouse Cubic, EDS, ICL Enterprises and WS Atkins.

Connect, a communications package covering an optic fibre network and train radio, is still at the bidding stage and no decision is expected before the end of the year.

There may be a short delay while the new Transport Secretary reviews the detail of the *Power* and *Prestige* deals, but both are likely to go ahead in the second half of 1997. While Labour will replace PFI deals with what it calls 'private-public partnerships' the basic principle is unlikely to change much.

In essence, LU contracts out investment and maintenance over a period corresponding to the probable life of the assets that its private 'partner' is expected to provide and install. Output is measured in terms of the service delivered. The risk that investment will be delayed or equipment will fail to perform as specified is thus transferred to the contractor.

Proposal came from supplier

Faced with a dearth of orders for new trains owing to privatisation of British Rail, ABB Transportation (now Adtranz) offered to supply and main-

One of the first trains for the Northern line stands on the test track at GEC Alsthom's Metro-Cammell works. Power for test running is delivered from a skate running along an overhead rail

LU PFI deals in progress

	Equivalent investment
Deal signed 1995:	
Northern line trains plus maintenance	£400m
Deals for decision in 1997:	
Power generation and distribution (*Power*)	-
Ticket sales and checking (*Prestige*)	-
Radio and optic fibre communications (*Connect*)	-
Combined total	£400m to £600m
Investigation and Assessment:	
East London line extensions	£120m
Piccadilly line extension to Heathrow Terminal 5	£70m
Croxley Link	£25m
Escalator renewal and maintenance (LU has 303)	-
Northern line modernisation Phases 2 and 3	-
District line, refurbished trains	-
Victoria line, new trains	-
Wembley Park, rebuilt station	-
Upgrading of track	-

tain Northern line trains in return for on-going performance related repayments late in 1993. After the Treasury had been persuaded that train suppliers could not be expected to assume more than a minority share in the revenue risk as well, the Transport Secretary (then John MacGregor) authorised LT on March 29 1994 to invite bids.

The fact that it took a further year to close the deal underlines the comment made by LT in its evidence to the House of Commons Transport Committee in February 1997 that 'PFI projects are complex and relatively new. Consequently, they take a considerable time from inception to agreement (eg 18 months to 2 years) and do not lend themselves to making prompt adjustment for annual changes in grant.'

This is a reference to the fact that LU is currently funding some £200m of annual investment out of operating profit (gross margin) with the bulk coming from government as grant. PFI deals were originally presented by the last government as a means to bring in additional investment. LT still takes this view, saying in February that it regards them as 'supplementary to its investment funded through grant and gross margin contributions.'

By 1996, the government had started to treat PFI as a mechanism for replacing capital grants with future repayments out of gross margins. Thus its projection in November 1996 that LU's core investment (which excludes JLE spending) would 'average around £525m a year' to March 2000 included notional sums for *Power*, *Prestige* and *Connect* even though the outcome of these negotiations was still uncertain (left).

Economic efficiency goal

If PFI were simply a matter of deferred payment it would undoubtedly cost the taxpayer more than capital grants. However, the theory behind such deals is that giving the contractor flexibility to design trains for minimal whole life cost, and making him assume the risk of failure, would lead to greater economic efficiency overall.

So far so good seems to be the verdict to date, notwithstanding the fact that delivery of the trains has slipped by several months.

The first train arrived in December 1996, and after a programme of tests elsewhere was expected to begin trials on the Northern line on May 15; it is due into service in September, and the last of the old trains should be replaced by January 1999.

The good news is that RMS is achieving and sometimes exceeding availability and reliability targets for the 1959 and 1972 stock despite the fact that it is having to remain in service longer than had been planned. Current targets are based on levels previously being achieved by the two depots under LU management.

Once the new trains come in, RMS has to make up to 96 six-car trains available each weekday and hit a reliability-in-service target that is much higher than at present. Income from train delivery is reduced when the reliability target is missed, as trains not available are not paid for. RMS receives no bonus for being able to beat the target – the choice of building 106 trains was a commercial decision taken by GEC Alsthom, not LU.

Harker says RMS 'took over the two depots very successfully and people seem to be happy.' He accepts that 'the 1959 stock is at the end of its design life and deteriorating rapidly ... the delay means that RMS has to work that much harder.'

In fact, had the PFI not gone ahead, Northern Line train replacement would not have occurred until 2005-06, with the 1959 stock being refurbished to extend its service life to 45 years.

Shorter trains

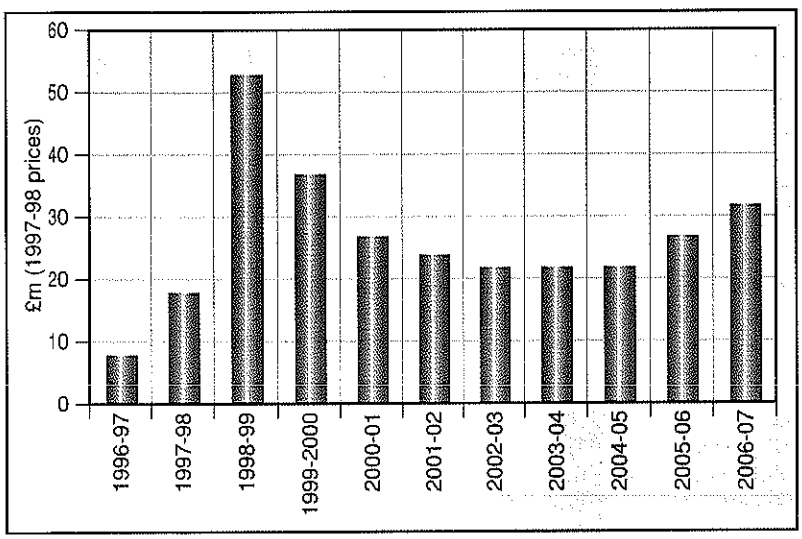
While the new trains are similar in many respects to the new Jubilee line fleet (RG 1.96 p30), the AC motors are powered by insulated-gate bipolar transistors instead of GTO thyristors. One advantage is that IGBTs operate at higher frequencies and immunisation of signalling is therefore less of a problem.

Six-car trains were dictated by the short tube station platforms. The seven-car trains currently project into the tunnel at each end, a practice that HM Railway Inspectorate would not be willing to see continued with a new fleet. Harker says there will be no loss of capacity, even at existing headways of 27 trains/h, because of the high density layout and replacement of two intermediate cabs by a locked panel for use in depots. The cars are also slightly longer.

Safety is enhanced by better crashworthiness, and security by internal video recording if the alarm handle is pulled. Automatic announcements during stops will advise the name of the next station and the train's destination and route, which can vary. The Northern line is the last on the LU network to have guards, so driver-only operation will be universal from early 1999.

Peter Campbell of the Northern line development team points out that LU has had to fund restoration of minimum standard clearances in a number of places. Although the Northern line cars are built to the standard tube profile (which is slightly smaller than the Jubilee stock), 'the tunnels have distorted in places and we are restoring those sections where they no longer meet the gauge.' Some sections were opened almost a century ago, although the original City & South London portion (the world's first deep tube dating from 1890) was enlarged in the 1920s.

In fact, the £400m generally quoted as the capital value of the Northern line trains deal in net present value terms excludes a further £120m of conventional investment by LU. Apart from clearances, this covers immunisation of the existing signalling by replacing some track circuits, upgrading traction power supplies, and track work required to meet standards specified in the PFI deal for the trains. All this is due to be completed 'before we get the full complement of new trains', according to Campbell.



Graph showing net adverse impact of Northern line PFI deal on LU's Gross Margin to 2006-07. (data from LT memorandum to the Transport Select Committee)

Modernisation phased

While the early arrival of new trains will certainly benefit passengers, an unfortunate consequence of the PFI deal is the way it has forced LU to phase upgrading of the Northern line over a decade or more instead of renewing trains, track, power supplies and signalling simultaneously in order to elminate wasted work.

In fact, some ancillary works were included in the PFI deal and are therefore the responsibility of GEC Alsthom. £20m has been spent on upgrading the depots to enable them to handle the new trains efficiently.

Expansion of overnight stabling sidings at High Barnet, Highgate and Edgware is not in the PFI deal, but forms part of the enabling works carried out by LU. RMS is responsible for putting trains into service from these points. The location of inspection and cleaning work is a matter for RMS to decide.

GEC Alsthom is also charged with procuring and installing any lineside equipment which forms part of a system that is partially on the rolling stock. The list includes: in-cab CCTV for viewing platforms during door operation by the driver, upgrading the present VHF train radio prior to a new UHF system being introduced, and 'right-side door enable' which prevents doors opening on the non-platform side.

Train control package

Still to come – when LU can find the money – is Phase 2 of the whole project. The most important element will be complete replacement of the existing two-aspect colourlight signalling with a train control package that may take the form of a 'private-public partnership' – or whatever the favoured term may be three years hence. LU will assess conventional capital funding options as well as PPP/PFI options.

Signalling is likely to be transmission-based with a new control room constructed to replace Cobourg Street, which was built in the mid-1960s for the Victoria line. In line with LU policy, ATO will be specified for the new train control package. Harker says it will be up to the supplier to make proposals in line with the performance specification.

To match the GEC Alsthom train service contract, the signalling must support a reliable flow of 36 trains/h between Morden and Kennington within a specified journey time. The contractor will doubtless be expected to maintain the equipment within a framework of performance standards, which means that he assumes the technical risk.

Track and stations

Phase 3 covers comprehensive upgrading of track, structures and stations. The PFI trains contract defines a minimum standard of track that they will be expected to run over without GEC Alsthom being able to claim compensation for extra maintenance costs or damage to the bogies. This has been achieved under the £120m Phase 1 works now nearing completion.

There are ten stations on the southern leg, refurbishment of which is complete at Balham, Clapham Common and Clapham South, with four more to be completed in 1997-98 (Clapham North, Tooting Broadway, Tooting Bec and Oval). Cutbacks in grant funding have forced LT to defer refurbishment of three stations (Colliers Wood, South Wimbledon and Morden) until 2001, while work on other stations, such as Kennington, has been postponed indefinitely.

Trains for the Jubilee line are also being built by GEC Alsthom at its Metro-Cammell works in Birmingham, but they are likely to be the last substantial build to be owned outright by LU

A price to pay

While LU is quite willing to press ahead with PFI/partnership deals in an effort to improve efficiency and close the grant funding gap, Campbell notes that a great deal of effort was required to secure the Northern line PFI deal. However, 'this has allowed the acceleration of our investment programme, which would not have been possible otherwise.'

Harker points out that there are technical problems too, despite the design responsibilities and risk transferred to the contractor. There are still interfaces to be watched, and performance specifications are not as simple to write as some people assume ... 'you have got to create a jigsaw puzzle with pieces that fit, and make sure you don't get caught out somewhere in the middle.' ❑

Government estimates of core investment funding available to London Underground

	1997-98	1998-99	1999-2000	Totals
PFI projects[1]	£247m	£124m	£104m	£475m
Other sources	£345m	£314m	£436m	£1 095m
Totals	**£592m**	**£438m**	**£540m**	**£1 570m**

1. Northern line trains, Power, Prestige and Connect

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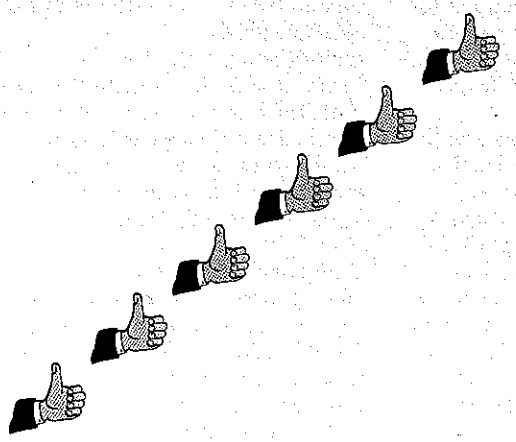

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Automated U-Bahn operation passes first milestone

A successful test run on Frankfurt U-Bahn Line U4 in December proved the practicality of automatically driving an existing metro trainset using radio-based data exchange

Christian Lambrecht and **Jörg Ebel***

A SPECIAL TRAIN carried invited guests from Seckbacher Landstraße to Hauptbahnhof on Line U4 of the Frankfurt U-Bahn on December 5 last year. Operating between regular services, the train was the first official demonstration of fully-automated operation, marking a significant milestone in a three-year research project. To make the demonstration of the first phase results as impressive as possible, the vehicle was driven with the cab completely unoccupied.

Stadtwerke Verkehrsgesellschaft Frankfurt-am-Main launched its FBS programme (*Flexibilisierung des Beförderungsangebots bei U- und Stadtbahnen durch fahrerlosen Betrieb*) in mid-1995. The aim is to prove that retrofitting a conventional metro line can provide greater operating flexibility and improve the quality of service to the passengers. Drivers who are currently tied to their cabs will be freed to act as roving passenger attendants at the stations or in the vehicles, and the number of trains in operation can be altered on demand for relatively short periods of time.

Particularly critical is the need to demonstrate that automation of an existing line can be achieved without developing new technical solutions or surmounting legal obstacles.

The project is being carried out in co-operation with the signalling division of ABB Daimler-Benz Transportation GmbH in Braunschweig. SVG defined the operational requirements and specifications, leaving Adtranz to come up with the technical solutions. SVG has provided the workshop facilities, vehicles and route, while Adtranz is supplying the prototype equipment for the vehicles, track and control centre, and is conducting the practical tests.

Technical specifications

FBS is intended to demonstrate the potential of automation to increase operational flexibility and service quality. Initial experiments are being conducted with two vehicles on part of Line U4, running from the reversing siding beyond the terminus at Seckbacher Landstraße to Hauptbahnhof, including the stations at Seckbacher Landstraße, Bornheim Mitte, Höhenstraße, Merianplatz, Konstablerwache, Römer and Hauptbahnhof.

In order to minimise the costs and disruption of conversion, SVG wanted to avoid installing extra lineside equipment, and to use the existing route interlockings unchanged. This was particularly relevant because FBS trials were to be done whilst the line was in revenue service, and would see a mixture of automated and manually-driven vehicles using the same tracks.

The final system architecture (Fig 1) makes extensive use of hardware and components already available from or under development at Adtranz Signal. The function groups marked with black corners show the Adtranz development work. The complete system divides roughly into four subsystems: control centre, lineside equipment, vehicles, and a radio data link which forms the connecting structure between the other three.

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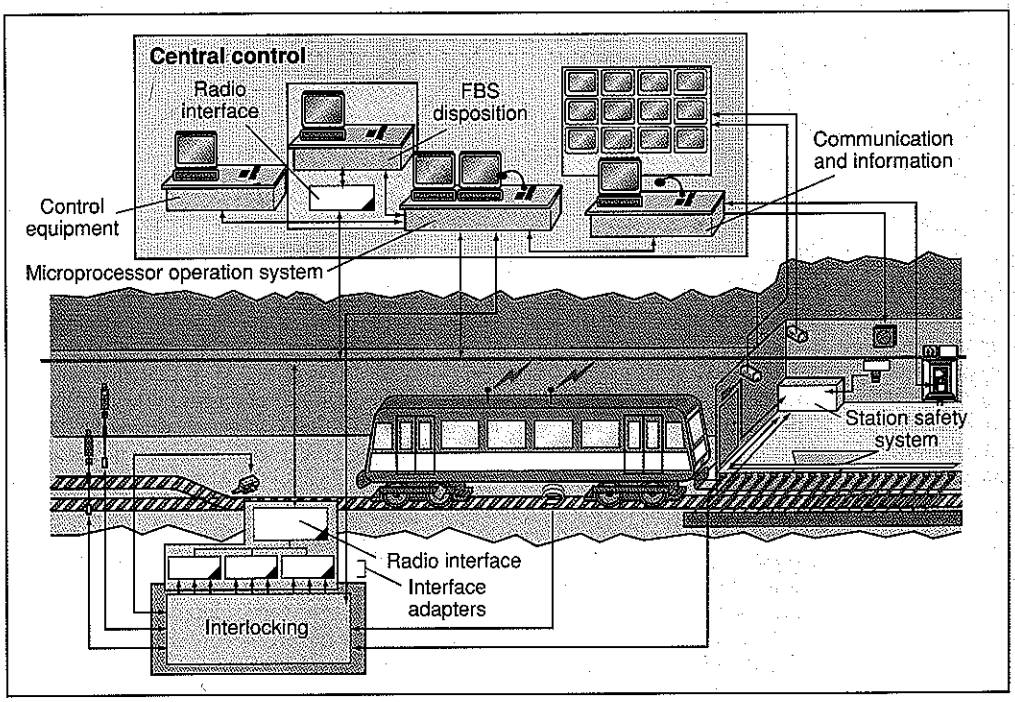
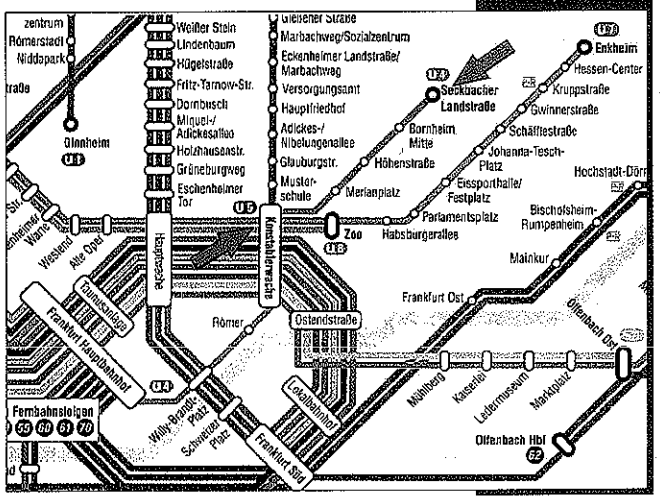


Fig 1. Four subsystems combine in the FBS architecture controlling driverless trains in Frankfurt: control centre (yellow), interlockings (blue), vehicle (orange), and radio data network (red lines)

The existing Line U4 control centre has been equipped with an 'FBS disposition system', which sends trip orders to the automated vehicles and receives status or disturbance reports from them. This provides the interface between the central operator and the FBS system.

Along the route, interfaces are provided to the existing interlockings and station equipment. Each station in the test area has been fitted with a 'danger zone supervision system' in accordance with the BOStrab guideline *Fahren ohne Fahrzeugführer*. This recognises any critical objects blocking or infringing the track area in the station, and constantly exchanges status data with the automated vehicles via the radio data link.

At each of the interlocking cabins, an



Automatic operation is being tested on Frankfurt's U-Bahn Line 4 heading northeast from the city centre

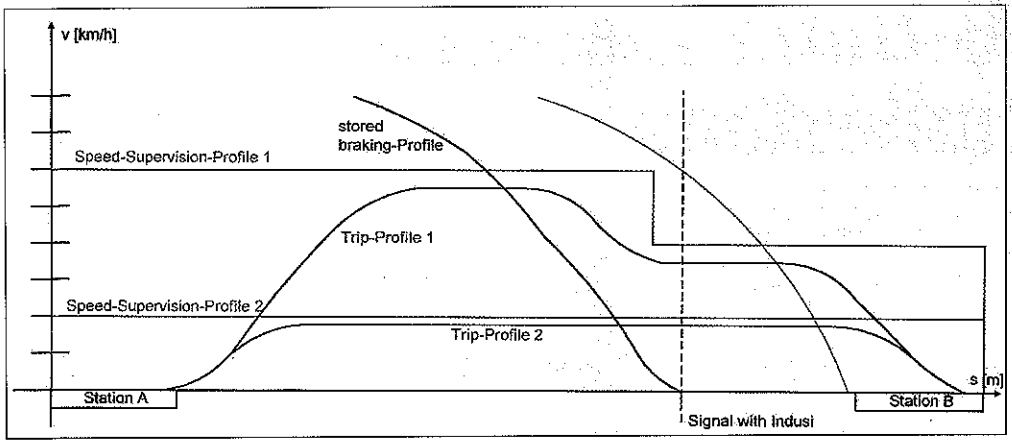


Fig 2. The ATO equipment drives the train following a pre-programmed Trip Profile within the constraints of speed supervision and braking profiles

interface adapter continually scans all the information from the interlocking regarding route settings, signal aspects and speed restrictions, which is also transmitted to the trainborne automation equipment via a radio data module.

The intelligent vehicle

Two of SVG's existing Duewag Series U3 articulated LRVs have been equipped with ATO equipment to perform the tasks of the human driver. The idea is that each 'intelligent vehicle' will act autonomously just like a manually-driven vehicle.

The trainborne automation package is based around the Adtranz MCDS system architecture (Microcomputer Controlled Distributed control System). The backbone of the whole system is a single CAN databus, through which all the vehicle modules and sub-systems communicate. It is designed as a single channel, with the safety of information exchange protected by a vital protocol. This allows both vital and non-vital information to be exchanged using the same path.

All the vehicles in the train are also connected by a second databus, known as the Train Bus. The main purpose of this is to ensure that the automation equipment in the leading vehicle controls the complete train. Like the CAN bus, the Train Bus is single channel. Apart from signalling a change in the direction of travel, the Train Bus carries very little information, which means it can be designed for low speed data transmission. This allows the inter-car connections to be made by a simple arrangement of clutch connector contacts.

The vehicle ATO is designed as a non-vital component. In the automatic mode the ATO merely drives the train along the track following a projected Trip Profile (Fig 2). Associated Trip and Braking Supervision profiles will stop the train in front of any conflict point. The ATO equipment evaluates the various active profiles and controls the train speed accordingly.

All the profiles are stored in trainborne vehicle databases. The Trip and Braking profiles are kept in a simple database, whilst the related supervision profiles are stored in a vital database for use by the Automatic Train Protection subsystem. Whilst the Trip profile is valid for the whole of the set route, separate Braking profiles are held for each specific conflict point. By comparing the two profiles applicable at any given time, the ATP will generate a local speed restriction for any given position on the track.

Further speed restrictions come from two sources. An Additional Speed Limit is used to feed back the Commanded Velocity currently being demanded by the ATO's speed regulator. Immediate Stop instructions are handled by a special algorithm which generates a series of decreasing velocity values to bring the train to a stop using the maximum deceleration rate currently available from the propulsion and braking equipment.

By comparing all the restrictions in force at a given instant, the ATP determines a minimum velocity value, which serves as the reference magnitude for the speed regulator in the ATO module. When the train speed falls below the level where dynamic braking loses efficiency, the vehicle's existing propulsion/brake controller automatically switches over to the mechanical brake to bring the train to a stand.

The Trip and Braking profiles are data sets containing a start velocity value, an applicable acceleration rate, and a target position where the next data set becomes valid. For acceleration from rest, where the velocity is zero, constantly increasing velocity values are calculated taking into account the acceleration capability of the train. To coast at constant speed the related data set shows a zero acceleration, whilst deceleration is indicated by a negative acceleration. In principle, every set speed source computes the current value with respect to the start velocity for the current data set and any acceleration at the current train position.

Existing train equipment, such as the external door mechanisms and their passenger safety detectors, is connected to the MCDS through interface adapters, which are located as close as possible to the objects they control (Fig 3). All the necessary status information is read in and control commands are presented to the peripheral. The adapters are based on vital 2-from-2 computer processing with vital double channel interface circuits.

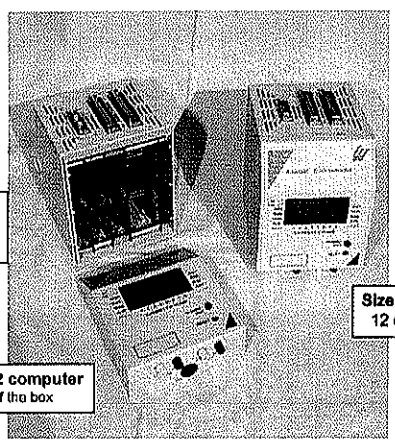
The Speed & Position Control system is also designed as 2-from-2. But instead of using input/output circuits the SPC uses odometers to calculate the train location. The odometers are normalised at regular intervals from IBIS (*Integriertes Bord Informations System*) beacons installed along the track. To avoid any problems of wheelslip or slide, the odometers are installed on two non-powered axles.

Automatic Train Protection

Train speed supervision is the responsibility of the vehicle ATP, which is also built up as a vital 2-from-2 microprocessor system. It evaluates the current Trip and Braking supervision profiles and compares the results with the actual train speed. The ATP also activates the correct INDUSI cab signalling sensor on the train. If any violation of any supervision profile is detected, or an active INDUSI signal is received, the emergency brake is applied.

The ATP module also controls the data exchange to the route interlocking by which data on the status of the next track section and station is obtained. A Radio Interface provides the data communication channel between the vehicle, the interlockings and the control centre. This module is also linked to the CAN bus through a vital 2-from-2 microprocessor. However, the interface itself is a single channel system. Vital data transmission is achieved by the use of handshake protocols and data encryption.

Fig 3. On-train equipment is connected to the vehicle's databus by object controllers using 2-from-2 vital processing



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1. Lambrecht C and Feldt H-J. Flexibilisierung des Beförderungsangebotes, *Der Nahverkehr* 12.95.
2. Gille A, Reppert S, and Ruckser G. MCDS als Bestandteil funkbasierter Betriebsleittechnik, *Signal+Draht* 10.96.

Changes to the controls in the driving cab have been kept to a minimum. In effect, the only addition is a switch to change between manual and automatic operation. In the manual mode all output from the automation equipment to the train is prevented vitally, allowing the train to be operated in the traditional way.

For the testing phase, where the automation equipment is supervised by a driver, additional information is presented on a Man-Machine Interface display. This is a commercial-quality Liquid Crystal Display unit, which shows the target and actual speeds, current train loction, vehicle conditions, and the status of the next block and next station. Train control buttons are provided to initiate a trip start or command an Immediate Stop.

Operating concept

Once the whole line has been automated, operational control will be very straightforward. At the control centre the FBS disposition system will co-ordinate the running sequence for the automatic trains. According to the schedule, trip programs will be generated for each train and sent to them by radio. This trip program will set out a sequence of 'drives' and operational stops, defining the train's behaviour. The disposition system display will provide the control centre staff with all relevant data about the movement of the automatic trains.

On the train the ATO will follow the active trip program, driving and stopping as defined in the trip program without external intervention. The drives are based on the predefined speed profiles available from the ATO's onboard database, which are constantly compared to the actual speed and location as determined by the Speed & Position Control.

For boarding and alighting at stations, the train doors will be released for opening at the correct side and closed automatically just before the next drive. The existing door mechanisms are just one example of functions already built-in to the existing vehicle controls which can be incorporated into the ATO via interface adaptors. This means they can still be used as usual in manual operation when the ATO has been switched off.

Vital control of the track equipment is managed by conventional interlocking machines. Using the radio data links, the automated trains constantly request information from each interlocking in turn, such as the current signal aspect and the status of the interlocking routes. Track sections which have not been released for use are protected by conflict points. The train's ATO database contains profiles for service braking to a stop at every possible conflict point. The ATP supervises the braking to meet the right profile, and applies emergency braking in the event of any violation.

Vital train separation is still performed by the existing interlocking machines in the conventional way, allowing for the mixed operation of automatic and manually driven trains as necessary.

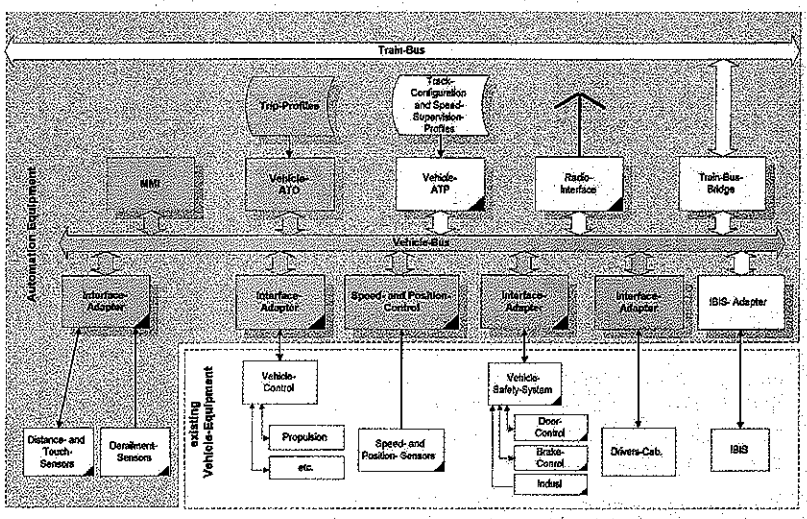


Fig 4. The FBS automation package and databus are overlaid on the vehicle's existing equipment

Demonstration milestones

The FBS research programme has been divided into four main testing phases. Each of these contains a milestone at which the results are presented. The first two of these phases are mainly vehicle-oriented.

The first step covered testing of the vehicle-borne automation components. The aim was to show that the extra automation equipment can control the vehicle correctly, and that it is capable of driving the vehicle correctly and performing such functions as automated door operation. In this phase the driver retains the responsibility for safety management during the test runs. Fig 4 shows the the essential function groups for this phase as marked rectangles. Vital functions are not necessarily vital at this stage.

The second phase covers the testing of vital functions on the vehicle, the radio data link, and the interfaces to the existing interlockings. In this stage the vehicle gets the current status of the interlocking by radio, supervises the current speed against the speed supervision profiles and performs emergency braking if necessary. The driver is still responsible for ensuring safety, because the vital systems have not yet received formal approval.

The third phase covers testing of the lineside vital equipment, especially at the stations. In parallel to the tests will be the start of the formal approval process. The last phase will test the FBS-disposition system at the control centre, and will be completed with the formal approval of the complete system.

The presentation on December 5 1996 unveiled the results of the first phase, with the guests taken for a ride on an automatically-driven train. Although the cab was empty for the demonstration, a driver was legally required to take responsibility for safety, so a fallback intervention control point was established in the saloon behind the cab, and the connecting door removed to give the 'driver' a clear view onto the track.

At the time the radio data communication was only installed on part of the route, so the driver had to acknowledge each signal aspect on his cab display, using an ETCS-style touch screen (Fig 5). For demonstration purposes he omitted to acknowledge one aspect, successfully causing the train to brake automatically to a stop in front of the signal.

This presentation provided an impressive demonstration of the first phase, with the automation of the various train operating functions:

- driving between stations, including slow zones;
- keeping to the commanded speed, even on gradients;
- vehicle response to different signal aspects and permissible speeds;
- precision braking to a stop at every station, to an accuracy better than 300 mm;
- enabling the door opening on the correct side at each station;
- observance of the adjustable minimum station dwell time;
- starting away and continuing the drive following the receipt of a departure signal from the driver.

The second phase milestone is scheduled for September 1997, and the project is due to be completed by mid-1998. ❑

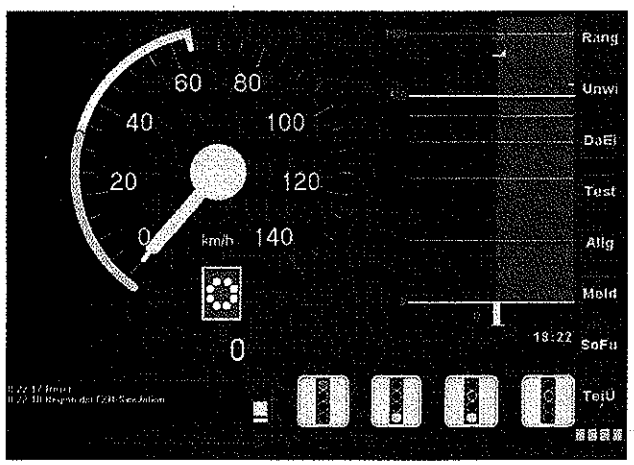


Fig 5. During the testing phase an LCD man-machine interface provides information for the supervisor on the train

Ten years on; where do we go next?

A decade after the first purpose-built low-floor tram network opened in Grenoble, over 1 300 cars are in service and another 600 on order. Harry Hondius MSc reviews technical developments over the past 10 years and assesses where the market is heading

On May 22 Mülheim-an-der-Ruhr rolled out one of its 1982-built Stadtbahn M6D cars rebuilt with a composite low-floor centre-section from Schindler, Fiat-SIG and MGB

IT WAS IN September 1987 that the world's first low-floor tram network opened in Grenoble, with a fleet of 20 TSF-2 trams supplied by GEC Alsthom. Early in 1990 the first 100% low-floor car was unveiled to the public – the Bremen-MAN GT6N prototype. By the end of that year Duewag had supplied its first low-floor car to Kassel and the first Duewag/Vevey car had arrived in Bern.

Today, a new tram design announced anywhere in the Western world is virtually certain to be a low-floor vehicle. For new high-platform light rail networks, production of high-floor LRVs continues at about 100 to 130 cars a year.

So what has 10 years of low-floor tram development brought to the operators and to the industry? On the positive side, low-floor cars offer much easier boarding for all passengers. If door speeds are correctly selected, this can help to reduce boarding times at stops. Lower platforms can be provided more easily to further enhance the boarding comfort, without being obtrusive in the city landscape.

AC traction motors have proved very robust, and do not require the same level of maintenance and servicing as DC motors. They are also better able to stand overloading. Acceleration and braking have been greatly improved, and high regenerative braking rates almost to a standstill offer reduced energy consumption and longer life for mechanical brake components. Modern control electronics have made wheel flats a rarity. Together these developments have led to a safer vehicle which is easier to drive.

At the same time, there have been many negative experiences. The wheels are much nearer to the passenger, making it far more difficult to keep the interior noise levels as low as before. Many of the new technologies have proved noisier than expected, notably the control electronics and brakes. It seems unbelievable that electric under-seat heaters should produce the noise they do; no modern bus heating system produces such noise. Overall noise levels can often be unacceptable, given the high price paid. The industry failed to address this problem promptly or adequately; only recently have user specifications forced suppliers to start investigating noise problems seriously.

Low-floor cars are generally relatively heavy, with average weights around 20% higher than vehicles built in the 1960s. As a result, net energy consumption is not always reduced. Many of the innovative traction drives, although tested with prototypes, have caused serious, prolonged and often repeated troubles when entering service.

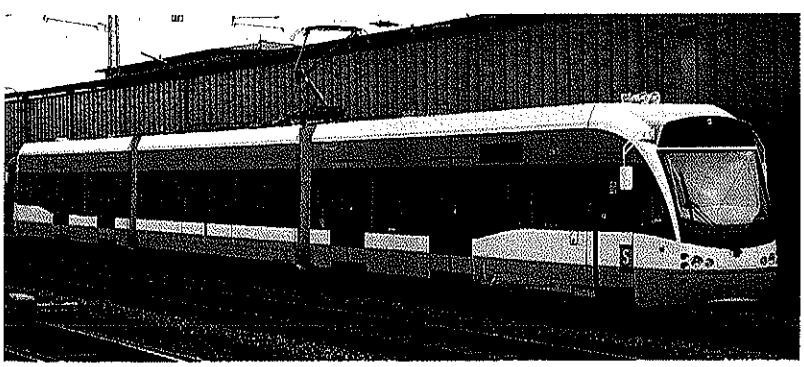
Long-standing lessons from the past about the tough steel-wheel/rail environment, with its extremely high vertical *g* values, appear to have been forgotten. Hub motors made houses vibrate. Single-wheel drives of all kinds caused high noise and high wear. Cars sometimes derailed. Having independent wheels has not stopped them shrieking in curves or really diminished wheel and rail wear.

Too many of the modern designs have proved to be particularly sensitive to the quality of the track. This applies especially to the cars using single 'axles' with individual wheels, where any deterioration in track maintenance standards can lead to noisier running. Commissioning of series-built cars has often taken up to or over a year, before the running characteristics have settled down to

Table I. Market share of low-floor trams supplied or ordered up to April 1 1997 (Western suppliers)

Mechanical parts	Orders	Options
Siemens Verkehrstechnik	652	507
Duewag	616	391
SGP	36	116
Adtranz	538	160
AEG	408	96
Variobahn	58	64
Eurotram	72	–
GEC Alsthom	357 (1)	80
TSF 1 (Nantes type)	46	–
TSF 2 (Grenoble type)	116	–
T 2000 (Brussels type)	51	–
Vevey	20	–
LHB	124 (1)	80
Breda	125	–
Vevey	73 (2)	–
Fiat	58	–
Bombardier Eurorail	45	–
Firema	43	15
Socimi	35	–
DWA Bautzen	12	10
Schindler/Fiat SIG	6	11
Total	**1 944**	**783**

1. includes 30 trailers
2. includes 46 middle-floor cars



Below left. The first Bombardier/Kiepe/Elin Saarbahn medium-floor two-system LRV has been tested on DB tracks around Trier

Table II. Electrical equipment for low-floor trams ordered to April 1 1997

Supplier	Total	Chopper	VVVF Inverter	GTO Inverter	Bipolar Inverter	IGBT Inverter
Adtranz	951					
ABB	(541)[1]	69	–	–	358	114
AEG (Germany)	(251)	25	–	–	–	226
AEG (USA)	(159)	34	–	25	–	100
Siemens	393	14	–	270	–	109
GEC Alsthom	248	162	–	51	–	35
Kiepe	139	–	–	127	–	12
Ansaldo	71	54	–	–	–	17
Holec	45	–	45	–	–	–
Elin	36	–	–	–	–	36
Parizzi	28	–	–	–	–	28
Marelli	2	2	–	–	–	–
Total	**1 913[1]**	**360**	**45**	**473**	**358**	**677**

1. Includes 46 middle-floor cars

Chopper: DC motors with GTO thyristor chopper controls

VVVF: Three-phase AC motors with variable-voltage, variable-frequency thyristor controls and intermediate voltage circuit

GTO: direct Pulse-Width Modulation using air-cooled GTO-thyristors

Bipolar: Direct PWM with three point water-cooled bipolar transistors

IGBT: Direct PWM using Insulated Gate Bipolar Transistors in three point air-cooled (Adtranz) or two-point water-cooled (Adtranz, Elin, GEC Alsthom, Siemens) or air-cooled arrangement (Ansaldo, Kiepe, Siemens)

levels that are acceptable to the end user.

The fierce market competition has seen too many completely new designs launched in a too short a period, overloading the engineering and testing capacity of suppliers when serious problems arose. Too much innovation in too short a period has led to high remedial costs for the builders. Few suppliers can have earned much profit from low-floor trams, and many will have made none at all. A consolidation period in development would be highly desirable, but there seems no prospect of this in the near future.

Orders grow, but market slows

Comparing the low- and medium-floor tram car market situation on April 1 1997 (Table I), with the position a year earlier on the same basis (DM96 p23), we can see that total orders for Western European suppliers rose from 1 664 to 1 944 and the outstanding options fell from 949 to 783. Out of the 280 cars ordered, only 122 came from the 'options reserve'. Around 1 300 cars have been delivered so far, leaving some 650 firm orders on the books to keep the factories busy. In addition to these, Bielefeld proved the exception to the rule by ordering 16 high-floor trams and 8 matching trailers.

Fig 5. Dresden has bought eight 65% low-floor bi-directional cars from Siemens/DWA/Adtranz

Adding orders and options together to give an indication of the market strength of the various groups, Siemens Verkehrstechik has 43% of the market, 1 159 out of 2 727 cars. Adtranz has 26% with 698 cars, and GEC Alsthom 16% with 437. Breda (with Ansaldo and Firema now part of the same group) has 125 cars or 5%, leaving just 10% for the other four: DWA/Vevey, Fiat, Bombardier Eurorail and Schindler.

In the electrical field (Table II) Adtranz is the clear leader with a 50% market share, followed by Siemens 20·5%, GEC Alsthom 13% and Kiepe 7%. Again there is just 10% left to divide between four groups: Ansaldo, Elin, Holec and Parizzi. Looking at the control technology, it is clear that IGBT inverters have definitively taken the lead for new orders.

Since April 1 Montpellier has ordered 28 Citadis 301 cars from GEC Alsthom (RG 5.97 p277), and Dublin has confirmed that it plans to buy 30 of the same design. However, it is extremely difficult to give any prognosis on further contracts. Orléans has also decided to build a new tramway (RG 3.97 p169), and long-awaited series orders might eventually start flowing in Italy. German cities will continue to order cars, albeit on a more modest scale than in recent years. In total, an order level of around 200 cars per year might be considered realistic.

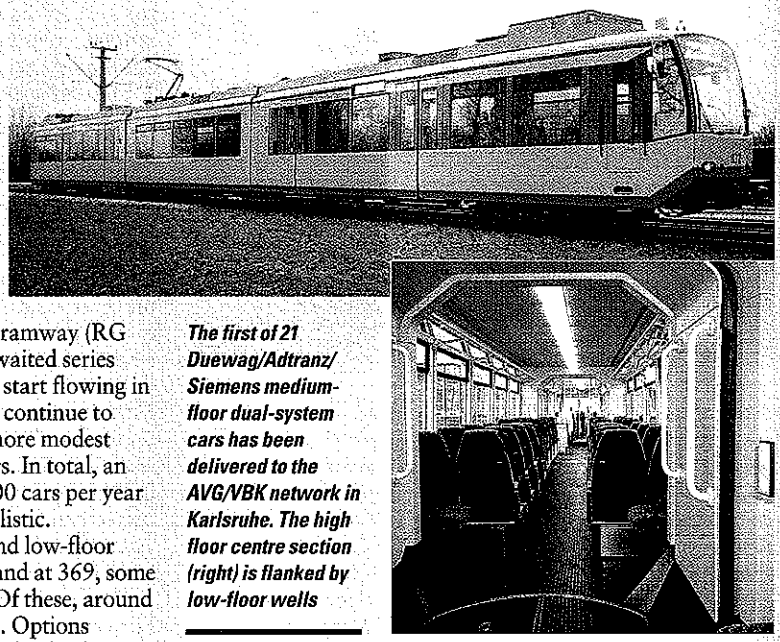
Orders for medium and low-floor LRVs (Table III) now stand at 369, some 70 more than last year. Of these, around 205 have been delivered. Options remained stationary. Market leaders in this segment are still Bombardier Eurorail and Kiepe Elektrik, although it is interesting to see the first penetration in this market by the Japanese, with Kinki Sharyo picking up an order for 45 cars for New Jersey Transit.

Industry groupings still changing

Of the 652 cars currently on order from Duewag, 219 will have bodies supplied by DWA Bautzen, which will undertake final assembly for 210 of them. Bautzen is also supplying bodies for the 15 LHB cars to be delivered to Magdeburg and 23 Variobahnen for Chemnitz, using LHB and Adtranz designs respectively.

As was to be expected, DWA Bautzen is emerging as a new player in the market, and looks likely to stay for a while. DWA has started to win orders on its own, beginning with 12 cars for Kassel in conjunction with Kiepe Elektrik (RG 5.97 p278). In early May DWA confirmed its purchase of Vevey Technologies from the Dutch-based Begemann Rail Group, adding small-wheel low-floor, VAL and Urbos technology to its competence.

Siemens Verkehrstechnik has completed its internal reorganisation, leaving Duewag in Düsseldorf and its counterpart Siemens Duewag Corp in Sacramento as the 'centre of competence' for urban rail business. Bogie design and fabrication have been concentrated at the SGP works in Graz. A similar concentration can be seen at Adtranz, where the ex-MAN Nürnberg works is the main urban transport centre, with bogies concentrated at Siegen. It may well be that in future Adtranz tram body construction will be entirely contracted out, as is happening with the Chemnitz Variobahn cars.



The first of 21 Duewag/Adtranz/Siemens medium-floor dual-system cars has been delivered to the AVG/VBK network in Karlsruhe. The high floor centre section (right) is flanked by low-floor wells

Following a ruling of the EU competition directorate, Adtranz has sold its stake in Kiepe Elektrik to Berlin Elektro-group, or more specifically its Schaltbau AG subsidiary; the group already owns coach refurbishing specialist PFA of Weiden. LHB will now market GEC Alsthom electrical traction equipment in Germany. Parizzi has entered the tram field for the first time, enabling Fiat to offer a total systems package.

Table III. Market share of low- and middle-floor LRVs ordered by April 1 1997

Mechanical parts	Orders	Options
Bombardier Eurorail	187	53
Siemens Verkehrstechnik	122	–
Kinki Sharyo	45	–
Firema	15	–
Total	**369**	**53**

Electrical Equipment	Orders	Options
Kiepe (Elin motors)	68	–
Kiepe (GEC Alsthom motors)	119	53
Siemens	71	–
Japanese (supplier unknown)	45	–
Adtranz	51	–
Ansaldo Trasporti	15	–
Total	**369**	**53**

Extensions back in vogue

An interesting development in the last year has been the revival of interest in lengthening existing high-floor cars

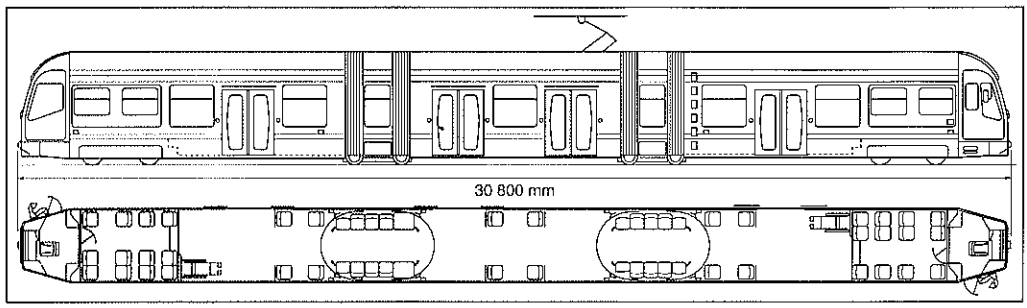
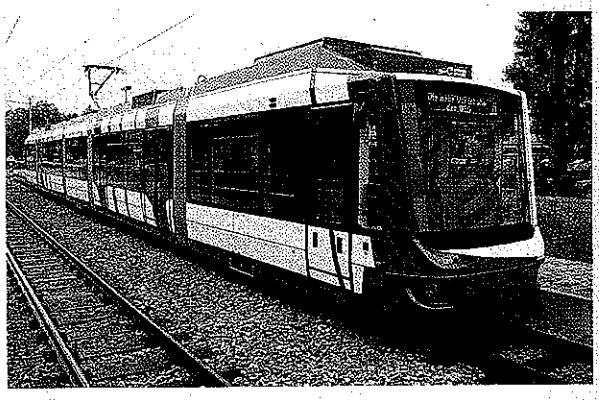


Fig 1. Roma's ATAC has selected this Fiat/Parizzi design



OEG of Mannheim has put into service its six 32 m long, 2 500 mm wide Variobahn cars with 65% low floors. Top speed is 80 km/h and the weight 38 tonnes

with a low-floor centre section. For a long time it looked that the 92 lengthened cars on four systems would be the only examples of the concept, but Duisburg's DVG has now decided to convert its 45 GT8NC cars built in 1986-93 to GT10NC by adding a 7 000 mm long low-floor section.

A joint venture of Mittenwalde Gerätebau, Schindler Waggon, and Fiat-SIG has picked up a series order to lengthen 16 Tatra KT4D cars in Cottbus with a 8 660 mm low-floor centre section offering a floor height of 350 mm over a length of 6 750 mm. These innovative centre sections are formed of a wrapped glass-fibre composite bodyshell on a galvanised steel frame, and run on two Fiat-SIG two-wheel trucks steered from the articulations (RG 5.96 p250).

The converted cars must be good for another 20 years service, so Kiepe IGBT choppers are to be installed, and the CKD motors are likely to be replaced by a more powerful version. The cost of the transformation will be around DM750 000 per car, of which DM225 000 will come in GVFG subsidy. Another nine conversions are expected to follow in 1998. On May 22 Mülheim-an-der-Ruhr unveiled a similar extension to one of its 1982-built M6D cars, which has involved more extensive changes than for the KT4Ds, at a cost of around DM650 000.

In December 1996 Basler Verkehrsbetriebe ordered 28 composite low-floor sections from Schindler Waggon and Fiat-SIG to enlarge its six-axle articulated cars bought in 1990-91. The length of the new centre part is the same 8 660 mm, with the two-wheeled trucks 4 600 mm apart. The weight is around 8 tonnes, and the cost SFr586 000 per car.

Thus for around DM34 000 per m² of floor space, it is possible to add a small low-floor area to modern cars. The riding qualities of the Cottbus car are quite acceptable, although the KT4D parts showed a tendency to light galloping at 50 km/h. As with other single axle types, the riding qualities of the centre section are directly related to the quality of the track and show a tendency to rumble.

Part-low-floor developments

Looking at the various categories of cars with 60 to 70% low floors, as defined in DM95 (p26), the number of **Category A** cars remains unchanged at 159. **Category A2** has expanded to 61 cars with the arrival of two new designs.

The first of 15 Bombardier/Kiepe/Elin cars for Saarbrücken has been rolled out and is successfully undergoing tests on DBAG tracks between Trier and Mettlach. The riding qualities at 100 km/h on the curved track along the Mosel river valley are very good.

The first of 21 dual-system cars for Karlsruhe's AVG/VBK group has been delivered by Duewag and Adtranz. This medium-floor car is derived from the 36 all-steel dual-system cars already in service, with Adtranz bogies and Siemens transformer/rectifier. The latest cars use an Adtranz AC-drive using water-cooled 125 kW motors and bipolar transistor inverters, the same as the 20 medium-floor cars built for the city's 750 V DC routes last year.

The two dual-system cars have the same outer dimensions, but the Saarbahn versions have all axles motored, against only half in Karlsruhe. Floor height in the outer sections where the doors are located is 400 mm for the Saarbahn and 630 mm for the VBK cars. Total weight, power/weight ratio and price are similar. The VBK cars have double glazed coated windows and air-conditioned cabs. The Saarbahn cars have air-conditioning in both the centre modules and the cabs.

The Saarbahn car's end sections are similar to Bombardier's latest LRVs for Köln, with a welded steel underframe and body framing, onto which aluminium outer plating is glued. The roof has a riveted aluminium frame with glued-corrugated stainless steel plates. The tubular steel front ends covered with glass fibre mouldings are bolted to the underframe. The centre car is made of riveted aluminium. The bogies are identical to the Köln ones, but have a lower gear ratio to give a top speed of 100 km/h. The only fundamental difference is that the Elin four-quadrant controller allows regenerative braking when running on 15 kV.

Category B cars with small diameter bogies have reached 208 cars and 30 trailers. Magdeburg has ordered a further 15 cars from LHB, whilst St Etienne is buying 20 more from GEC Alsthom, Duewag and Vevey, largely identical to an earlier batch of 15, but with an Onix AC traction package.

Leipzig has decided to stop its present order for NGT8 cars after deliveries have reached 55, and is seeking bids for 50 low-floor trailers to be used with the 169 modernised Tatra T4D cars. After that Leipzig will revert to buying low-floor cars, but these will be six-axle NGT6s which can be used in multiple or to haul the low-floor trailers.

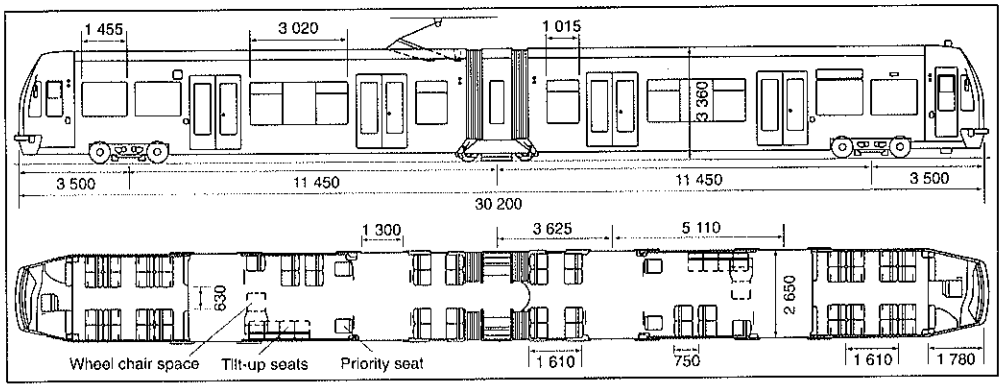
The first move by the new chairman of Rheinische Bahngesellschaft in Düsseldorf was to cancel the letter of intent for 15 low-floor trailers and its option for 44 more. As former technical director of Bremen's tramway, where he oversaw orders for 78 eight-axle 100% low-floor trams, he wants no trailers.

In the multi-articulation bracket (**Category B1**), there is a total of 507 cars, making it the second largest category. Dresden has increased its order from 20 to 60, which covers 52 unidirectional and 8 bi-directional cars. Belgium's De Lijn has ordered six single-ended trams for Antwerpen and three bi-directional cars for Gent. Although metre gauge, these will be very similar to the Dresden cars, but with an extra front entrance door. Over the next five years, De Lijn expects to receive 31 single and 14 bi-directional cars. Siemens is the general contractor, supplying the SIBAS 32 controls and trucks. DWA Bautzen will build the bodies, and Adtranz will supply the rest of the electrical equipment, including water-cooled motors and HITRAM IGBT inverters. Average price is around DM49 000 per m².

Signalling the beginning of the long-awaited renaissance of the Italian tram (RG 7.96 p427), Roma has ordered 28 multi-articulated cars from Fiat and Parizzi; they are a 30·8 m long bi-directional version of the Torino cars delivered in 1990. The first contract for Fiat to act as systems provider sees Parizzi supplying the four 178 kW AC-drives with IGBT inverters. Styling will be by Giugiaro, and the price is reported to be around DM45 000 per m².

Germany's OEG has put into service

Fig 2. The 65% low-floor car for Croydon to be supplied by Bombardier Eurorail and Kiepe is a lengthened version of the Köln 4000 medium-floor car, with a 70 km/h top speed and a weight of 36 tonnes



its six Variobahnen with 65% low floors; these have excellent riding qualities at 80 km/h.

GEC Alsthom has been named as the preferred bidder for the Dublin LUAS project (p36), ahead of the Siemens Combino. The 29 bi-directional Citadis 301 trams will be either 29 or 39 m long and 2 400 mm wide. The LHB-built medium-floor end bogies will resemble those of the Magdeburg cars, and the centre truck the Grenoble design. The Neermann-styled riveted aluminium body will come from Aytré, with pre-fabricated front ends bolted to the underframe.

In **Category B2**, multi-articulated LRVs, recent developments have seen the total jump to 240 cars. VBK of Karlsruhe has ordered 10 lengthened versions of its earlier design, of which 20 are in service (RG 6.95 p342). The 38·7 m cars have a Bo'2'2'Bo' axle arrangement and a floor height of 407 mm over 72% of the length. Weighing 48·1 tonnes (469 kg/m²), they will seat 118. With a width of 2 650 mm, the price works out at DM41 125 per m².

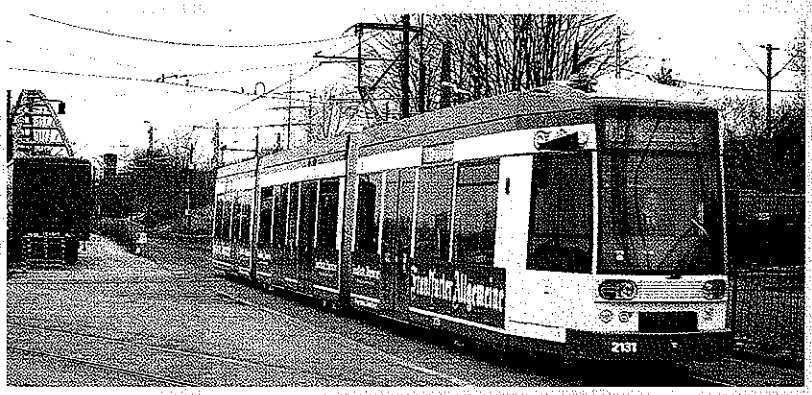
Bombardier and Kiepe have almost completed deliveries of the second batch of 40 K4000 cars to Köln, and have just received confirmation of the final option for another 40.

Kinki Sharyo entered the US market with an order for 45 cars for New Jersey Transit; 29 to work the new Hudson-Bergen line in Jersey City and 16 for the modernised Newark subway. The electrical supplier is not yet known. The 26·7 m long cars will be 2 680 mm wide, with 720 mm high floor ends connected by ramp to a 350 mm low-floor section where the doors are situated. Wheel diameter is 590 mm.

To the distress of the suppliers, the 15 Firema/Ansaldo cars for Birmingham will not have end sections identical to the Oslo cars as planned, nor AC drives. Centro did not want to be the first British light rail operator to adopt AC traction, and opted instead for GTO choppers and DC monomotors.

As part of the Tramtrack Croydon Ltd DBOM concessionnaires, Bombardier Eurorail is to supply 24 bi-directional cars, as a development of the K4000 type. The Kiepe electrical equipment will be identical. They will be 29·9 m long and 2 650 mm wide, with 580 and 350 mm floor heights linked by a ramp, as in the Wien T68 cars. Fixed seats for 64 are envisaged. The cars will be built in Wien by BWS, with bogies from Manage. The first will be built and tested in Wien, and the rest will be assembled and finished in the Bombardier Prorail workshops at Wakefield. The reported price of £35m would correspond to around DM4m per car, or DM50 000 per m²!

Category B3 cars with EEF-trucks have increased to 194, as Halle exercised an option for 38 cars. The total of **Category B4** cars with steered two-wheel trucks now stands at 72, because the Rheinbahn order has been increased to 48. These are likely to be the last of the type. No more orders have been placed in categories **B5**, **B6** or **B7**, although it is expected that Wien is to order 10 extra T 68 cars.



Düsseldorf's Rheinbahn is buying 48 Duewag/Kiepe 65% low-floor cars with steered two-wheel bogies. The 27·5 m long, 2 400 mm wide cars weigh 33·5 tonnes

This year sees a new **Category B8** covering eight-axle cars, using classic motor bogies with floating articulations and four wheel carrying bogies with normal diameter wheels. Kassel has ordered 12 cars from DWA and Kiepe for around DM40 000 per m² (Fig 3).

This brings the total of low-floor cars in the 10 to 70% low-floor band to 1 178, or 62% of all orders. The part-low-floor LRV total stands at 369.

In **Category C2** it looks at present as if the AEG/MAN car has reached the end of its cycle; only one car was ordered in the last year, for Kumamoto in Japan. The type has been undertaking demonstration tests in 12 cities including Warsaw (RG 7.96 p547), but only Berlin finally decided to buy 120 cars of which 60 are in service. Deliveries of the other 60 will start soon. The option for 80 cars has been cancelled, as BVG plans to call tenders against a new specification. The same has happened in Augsburg, and the Bremen options have also disappeared as BSAG feels it has enough low-floor cars for the time being. Only 96 options remain.

Still to be delivered from the Nürnberg works are 26 second generation GT8N cars for Nürnberg and another 20 for München. Stadtwerke München has returned its first three GT6N prototypes in part exchange for three more GT8N cars. However, press reports suggest the design still has problems. The BVG cars are plagued with mechanical defects, with one third of the fleet out of 51 cars, whilst Schindler and Fiat-SIG have just 6.

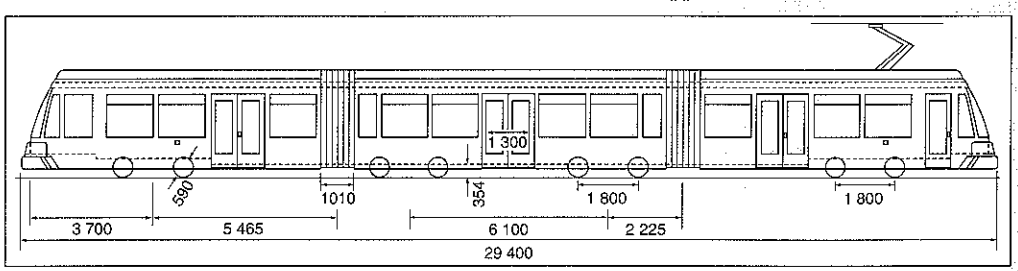
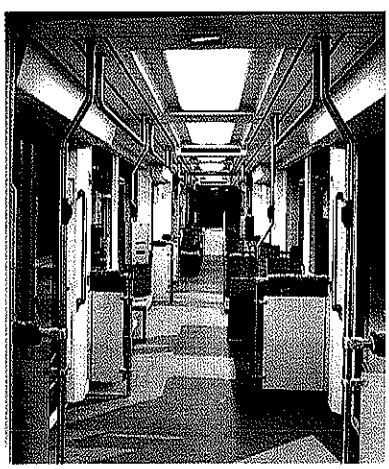


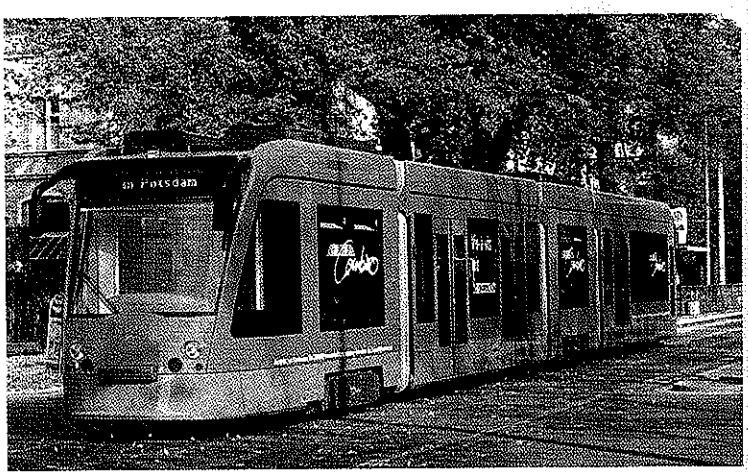
Fig 3. Kassel has ordered 12 of these cars from DWA Bautzen and Kiepe

Below: Duisburg's 33 780 mm long and 2 300 mm wide all-low-floor Adtranz Variobahn cars are driven by 8 gearless hubmotors. Each 35·6 tonne car seats 48 passengers (left)

All-low-floors

The four main categories of 100% low floor cars (C1, C2, F and G) now account for 736 cars or 38% of the total. Adtranz is the clear market leader, with 408 AEG/MAN cars, 72 Variobahnen (including the 20 Würzburg cars delivered by LHB and Siemens, which have Adtranz trucks, and clearly belong to this category), and 72 Eurotrams. Siemens follows with 49 Combinos, 36 ULF and 40 Frankfurt R-cars, for a total of 125. GEC Alsthom and Bombardier have supplied





Following tests with the Siemens Combino prototype, Potsdam has ordered 48 cars for delivery by 2009

use. All 12 Braunschweig cars were taken out of service for 6 weeks following the discovery of bogie defects.

Variobahn orders increased by 23 with an order from Chemnitz. Duisburg has taken delivery of its Variobahn, which has a much improved design. The trucks are simplified from the Chemnitz version, as it was not felt necessary to give the wheels freedom to move sideways in curves.

Siemens has successfully tested its Combino prototype (RG 8.96 p512) in Potsdam, Düsseldorf and Austria, including 15 000 km on the Wiener Lokalbahn line to Baden. Riding qualities remain excellent up to the top speed of 68 km/h, and the next step is to tackle the noise levels.

Potsdam has ordered 48 cars to be delivered in batches of four until 2009 (RG 2.97 p75); these will be equipped with front and rear end doors. The price for the first 12 cars is around DM41 000 per m². The prototype will be exhibited at the UITP Congress in Stuttgart in June before spending two months running in Potsdam over the summer.

The new chairman of Düsseldorf's Rheinbahn wants 100% low-floor cars, and it looks as if the company's option with Duewag and Kiepe for 90 more 27·5 m cars with 65% low-floors might be converted into seven-section articulated cars to a tailor-made design by Rheinbahn using Combino elements (p39). Three long centre modules derived from Combino (of which two or three would be powered with Kiepe Elektrik equipment) would enclose two shorter non-powered modules. The two end modules would have a small wheel bogie at the outer ends, to permit double entrance doors at the front. Rheinbahn expects this 40 m vehicle to work out cheaper than a relatively conventional 27·5 m vehicle plus a 14·2 m low-floor trailer!

Wiener Verkehrsbetriebe has ordered 10 ULF type A cars 23·6 m long and and 24 of the longer 34·9 m Type B. Both will be 2 340 mm wide, giving a combined price of DM55 756 per m². These include some significant technical changes from the prototype.

The transversal steering of the non-motored axles will be simplified, allowing the individual wheels to swivel around a vertical axle. A leaf spring steers them back to the parallel course, and the whole wheelset is still steered from the articulation. Primary springing will now take 20% of total sprung weight, compared with 10% before.

Essential measures have been adopted to try and reduce the overall noise. SAB V60 wheels will be used, and the disc brakes of the powered wheels will be placed on the motor axle. The steel bodies will be supplied by BWS.

Wien has ordered 24 Type B ULF cars 34·9 m long from Siemens Verkehrstechnik SGP and Elin; the series version is expected to weigh 42·5 tonnes

Hub-motored cars

In Category F, the 20 type R cars in service in Frankfurt since 1993 and the 20 new ones, of which the first was delivered recently, will be equipped with a hydraulic device to stabilise the cars and prevent high transverse forces when braking in curves. This is intended to overcome the risk of derailing under special circumstances and in depot yards. As with the AEG design the bogies are placed centrally under each body section, with hub motors driving the outer bogies and the centre unit unpowered.

Of the 51 GEC Alsthom/Bombardier Eurorail cars supplied to Brussels, only 38 are presently diagrammed for regular service. On some routes for which the cars were intended, the hub motors were found to generate excessive levels of vibration in the houses alongside the line.

The Adtranz Eurotram continues to sell well. Strasbourg has ordered a further 26 cars, of which 16 will be the same 33·1 m as its originals, and 10 will be 43 m long. The average price is reported to be DM57 000 per m². They will be built at Adtranz, Derby, and be assembled by Lohr Industrie in Düppigheim, where the *région* has financed construction of a test track.

After testing Breda's VLC, Fiat's Torino car and the Strasbourg car (RG 4.96 p182) Milano ordered 20 unidirectional Eurotram derivatives 34 m long, with 62 seats. There will be a number of very sensible design changes. The upper end of the glass surface of the 'cupola' that houses the driver is considerably reduced. The impractical and slow single-leaf doors 1 500 mm wide are replaced by a more normal pair of 1 300 mm doors, whilst the 'bretsels' blocking the flow of passengers from the entrance platforms to the interior saloons also go. Parts of the cars will also be made in Derby, but final assembly will be in Italy. The price is reported to be DM43 000 per m².

Also in Category F, Schindler and Fiat-SIG have finally won an order after testing their Munico for over 36 000 km in Zürich, Basel, Helsinki and Augsburg. Zürich is to buy six Cobra cars, with an option for another 11. (RG 11.96 p708). The 35 470 mm long 2 400 m wide cars will be designated Be 5/6, with an axle arrangement of A'A'+ ½ A' ½ A'+A'A'. Five ABB AC motors of 80 kW will drive the car, but in the centre powered module, only the inner two wheels are driven.

Using essentially the same concept as the composite centre sections for Cottbus and Basel, the 96-seat cars have a calculated weight of only 35·87 tonnes or 421·2 kg/m², which would be an all time low! The price is also low, at DM41 970/m². Schindler, Fiat-SIG and MGB look certain to continue to market this car for German metre gauge systems such as Augsburg.

After tests with its radially-steered Urbos two-wheel bogie in Rotterdam during 1995, Vevey established that it could not fulfil the requirement of a fully-loaded axleload of less than 10 tonnes, and abandoned the two-wheel bogie. Vevey subsequently developed a 100% low-floor design using bogies with 560 mm wheels and a wheelbase of only 1 000 mm. A transverse AC motor will drive two wheels on each side through gears and flexible couplings. Use of bogies means eight seats per bogie must be placed on boxes.

This solution was offered to De Lijn in collaboration with CAF and Holec. A Bern four-axle tram is to be equipped with two Urbos bogies and four Holec AC motors, and tests should start this autumn. If the Leeds light rail project

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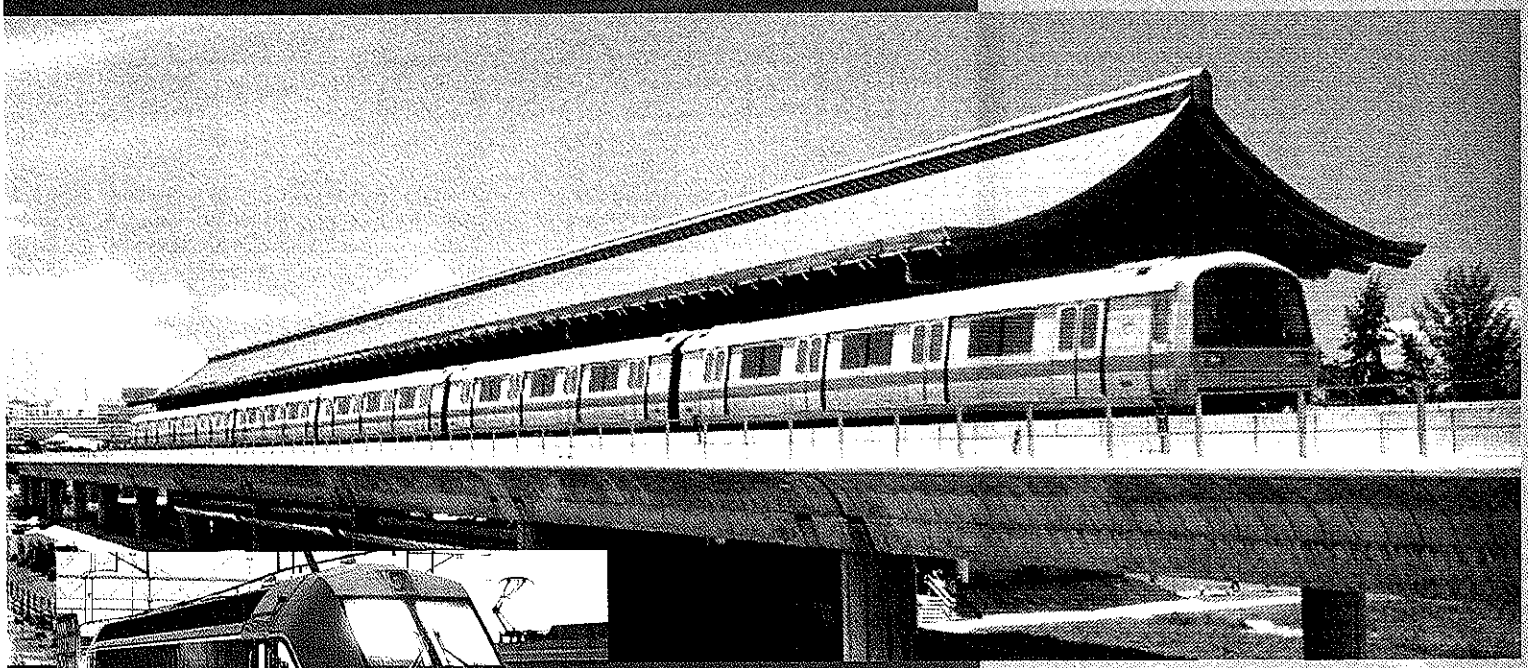

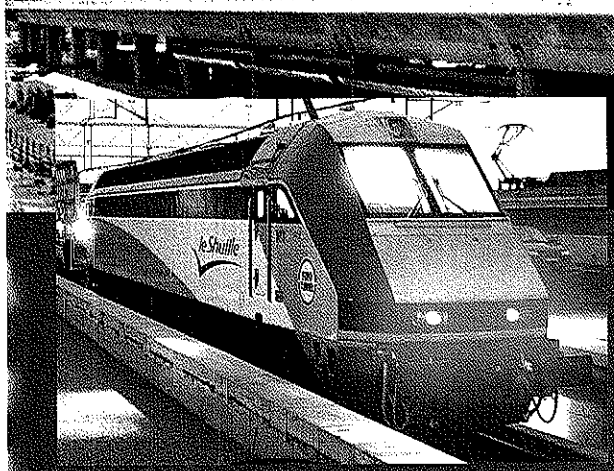

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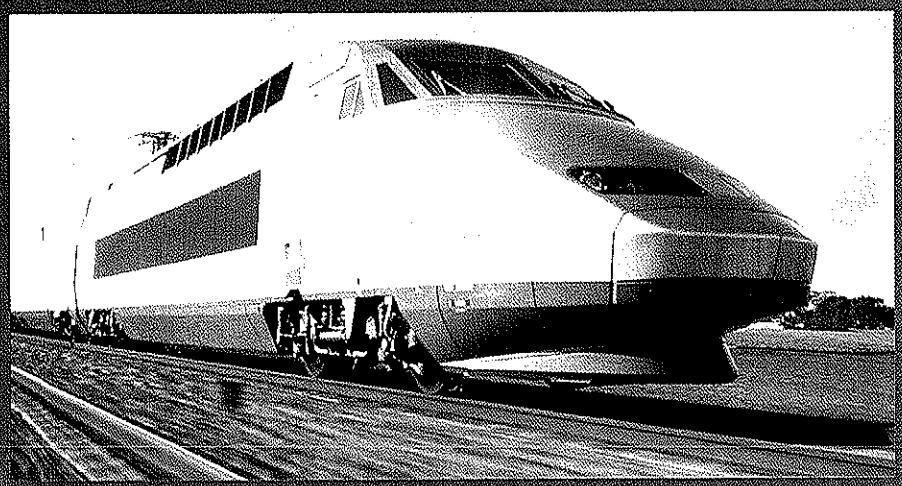

The new SAB WABCO Group

On January 1st, 1997, the railway operations of the Swedish Cardo Group and the German Thyssen Industrie AG were united into one multi-national company called SAB WABCO.

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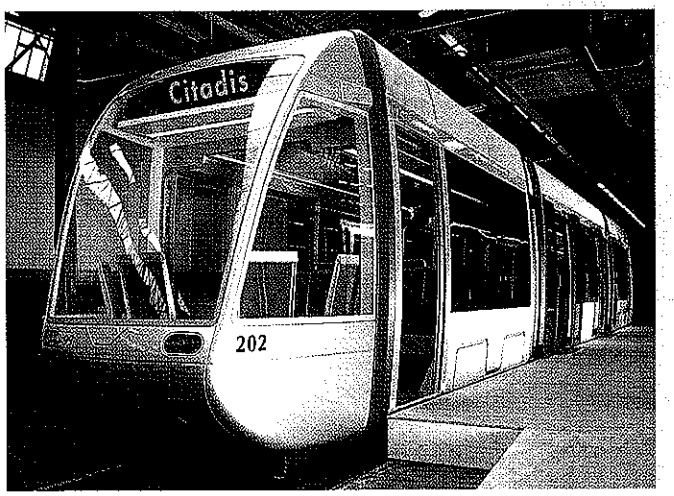

On April 26 Montpellier ordered 28 Citadis 301 cars from GEC Alsthom for Fr300m, with delivery starting in December 1998. The 65% low-floor car will look very similar to the all-low-floor Citadis 202 design currently being promoted

goes ahead, Vevey is in line to supply 13 cars 25·75 m long and 2 500 mm wide cars on three bogies, similar to the Genève arrangement, but with all wheels driven.

Business outlook

As the world's operators appear to have deliberately rejected the only way to obtain substantially lower tram prices and good, widely proven vehicles – pooling purchases – the constant drive for new and possibly 'cheaper' solutions seems set to continue. The latest attempt to build a sturdy, simple and low-maintenance car, the Combino, which cost Siemens around DM20m, is already struggling to meet all the detail wishes of different operators. What is perfectly normal for buses seems impossible with trams! Düsseldorf is a particularly graphic case.

Above all, it seems that every operator now wants a car to its own tailor-made design, but at an 'off-the-peg' price. For the time being it looks as if this tendency is partly successful, for example Kassel's order for DWA and Kiepe. Whether the suppliers can actually build such designer cars for economic prices remains a moot question. The lowest price for 2 300 m wide 30 m long cars seems to be settling at around DM40 000 per m².

The only low-cost designs ordered so far are Combino and Cobra. GEC Alsthom is continuing to promote its Citadis 202 all-low-floor car with two trucks powered by hub motors of the Brussels type. This 22 m car with two articulations would seat 50. It would use a riveted aluminium bodyshell and pre-assembled cab end modules.

The next step in this 'race to progress' is likely to be the introduction of synchronous hub motors with permanent magnets, which will allow much higher torque and much lower weights, down to just 1 kg/kW. Such motors have recently been introduced in trolleybuses and diesel-electric buses, but it remains to be seen whether such light machines are able to withstand the rail environment, including vertical accelerations in the order of 10 to 20 *g*. Light motors would help to overcome the heavy unsprung loads which have been associated with hub-motors and if produced in greater volumes could help reduce the present high costs of the hub motor option.

US operators have traditionally been prudent and are well advised to stay with 60 to 70% low-floor solutions utilising classic drive packages in order to guarantee robust and simple vehicles.

Another interesting question is whether the European international open tendering rules will really succeed in opening up the borders? So far three French cities have bought non-French designs: St Etienne with 35 Vevey/Duewag cars, but using a GEC Alsthom drive, Lille has 24 Breda/Westinghouse cars and Strasbourg has opted for 52 cars to an Italian design, built in Britain using German/Austrian electrics. Of 273 cars ordered by French cities, 162 were from GEC Alsthom. Will Siemens and Matra stand a chance with Combino?

Bombardier Eurorail's plants in Wien, Brugge and Manage have broken into the German market with 80 cars for Köln and 15 for Saarbrücken, albeit with Kiepe electrics and AC motors from France. Oslo has ordered 17 cars from Ansaldo and Firema, whilst De Lijn has gone for German technology with 45 cars from Siemens, DWA and Adtranz. Will this trend continue? ❑

High-speed gates speed Seoul throughput

THE FIFTH metro line in the South Korean capital was officially opened on December 31 1996. Line 5 has been equipped with automatic fare collection equipment by Thorn Transit Systems International, but required modifications to the standard gate design in order to handle a projected throughput in excess of 60 passengers per gate per minute.

For several years Seoul Metropolitan Subway Corp has standardised on Edmonson-sized magnetic strip tickets with a plasticised thermal print surface. Unlike earlier installations, the Line 5 gates have been designed to accept and read tickets inserted in any of the four orientations, avoiding any risk of delays caused by wrongly-inserted tickets.

The gates on Line 5 stand 'normally open', with electrically-powered flaps closing only if a passenger tries to pass without inserting a valid ticket. Sensors located at various heights within the gates prevent more than one person seeking to gain access with a single ticket, but can differentiate between a person and a large item of luggage. For safety reasons the barrier flaps do not move if a passenger or item becomes trapped. The flaps will automatically lock in the open position in the event of an emergency requiring evacuation of the station.

The revised gate design allows for retrofitting of readers to handle contactless smart cards, which are under consideration for future ticketing policy. Thorn has also been contracted to provide fare collection equipment on Lines 7 and 8, which are now under construction, and has demonstrated various smart card options to SMSC. ❑

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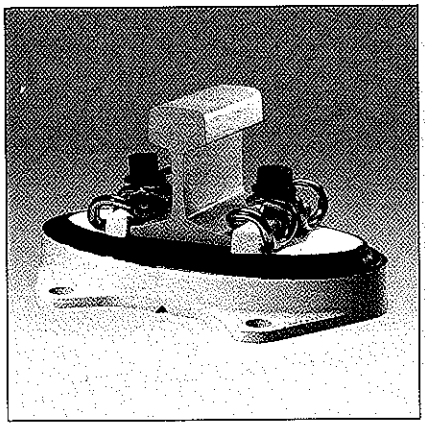

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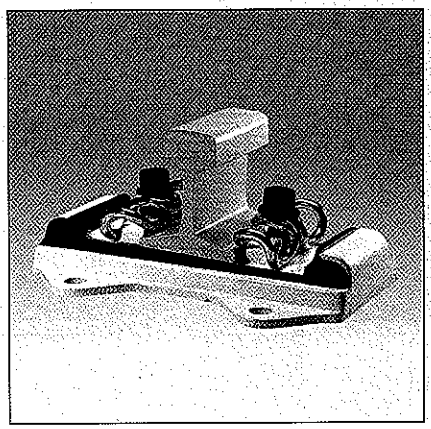

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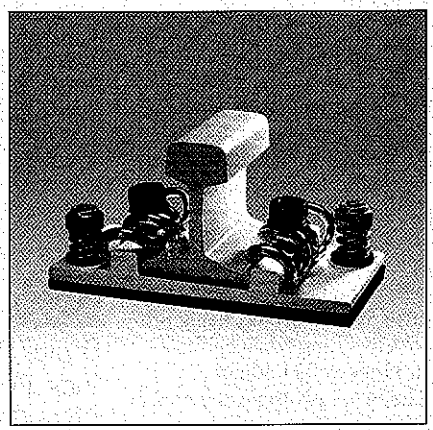

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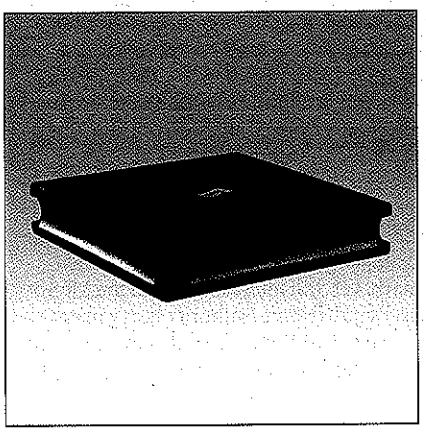

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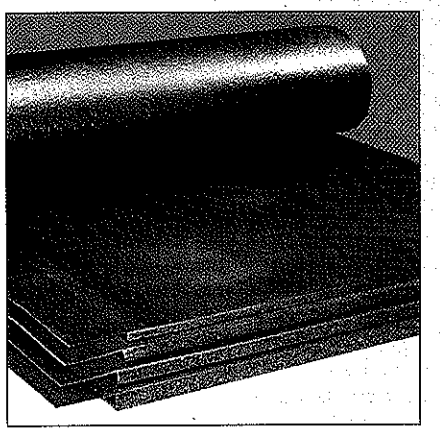

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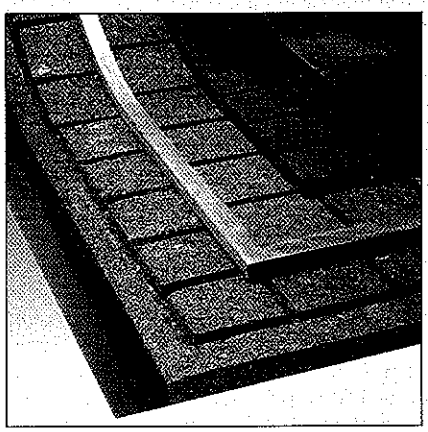

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BERTS on course to open in 1998

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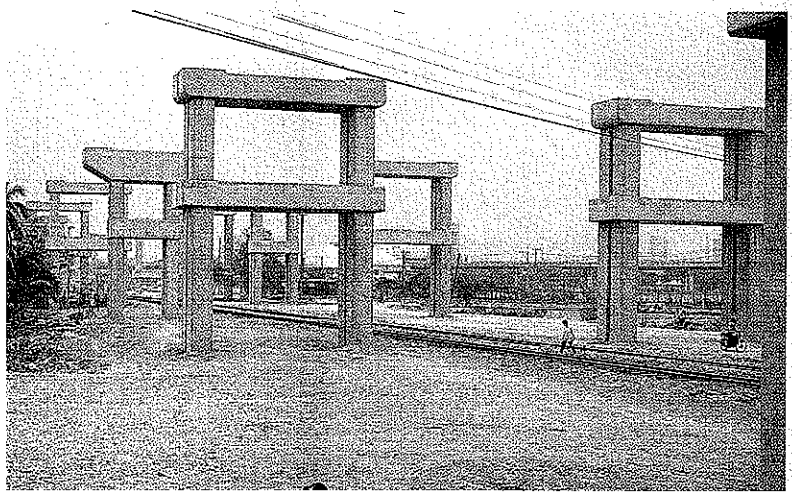


Over the past three years, support structures for the BERTS network have been installed along the SRT main lines leading north and east out of Bangkok

A VERITABLE FOREST of concrete pillars is taking shape along both sides of the main railway line leading north from the Thai capital. Destined to support an elevated metro, railway and road network, they are the first hard evidence of the innovative Bangkok Elevated Road & Transit System project being promoted by Hong Kong entrepreneur Hopewell Holdings.

The BERTS project originated in 1990, when Hopewell Managing Director Gordon Wu became stuck in one of Bangkok's notorious traffic jams. Why not build an elevated transport network along the existing railway corridors, keeping road and rail traffic clear of the city streets? By the end of the same year, Hopewell (Thailand) Ltd had signed a 30-year concession agreement with the Thai Ministry of Transport & Communications and State Railway of Thailand giving rights to exploit the SRT rights-of-way on a build-operate-transfer basis. This came into effect on December 6 1991, and has now been extended to 38 years.

Under the agreement, HTL will build an elevated road and rail network costed at US$4bn. The top level of the structure will carry a six-lane toll highway, with the rail tracks running on a lower level within the concrete box girder structure. Removal of the railway from ground level will allow property development in the form of shops and offices underneath the viaducts.

Two separate rail operations will be incorporated into the elevated structures. As well as relocated tracks carrying SRT's metre-gauge main lines there will be standard-gauge tracks for an electrified 'community train' network resembling a classic heavy metro. Openings in the central reservation of the roadway will ensure adequate ventilation from the tracks used by SRT's present fleet of diesel trains, although the structure clearances will make provision for main line electrification at a future date.

HTL is responsible for financing, design, construction, operation and maintenance of the entire project, except for maintenance of the railway tracks which will be done by SRT. As part of the development project, HTL will provide houses, a school and hospital for SRT; HTL's property development is separate from the funding agreement with the German-led banking consortium for the E&M package.

Two-stage project

Phase I of the BERTS programme covers north-south and east-west corridors totalling 44 km. Under a revised timescale agreed with the Thai government last year, the toll roads and elevated SRT tracks are to be completed intime for the city to host the Asian Games in 1998, with the CT network to follow.

The first route will start at Rangsit in the northern suburbs, and head south past Don Muang international airport to Bangsue, Samsen and Yommarat. A triangular junction just north of Yommarat will connect to the east-west following SRT's eastern railway through the city to Huamark. This route will include a 3·3 km branch without a toll road, running south from Makkasan to Rama IV, close to Bangkok's port district.

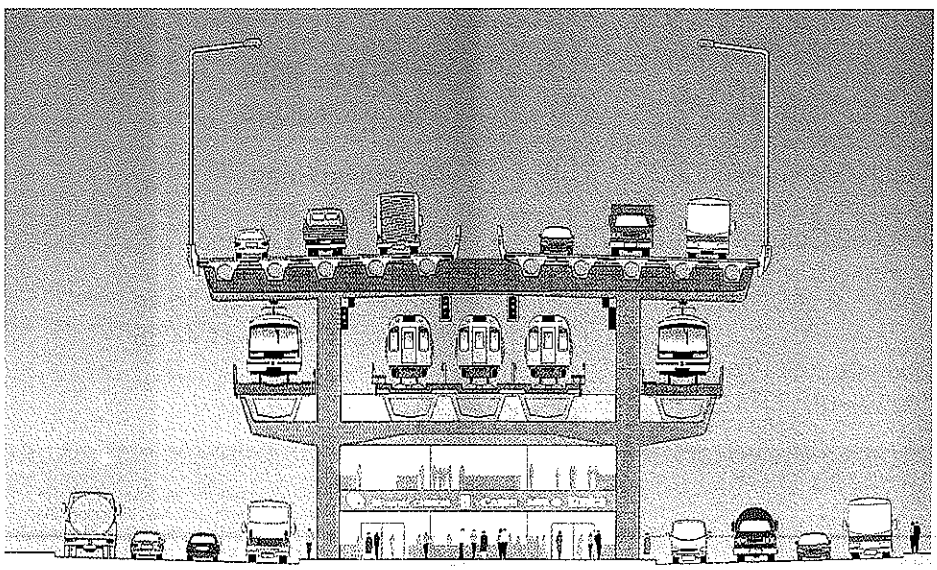
Phase I of the BERTS community train network will serve 30 stations. There will be interchanges with SRT at Rangsit, Don Muang international terminal, Bangsue, Samsen, Makkasan and Huamark. CT will interchange with the Metropolitan Rapid Transit Authority heavy metro line at Asoke and Rama IV, and with Tanayong Group's Bangkok Transit Systems Corp elevated rail network at Phoyathai.

Contract responsibilities

The BERTS concept and master plan has been developed by Tileman Transportation Systems and Ove Arup & Partners International, who are responsible for transport planning, envi-

Table I. Split of responsibilities within the Anglo-German BERTS supply consortium

Overall consortium management			Siemens
		Community Train	**SRT upgrade**
Project management		Siemens	Adtranz
Signalling		Siemens	Adtranz
Central Traffic Contro		Siemens	Adtranz
Telecommunications		Siemens	Adtranz
SCADA		Siemens	–
Automatic Fare Collection		Siemens	–
Overhead line equipment		Siemens	–
Power supply		Siemens	–
Vehicles	Leadership	Adtranz	–
	E&M	Adtranz	–
	Propulsion	Siemens	–
	Bogies	Siemens	–
	Brakes	Siemens	–
Trackwork		BB	BB
Workshops/Depot		Siemens	Siemens
Stations		Siemens	BB



Cross-section of the Berts elevated structures showing the community train, elevated SRT tracks, property development and tollway above

ronmental and safety policy, and civil engineering and station design. A multi-disciplinary design team based in London is connected via data links to project offices in Bangkok and Hong Kong.

Civil engineering began in May 1993, when Thai Bauer Ltd was awarded a contract to drive the 1 500 mm diameter piles which will support the elevated structure; many of these concrete piles are 55 m long. Casting plants have been set up at Paholyothin and Klong Ton to produce the precast concrete beams for the main structures. Construction work will progress outwards from these sites so that the beams can be moved along the completed structure with mimimal impact on existing traffic conditions.

With the civil works under way, HTL awarded a US$1·3bn mechanical and electrical equipment contract on October 7 1996 to a consortium of Siemens AG of Germany and the British MTB group combining Adtranz UK with Balfour Beatty. This covers the design, supply, instalaltion and commissioning of the BERTS CT network and the SRT upgrading.

As consortium leader, Siemens is responsible for project management and system design, and its share of the contract amounts to some US$974m including maintenance over a five-year period following opening (Table I).

Siemens will be responsible for E&M works on the CT network, including the supply and installation of 25 kV 50 Hz overhead electrification, fed by 230 kV substations. Siemens will equip the CT stations with lifts, lighting and air-conditioning, and fare collection. The CT signalling will including centralised traffic control, electronic interlockings, ATC, ATP and ATO, and positive train identification. Telecommunications include radio, fibre optic and telephone links, CCTV, passenger information displays and public address at the stations. The CT will also have a Supervisory Control & Data Acquisition (SCADA) system to manage traction and auxiliary power supplies.

Balfour Beatty will be responsible for the trackwork on both CT and SRT, and will fit out the SRT stations. Both routes will use UIC 60 rail attached to concrete sleepers laid on ballast; the 230 track-km will together consume 30 000 tonnes of rail, 330 000 sleepers and 600 000 tonnes of ballast. Adtranz is responsible for signalling, central traffic control and telecommunications for the upgraded SRT routes. The signalling and CTC will be compatible with similar equipment already installed elsewhere on the SRT network.

Rolling stock

Adtranz (UK) will deliver the fleet of 172 EMU cars to work the CT services. The aluminium bodyshells will be assembled at the company's Derby works. Siemens will supply air-sprung bogies, regenerative and disc brakes, and the electrical equipment, including pantographs and electronic control systems with integrated diagnostic capability.

The air-conditioned cars, each 3·1 m wide and 3·7 m high, will be marshalled in four, six, eight or nine-car trains; a 92·1 m four-car set will accommodate 1 272 passengers. There will be five doors per car side and full-width gangways between vehicles. Maximum speed will be 80 km/h and acceleration 1 m/s², allowing 2 min headways at peak times. Commercial speeds of 40 km/h including stops are envisaged, giving a 40 min journey time between Rangsit and Hualampong.

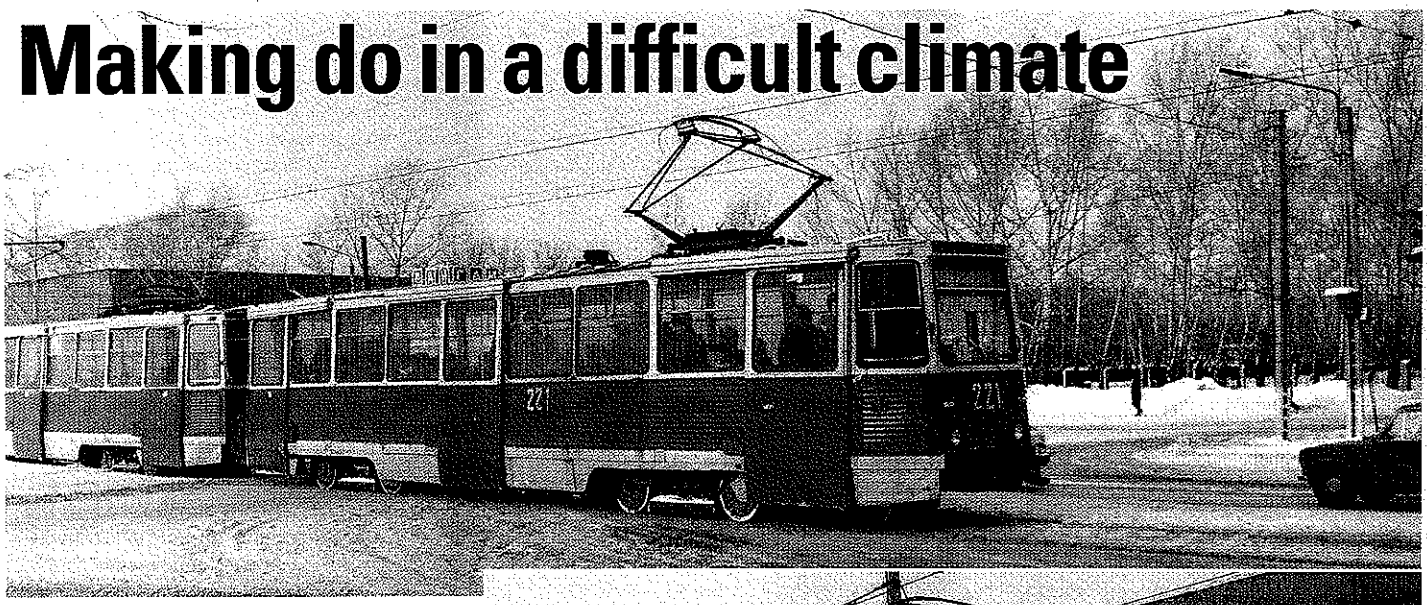
Siemens will design and equip the CT depot and workshops at Prempracha, together with a new depot for SRT to replace existing installations which will be isolated when the main line is elevated. The CT depot package encompasses air-conditioning, maintenance management systems and provision of workshop equipment including road/rail maintenance vehicles.

The main line tracks are due to be handed over to SRT in mid-1998, so that services can be stepped up in time for Bangkok to host the 1998 Asian Games that autumn. The tollway routes will also be open in time for the games.

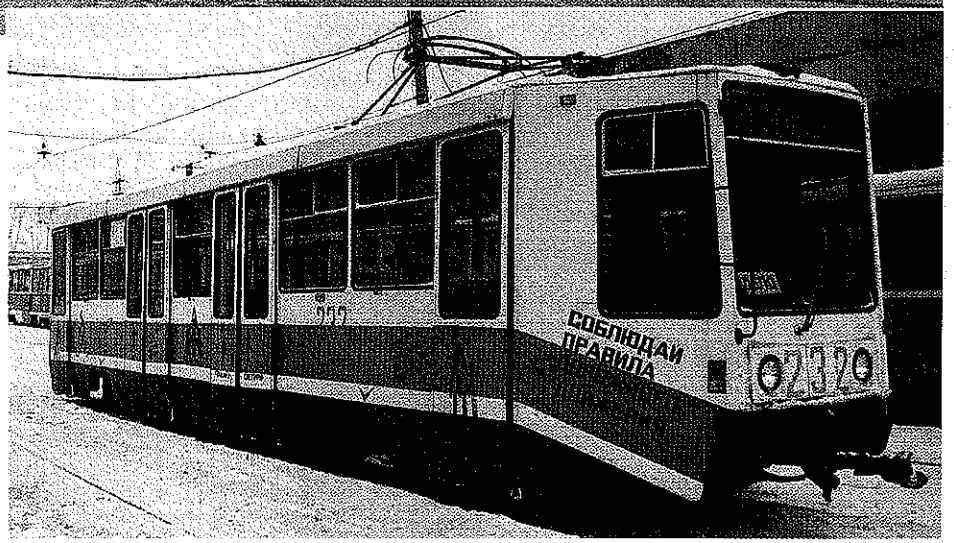
The community train project will take longer to complete, with services now expected to start in June 2000. Adtranz has already shipped a prototype car body to Bangkok, and a second is undergoing proof loading tests at Derby. The first series-built trainsets are expected to start test running in Bangkok in 1999.

In the longer term Hopewell envisages a second phase of BERTS routes, with corridors heading west and southwest across the Chao Phraya river to serve Bangkok's western suburbs of Wongwian Yai, Ponimit and Taling Chan. These would add a further 16 route-km and 14 stations to the network. ❑

Making do in a difficult climate



H M Nonko
Managing Director
Biysk Tramways



SITUATED on the banks of the River Biya in the south of Western Siberia, Biysk has a population of approximately 250 000. The town is around 270 years old, but the tramway only dates from 1960, when the first factories were developed.

The initial 10·6 km line from Mayakovskovo to the Western boundary of the city was inaugurated on June 13 1960, and was worked by five KTM-1 trams supplied by the Ust-Katavskiy wagon factory.

Over the next 20 years the network was gradually expanded to its current six routes, with a total length of 71 km. The depot was enlarged to accommodate 100 vehicles, and six substations built to power the various routes.

All of the trams have been supplied by the Ust-Katavskiy factory. The current fleet comprises 97 KTM71-605 series (top), of which 66 operate in multiple formation, and four of the more modern KTM71-608K (right) design. There are also nine service vehicles used to clear snow, maintain the trackwork, and keep the overhead wiring in good repair.

Although the cars are not particularly modern and are underpowered by today's standards, they are relatively spacious and comfortable for the passengers. They have also proved extremely robust and hard-wearing, even in the difficult climate of Siberia with daily temperature ranging from +5 to -20°C.

The tram routes remain the core of the town's public transport network, and traffic levels are continuing to grow. In 1991 we carried 36·6 million passengers, but by 1995 this figure had increased by another 10 million.

Municipal funding

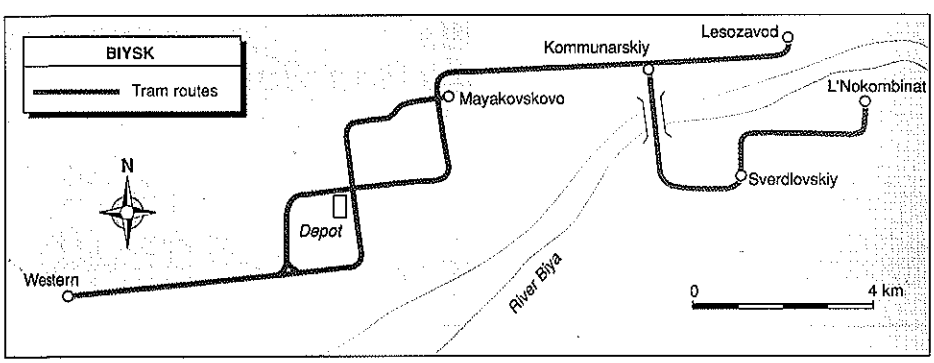
The tram network is owned and managed by the municipal authorities, which means that we have no control over our fare structure. The standard fare is 1 000 roubles, which is only about half of the costs of operation; to break even we should be getting around 2 000 roubles per trip.

The difference is supposed to be met by a direct subsidy from the municipal government. Unfortunately, in recent years the town has suffered from substantial budget deficits, and we have not received as much support as we should. We have been trying to make good the difference by encouraging extra ridership, but the task has not been easy.

An area of particular concern is concessionary travel. There are 32 different categories of 'preferential passengers' ranging from jobless, pensioners and invalids to participants in the Great Patriotic War. As a result, the proportion of preferential passengers is close to 70% of all the passengers carried.

The complex economic situation in which we find ourselves does not allow us to carry out as much maintenance and modernisaion as we would like. The main objective at present is to keep the rolling stock in good working order, so that we can continue to serve our customers.

With the circumstances currently prevailing in Russia, it is difficult to make long-term plans, but we are committed to a long and successful future for our tramways. At present the maintenance depot is being equipped with new machinery, and we are renewing sections of the track and overhead wiring. Traction motors, rail brakes and bogies are also being overhauled and renewed. All the vehicles and control points are being provided with radio links, which will help us to move the traffic more reliably and consistently. ❑



100 years young and going strong

The city centre tunnel at the heart of Boston's Green line light rail network celebrates its centenary on September 1. William D Middleton reports

Typical reserved-track station at Beacon Street on the Green line's C branch to Cleveland Circle

AMERICA'S FIRST underground railway opened on September 1 1897, between Public Garden and Park Street, easing the traffic congestion that had developed as trams vied for road space on Boston's Boylston and Tremont streets. The cut-and-cover tunnel handled 50 million passengers in its first year of operation and was ultimately extended to 9·2 km.

Today the Central Subway remains at the heart of the four-route, 37·6 km Green line light rail network operated by Massachusetts Bay Transportation Authority. One of the most heavily used parts of the MBTA system, the Green line serves 13 underground and 57 surface stations, and handles an average of 225 000 passengers a day. Three of the surface routes are largely segregated from street traffic on median strips, while the fourth and longest route to Riverside uses a former commuter railway converted to light rail in 1959.

Improving accessibility

Green line modernisation accounted for much of MBTA's infrastructure investment during the 1980s. Surface track rehabilitation was followed in 1985 by a four-year, US$22·3m programme to renew track and signalling in the Central Subway. Other work included epoxy injection repairs to the tunnel structure, rebuilding and strengthening of the entrance and exit ramps and construction of 15 new ventilation shafts. Power supply improvements and renewed overhead catenary throughout the network enabled the operation of trains of up to three cars, and the line was equipped with automatic vehicle identification.

MBTA is now moving ahead with a comprehensive accessibility programme, with low-floor cars and modifications to permit access by the disabled at all key stations. A 1992 study designated these as seven underground and 20 surface stations where boardings are at least 15% greater than the rail average, interchanges with other MBTA rail or bus services, termini and stations serving activity centres or other major trip generators for the disabled. The study developed a project design manual and designs for the key stations.

Except for a few underground stations, the accessibility programme should be complete by the end of 2000. Design work is in progress or about to begin for most stations, and construction is already under way at Haymarket.

At surface stations platforms will be raised to 200 mm above the top of rail, with detectable warning strips along the edges. Kerbs will be lowered, ramps installed, and accessible track crossings provided, together with new signs to suit the Americans with Disabilities Act.

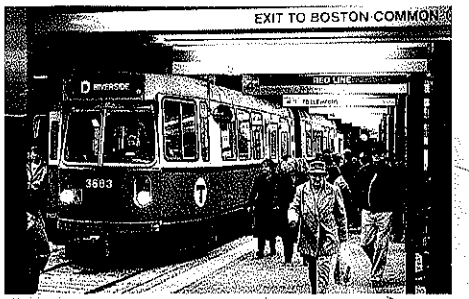
Underground stations will get similar platform improvements and lifts to track level; at least 50% of station entrances will be accessible.

In the longer term, all stations will be made accessible as part of improvement or rehabilitation projects. Although full accessibility at all key stations will not be possible until the low-floor LRVs are in service, MBTA has made some interim improvements: nine surface stations have been equipped with lifts or ramped landings giving access to the high-floor cars.

North Station works

Extensive works are under way at North Station, where the Green line interchanges with MBTA commuter trains and the Orange line heavy metro. Emerging from the subway near Haymarket, Green line trains run into a surface terminal across Causeway Street from North Station, or into an elevated station to continue across the Charles River to Lechmere.

Under a project begun in the mid-1980s the commuter rail terminus has been rebuilt with a car park and sports arena over the tracks and a



Above: Park Street subway station in March 1997, following the disastrous flood last October
Main picture: Early days at the Maverick Square subway portal Photo: Library of Congress

Centennial celebrations

MBTA launched its centenary celebrations for America's first subway on March 28 1995, when Boston Mayor Tom Menino and other officials re-enacted the 1895 groundbreaking. This year's events began at the annual 'First Night Boston' New Year's Eve celebration, and will continue until September 1. Activities include displays at Massachusetts Horticultural Society's New England Flower Show and on Boston Common; an exhibition at the State Transportation Building and MBTA headquarters; a centennial 'wrapped' trolley; a new museum at South Station and various commemorative and promotional items. The final event on September 1 will include a procession of dignitaries to Park Street station, followed by a trip through the subway to Boylston Street in a parade of historic rail vehicles. ❑

federal government office building on an adjacent site. Yet to come are two new office buildings on the site of the Boston Garden Arena, and a new Green line alignment under the site.

This alignment will include an underground station giving direct interchange to the existing Orange line platforms. Southbound metro and light rail services will use a large island platform, while northbound Green line trains will stop at a mezzanine level linked to the Orange line platforms by escalators and lifts. An underground passage will link the station to the arena, offices and commuter rail terminus.

The underground alignment beneath the arena and car park has been completed, and the surface terminus was closed in March to allow work to begin on the new station. Construction has yet to begin of the tunnels under the Boston Garden site and the connections to the extended city-centre tunnel and the existing Lechmere route surface alignment near Science Park. The North Station project is scheduled for completion by 2003, with the MBTA portion expected to cost around US$400m.

section, opposite the cab, is required by the present pay-as-you-enter regime. It has yet to be determined how disabled patrons will obtain their tickets, but MBTA may switch to barrier-free proof-of-payment, with off-vehicle ticket vending machines.

In addition to meeting the needs of the disabled, MBTA expects that the faster boarding and alighting enabled by low-floor vehicles will significantly reduce station dwell times. Director of Subway Operations Michael H Mulhern says the cars 'will be a major first step in increasing Green line throughput and decreasing running times'.

Delivery of the Type 8s will complete MBTA's Green line vehicle replacement strategy. After decades of operation with PCC trams, the system was re-equipped in the 1970s with 130 Boeing-Vertol Standard LRVs. But despite extensive retrofit and modification programmes, these vehicles were never able to achieve acceptable standards of reliability, and MBTA began to replace them in 1986 with 100 high-floor Type 7 vehicles supplied by Kinki Sharyo of Japan.

To further reduce its reliance on the trouble-plagued Boeing-Vertol cars, MBTA ordered an extra 20 Type 7 vehicles in 1995. The first of these was delivered on March 4, and began acceptance trials two days later. Until all of the Breda Type 8 cars have entered service, MBTA will retain 55 Boeing-Vertol cars, which have been overhauled by Amerail at Hornell, New York.

Work to improve their reliability has concentrated on bogies, the hydraulic brakes, centre articulation connections and replacement of plug doors with twin-leaf folding doors.

The 100-year flood

MBTA's Green line modernisation programme suffered a major setback last year, when massive flooding inundated much of the Central Subway. Beginning on Sunday October 20, a record storm dumped over 300 mm of rain on the Boston area in a 36 h period, overtaxing the city's drains and causing the Muddy River to overflow its banks. By 18.00 water had entered the Fenway subway portal on the Riverside Line, and within a few hours much of the subway was flooded. Services were curtailed, with a shuttle bus replacing the Monday morning peak.

Seven underground stations were flooded, with Kenmore under more than 6 m of water. Eleven escalators were damaged, along with power supply, communications, and signalling installations. Over 900 m of track was wrecked, and nearly 500 tonnes of ballast washed away.

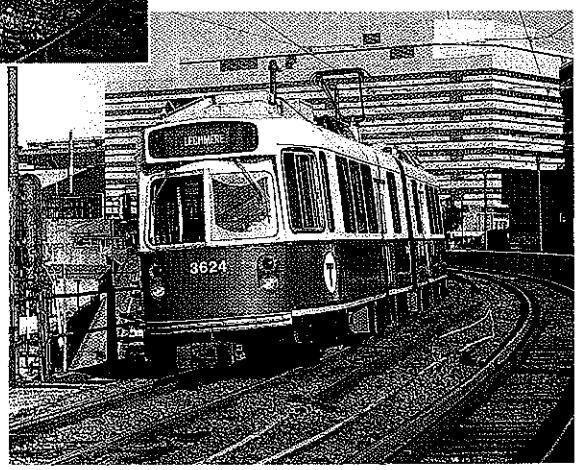
Contractors, other public agencies, and MBTA forces pumped over 500 000 m³ of water from the subway, cleaned the stations and tunnels, and completed emergency repairs to permit a resumption of service. Some trains returned to the subway on the Wednesday, and full services were restored over the whole network by the following Sunday.

Pending replacement of the signalling, trains have been running at reduced speeds, controlled by flagmen. This increased journey times by 8 to 10 min, but by February the delay was down to under 4 min. MBTA expects to restore normal trip times by mid-summer, but repairs will not be completed until early 1998. The final bill could be as high as $40 m. ❑

Future extensions

While MBTA is presently concentrating on rehabilitation and modernisation, two Green extensions are on the cards. One involves the restoration of services on the final 3·4 km of the Arborway route to an interchange with Orange Line and commuter rail services at Forest Hills. Services were cut back to Heath Street when PCC operation ended in the mid-1980s, because non-segregated running on the final section presented problems of sharing congested, narrow streets with other traffic. Providing disabled access is also difficult at stops on the street section.

A longer-term project envisages 9·2 km of new construction to extend the Lechmere route northwest to West Medford, to serve Tufts University. ❑



Green line routes are mainly segregated from street traffic, as on the Arborway branch (left) but the Riverside route (centre) is a former suburban railway converted in 1959. The Lechmere branch (below) uses an elevated alignment to cross the Charles River

Low-floor cars

The key to Green line accessibility is a fleet of 100 low-floor light rail vehicles ordered from Breda early in 1995 for US$215m. Designated Type 8 by MBTA, a prototype is to due to be rolled out later this year. Production deliveries will begin in May 1998 and continue at a rate of at least four vehicles per month for the next two years.

Each double-articulated car will have a low floor for 70% of its 22·5 m length, extending through a short centre section mounted on four independent non-powered wheels. High floor sections will remain at each end, over conventional power bogies. The cars will have AC traction drives and computer-based diagnostic systems. MBTA plans to run the new cars in multiple with the existing high-floor Type 7s, so as to provide an accessible vehicle in every train. Regular service with low-floor vehicles is expected to begin in November 1998, with all Type 8s in traffic by November 2000.

There will be two doorways on each side of the low-floor section, with folding twin-leaf doors. A retractable bridge plate at each doorway will permit wheelchair boarding and alighting. An extra entrance in each high-floor

Growing and investing in the private sector

The main line interchange station at Retiro on SUBTE Line C has been extensively modernised with new signs and automatic fare collection equipment

José A Barbero
Planning Manager
Metrovías SA

OPERATION of the Buenos Aires metro network (SUBTE) and the Urquiza line commuter service from Federico Lacroze to General Lemos has been in the hands of private-sector concessionaire Metrovías since January 1 1994. Since that time initial difficulties have been overcome and far-reaching changes are helping to provide a better quality of service for passengers.

In 1996 the one pre-metro and five heavy metro routes that comprise the SUBTE network carried 199 million fare-paying passengers, an increase of 37% over the last year of public-sector operation. Since then, Metrovías has introduced over 140 extra metro cars and reinforced train diagrams to provide additional capacity at peak periods in particular. Train-km have risen by 35% from 19·9 million in 1993 to 26·8 million in 1996, with headways reduced by almost 2 min. Trains now operate at 3 min headways on four of the five routes.

The number of passengers carried on the Urquiza line in 1996 was 24·9 million, an increase of 49% on 1993. Efforts to combat fare evasion, with staff deployed on station platforms to check tickets at both ends of a journey, have resulted in a major increase in fare revenue. Train reliability, in terms of timetabled services actually run, has increased from around 95% in 1993 to 99% in 1996, and punctuality has risen from 92% to 98% over the same period.

Since the very start of operations, improved standards of customer care have formed an important part of the Metrovías strategy. A Customer Care Centre has been set up, complaints procedures established and training provided for staff who come into direct contact with the travelling public. Passengers have also appreciated improved standards of train and station cleanliness, as well as security improvements comprising the deployment of private security guards and new agreements with the police.

SUBTE investment commitments

- Purchase of 80 cars;
- New signalling system on four lines;
- Operations control centre;
- Track-to-train communications system;
- Transformer substations and power supply improvements;
- Removal of all materials containing PCBs;
- Catenary replacement;
- Track renewal;
- Escalator renewal;
- Pump renewals and drainage renovations;
- Station and tunnel ventilation upgrading;
- New workshop facility;
- New interchanges and refurbishment of existing station facilities.

Urquiza investment commitments

- Track renewal;
- Elimination of level crossings;
- Refurbishment of eight EMU cars;
- New workshop equipment;
- Radio communications system;
- Renewal of third rail;
- Replacement of medium-voltage cabling.

Investment up, subsidy down

The 20-year concession contract includes major investment commitments which concentrate on the replacement of life-expired assets (box). Metrovías has already started work on the main projects timetabled for the first years of the concession, spending US$143·6m on SUBTE and US$6·6m on the Urquiza.

Metro projects currently under way include track renewal, installation of a new signalling system and operations control centre, renovation of transformer substations and the installation of new escalators. Track renewal and the replacement of medium-voltage cabling have begun on the Urquiza route, where a new communications system is also being installed.

With the agreement of the Argentine government, Metrovías' original investment plan was modified to include the purchase of rolling stock. Line B has been equipped with second-hand cars from Japan to replace vehicles that were over 60 years old. Sold by Tokyo's Teito Rapid Transit Authority after 25 years of service, the new stock was heavily overhauled by TRTA before the transfer to Metrovías.

Using its own funds, the concessionaire has begun a US$20m programme of station refurbishment, which includes the design and installation of new signs to guide passengers around the system. All the principal SUBTE stations are due to be refurbished by the end of 1998, and eight have been treated so far.

Under the concession system adopted for the privatisation of the Buenos Aires commuter and metro networks, bidders were expected to introduce operating efficiencies so as to require less subsidy, whilst keeping fares at existing levels. However, it is not easy to produce meaningful comparisons with the subsidy required in the public sector; the support for each commuter route cannot easily be identified within the large subsidies paid to Argentine Railways to operate the national network, and complete figures for SUBTE are not available.

A recent study has compared commuter subsidies paid out in 1995 with 1986 (the hyperinflation of the late 1980s preventing any meaningful comparison with a more recent year), and the amounts set for the mid-point of the concessions around 2000. With fare prices in real terms remaining roughly the same, the support required by commuter operators in 1995 to meet operating deficits is less than a third of that required under state control in 1986. The suburban railway concession agreements contain a declining support profile, with subsidy due to fall to around half its present figure by 2000. Analysis of past and present funding of SUBTE operations has produced similar results.

Customer satisfaction

The first three years of private operation on SUBTE and the Urquiza line have seen subsidy reductions without fare rises and the implementation of long-delayed investment projects – at contract prices which appear to be well below those paid in the public sector. Services have undergone substantial improvement, with more trains on some routes and better punctuality and reliability throughout.

As a result SUBTE passenger numbers have increased by 38% since 1994. A similar increase has taken place on the Urquiza line, but widespread fare evasion before privatisation means it is difficult to arrive at an exact figure. An additional 500 000 trips a day have been won from buses and private cars, generating considerable user and non-user benefits.

The results of customer satisfaction surveys provide the best evidence of an improved service. In June 1994, 46% of passengers agreed that service quality was good or very good, largely due to immediate improvements undertaken by Metrovías such as cleaner trains, fewer cancellations and better customer service. A survey undertaken in March 1997 revealed that this figure had risen to 90%. ❑

Line 2 poised to cross the Nile

Eng M E Abdel Salam
Chairman,
National Authority for Tunnels

PRESIDENT Hosni Mubarak inaugurated the northern section of Line 2 on October 1 last year, improving access to fast public transport for thousands of Cairenes. While the impact on the city's almost continuous traffic jams will be limited, the start of revenue services on October 2 means that there is at least a fast and comfortable alternative.

Already Line 1 has proved its worth. This 42 km north – south regional metro line was inaugurated in 1987, using a 4·7 km cross-city cut-and-cover tunnel to link the Egyptian National Railways commuter lines, running north to El Marg and south to Helwan. Line 1 now carries 1·2 million passengers each day, well on the way to the ultimate design capacity of 2 million.

Severe disruption in the city centre during Line 1's construction, the requirement for a Nile crossing, and advances in tunnel boring technology led to a decision that the central section of Line 2 would be built as bored tunnel. Its planned 19 route-km will eventually have 18 stations, including two interchanges with Line 1, and another with the projected Line 3 at Attaba.

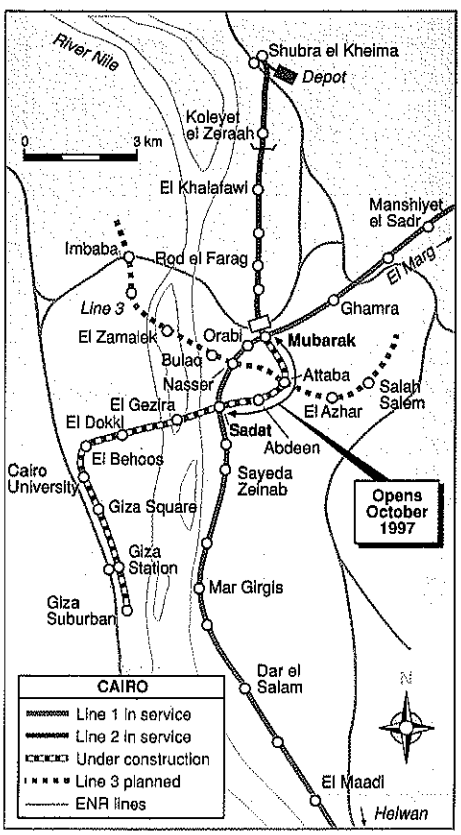
Construction has been divided into four sections, which are paired into two main phases:

- Phase I comprises sections 1 and 2. Section 1 is the 8 km now open, running south from the northern suburb of Shubra el Kheima to the Line 1/ENR interchange at Mubarak in central Cairo's Rameses Square. Section 2 will continue the line under the city centre to the Sadat interchange station in Tahrir Square; this 3·3 km is expected to open in October 1997.
- Phase II is made up of sections 3 and 4. Section 3 runs west from the city centre, tunnelling under the Nile to reach Cairo University. Section 4 then heads southwest alongside the existing railway to Giza.

Section 1 has one elevated and one surface station. The other six (including Mubarak) are underground, and are equipped with escalators and lifts, ventilation equipment, and automatic fare collection entry and exit gates. Line 2 is fitted out with a comprehensive communications network including lineside telephones, in-cab radio, station public address and closed-circuit TV, time distribution from a master to clocks around the network, and fire detection.

All of these functions are supervised from the main control room for Lines 1 and 2 in the Rameses complex adjacent to Mubarak station. This also handles train control and management of the power supplies for traction and the station equipment. Unlike Line 1 which uses 1·5 kV DC overhead, Line 2 is energised at 750 V DC via a third rail. The line has been equipped with a French design of centralised train control; the signalling allows for trains to be driven automatically or manually using lineside signals.

NAT Chairman M E Abdel Salam (far right) joined Egyptian President Hosni Mubarak (left) in the cab of the Line 2 inaugural train on October 1 1996



Regular services on Phase I of Line 2 have been providing much-needed transport capacity in the northern suburbs of Cairo since October 2 last year

Rolling stock

Phase I of Line 2 is worked by 15 six-car trains, which were built by Mitsubishi, with Kinki Sharyo, Toshiba and local manufacturer SEMAF. Automatic train operation equipment came from Alcatel-Alsthom of France, as part of the Interinfra consortium responsible for most electrical and mechanical work. The trains are formed as 30 half-sets each comprising a driving motored car, non-driving motor

car and a motor car with hostler controls for shunting in the depot.

The fleet will be expanded with a further build of 16 half-sets, bringing the fleet to 138 cars. As traffic grows, and Phase II comes on stream, we plan to strengthen the fleet gradually by adding further sets and an extra two trailer cars per set. Station and depot design was carried out with eight-car trains in mind, and Line 2 will eventually be operated by 38 eight-car trains.

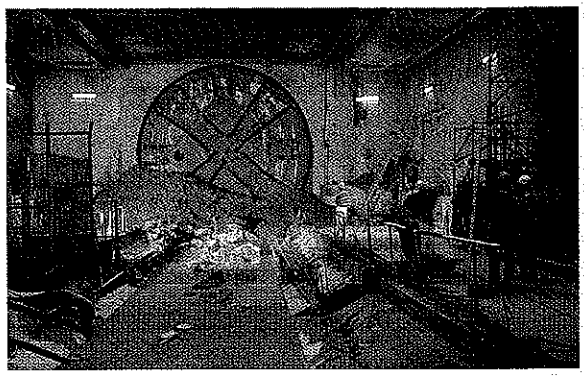
Each six-car set is able to carry a maximum of 1 340 passengers, but this will rise to 1 796 when the extra vehicles are added. With a minimum headway of 2 min, that gives the line a maximum capacity of nearly 54 000 passengers per hour in each direction.

A 15ha workshop complex has been completed at Shubra el Kheima. This will service the Line 2 fleet, including cleaning, light repairs and overhauls. Trains are fitted with computerised fault-diagnosis equipment to advise depot staff what work is needed on each train.

On April 23 last year, the Metro Organisation announced that routine daily maintenance of the Line 1 fleet at Tura would be carried out by an Egyptian-Japanese joint venture. The Line 2 fleet will be maintained by Mitsubishi for the first two years under the terms of the supply contract.

Tunnelling progress

At the end of April, slurry shield tunnel boring machine 'Nefertiti' broke through into the cut-and-cover box of El Dokki station on the Nile west bank, completing 1·75 km of tunnel on Section 3 of the line, between Sadat and Cairo University.



The Line 2 tunnel boring machine building the cross-river tunnels broke through into the station box at El Behoos on November 24 1997

Work on this segment began in 1995, with the TBM entry shaft and ramp north of CU station, and is due to be completed in 1999. It comprises 4 km of 9·4 m diameter bore, a 0·5 km ramp and 1 km at grade. This section also includes the first tunnel crossing under the Nile, which due to the shallow ground depth requires river bed reinforcement. One of the two Herreknecht TBMs used for construction of Phase I has been refurbished for Phase II and modified to work at higher pressures at a depth of 30 m when crossing under the Nile.

The TBM's cutter wheel excavates with flat chisel teeth and double cutting discs, the working face being restrained by the pressure of the slurry, which is treated at the surface. The TBM is articulated so that it can bore curves as sharp as 200 m in radius. It installs eight-segment 1·5 m tunnel lining rings with continuous grouting. Settlement has been on average just 20 mm, with good watertightness. This is significantly better than other TBMs used in the Cairo area, and can be attributed to the continuous grouting system installed in the back-up train.

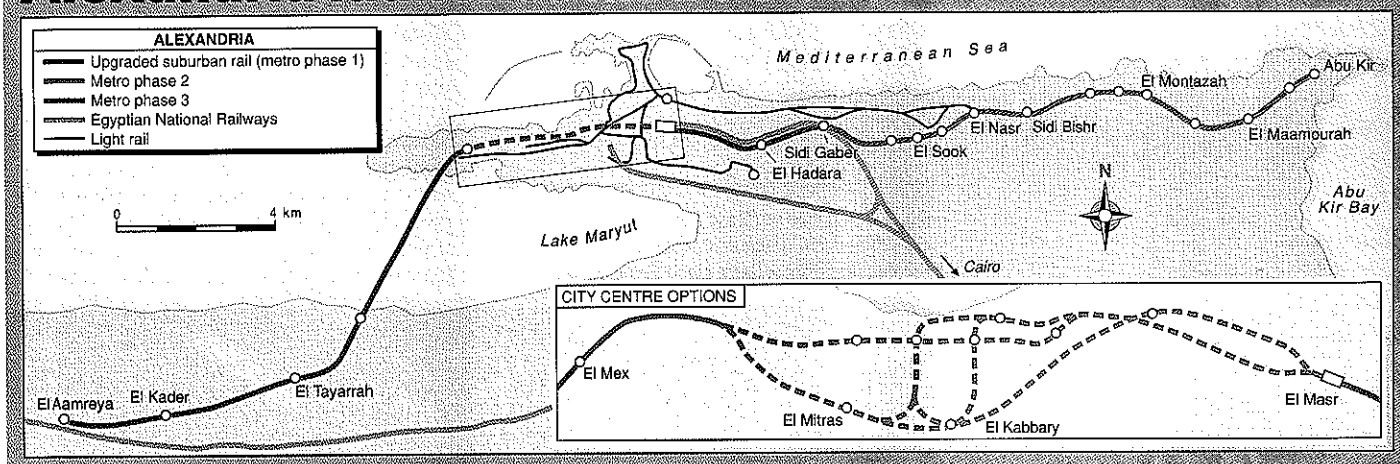
As on Phase I, the 470 m ramp from the tunnel to the surface at Cairo University and the three 20 m deep station boxes were constructed top-down as cut-and-cover sections.

With Section I in service for almost a year, the 3 km second section between Mubarak and Sadat is on schedule to open in October. Station fitting-out and electrical and mechanical equipment installation are well advanced.

The last section of the line, south from Cairo University to Giza Suburban, will be a mixture of at-grade and elevated alignment. It will include an interchange with ENR's Upper Egypt main line at Giza Station.

With a second metro route complete, a further four million of the capital's population will have access to rapid, efficient transport. It is hoped that work on the third route, from Salah Salem to Imbaba, can be started early in the next century, providing an east-west link and a second Nile crossing. ❑

Alexandria launches metro studies



IN EGYPT's second city Alexandria, plans are firming up for a 55 km double track regional metro running east-west parallel to the Mediterranean coast. Able to handle a minimum of 40 000 passengers/h in each direction at peak hours, it would involve the conversion of some existing rail routes and new construction in the central area.

After competitive international tendering, National Authority for Tunnels signed a contract on January 29 with a consultancy group led by Systra-Sofretu-Sofrerail of France. Under the FFr30·3m contract, Systra will work with the metro authorities from Marseille, Lyon and Milano and local firm Arab Consulting Engineers to undertake preliminary studies for the project over a period of 18 months starting in April. These include comparison of technical approaches to civil engineering, structures, equipment, and construction methods.

Following the preliminary study, the consultants will develop detailed designs for the first phase of the project, covering the conversion of the existing 22 km suburban railway running east from Alexandria's main terminus station at El Masr to Abu Kir. This is currently worked by diesel trains, which serve 16 stations. Detailed design covers the fixed works, track, electrical and mechanical installations, automation equipment and rolling stock.

The consultants will also prepare dossiers for the different technical contracts, enabling NAT to launch a call for tenders for construction of civil works, power supplies, systems, E&M equipment, track and rolling stock.

Phase II of the regional metro covers the central section of the route, running from the terminus at El Masr across the city centre to El Mex. The 12 km corridor is likely to be in tunnel beneath the city, and a number of alternative alignments are to be studied. Phase III would extend the line westwards for a further 21 km to reach the growing town of El Aamreya. This will entail crossing Lake Maryut, a large inlet just west of the city, where it may be possible for the railway to make use of the existing causeway carrying the main line from El Mex to Marsa Matruh. ❑

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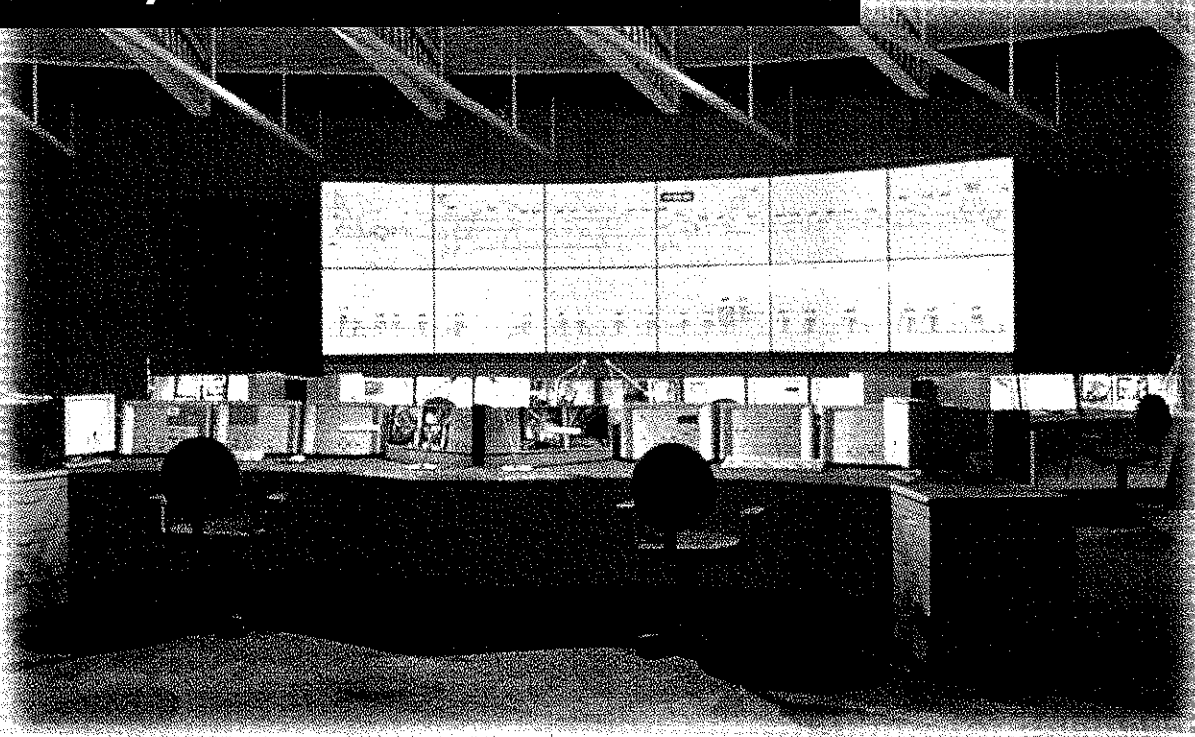

Photo courtesy of The Jubilee Line Extension Project

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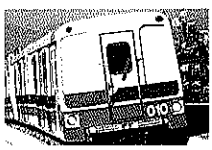

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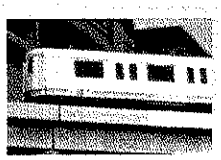

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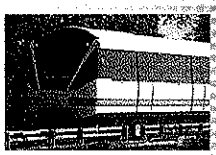

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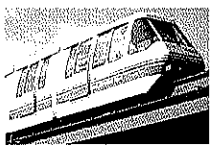

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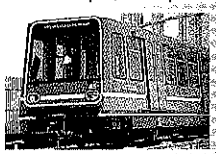

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Rail takes the strain as Irish capital grows

NEXT YEAR is due to see the start of construction on the first phase of a three-line light rail network in Dublin. Linking rapidly-growing outer suburbs to the city centre, the first two lines are expected to open in 2000. Sleek articulated LRVs will whisk their passengers along the city's streets, retracing the routes of the Dublin United Tramways abandoned in 1949.

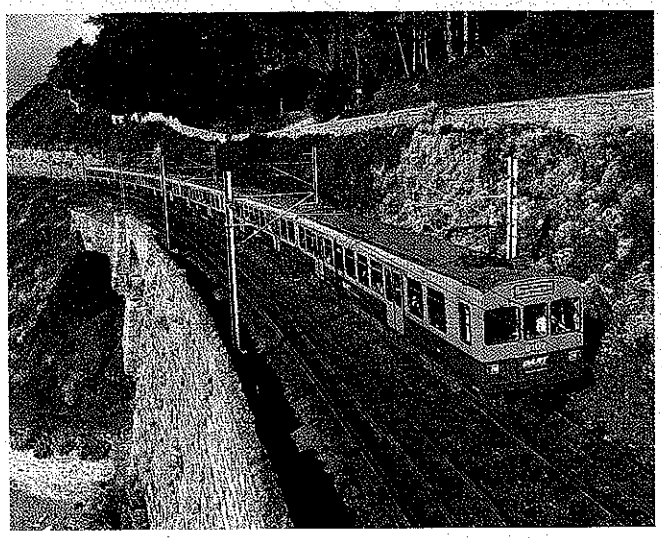
However, the light rail project is but one aspect of a massive investment in the Irish capital's rail network now being overseen by state transport company Coras Iompair Eireann. The Dublin Area Rapid Transit electrified suburban line is being extended, and upgrading is under way on the diesel suburban routes.

Ireland's National Development Plan, co-funded by the European Union, is providing I£1bn for transport infrastructure investment in 1994-99 under the Operational Programme for Transport. Of this, over I£600m is for rail.

Within a decade the main line railways and those serving the Dublin commuter belt have moved from a state of severe underfunding to one of intense capital investment. From a position some years ago when the government foresaw 'no further substantive investment in the railways' the situation has radically altered. In line with EU policy, all political groupings now accept the importance of maintaining and developing railway infrastructure and services.

At the same time, there has been a major population expansion in the Greater Dublin Area, parts of which have seen growth of almost 10 per cent in the past five years. With almost one third of the Republic's population now living within commuting distance of central Dublin, the railway is experiencing difficulty keeping pace with the demand for greater capacity and frequency. In 1996 CIE's railway operating subsidiary Iarnród Éireann carried a record 25 million passengers on its suburban and inter-city services. It is on course to break the record again in 1997.

Dr Ray Byrne
Head of Programmes & Projects
Coras Iompair Eireann



DART electric services run along the Irish Sea coast at Killiney, and will do so between Bray and Greystones on the future southern extension

DART goes north and south

The first major railway reconstruction project in Ireland this century was the 1·5 kV DC electrification of the 33 km Howth – Bray coastal corridor in 1985. This resulted in a dramatic transfer of commuters from private cars to public transport. Known as DART, the line is worked by 40 two-car EMUs supplied by Linke-Hofmann-Busch; these can run in multiple up to six cars, depending on demand.

In May 1995, the then Transport Minister Michael Lowry authorised a long-planned 7·7 km southern extension of DART from Bray to Greystones. Threading the overhead wiring through the tight tunnels on this single-track coastal section is not easy, but work is on schedule for a start of services in mid-1999. Total cost is I£8·7m, of which the majority is coming from the EU Cohesion Fund.

A second DART extension was included in the same Dublin Transport Initiative, but not formally authorised until 1996. This covers a 6·8 km section of the main Dublin – Belfast line northwards from Howth Junction to the coastal town of Malahide, costed at I£7·6m; once again it will be aided by the EU Cohesion Fund. Electric trains are expected to reach Malahide in 1999, replacing the existing service of push-pull diesel trains.

Two new stations are being added to the core section of the DART route – at Barrow Street in the city centre, and alongside the main depot at Fairview on the northern leg between Connolly and Howth Junction. On the southern route, the DART station at Dun Laoghaire is being extensively rebuilt at a cost of I£1·2m to improve the access to the Ferryport terminal – the original harbour branch having been abandoned at the time of electrification.

DART is currently carrying about 70 000 passengers/day, with peak hour headways down to 3 ½ min in the central area. With traffic growing steadily, congestion is becoming common at peak times. To provide relief and boost capacity for the future extensions, IE has called tenders for another five 2-car EMUs. The bids are now being evaluated, with the aim of placing a contract in time for the units to enter traffic in 1999. The procurement will be grant-aided by EU Structural funding.

Track upgrading and signalling improvements are also being considered on the critical 'Loop Line' section where DART crosses the River Liffey in the city centre, linking Connolly station on the north bank with Tara Street – Ireland's busiest commuter station – and Pearse station on the south bank.

A pair of Japanese-built Arrow railcars call at Sallins with a Kildare-bound suburban service from Dublin's Heuston terminus

Suburban revival

As well as the electrified route, Dublin is also served by 'outer suburban' trains operating on the IE main line network radiating to the north, west, southwest and southeast. Services are worked by a mix of loco-hauled trains using General Motors diesel locos, or the 17 'Arrow' diesel railcars purchased from Tokyu Car Corp of Yokohama in 1994 for I£18m.

The fastest-growing catchment area for suburban traffic is Maynooth, 24 km west of the city on the Sligo line. Rapid industrial expansion, intensive house-building programmes and the proximity of a major university campus have all fuelled this growth, which started with the introduction of suburban services in 1981 calling at eight new or re-opened stations.

Two more stations are now being added, of which that at Kilcock is completely new. The inner-city station at Drumcondra on the northern edge of the central area sees the re-opening of an earlier station which closed in 1907.

The arrival of the Arrow railcars in 1994 co-coincided with the inauguration of a new suburban service from Heuston, Dublin's largest main line station, to Kildare, 48 km southwest

of the capital to cater for the rapidly expanding towns and suburbs along the Cork main line. This I£13·2m project involved the reopening of three stations closed between 1957 and 1963, and construction of a fourth.

IE has now ordered a further 27 railcars, this time from GEC Alsthom Transporte of Barcelona. Although these units are intended to operate medium-distance inter-city services, they will be compatible with the existing Arrow stock, and it is likely that many will be pressed into service on the busiest commuter routes where demand has already outstripped capacity and railcars are more suitable than loco-hauled trainsets. The I£23m procurement is being funded from CIE's own resources.

The new railcars are based on the Channel Tunnel night stock, but with features from the railcars which GECAT is supplying to Finnish State Railways (RG 3.97 p138). Delivery of the first units is scheduled for the end of 1997.

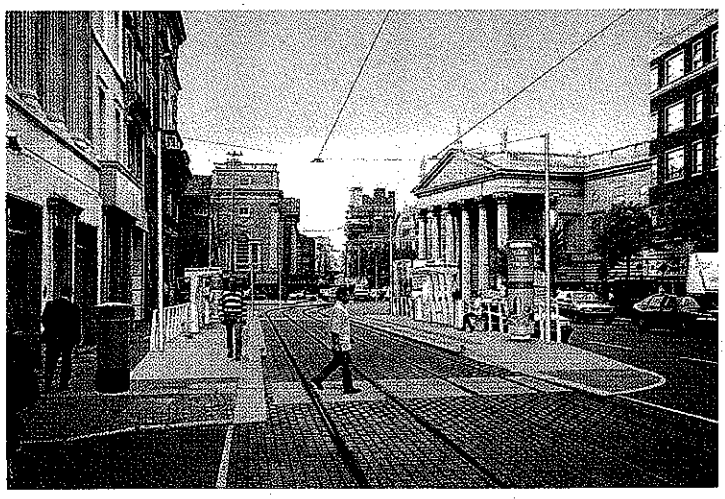
Light rail adds speed

The next addition to Dublin's railways will be a three-line light rail network, for which CIE is responsible for design, construction and operation. It is being marketed as LUAS, the Gaelic word for speed. Funding has now been committed for the I£230m first phase of the project, covering two of the three routes. The order to permit construction was lodged with the government at the beginning of May, enabling the sworn Public Inquiry forming a key element of the formal planning approval process to start this summer. Ministerial approval will then be sought, and if successful, this will allow work to get under way early next year, with services starting in 2000.

The light rail project dates from 1992, when a Dublin Transportation Initiative was established by the government to address the worsening congestion and pollution in the capital. This was largely caused by the growth of private car use, fuelled by a wholly-inadequate public transport system little altered since the original trams were swept away in 1949.

The Initiative included representatives from CIE, Dublin Corporation, local authorities from the surrounding counties, the various political parties, the Gardai (the republic's police force), city business interests and motoring and community organisations. In its final report the DTI proposed a multi-modal mix of investments to provide an optimal solution. These included light rail, 'quality bus corridors', a port access tunnel and improved suburban rail services.

Construction of an underground metro, as proposed for DART in the mid-1970s, was rejected as inappropriate: it failed to tackle the variety of traffic problems, did not support the promotion of urban renewal around the city, and would generate excessive capital and running costs. Serious environmental and personal safety concerns were voiced against a metro – or even for a short underground rail link in the city centre – and public opposition was strong.



Artist's impression of the LUAS light rail station in Dublin's Westmoreland Street serving Trinity College

Three light rail routes were identified, running southeast to Dundrum, southwest to Tallaght, and north to Ballymun. The two southside corridors had the highest car ownership in the region, and therefore some of the most congested arteries leading into the city centre. Following the publication of the Initiative's proposals, a public consultation process began, with more than 350 public and local business meetings. These included consultations with business, community and political panels. Apart from a few minor exceptions, the project met with overwhelming support.

For design of the network, CIE engaged the French transport consultancy Semaly, which was responsible for the development of various French tramway schemes and the Lyon metro. Semaly began work in 1995. A project management contract for the first phase of the line was awarded to the British civil engineering contractor Bovis in 1996.

Phase I provides for 22·5 km of double-track route serving the two southern corridors. Around 70% will be on reserved alignment, with street running restricted to the city centre, where car traffic will be segregated from trams on the roads to be used by the light rail line.

Starting from Dundrum in the southeast, LUAS will follow the former Bray – Harcourt Street branch of the old Dublin & South Eastern Railway. Despite great public misgivings, this suburban line was closed in 1958. From the old terminus at Harcourt Street, LUAS will run via St Stephens Green and Westmoreland Street, serving Trinity College before crossing the River Liffey on O'Connell Bridge.

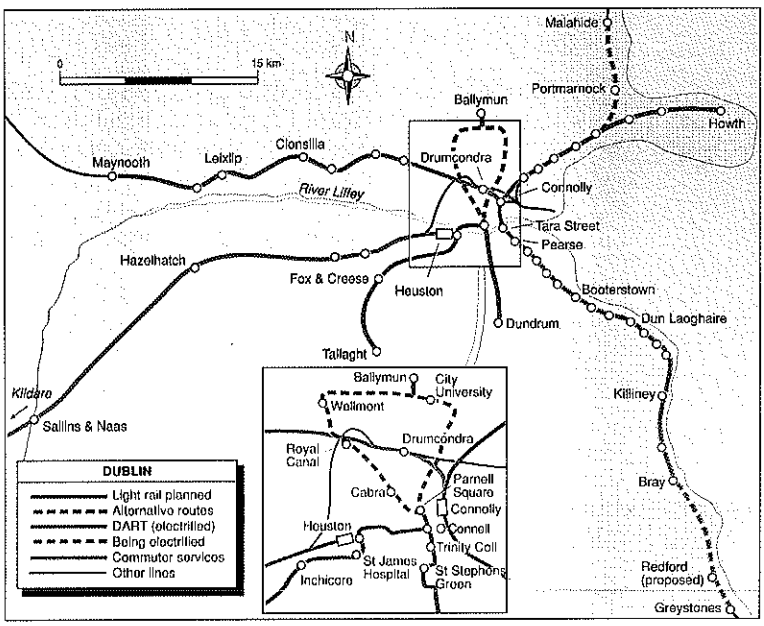
Turning left in O'Connell Street, the line will run via Abbey Street, behind the Liffey Quays through Smithfield, to reach Heuston station and St James Hospital. Heading out of the city through Inchicore to the large satellite town of Tallaght, the southwestern branch will run for much of its route on roadside reservations.

Construction of the Northside route to Ballymun will form Phase II. Two options are under consideration, both diverging from the Phase I corridor at O'Connell Street and heading north to the Rotunda Hospital in Parnell Square. From here, a mainly on-street option would serve Drumcondra and Dublin City University. The other would follow the former railway alignment from Broadstone via the heavily populated suburbs of Cabra and Finglas before turning east to Ballymun.

LUAS will be operated by a fleet of 30 articulated low-floor LRVs, with a length of around 30 m. The vehicle specification preparedby Semaly allows for a capacity of 235 people per vehicle, of which 60 would be seated, and requires the design to allow for the addition of extra modules to raise the capacity of the vehicles in the future. Detailed design will be left to the supplier. GEC Alsthom's Citadis 301 design has been confirmed as the favoured car.

On May 1 Transport Minister Alan Dukes announced that a 1·5 km extension of the Dundrum line from Ballaly to Sandiford would be added to Phase I at a cost of I£14·5m, and that public consultation for the Ballymun line would start 'immediately'.

Maximum speed will be 70 km/h on the suburban reserved track sections, and 30 km/h in the city centre. Typical journey times from O'Connell Street will be 22 min to Dundrum and 38 min to Tallaght. Services will initially run at 5 min intervals in the peak and every 12 min off-peak. ❑



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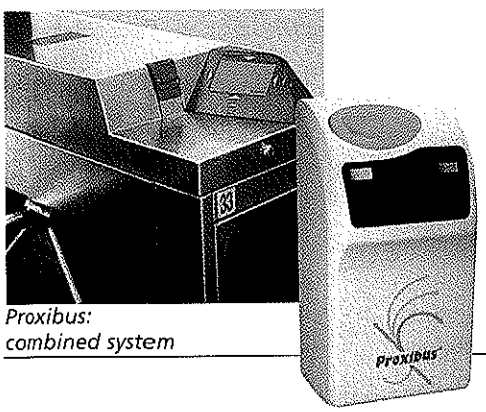

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Stadtbahn and tram underpin long-term expansion strategy

Dr-Ing Herbert Felz
Chairman
Rheinische Bahngesellschaft AG

The Rheinbahn Stadtbahn routes are operated by bidirectional B80D cars supplied by Duewag between 1981 and 1993

LATER THIS YEAR should see the publication of a report into extending the tram network serving the outer suburbs of Düsseldorf. For the past 15 years, the city council has worked closely with the local public transport operator Rheinische Bahngesellschaft AG to develop an integrated network of light rail, tram and bus routes, and construction of the light rail core is well advanced. The first cross-city corridor was completed in 1988, the second will be finished in 2001, and planning is well advanced on a third. So we felt the time was right for a closer look at optimising the complementary tram and bus routes. A feasibility study is being carried out, and the first results are expected shortly.

Rheinbahn operations are centred on the city of Düsseldorf in Germany's industrial Rhein-Ruhr conurbation, serving an area of 715 km² with a population of 1·2 million. Around 180 000 out of the city's 340 000 workers commute from the surrounding area. In addition, the airport, university and international exhibition centre all have their own special transport requirements. At present the network comprises seven light rail (Stadtbahn) routes totalling 65 route-km, 12 tram lines amounting to 83 route-km, and 75 bus routes. Annual ridership is about 200 million, divided equally between the three modes.

Light rail was adopted in Düsseldorf as an alternative to metro construction, mainly because it offered much lower capital costs. Another key benefit has been the shorter implementation times made possible by step-by-step conversion of existing tram routes. Dedicated rights-of-way on the surface continue to form the majority of the Stadtbahn network, linked by tunnel sections under the city centre. These tunnels are equipped with ATO and ATP, whilst above ground the LRVs are mainly driven 'at sight' in conjunction with traffic lights giving them priority at road junctions.

Extensive information systems guide passengers around stations and explain how to buy and validate tickets. In the tunnels and at major surface stops, the displays announce the train destinations. In this way, Rheinbahn has been able to create a high-quality environment which makes public transport more attractive.

On all routes passing through the city centre, a fundamental 10 min headway is operated during the day, with shorter headways over the core of the system where several routes converge on the same line. Operations are managed from a control centre, with computer control of the tunnel section automatically comparing train positions with the operating timetable to ensure that the LRVs are routed onto the correct surface routes.

The light rail fleet comprises 104 six-axle, bidirectional, single-articulated B80D LRVs, built by Duewag between 1981 and 1993. Each is powered by two 235 kW motors and is fitted with regenerative braking. The two-section cars each accommodate 70 seated and 107 standing passengers. They are equipped with retractable steps to allow for high-level platforms in the tunnels and low-level boarding on the surface routes.

Rheinbahn is taking delivery of NF-GTL three-section articulated cars with 61% low floors from Duewag, with Kiepe electrical equipment, to improve service quality on its remaining tram routes

Light rail expansion

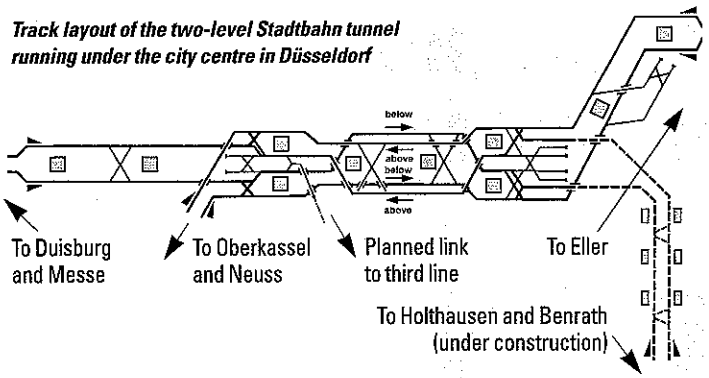
Our current development plans envisage that the light rail network will be extended to 80 route-km, serving 87 stations at an average spacing of 920 m (map). Three main corridors form the basis of the final network, with core sections passing under the city centre in tunnel and branching out in the suburbs on both sides. Of these three corridors serving the axes with heaviest traffic, two have been brought into service since 1988.

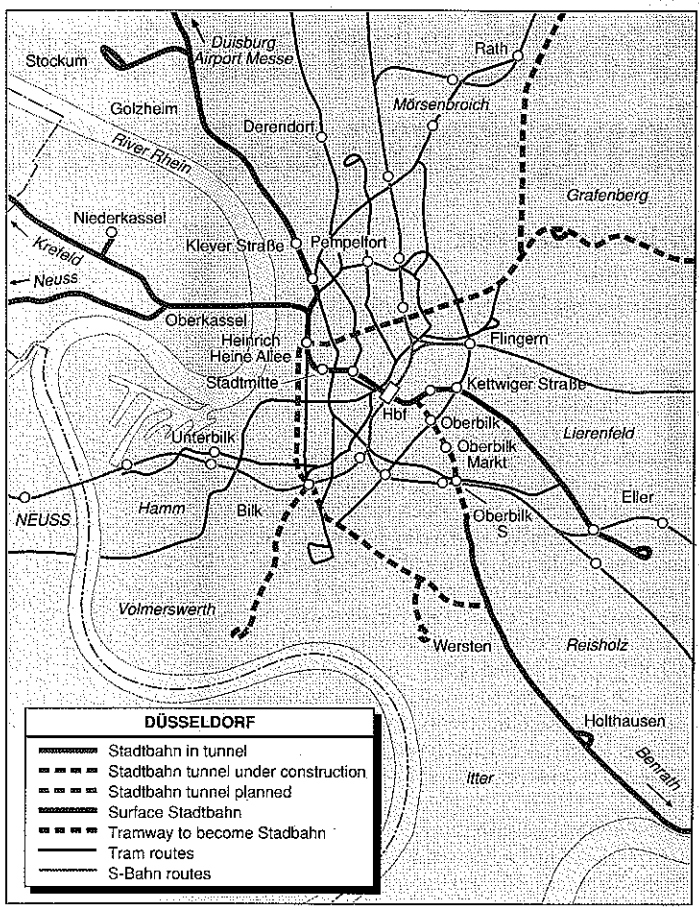
At present the seven light rail routes feed into a 9 km city-centre tunnel from Klever Straße to Kettwiger Straße, serving eight stations. A second tunnel feeds in Stadtbahn services from Neuss and Krefeld coming across the Rhein, and then parallels the main bore for 1·6 km between Heinrich-Heine-Allee and Hauptbahnhof. Over this section the two routes are paired by direction on two levels, allowing LRVs to cross from one route to the other without conflicting movements. The city centre section now sees 48 LRVs per hour in each direction at peak periods.

A 2 km three-station tunnel extension is currently under construction from Hauptbahnhof

Düsseldorf

Track layout of the two-level Stadtbahn tunnel running under the city centre in Düsseldorf





to Oberbilk S, where another interchange will be provided to German Railway's Düsseldorf S-Bahn network. This is due to open in 2001, completing the second cross-city corridor.

Preliminary planning work has also been completed for the third light rail tunnel, between the S-Bahn stations at Wehrhahn and Bilk, but no date has yet been agreed for the start of construction. Looping around the west side of the old city centre, this would replace an existing surface tram route. Interchange would be provided with the other two tunnel routes at Heinrich-Heine-Allee. Existing tram routes fanning out from the ends of the new tunnel will also be upgraded to surface light rail standards.

Other high-priority projects include a new route to the Messegelände exhibition centre north of the city, a connection between the new Düsseldorf Airport station on DB's InterCity network and the airport itself, and a link from the Messegelände to the airport. The exhibition grounds and airport lie on either side of the present U78/U79 corridor from Düsseldorf to Duisburg, and could be linked by a single route which would continue past the airport to the new station.

Another project currently under discussion is the construction of a new bridge across the Rhein, specifically for pedestrians, cyclists and LRVs. This would provide a direct connection from the Messegelände and airport to the routes on the left bank of the river.

Trams remain complementary

Unlike some cities which have phased out their remaining tram routes following the construction of light rail and metro routes, we see a continued role for tram and bus routes as lower-density feeders complementing the high-capacity Stadtbahn core. The tram/bus route optimisation study now under way will highlight the scope for building new tram routes and connections to improve service to the lower-density outer suburbs, and ensure convenient interchange to and from the Stadtbahn routes at logical traffic nodes.

The city council has recently launched a programme to help increase the end-to-end commercial speeds achieved on the classic tram routes. This includes the adoption of 'green wave' traffic light phasing to give the trams a clear run, greater segregation of trams from other road users where possible, and enhancements to the stops to speed boarding and alighting times.

The present tram fleet comprises a mixture of 92 Duewag GT6 and GT8 articulated cars dating from 1956-69, and 67 of the more modern GT8S and GT8SU derivatives supplied in 1973-75. These will be successively replaced by modern low-floor trams accessible to passengers with restricted mobility.

In 1995 we ordered a prototype batch of 10 Type NF-GTL vehicles from Duewag with Kiepe electrical equipment, together with an option for a further 128. The NF-GTL is a three-section articulated car, with conventional motor bogies at the outer ends and two unpowered steerable single wheelsets supporting the centre section. The low-floor section accounts for 61% of the total floor area, with a height 350 mm above rail and the doorways at just 290 mm. The relatively large quantity enabled us to negotiate a very keen price of DM2·7m per car. The first vehicles were delivered last year (p 21) and have now entered service. The firm order has been increased to 48 cars, but the question of exercising the rest of the option is still under discussion.

In the longer term we would like to move to 100% low-floor capability, and to this end we have started developing a vehicle concept known as R100 (Rheinbahn 100%). Initial design studies have been contracted to Professor Helmut Staubach, a Berlin-based design consultant, and he has already created an artist's impression of the exterior styling (left).

But although great importance is attached to technical developments, we also see improved standards of customer service as a major goal for the whole Rheinbahn operation. Today's public transport passengers can no longer be treated as 'self-loading freight', but must be seen as customers who expect to get a high quality of service for which they have paid. For this reason we are putting considerable emphasis on staff training programmes as part of our overall development strategy. ❑

Artist's impression of the proposed R100 all-low-floor tram currently being developed

Rail modes prosper as economy recovers

PUBLIC transport in Finland's capital enjoys a healthy 70% share of rush hour journeys into the city centre, and 60% of off-peak business. Situated on a tongue of land jutting into the Baltic Sea, the heart of this city of 500 000 people is poorly suited to road transport. This has long been recognised by the city authorities, and even in the 1970s when car ownership rose quickly, policies strongly favoured public transport.

Our goal is to maintain this share of traffic and perhaps increase it by improving metro, tram and commuter rail services. We are very conscious that only 25% of orbital journeys in the region are made by public transport.

The first half of the 1990s saw rail expansion in several parts of the city. The single metro line has been extended in both directions, starting in 1989 with a 1·6 km extension east from Kontula to Mellunmäki, which now handles about 14 000 passengers a day. This extension took the metro into the neighbouring community of Vantaa, and for the first time the city of Helsinki did not have to find the full cost of metro works from its own funds – the national government and the municipality of Vantaa contributed 30% towards the cost of building the line.

A 1·2 km western extension followed in 1993. This took the line from Kamppi in the city centre to the western extremity of the peninsular at Ruoholahti. This station is now handling 15 000 passengers a day, including park-and-ride and bus passengers arriving from Espoo on the motorway which links that town to Helsinki across a chain of small islands.

March 1 1995 saw the opening of a new station in the heart of the city, which was previously served by only two stations. Kaisaniemi is not far from the university and administrative district and the number of passengers using it is growing rapidly – around 19 000 a day at present. Indeed the volume of traffic on the whole line is rising all the time and is currently running at 41 million passengers a year.

Construction is well advanced on the metro branch to Vuosaari which will cross an inlet from the Baltic sea between Puotila and Rastila

Martti Lund
Managing Director
Helsinki City Transport

Regional strategy

In 1995 the city authorities finalised a comprehensive regional transport plan covering the 25 years to 2020. This provides for no less than 60% of the finance set aside for transport to be dedicated to improving public transport, with rail enjoying priority.

The first fruits of this plan will be the completion of the long-planned second branch of the metro, which is now expected to open towards the end of 1998. Running for 4 km east from Itäkeskus to Vuosaari, it will have three intermediate stations. Trains from Ruoholahti will run alternately to Mellunmäki and Vuosaari, providing a 6 min interval service on each branch.

A further 12 trainsets will be needed to work the expanded network, and we hope to place an order by the end of this year. During the coming winter, city planners and transport operators will be sitting down to draw up proposals for further development of the metro.

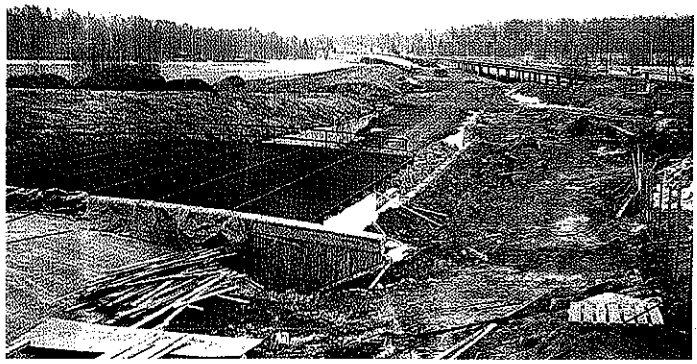
Low-floor EMUs to boost rail use

In conjunction with the new regional plan, major changes were introduced at the end of 1995 in the way suburban rail services are managed. Helsinki Metropolitan Area Council took over direct responsibility for stopping trains serving the area within a 30 km radius of the city, and awarded a 10-year contract to Finnish State Railways for their operation.

Construction of additional tracks for local trains has allowed Helsinki commuter services to be stepped up at stations such as Malmi

The agreement calls for VR to purchase new suburban rolling stock in the next few years, and the process started in April 1996 with an order for 10 two-car EMUs to be supplied by Fiat Ferroviaria of Italy. These will have a much more stylish appearance than the present EMU fleet, and will have much lower floors in order to simplify boarding and alighting from the 530 mm high station platforms. Due for delivery in the autumn of 1998, these EMUs are expected to attract more passengers.

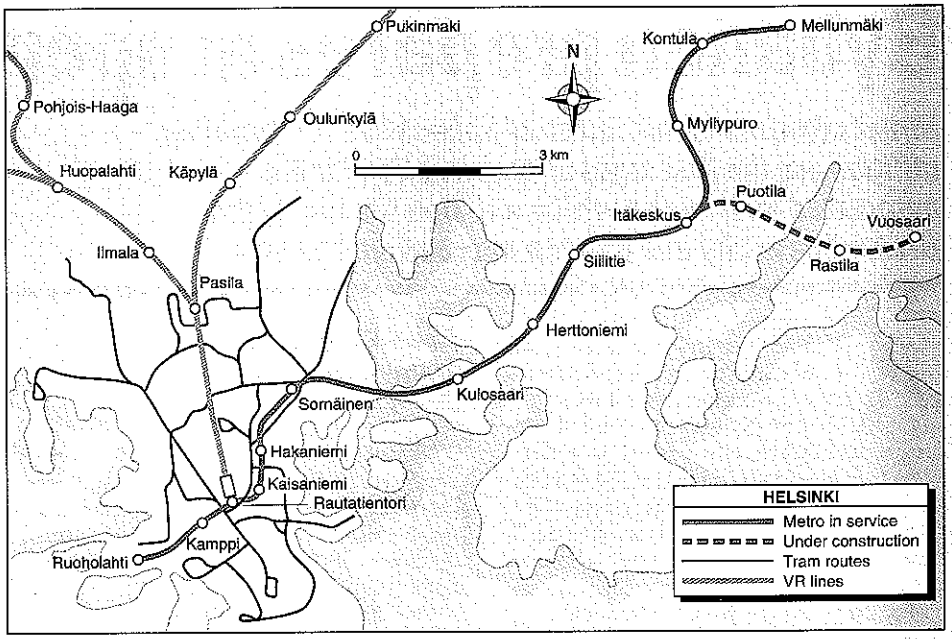
On August 12 1996 dedicated tracks for local services, on the German S-Bahn model, were inaugurated on the main line out of Helsinki. This has allowed more frequent services to be introduced, with local trains running every 5 to 7 min within the city boundaries. Running due north from the cen-



tral terminus, the eastern tracks carry the suburban services, with long distance trains using the pair on the west side. Four tracks are provided both north and south of Vantaa, but the S-Bahn concept cannot be fully implemented until a fourth track is built through Vantaa station itself. However, no schedule has yet been agreed for the construction of this missing section.

The changes to suburban rail services have been accompanied by a major restructuring of public transport provision in the areas served by rail. Some bus routes which used to parallel the railway into the central business district have been reduced in frequency or eliminated, being replaced or supplemented with routes feeding suburban stations. Passengers are being encouraged to use the train for the inner-suburban leg of their journey.

The dedicated tracks, higher frequencies and shortened journey times have encouraged more passengers to ride the trains. In the first few months after the changes, a 35% increase in passenger journeys was registered from commuter stations along both the main lines out of the city.



Trams rejuvenated

Travel by tram has also been boosted by the new emphasis on public transport; over the last two years we have seen a 6% increase in patronage on the 75 route-km metre-gauge network. This was generated by the general recovery of the Finnish economy from a deep recession, combined with increasingly severe parking restrictions in the city centre and improvements to the travelling environment.

A FM7 'short hop' tram ticket, FM2 cheaper than the standard single fare but without allowing transfers, has also boosted traffic. Tram stops have been rebuilt with higher platforms and new shelters, and we have maintained a strict cleaning programme.

To replace the last of the classic four-axle bogie tramcars retained for peak hour extras, 20 all-low-floor trams were ordered from Adtranz at the beginning of 1996, with an option for 20 more. They will be assembled in Finland by Rautaruukki Oy, for delivery between mid-1998 and 2000. Based on the Variotram concept, the 24 m long five-section articulated cars will be carried on three bogies, with all axles powered and a 300 mm floor height throughout. They will have more seats than the existing Valmet articulated trams, although overall capacity will be about the same. ❑

Bybanen prepares to open in 2000

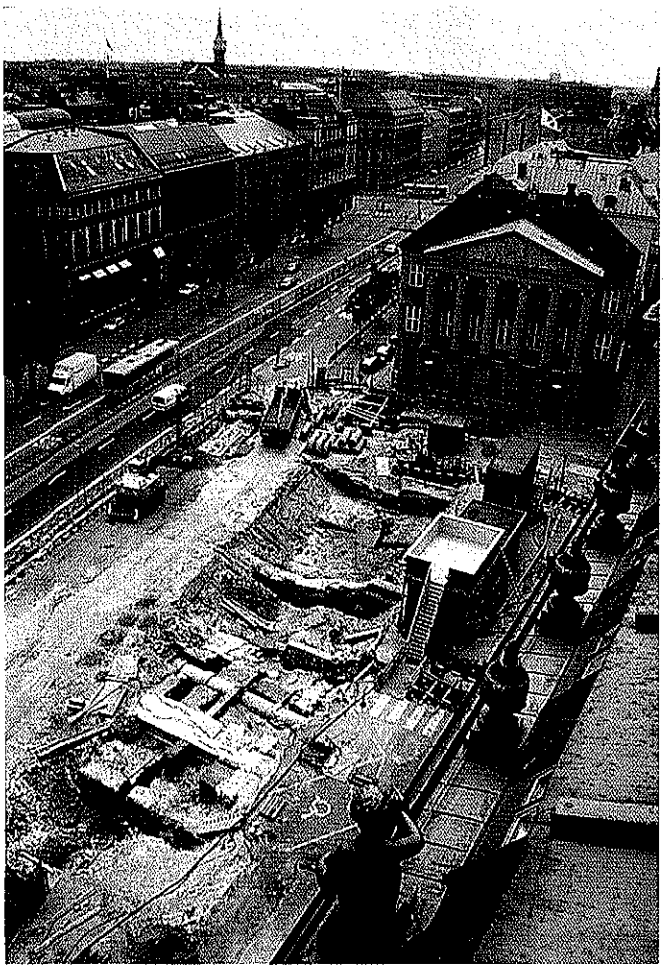
Street closures in the centre of København for rerouting utilities are the first signs of construction for the automated mini-metro which will link the city to the Ørestad new city and Kastrup international airport

Anne-Grethe Foss and **Torben Johansen** *

ARCHAEOLOGISTS at work outside the Magasin du Nord department store in København's historic Kongens Nytorv square discovered last summer that the city is at least a century older than historians had believed. For much of the busy Christmas shopping season, the foundations for the fortifications adjoining the 11th century harbour were clearly exposed to the view of curious passers-by.

The dig by experts from the National Museum was one of the biggest to be conducted in the heart of the Danish capital. It was made possible by the decision to build an automated metro under the city centre, so all the artifacts and historic structures had to be carefully removed from under the road between the National Theatre and Danske Bank, to make way for construction of Kongens Nytorv station.

An archaeological dig by the city municipality preceded construction of the Bybanen station at Kongens Nytorv



There have been many proposals for a cross-city metro in København over the past 20 years, but it was not until mid-1993 that a formal project was launched as part of an urban development scheme on the island of Amager authorised the previous year.

Ørestadsselskabett, owned 55% by the municipality and 45% by the Danish government, was formed to promote the development of a 'new city' known as Ørestad and a railway to link it with the city centre (RG 12.93 p823).

After consideration of tram, light rail and heavy metro, the decision to go for an automated mini-metro, now known as Bybanen, was taken in October 1994. International tenders under EU rules were invited in July 1995, with final bids in February 1996. After extensive negotiations during the summer, two contracts for the civil works and railway installations were signed on October 3 1996.

Y-shaped network

The Bybanen network is to be built in three phases, starting with the route from Vestamager in the Ørestad zone to an interchange with the cross-city S-bane corridor at Nørreport, just north of the city centre. This phase will also include a branch from Christianshavn to Lergravsparken to serve the built-up northern part of Amager.

The second phase will continue the initial route westwards from Nørreport to Frederiksberg, to take over existing but under-utilised S-bane tracks to another major interchange at Vanløse. The third stage will extend the Lergravsparken branch south along the line of DSB's freight-only Amager branch to Kastrup international airport. Total length of the network will be 22 km, with 24 stations including eight underground.

Whilst ØSSK is promoting phase 1 directly, the two later phases will be undertaken as joing ventures with the neighbouring municipalities. Phase 2 is the reponsibility of the Frederiksbergbaneselskabett, which is owned 70% by ØSSK and 30% by Frederiksberg municipality. The Østamagerbaneselskabett in charge of phase 3 is owned 55% by ØSSK and 45% by København Amt.

When the contracts for the first phase were awarded, ØSSK reached a supplementary agreement with the Frederiksbergbaneselskabett, which will enable construction of the Nørreport – Frederiksberg section to be brought forward into the initial phase. Along with some preparatory works beyond Lergravsparken, this will bring all of the 8 km of tunnelling into one programme and reduce disruption in the longer term.

The current timetable for construction envisages the Vestamager – Nørreport line opening in October 2000, with the short extension to Frederiksberg in May 2001. The target for the remainder would see Bybanen trains running to Vanløse by 2003 and to Kastrup airport in 2004. The Bybanen will interchange to the S-bane at Nørreport and Frederiksberg (later Vanløse), and also with the Øresund rail link at Ørestad and Kastrup airport.

Construction strategy

The DKr3bn civil engineering contract was awarded to the COMET consortium, headed by Tarmac Construction of Great Britain with Bachy, Ilbau, SAE-International, Astaldi and Christiani & Nielsen. The contractors were able to move onto site during January, following the completion of utilities relocation and archaeological work.

Through the Ørestad zone, Bybanen will be at grade, apart from a short elevated section near the university. From Islands Brygge to Frederiksberg will be bored tunnel, and the existing S-bane section on to Vanløse is largely at grade or on embankment. The branch to Kastrup will run in tunnel to Lergravsparken, and then on the surface along the eastern coastal strip of Amager to the airport.

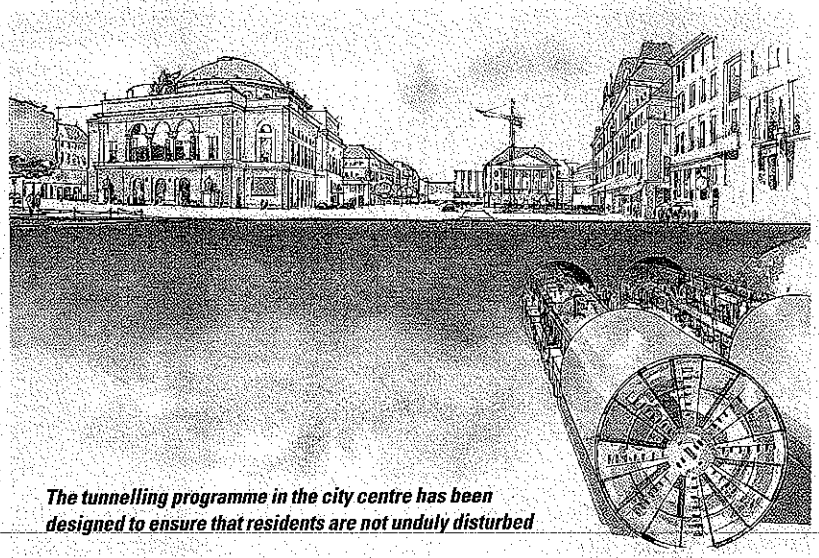
The parallel 4·9 m running tunnels will be bored with earth-pressure-balance TBMs, which are now being assembled by Mitsubishi France ready to start work in early 1998. The station platforms will be 18 m below ground and the running tunnels 5 to 10 m deeper, keeping 99% of the tunnelling in the underlying limestone strata rather than the alluvial mud of the harbour area.

A complex boring programme has been agreed to minimise the impact on residents and allow most materials to be moved in and out by water. The first leg will be bored from Islands Brygge to an access shaft near the future junction site at Christianshavn. After this, the TBMs will be lifted out and transferred to the main working shaft on the waterfront at Havnsgade. From here they will bore

** Anne-Grethe Foss is Managing Director of Ørestadsselskabett, and Torben Johansen is Technical Director*

back through Christianshavn to the exit ramps beyond Lergravsparken, and again be returned to the harbour shaft. The final drives will run north across the city to Nørreport and then west to Frederiksberg.

A continuous walkway will be provided in each tunnel, allowing passengers to be evacuated in emergencies. Intermediate evacuation shafts will be provided between the more widely spaced stations, ensuring that no escape route is further than 600 m. These shafts will take the form of concentric rings, so that the emergency services can gain access using fixed ladders or hoist equipment up and down the central bore whilst passengers are leaving via spiral stairs in the outer ring.



The tunnelling programme in the city centre has been designed to ensure that residents are not unduly disturbed

Airy and open stations

The underground stations and evacuation shafts will be built by cut-and-cover. Top-down construction between cast in-situ concrete pile diaphragm walls is envisaged, because of some very narrow sites in the winding streets of the old city.

Considerable emphasis has been put on making the stations open and airy, with skylights and light wells to illuminate the platforms and escalators. The platforms will be 40 m long, with glazed screens to prevent passengers falling under the automatic trains.

Small mezzanine areas below the street at each end of the station box will accommodate automated ticket machines, but there will be no permanent station staff, and no retail kiosks to create dirt and litter, or encourage people to hang around the stations. Similarly, with Bybanen an integrated part of the existing HT-DSB zonal ticketing scheme, there will be no gates or barriers controlling entry to the stations.

The ground level and elevated stations in the Ørestad will be built in conjunction with the various development schemes. A Finnish design company has developed the overall concept for the zone, and ØSSK has started awarding concessions for the different developments. Each promoter will then bring in architects for detailed design of the individual elements.

As an example of the partnership approach, three groups will be involved in the new Ørestad interchange station connecting the Bybanen to the Øresund international rail link, which is due to open between København and Kastrup airport in June 1998. The main line trackwork and platforms will be built by link promoter A/S Øresundsforbindelsen, whilst ØSSK will be responsible for the Bybanen platforms and the station buildings will probably form part of the adjacent property development.

The whole metro will be fully accessible for disabled passengers, with lifts at all stations and level boarding from the platforms, even though the proportion of disabled users is expected to be 3% or less.

Automation equipment

The DKr1·2bn electrical and mechanical contract has been awarded to Ansaldo Trasporti of Italy. This covers the supply and installation of track, 750 V DC third rail power supplies, signalling and automation equipment, station equipment, and of course the rolling stock. Some of the mechanical work has been subcontracted to Breda and Firema.

The initial contract covers 19 trainsets, and provides an option for a further 17 sets to work the later phases of the project. Each 39 m long train will comprise three body modules, carried on three powered and one unpowered bogie (RG 12.96 p784). Full-width inter-car gangways will provide an open interior throughout. Each train will be able to carry around 320 passengers, of which up to 96 will be seated. Top speed will be 80 km/h, giving a commercial speed including stops of around 40 km/h.

The trains will be fully automated, using the equipment developed for the Los Angeles Green line by Ansaldo subsidiary Union Switch & Signal (RG 3.93 p177). However, driverless does not mean unmanned. The intention is to have some form of train captain on board most services to provide passenger information and security reassurance, although the captain will be able to get off and deal with an incident, leaving the train to continue by itself.

The depot and control centre for the network will be located at Vestamager, between the last two stations of the Ørestad branch.

Operate and maintain

As well as the E&M contract, Ansaldo has been awarded a second covering the operation and maintenance of the line for the first five years. Worth DKr500m, this will ensure that the contractor delivers a complete operational system, and has an incentive to make it work.

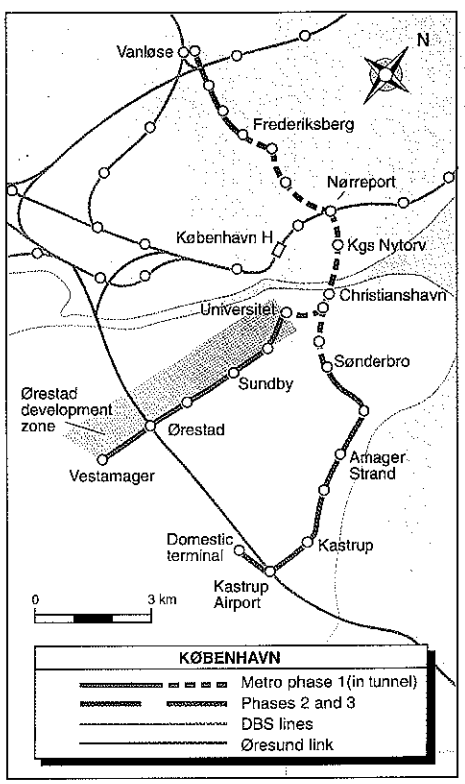
Ansaldo will employ all the staff, and will operate to an agreed schedule, although ØSSK will carry revenue risk up to a guaranteed minimum level of patronage. A penalty and bonus regime provides for fines if the contractor fails to meet specifications on punctuality, cleanliness, and other service quality issues, whilst bonuses will be payable if the line attracts extra patronage above the agreed rolling targets.

There is an option for a three-year extension to the operating concession. Beyond that, ØSSK plans to invite open bids for operation of the Bybanen every five years, to get the best quality of service at a competitive price.

Minimum headways on the core section have been set at 90 sec, with trains to run at 3 min intervals off-peak and a mimimum of every 6 min in the late evenings – giving 12 min headways on the two outer branches. Forecasts envisage the Bybanen carrying 60 million passengers/year in 2004 and around 77 when Ørestad is completed, with peak flows of 8 000 passengers/h in each direction.

The busiest station is expected to be Nørreport, which will be used by 50 000 passengers/day of whom half will be interchanging to or from the S-bane. Underground passageways will provide a direct link between the two sets of platforms, avoiding the need for interchanging passengers to ascend to the surface and cross the road to the other station.

Most traffic will come from existing parts of the city, being attracted from bus, car or S-bane, rather than from new office or residential developments around Ørestad. But when Ørestad is completed in 25 to 30 years, urban growth may well push total traffic beyond the present forecasts. Theoretical capacity of the Bybanen with trains carrying 300 passengers running every 90 sec is around 12 000 passengers/h. ❑



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Tri-Rail on track to long-term future

Gilbert M Robert
Executive Director
Tri-County Commuter Rail Authority

A RIBBON-CUTTING ceremony on October 28 last year marked the opening of Tri-Rail's 18th station, at Mangonia Park in the northern part of Palm Beach county. The 6·1 km extension from West Palm Beach lengthens southern Florida's commuter rail corridor to 113 km. Located at 45th Street Palm Beach, Mangonia Park serves several local hospitals. Built by local contractor RPM to a design by engineering and architectural specialists Gee & Jensen, the $1·3m station includes a dramatic tubular-steel roof and 277 park-and-ride spaces.

Mangonia Park is just one of a string of capital investment projects which are helping to turn Tri-Rail into a driving force for the 21st century. As I explained in DM91 (p47), the Miami – Fort Lauderdale – Palm Beach commuter service was only intended as a temporary relief to the parallel Interstate 95 during a five-year road rebuilding programme. Backed by local politicians in Dade, Broward and Palm Beach counties, the operation was set up on a shoestring, with second-hand diesel locos and a handful of double-deck coaches.

Double-tracking work is well advanced on the 19 km central section in Broward county; in the longer term Tri-Rail would like to double the whole route

The single-track former Seaboard Air Line from Orlando to Miami was taken over from CSX Transportation by Florida Department of Transportation, although CSX continues to run freight trains. Other than a handful of stations shared with Amtrak, Tri-Rail's stops were basic platforms with waiting shelters.

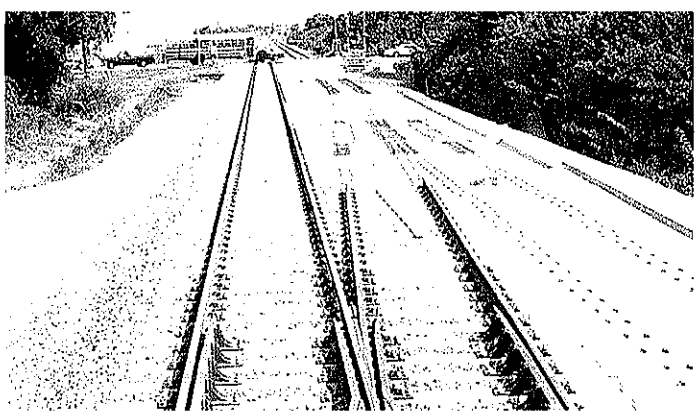
When services began on January 9 1989, there were just eight trains each way per day, at peak times only. Subsequent years have seen the addition of reverse-commute and inter-peak trains, followed by Saturday and Sunday services, up to the current level of 84 trains each way per week. This helped to boost annual ridership from 780 000 in the first year to a peak of almost 3 million in 1993. The last three years have seen a slight fall-off following completion of the highway works, but Tri-Rail is still handling around 7 500 passengers/day.

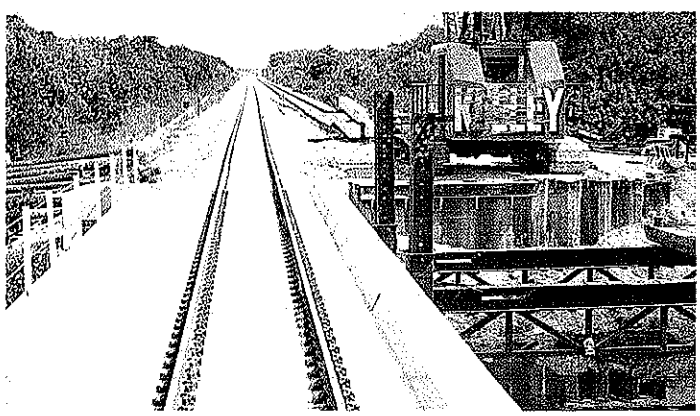
A Wackenhut contract security guard acknowledges the arrival of a Miami-bound train at Lake Worth station, Palm Beach county; new ramps have been provided to give level boarding for disabled riders

Infrastructure strategy

The last seven years have shown that there is a long-term role for commuter rail in southern Florida, which is one of the fastest growing regions of the USA. In 1995, Tri-Rail's Board of Directors and Florida DoT launched a $415m investment plan to transform the operation for the next 20 years. Board Member Ed Kennedy says that 'in 10 or 15 years, Tri-Rail will probably be one of the major commuter rail operations in the United States.' Forecasts envisage our traffic reaching 56 000 passengers a day.

The principal element in the upgrading is double-tracking and resignalling of the entire corridor, currently costed at $357m. At launch the single-track line had just 10 passing loops, of which the longest was 4·3 km. This placed a severe restriction on the number of commuter





trains which can run, given that three Amtrak expresses and several CSX freights in each direction have to be threaded through the area. Following doubling, our aim is a 30 min interval service all day, with 20 min peak headways.

Limitations on capital funding mean that the work must be spread over a number of years, so we have initially concentrated on a 19·3 km section at the centre of the corridor. The new track from Fort Lauderdale to Pompano Beach was put into service at the beginning of September 1996, allowing the contractors to rip out and refurbish the original single line. Double-track operation began in December.

The first purpose-built double-track station was inaugurated at Cypress Creek on September 27, following a $6m reconstruction. The original basic facilities have been replaced by two 122 m raised platforms 5 m wide, with canopy roofs for their entire length. A pedestrian overbridge accessible by stairs, lifts and escalators replaces a foot crossing, and wheelchair ramps have been widened. Improvements to the landscaping, lighting and signage have also been made at the station, which is served by Broward County Transit and Tri-Rail bus services, and by a 500-space park-and-ride facility owned by FDoT.

Station reconstruction has in fact been under way since 1994, following the passing of the Americans with Disabilities Act in 1990. First to be completed was Tri-Rail's flagship, Metro-Rail Transfer, at 79th Street Hialeah, which is the busiest on the line. This was fully renovated in September 1994 at a cost of $1·5m.

Two completely new stations were opened on March 15 1996. Sheridan Street serves the southern part of Broward county, whilst Opaloka restores rail service to an historic community in the northern part of Dade county. Each cost around $900 000. They were followed in April 1995 by refurbishment of the SAL station at Fort Lauderdale station, in conjunction with Amtrak, which cost a further $500 000. A new park-and-ride facility has been provided, bringing total parking capacity along the line to over 6 000 cars.

Work is now getting under way on a $9·5m southern extension, which will bring the trains closer to Miami International Airport. The present terminus, on the site of the former Seaboard Hialeah station, is connected by shuttle bus to the airport some way to the south. Following an agreement with CSX, we are refurbishing another 3·2 km of track and building a new station opposite the airport. When this opens towards the end of 1997, the shuttle buses will be able to run directly to the domestic and international air terminals without being delayed on congested city streets.

This year will also see refurbishment work at Boynton Beach station in Palm Beach county and renovation at the Tri-Rail/Amtrak Hollywood Boulevard station in southern Broward, at a cost of $2m. A further $10m has been allocated for three new stations, which are all scheduled for completion in 1998. First, in September, will be an interchange at Fort Lauderdale Airport. New stations at Congress Avenue and Glades Road will replace the existing poorly-sited stop at Boca Raton. Following this, Deerfield Beach and Pompano Beach are both due to be rebuilt by July 1999 for $8m.

Rolling stock renewals

Tri-Rail's fleet began with five F-40PHLs rebuilt from Conrail GP40-2s by Morrison Knudsen in 1987. An extra GP40-2W was acquired second-hand from GO-Transit of Toronto, but has not yet been restored to operating condition. Three more F-40s arrived from MK in 1992, but differ from the originals in having a separate Caterpillar V12 engine to provide auxiliary head-end power.

Tri-Rail's busiest station, Metrorail Transfer at 79th Street Hialeah, was fully refurbished in 1994

Three new driving trailer coaches with full-width cabs and expanded provision for disabled riders were delivered by Bombardier in mid-1996

In 1995 we launched a rolling programme to refurbish the five original locos, and the first was completed in mid-1996. Another three F40s were bought from Amtrak for just under $1m and delivered earlier this year.

The intial 17 UTDC/Lavalin bi-level coaches, built as a follow-on to a GO Transit order, comprised 12 trailers with 158 seats and lavatories, and 5 push-pull driving cars with wheelchair spaces. UTDC successor Bombardier delivered three extra trailers in 1990, allowing us to expand train services.

The latest batch of five driving cars delivered by Bombardier in mid-1996 incorporate significant improvements. Full width cabs are provided together with large luggage racks, bike racks, four wheelchair spaces, and handicapped-accessible lavatories.

Refurbishment is under way at the Hialeah maintenance depot, in the northern suburbs of Miami, which was taken over from CSX in 1987. In the short-term, capital improvements are being made to improve the operation at Hialeah, including a new carriage washer, wheel drop pit, underfloor wheel lathe, and new stagings for maintenance access.

Plans are being prepared for construction of a completely new maintenance and operations depot, and a study is under way to see if it should be located at Hialeah or on a new site in West Palm Beach. At present two trains are out-stationed at West Palm Beach each night for the early morning commuter runs, and must be cycled through Hialeah for servicing during the course of each day.

A further major investment for 1997 is a satellite-based train tracking system, using GPS technology. This will enable us to keep track of all the trainsets in service, and provide accurate and timely information in the event of unexpected delays.

Management and finance

Tri-Rail has a small permanent staff, with the executive and administration located in Fort Lauderdale and operations staff at Hialeah depot. Our plans envisage construction of a new headquarters building at Boca Raton, adjacent to one of the new stations.

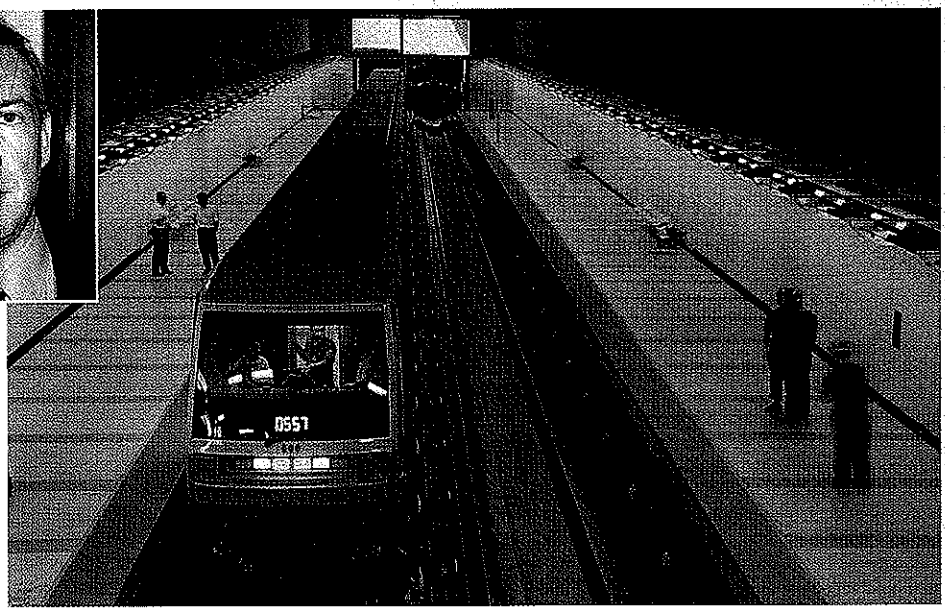
Most activities are contracted out to specialist suppliers. Train operations and maintenance are the responsibility of Herzog Transit Services Inc, and maintenance of the infrastructure is the responsibility of FDoT. As a legacy of the previous ownership, signalling and dispatching are handled from the CSX Dufford Operations Centre at Jacksonville. Security on trains and stations – including fare enforcement – is provided by uniformed officers from Wackenhut Corp.

Ticket sales staff are TRCA employees, but following the installation of Ascom ticket vending machines at all stations early in 1996 only three stations retain staffed booking offices. In April 1995 the original flat fare was replaced by six banded zones, helping to boost fare revenues from longer journeys – at present Tri-Rail recovers around 26% of its operating costs from the farebox with the remainder coming from state, federal, and county subventions. We are looking at the possibility of creating a regional transit authority to manage future Tri-Rail financing, using a mixture of local fuel, sales and property taxes.

Although the last couple of years have not been easy, Tri-Rail has started on the transition to a more secure future. Southern Florida's steadily growing population means mass transit has a major role to play. When our current investment programme is completed in 2000 we will be well-placed to meet that need. ❑

Line 5 will boost metro ridership

Daniel Fernández
President
Santiago Metro SA



APRIL 5 saw celebrations held in Santiago to mark the opening of a third metro line in the Chilean capital. Designated Line 5, the 10·3 km route is the first to be specifically designed to accommodate disabled passengers. It provides a significant addition to the rubber-tyred metro network which in 1996 carried a total of 178 million passengers, serving a city of 5 million inhabitants and covering 500 km².

Construction of the Santiago metro began in 1969, and the first line opened in 1975. This was followed by the first section of Line 2 in 1978. An extension of Line 1 east to E Militar was added in 1980, and Line 2 was extended north to Cal y Canto in 1987, providing a link with the state railway's Mapocho terminus. With completion of Line 5, the network now totals 37 route-km serving 49 stations.

Starting life as a department of the city government, the metro was restructured as a stand-alone company, Metro SA, in 1989. We broke even on our operating budget for the first time in 1995, although the company still receives public funding for capital investment projects. Last year, Lines 1 and 2 carried an average of 654 000 passengers each working day, and we anticipate that patronage will reach 1 million passengers/day by 2000.

Above and below ground

Designed to help alleviate growing transport problems in the centre of Santiago, Line 5 connects the city centre with the southeastern suburb of La Florida. Following three years of studies, construction began in 1994. For this work the route was divided into four sections.

The initial 2·4 km from the interchange with Line 1 at Baquedano to Irarrázaval has been built entirely underground, in order to preserve the Bustamente Park which lies across the route. The route rises to the surface about 600 m beyond Irarrázaval station, and runs on the the surface for the next 1·1 km. This passes close to the Line 5 maintenance depot, where a site has been reserved for a future station.

There is currently one other surface station at Nuble, after which the line climbs onto a viaduct constructed from prefabricated concrete spans carried on piers spaced 36 m apart. This elevated section is 5·8 km long and serves six stations. The last 0·5 km of the route dives back into tunnel to reach the terminus at Bellavista de La Florida. This includes a major bus interchange from which feeder services fan out to serve the outer suburbs.

The total construction cost of Line 5, as calculated in December 1996, amounted to US$483·4m. This includes US$164m for civil works, US$114·8m for electrical and mechanical equipment, US$167m for rolling stock, and US$37·3m for development and project management costs. By the end of February, construction work was 98% complete and 90% of the electrical and mechanical systems had been installed.

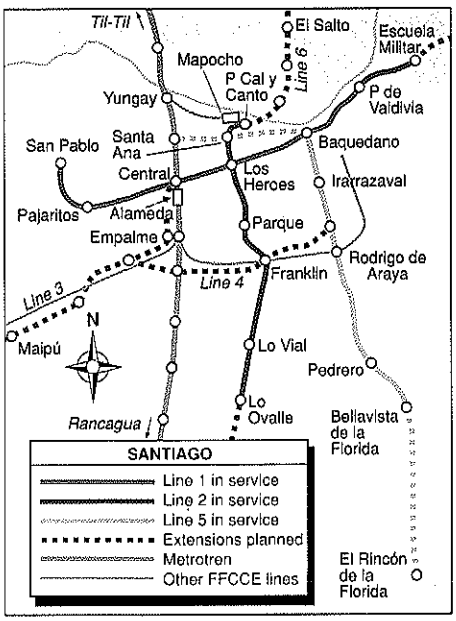
GEC Alsthom has supplied 12 six-car NS93 sets derived from the Paris MP89 design for Line 5, and is now building 12 more to augment the fleet operating on Lines 1 and 2

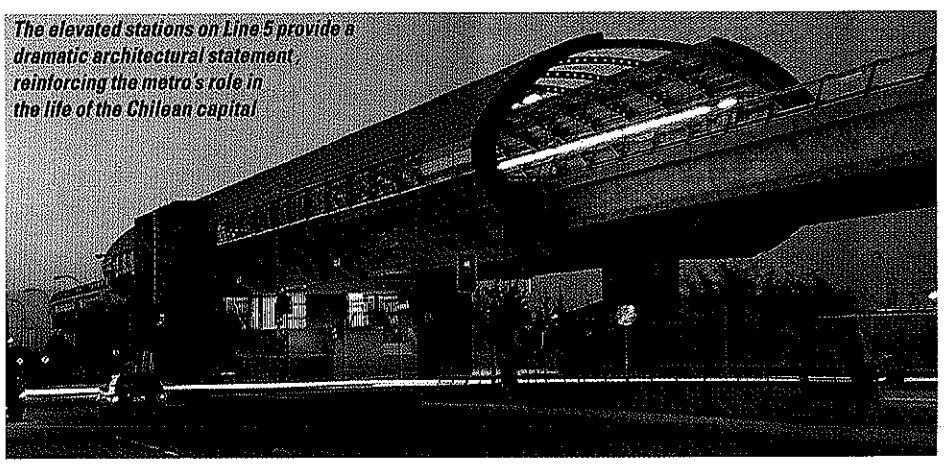
To comply with recent legislation on access for mobility-impaired passengers, all 12 stations on Line 5 have been equipped with lifts and other systems to make them fully-accessible. Setting the standards for future metro extensions, the facilities were designed following study of best practice worldwide.

Investing for the future

Metro SA's current investment strategy is targeted on meeting steadily growing demand by the application of new technology. The next big project to be completed is a US$40m renewal of the signalling, communications and train control system for Lines 1 and 2, which will enable us to provide a higher quality of service with greater operating flexibility.

Key to the project is a new network control centre, together with automatic train operation and a radio communications system. A US$30m contract for the ATC renewal was awarded to CMW Equipamentos of Brazil at the end of





The elevated stations on Line 5 provide a dramatic architectural statement, reinforcing the metro's role in the life of the Chilean capital

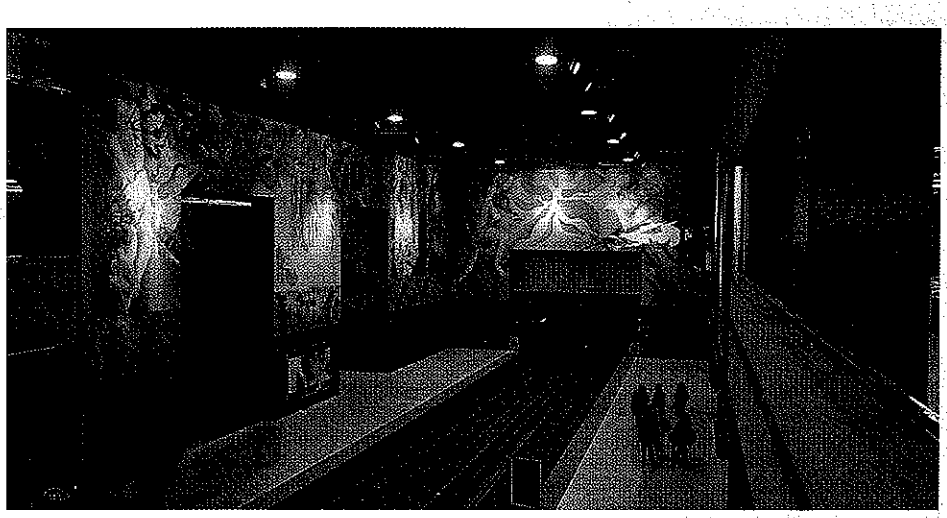
1994, and the work is due to be completed in November 1997. Train control equipment is coming from Syseca of France, which also equipped Line 5.

The resignalling will enable us to reduce the minimum peak-hour headways from the present 115 sec to just 90 sec. To make use of this, we are also installing a new reversing crossover at Las Rejas, west of the city centre, which will enable us to operate a more intensive service on the central section of Line 1.

The US$40m cost of the package will be repaid out of the savings generated by efficient management and tighter cost control, reducing the metro's dependence on continuing public-sector funding.

We are also investing US$120m on an extra 12 six-car trains to boost the capacity of Lines 1 and 2. These are currently worked by a fleet of 49 NS74a and NS74b trainsets delivered by GEC Alsthom in 1975-76, together with a single prototype NS88 trainset supplied by Concarril of Mexico in 1990.

In February, GEC Alsthom completed the delivery of 12 six-car NS93 sets for use on Line 5. These are based on the MP89 stock the company is building for the Paris metro, and were assembled at the CIMT works in Valenciennes. We ordered an extra five NS93 sets for Lines 1 and 2 in July 1996, and we were able to confirm the option for the remaining seven a couple of months later. The first Line 5 cars were delivered in December 1996, and the additional trains will follow them off the production line.



Underground stations on the Santiago metro are laid out on a dramatic scale, giving a feeling of space and light

Line 5 into the city

Last August, Chilean President Eduardo Frei announced a programme of further measures to reduce road congestion and pollution in the capital, which will also benefit the metro. The package includes a 2·8 km extension of Line 5 under the heart of the city, costed at US$140m. Running from Baquedano, the line will curve west to an interchange with Line 2 at Santa Ana, serving intermediate stations at Bellas Artes and Plaza de Armas. Initial studies and soil investigations for the extension began during the second half of 1996, and detailed engineering design should be finished later this year. We hope that tunnelling will begin next February, with the line opening early in 2000.

Further extensions planned for construction by 2015 include another eastern extension of Line 1, continuation of Line 2 south of Lo Ovalle, and extensions of Line 5 both south from La Florida and west from Santa Ana. Three new lines are also envisaged, designated Lines 3, 4 and 6, and a cross-city Metrotren suburban corridor will be created to make use of existing main line tracks (map). ❑

Line 2 construction pushes ahead

Chen Yi-Xin and **Gao Yan-Mei** *

ONCE AGAIN the streets of Shanghai's historic city centre are closed and boarded off for metro construction. Just three years after the completion of Line 1, civil engineering work is in full swing on Line 2, and the pattern is set to be repeated many times over as the city develops a comprehensive metro network for the 21st century.

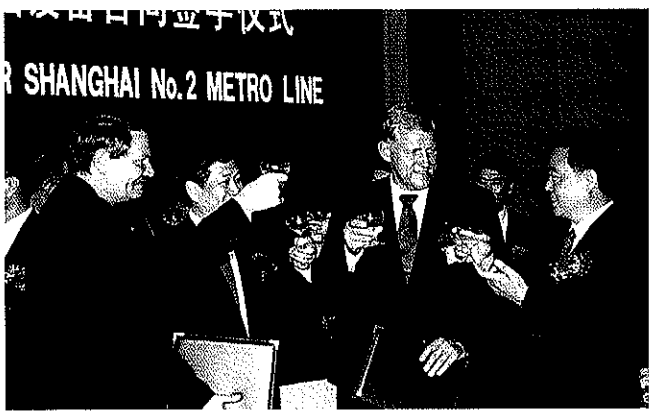
Running east-west across the city centre, Line 2 is one of the principal arteries of the future network. It will start from Hong Qiao International Airport in the west, and follow Tianshan Road towards the city, serving Zhong Shan Park and Jing An Temple before reaching People's Square. Here it will interchange with Line 1 in the very heart of the city.

Heading east along Middle Henan Road, it passes under the Huangpu river to the Lujiazui Finance & Trade Area within the Pudong Free Trade Zone. The route will follow the axial Dongchang Road through Pudong and then turn south through the planned Central Park to terminate at Long Dong Road, where it will connect to a planned main line railway station and the Pudong International Airport now under construction.

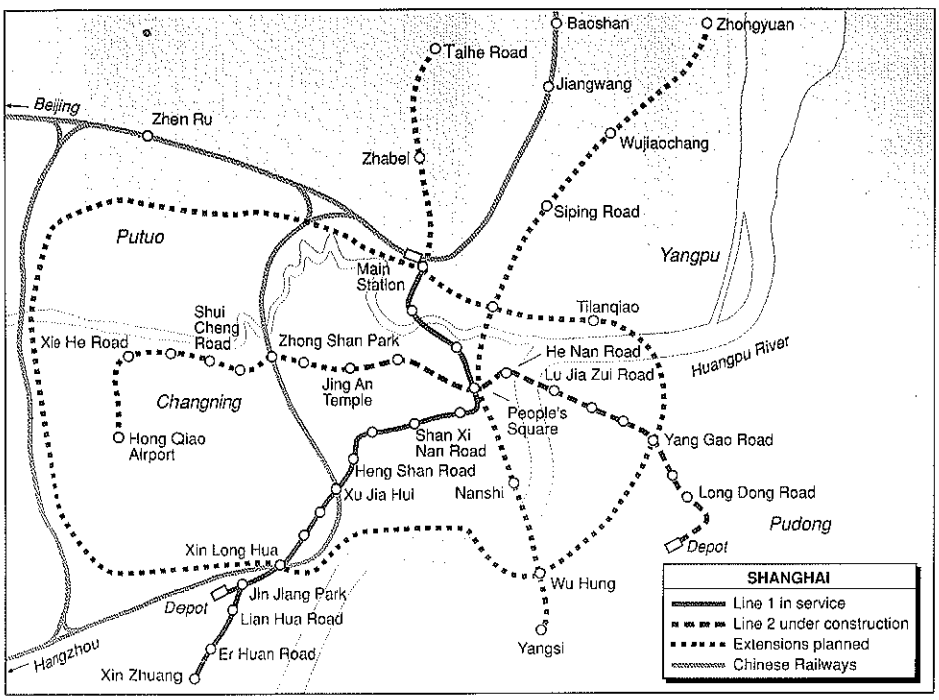
Total length of Line 2 will be 27 km, serving 17 stations of which 14 will be underground. The 13·6 km first phase covers the central and eastern parts of the route, from Jing An Temple to Long Dong Road.

Pudong changes plans

Design of Line 2 began in earnest in 1988, when Shanghai Metro and the Berlin Transportation Consulting Corp drew up a preliminary feasibility report. At that time no plans had been agreed to serve the Pudong New Area, so the eastern end of the line was intended to turn northeast after Middle Henan Road and serve some of the city's most heavily populated districts where heavy passenger flows could be expected.



E&M contracts for the first phase of Shanghai metro Line 2 were signed with the German Shanghai Metro Group in July 1996



All this changed in April 1990, when Premier Li Peng issued a declaration on the opening up and exploitation of the Pudong Free Trade Zone. Shanghai Municipal Government recognised the role which good urban transport could play in promoting the development of Pudong, and realigned the metro route accordingly.

There was a clear development of thinking from 'solving the existing traffic congestion at peak times' to 'distributing the traffic flows between appropriate modes' and finally to 'driving the traffic flows to encourage regional development.' The routing change has been of great significance in improving the attractiveness of Pudong for investment, which in turn has been beneficial for the whole of Shanghai. The city has resumed its traditional role as a window with bilateral relations, facing both outwards to the world and inwards to the whole of China.

Lines 1 and 2 will form a cross serving the heart of the greater Shanghai metropolitan region. With the outer ends connected by new orbital highways, the combined network will provide much needed relief to the city's crowded streets, and act as a centrepiece for long-term planning in the city.

Phase 1 is scheduled to open in 1999, with an initial peak hour flow of 37 000 passengers/h in one direction. By 2025 this is expected to have grown to 73 000 passengers/h. With eight-car trains running at 2½ min headways, the line will be handling almost 10% of all passenger-km in Shanghai.

Civil works

Construction work began at the Pudong end of the line in 1996. The tunnel boring machines are forging ahead, and six of the station boxes have been completed. All the boxes should be finished by the end of this year. Phase I is now expected to be open for revenue service by the end of 1999.

Line 2 will run in twin bored tunnels of 6·2 m diameter (5·5 m inside the concrete lining rings). No fewer than seven tunnel boring machines are in use on the project; five old ones transferred from Line 1 which were built by FCB of France, and two new ones supplied by another French company – Framatome. Careful construction work as the TBMs advance is limiting ground sinkage to between 10 and 30 mm.

Each station box will be 269 m long, containing 186 m platforms beneath a mezzanine level with automatic ticket gates. The two levels will be linked by Otis escalators. Because of the soft estuarial ground in Shanghai, the cut-and-cover stations are being built by the continuous wall method. Rolling stock, power supplies, communications, signalling, water supplies, ventilation and drainage will all be

** Chen Yi-Xin is Senior Executive at Shanghai Metro Corp, and Gao Yan-Mei is a specialist on international finance. Both hold masters degrees in International Economics & Management from Shanghai's Tiedao University.*

the same as on Line 1. Each station will have its own disaster alarms linked to the metro's existing emergency management system.

Total cost of Phase I is put at US$1·5bn, which is being funded by a mix of local funding and foreign loans. The overseas investments will be repaid by the Shanghai Municipal Government over the next 30 years. Domestic funds will be repaid from profits earned by land developments at the stations and along the line.

A co-operation and funding agreement paving the way for work to start was signed on February 8 1996 during a visit to Germany by Vice-Premier Zhu Rongji. After intensive negotiations, a formal contract worth DM730m was signed with the German Shanghai Metro Group towards the end of July. GSMG is the same consortium which equipped Line 1, and has also won a contract to equip Line 1 of the Guangzhou metro. The main partners Adtranz and Siemens will provide the rolling stock, power supplies, and telecommunications equipment.

Other international funding has included a US$80m loan from the French government towards the two extra TBMs and over US$500m from the United States to fund the signalling, ticket checking machines, and other high-tech systems.

Construction of Line 2 is being managed somewhat differently from Line 1. The original route was funded directly through the Municipal Government, as the only competent body at the time. Now that Shanghai Metro Corp is founded and functioning, the responsibilities have been split. The Municipal Government will oversee the investment in the tunnels and the E&M works, whilst SMC will contract for the construction and fitting out of the main lines; local regional governments will fund the investment on stations in their jurisdiction.

Similarly, the responsibility for the contracts, which on Line 1 was left solely to SMC, will now be split between SMC and local contractors assigned to the regional governments.

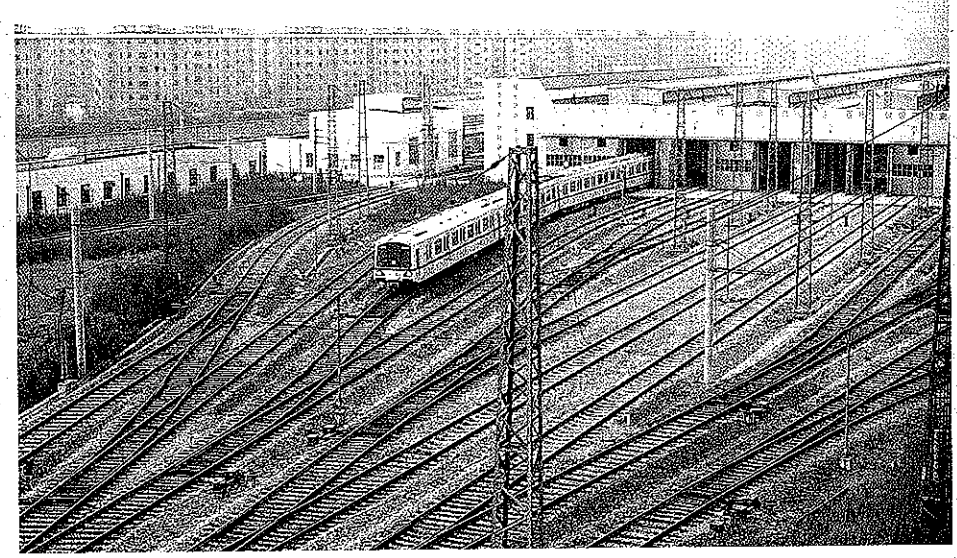
11-line network

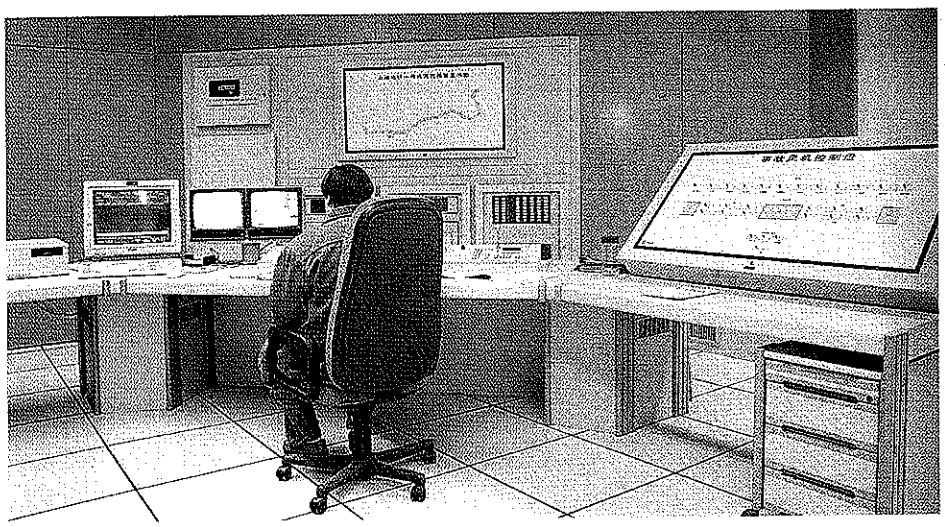
Long-term development programmes envisage that Shanghai's urban area will eventually expand to over 700 km², with a population in excess of 90 million. Clearly such massive numbers will require a very high quality transport network if the city is not to grind to a halt.

Our target is to expand the metro to handle 50% of all public transport trips, which would require a network of almost 400 route-km. To this end SMC is working on plans for a network of 11 lines totalling 320 km, which will be augmented by the existing surface railways and 100 km of elevated roads. The network will comprise six north-south lines, three running east-west, a circle and a semi-circle.

On December 28 1996 we inaugurated a 5·3 km southern extension of Line 1 from Jin Jiang Park to Xin Zhuang, with three extra stations at ground level. Planning is well advanced for a northern extension of around 12 km which will continue Line 1 from Shanghai railway station to Taihe Road.

Feasibility studies began this year for Line 4, which would start from the Zhongyuan resi-

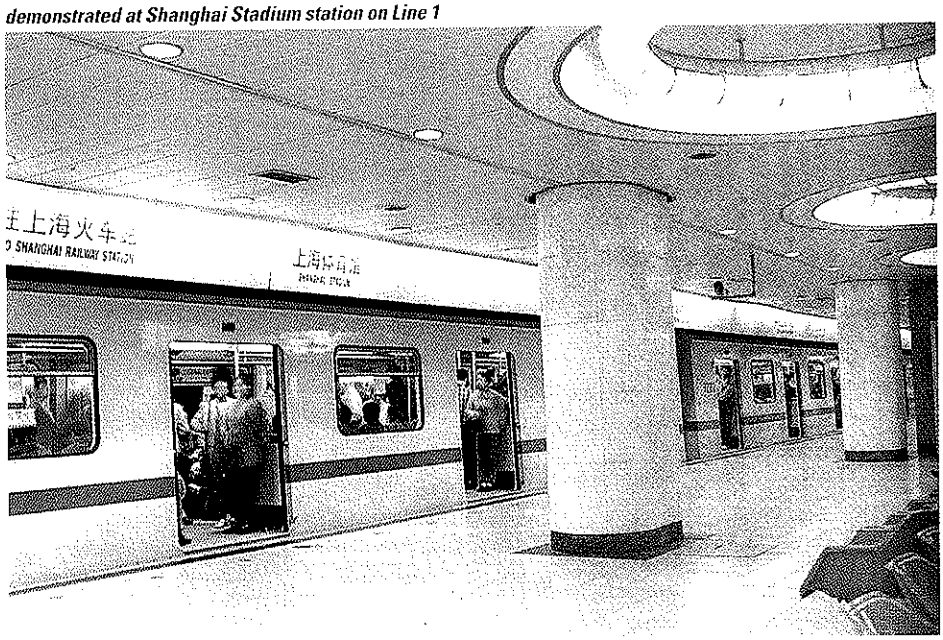




Top: The Line 1 depot at Jin Jiang Park will act as a model for the Line 2 depot at Long Dong Road in Pudong

Above: The Line 1 control centre will also be responsible for managing operations on Line 2 when it opens at the end of 1999

Below: Considerable effort has been put into making the underground station platforms light and airy, as demonstrated at Shanghai Stadium station on Line 1



dential area northeast of the city. Following Zhongyuan Road and Xiangyin Road to Wujiaochang, it would continue along Siping Road to Xizang Road, Lao Ximen and Xieqiao. Crossing the Huangpu river, it would terminate at Yangsi in Pudong. Total length would be 24 km, of which 4·5 km would be elevated. To be built in two stages, Line 4 would also interchange with Lines 1 and 2 at People's Square.

Shanghai Railway Administration has been contracted to undertake the feasibility research for Line 3, which is the western half of the future circle line. It would be completely elevated, following the alignment of the former 'inner circle' railway and a branch of the Songhu railway. Starting from Caoxi Road, it would serve Shanghai station and terminate at the Baoshan steel works. Design of the line is due to be completed by the end of 1999.

The eastern part of the circle starts from Yishan Road in the south, following Lingling Road, Danuqiao Road and Xietu Road to cross the Huangpu river at Dongjia Ferry. Continuing along Pudian Road it will turn north along Dongfang Road back towards the old city. It will then serve Tilanqiao and Zhoujiazui Road before reaching Shanghai railway station again. The 20 km route would be entirely underground, and would be linked into Line 3 to create a complete circle.

Phase II of Line 2, the northern extension of Line 1, Line 4 and the eastern semicircle will together add around 62 km to the SMC network. This will require an investment of about US$4·5bn in 1995 prices between now and 2001. Investment will then continue at US$450m a year with the aim of completing the whole network by 2010.

The citizens of Shanghai, the Municipal Government, and domestic and foreign contractors are all set to benefit from the metro programme. Investment rates, property values and economic development are rising continuously, as Shanghai resumes its historic role as the economic and financial centre of the entire Far East region. ❑

Line 2 will be worked by a fleet of 35 six-car EMUs to the same design as the 16 sets supplied for Line 1 by Siemens and Adtranz

Domestic funding and supply to unlock Chinese metro development

Prof Zhang Wuhua
Advisor, China Academy of Railway Sciences

LOCAL FUNDING of Chinese metro and light rail projects, along with local manufacture of equipment such as rolling stock and signalling systems, have gained much more significance following the government's freeze on construction imposed at the end of 1995 because of national budget constraints. This freeze has particularly affected the works in **Nanjing**, **Qingdao**, **Tianjin** and **Shenyang**.

One of the first fruits of the new policy has been the Changchun-Adtranz Railway Co Ltd joint venture to build metro cars, light rail vehicles, multiple-units and aluminium bodyshells at Changchun. With a staff of 800, this became operational on January 1. Of the US$41·4m start-up investment, Adtranz is providing 51% in cash and Changchun Car Co the remainder in the form of buildings, equipment and land.

Planned annual capacity is 160 vehicles, and the initial production includes the bulk of a batch of 174 metro cars ordered on October 9 1996 by **Beijing** Mass Transit Railway Corp. Costing US$94m, the order is backed by a loan from the Japanese government. Toyo Denki Seizo KK and Nichimen are supplying electrical and mechanical parts for the cars, 60 of which will be built by BMTRC subsidiary Beijing Metro Car Co.

The new cars have been ordered for the 13 km Fuxingmen – Bawangfen extension of Beijing's Line 1. With the existing network suffering from severe overcrowding as traffic grows by an estimated 20% a year, work on the extension has been allowed to continue, with tunnelling for Tian An Men Square station, the capital's largest, completed on September 24 last year. The opening date of the extension remains uncertain, but will definitely not be this year. Because of this continuing uncertainty, BMTRC has halted development work on its planned Lines 4 and 5; efforts to generate local funding for these from property development have proved difficult.

In **Guangzhou**, however, property funding is playing a key role in metro development. Proceeds from the sale of land and public housing have been combined with other sources, including bus shelter advertising revenue and a 5% tax on hotel bills, to meet the US$843m local funding element for Stage I of Line 1. Over the next 10 years Guangzhou expects to raise US$2·4bn for metro construction through property development, principally from the 6·6 km² Pearl River New City. This is expected to comprise the city centre of Guangzhou, and the Tianhe district.

The initial five-station section of Guangzhou Line 1 from Guanggang to Huangsha is due to open on July 1 this year, with the remaining 11 stations on the 18·4 km line scheduled to enter service in the second or third quarter of 1999. Good progress has been made in wet ground by Japanese tunnelling specialist Aoki, the only foreign civil engineering contractor on the project. The first of 20 trainsets for Line 1 was rolled out in Berlin by the German consortium of Adtranz and Siemens on November 27 1996.

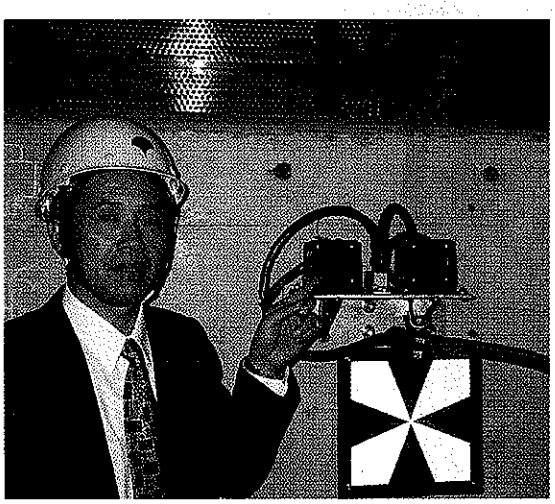
The climate of spending restraint has also prompted research by Adtranz, the Beijing Urban Engineering & Research Institute and Hamburg-Consult into ways of reducing the cost and increasing the capacity of mass transit systems for the Chinese market. A report on standards for integrated light rail systems was published last year, and a feasibility study has been prepared for upgrading the **Anshan** tram network.

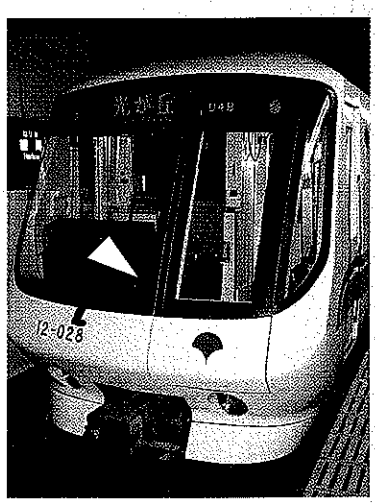
In spite of the recent restrictions, metro and light rail construction may enjoy something of a resurgence this year. It has been estimated that by 2000 one-third of China's 35 cities with a population of 1 million or more will have a metro or light rail system. Metros have been recommended for cities with 3 million or more inhabitants.

Construction of a 27·5 km elevated light rail line in **Wuhan** and a 16·5 km 13-station metro in **Chongqing** are expected to begin during 1997. ❑

Linear motor line to be extended

Mitsuo Kimishima
Chief of Planning
Railway Construction Division
Tokyo Metropolitan Government
Bureau of Transportation





Mitsuo Kimishima demonstrates the optical coupler which is used to transfer data from a transmitter on the front of the train (arrowed right) to a receiver (above), connected to the depot's rolling stock monitoring and maintenance system

BECAUSE OF the high costs of tunnelling in Japan, Tokyo Metropolitan Government (TOEI) was faced in the 1980s with the need to reduce the price of building metro lines in the capital. One way of doing this was to reduce tunnel diameters, and the government therefore designed Line 12 as a small-profile route. Linear motor traction and rigid catenary bars were chosen to minimise the height of the trains, and in this way the internal diameter of a single track tunnel was reduced from 6·2 m on the Shinjuku line, for example, to 4·3 m.

The first section of Line 12 between Hikarigaoka and Nerima in the northwestern suburbs opened in December 1991, and the plan was to continue on a radial alignment towards central Tokyo as far as Shinjuku, 14 km from Hikarigaoka. From Shinjuku the main part of the route was to form a 29 km loop encircling the main business part of the Japanese capital. The whole route was originally scheduled to open in 1996, but shortages of funds and construction delays held up the project. Line 12 is one of four in Tokyo that are operated by TOEI; the other nine are run by Tokyo Rapid Transit Authority (Eidan).

Work has since progressed on the second section of Line 12, and trains should start carrying passengers from Nerima to Shinjuku at the end of this year. The complete loop is due to be opened in 2000, although even that represents a tight timetable. Beyond that lie plans to extend the line 4 km further west as far as Oizumi-Gakoen.

When the loop round the city centre is complete, passengers will have access to numerous other rail routes – there is interchange to JR services and private railways at 22 of the 38 stations, providing the underground equivalent of JR's heavily used Yamanote loop line.

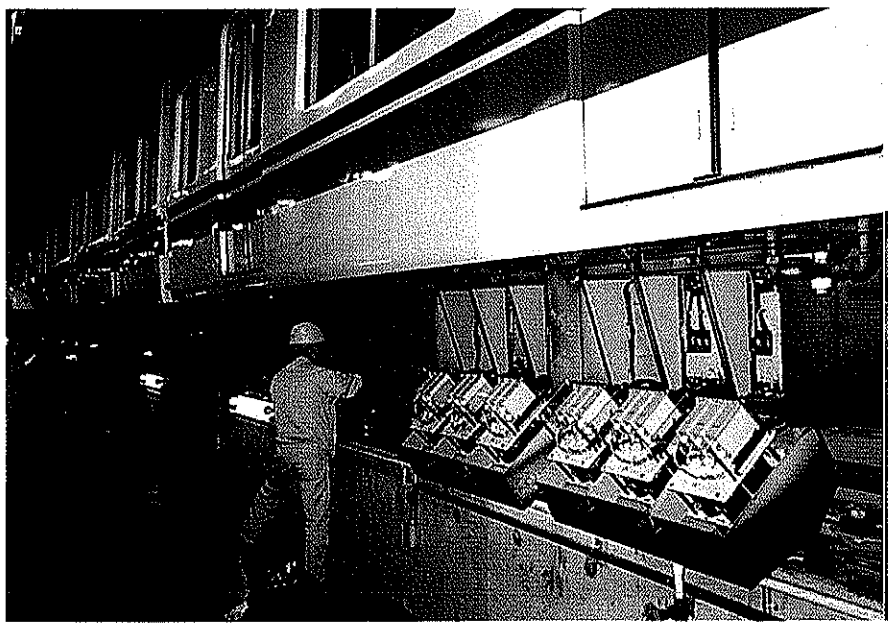
Fleet augmented

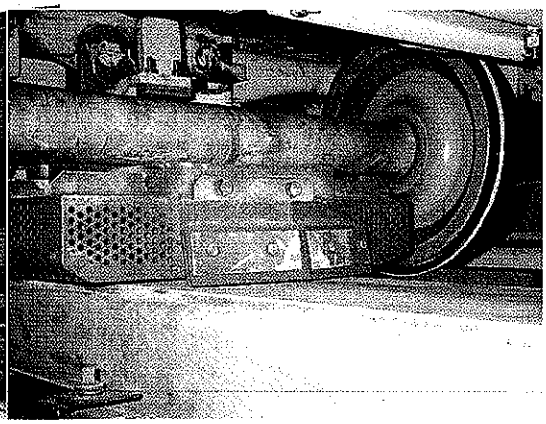
The rolling stock comprises an initial fleet of five six-car trains supplied in time for the original opening. Another set with detail modifications was added in 1994. To provide sufficient rolling stock for opening of the line to Shinjuku, the first of nine eight-car trains was delivered in March from Nippon Sharyo and Hitachi; Toshiba and Mitsubishi supplied some of the electrical equipment. In the same delivery are two more intermediate cars for each of the earlier sets, giving a total fleet of 15 eight-car units.

The section from Hikarigaoka to Nerimakasugacho is formed of two bores, but from Nerimakasugacho through Toshimaen to Nerima a double track bore has been constructed. In the single track bores there are wall niches accessed by steps to form refuges for staff in the tunnel, but on the double-track section a central pit is provided between the two tracks.

No effort has been spared to ensure that Line 12 is easy to use. Lifts and slopes make it accessible to wheelchair passengers, although this has added to the construction cost. At city centre locations lifts to the stations will be provided in adjacent buildings. Tactile markings are provided for blind or visually handicapped people, and ticket and information machines can respond to requests by 'speaking'. Low-level handrails for children are provided in passages.

Traffic to and from Hikarigaoka was heavy from the opening day. A complete town for 30 000 people has been built on a former US military base, and one section of the town lies directly above the Line 12 depot and workshop beyond the terminus. A second depot is being built at the far end of the city centre loop

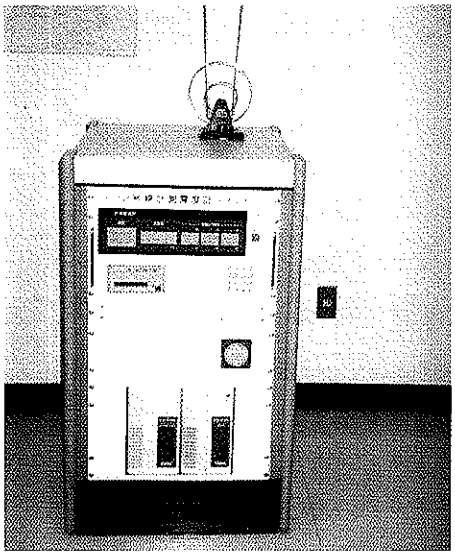




Tokyo Line 12 is operated by linear motor powered trains. As well as routine checks to the underfloor equipment (left), a key task undertaken at the Hikarigaoka servicing depot is to ensure the correct air gap between the underslung motors and the reaction rail (below)

at Kiba near Kiyosumi.

The Hikarigaoka maintenance depot is on three levels. A bogie inspection shop is provided on the ground floor, and below this is are the main car inspection bays. At the third basement level is an array of sidings. The depot is fitted with a sophisticated maintenance supervision system termed DSK. This has four principal functions: car inspection, car use monitoring, materials control, and life history supervision. Each of these functions is controlled from a workstation in the depot, where an optical LAN is used to store and move data.



In the main control room at Hikarigaoka is an earthquake detection device that will automatically reduce the speed of trains if a specified threshold on the Richter scale is exceeded

Line 12 will eventually serve 22 interchanges, forming a much-needed addition to Tokyo's rail network

When a train arrives in the depot the on-board equipment inspection system is activated, and data about the train's equipment is transferred by an optical beam transmitter in the cab to a receiver at the end of the track. The data passes through an interface to the LAN, allowing the depot staff to check any item and relate it to the relevant car's previous performance in its life history; they can print out any necessary details in Kanji (Chinese characters) script.

Equipment checked in this way includes train radio, ATO and ATC, brakes, pneumatics, door actuators and air-conditioning. Also fed to the LAN is information about the gap between the train's linear motor and the reaction plate in the track. This distance must be kept constant at 12 mm, which requires frequent attention because of wear of wheels and rails. The information is collected by a special gap monitoring device at the entrance to each depot track. ❑

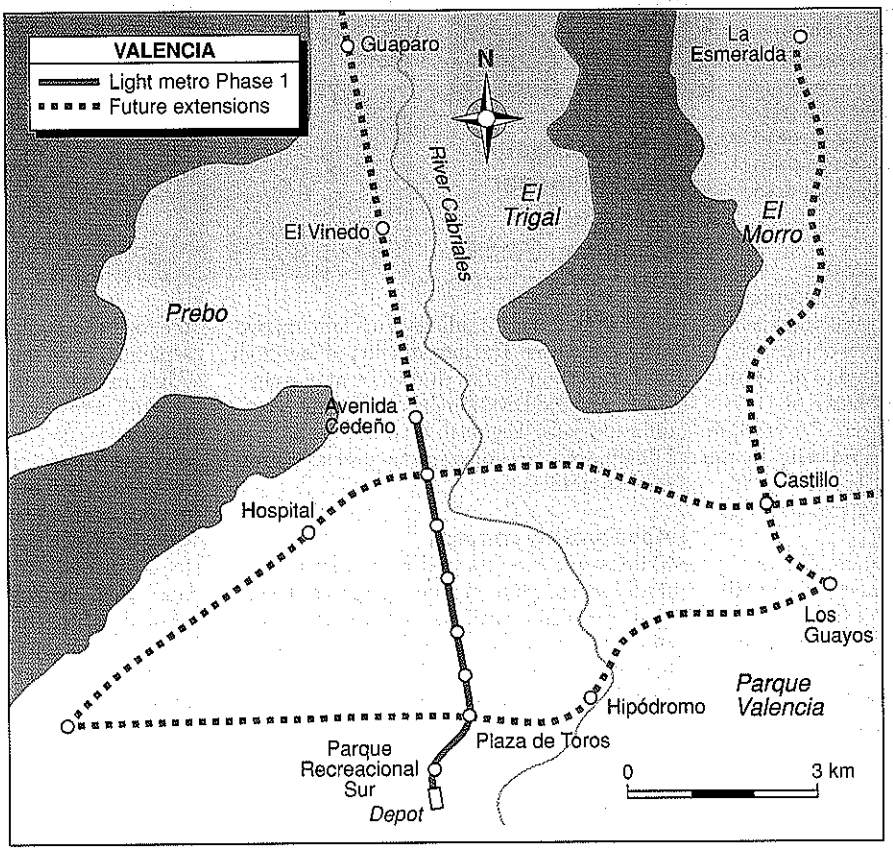
Investing in a better quality of life

Ing Luis Diaz Eliaz
President
CA Metro de Valencia

LOCATED in Carabobo state, 158 km west of Caracas, Valencia is one of Venezuela's fastest-growing cities. Its population has increased ten-fold since the 1950s, growing from less than 100 000 to over 1 million in the space of 40 years. Absorbing the neighbouring communities of Naguanagua, Guacara, Tocuyito, Los Guayos and San Diego, Valencia has transformed itself from a farming town into the centre of Venezuelan manufacturing industry. The city is also the major centre for administrative, commercial and service industries in the region.

This rapid growth has generated more traffic and increased the demand for public transport. Today Valencia suffers from serious road congestion, which is certain to get worse unless steps are taken to decrease reliance on road transport. Following Valencia's first municipal elections, the city authorities decided in 1990 to commission fresh studies into the feasibility of building a rapid transit network, and what characteristics this system should have.

The favoured solution is the construction of a light metro network serving the principal corridors, backed up by a feeder network of bus routes to less busy areas. The integrated solution will provide a comfortable, rapid and safe service. A reliable public transport network will help to relieve traffic congestion, whilst the use of electric traction on the trunk corridors will help reduce noise and air pollution. It is also hoped that the light metro will assist urban development and create jobs during the construction and operation phases.



Phase I starts small

In 1991 CA Metro de Valencia was formed to develop, build, commission and administer the light metro. Following a competitive tendering process, study contracts were awarded to Venezuelan companies later that year; the study period ran from January 1992 to August 1993. Soon after the studies were completed, survey work began along the alignment selected for Phase I, and a contract for preliminary civil engineering design was let in July 1994. Construction work began towards the end of that year. Agreement has now been reached for the supply of electrical and mechanical equipment, and operations are expected to begin in the second half of 1999.

The first line to be built is a north – south corridor through the heart of the city, along the valley of the Cabriales river. Phase I covers the 6·2 km southern section along Avenida Las Ferias from Avenida Cedeño in the city centre to Parque Recreacional Sur, serving eight stations. The main depot and workshops will be located at the southern end of the route. This will include a 2·3 km tunnel section and three underground stations with 120 m long platforms, for which a contract is due to be announced in the middle of 1997.

Government guarantees have been arranged for an international financing package to fund supply of electrical and mechanical equipment. Eximbank is providing US$80m for the first phase, with scope to increase this to US$150m to cover the second stage. A contract has been agreed with Siemens Transportation Systems of the USA, which will be implemented as soon as the funding package has been signed.

Siemens will provide the track, power supplies, fare collection and rolling stock for the initial section, including 12 light rail vehicles to the SD-400 design used by the St Louis Metrolink line. These will run at a maximum speed of 80 km/h, and will operate in pairs carrying up to 550 passengers per train, leaving two vehicles in reserve.

With trains operating every 4 min and offering an end-to-end journey time of just 12 min, design capacity will be 35 000 passengers/h in each direction. Initial demand is expected to be 10 500 passengers/h each way, leaving ample spare capacity for growth.

Four-line network

Once Phase I has been completed, the city will push ahead with construction of the the second phase of Line 1. This will continue northwards from Avenida Cedeño along Avenida Bolívar to serve the districts of El Vinedo and Guaparo and the northern suburb of Naguanagua.

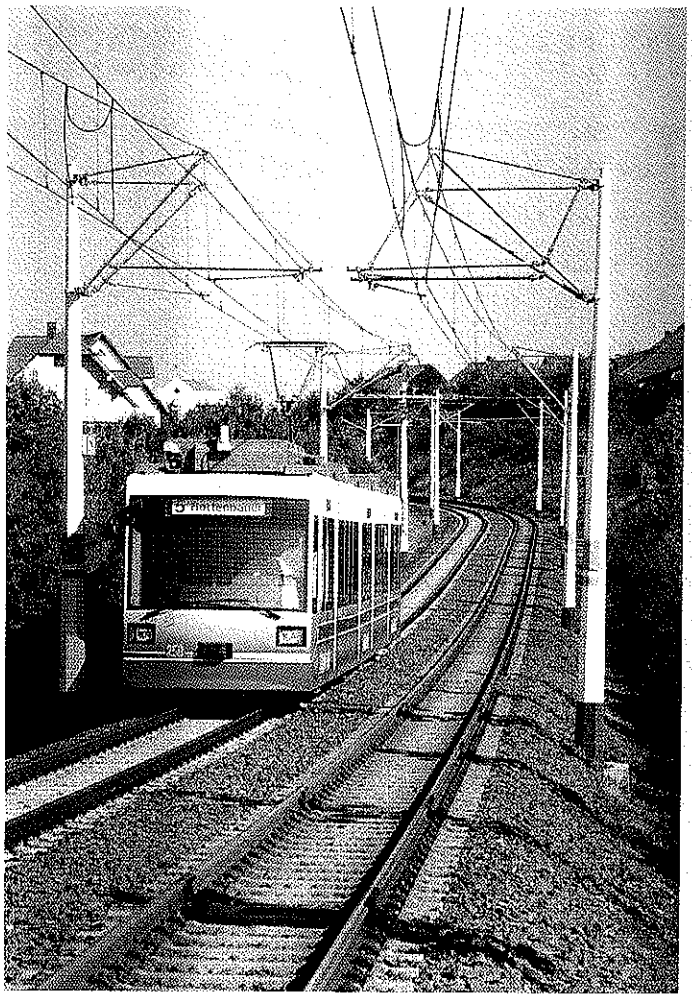
Three other lines are envisaged as part of the core network. The second will run east - west across the city, starting in the southwest. Line 2 will follow Avenida Lisandro Alvarado past the main hospital before turning east along Avenida Taha to an interchange with Line 1. Continuing east to the intersection of the ring motorway and the Valencia – Caracas motorway, it would then turn southeast towards the main industrial zone.

Line 3 would also run from west to east, looping around the southern suburbs. Starting from the same place as Line 2, it would head east along Avenida Sesquicentenario to an interchange with Line 1 at Plaza de Toros, just north of the terminus at Parque Recreacional Sur. Line 3 would then continue past the Hipódromo and along the edge of Parque Valencia to a terminus at Los Guayos in the southeast.

Line 4 would serve the eastern edges of the conurbation, following Avenida Industrial. Starting from the Line 3 interchange at Los Guayos, it would run north through the industrial zone to connect with Line 2, and then cross the Caracas – Valencia motorway corridor at Castillito. It would then head north through El Morro to a terminus at La Esmeralda, serving a populous residential area cut off from the main part of the city by a range of hills.

In the longer term, construction of the planned heavy rail corridor from Caracas to Puerto Caballo via Tuy Medio would bring inter-city freight and passenger services to Valencia. Topographical limitations would prevent the railway running into the city centre, so the main station would be built at Los Guayos and a second passenger station at Naguanagua. The light metro would play an important role as a feeder from these two stations to key residential, commercial and industrial areas around the city. ❑

Bavarian city goes greener



OPENING of the 5 km Line 5 to Heuchelhof on November 30 1989 proved a turning point for the tramway network in the historic Bavarian city of Würzburg, which sits astride the River Main among vine-clad hillsides. The modern features of the Heuchelhof line, and its GT-E cars with low-floor sections, were soon popular and helped to increase acceptance of the trams among the citizens of Würzburg.

In the mid-1980s the street-running sections of Würzburg's metre-gauge network were faced with increasing motor traffic that caused serious delays. At the same time passengers had to travel in an ageing fleet of first-generation articulated trams dating from the wave of modernisation in the 1960s.

The situation could not continue unchanged, and a decision was taken in 1986 to retain and extend the tramway network using dedicated rights of way and to introduce priority over other road traffic at junctions. A ruling was also made to keep the trams on the surface in a pedestrianised city centre. The overall length of the network now stands at 43·5 km.

Karl-Heinz Utschig
General Manager
Würzburger
Straßenbahn GmbH

Priority measures boost traffic

The priority measures and track relocation speeded up services and improved punctuality. Combined with the introduction of the first low-floor accommodation, fitted to the GT-E cars built by Linke-Hofmann-Busch of Salzgitter, and the opening of Line 5, this led to an increase in public transport ridership for the whole of Würzburg of 32·5% between 1989 and 1996. Within this the tram's increase was proportionally higher.

This boom in traffic led to a decision to order 20 GT-N all-low-floor LRVs from LHB at a cost of DM90m. The first car was delivered in spring 1996, and they entered service in September on Route 2. These six-axle cars with all axles powered, and the GT-E cars, cope admirably with severe gradients of up to 9·1% as they climb to serve new housing developments in the leafy southern suburbs.

With no further space available at Sanderau, a new depot to house the low-floor cars was built at Heuchelhof, at a cost of DM9m. It has 10 sidings, each holding two articulated cars. The introduction of low-floor cars also required the refurbishment of tram stops. Around DM2·5m has been spent on adjusting kerb heights to between 50 and 70 mm, so as to provide same-level access for the less mobile.

Acceleration concept

Major works are now under way to convert traditional street track into segregated rights-of-way, which we call our 'acceleration concept'. A 1 km section of Frankfurter Strasse has already been altered. Work started in March 1995 and it took just over a year to convert the traditional track in the centre of the road to a double track central reservation separated from single lanes of motor traffic by 750 mm wide strips planted with small shrubs.

Work started in November 1996 to rebuild Friedensbrücke. Dating from 1888, the bridge carrying Routes 2 and 4 across the river Main to Zellerau will be widened to 25 m over a period of three years at a cost of DM34m. This will allow both tram tracks to be moved from the centre of the road to a reservation on the south side, dividing a cycleway from four lanes of road traffic. The tracks will also cross the road junction into Luitpoldstrasse in a straight line rather than on the present curved alignment crossing a stream of traffic.

Work has also started in Virchowstrasse,

The 20-strong fleet of GT-N five-section 6-axle cars built by Linke-Hofmann-Busch with Siemens motors and Adtranz bogies have been introduced on Line 5. These high performance all-low-floor cars are equally at home absorbing passengers in the city centre (bottom left) and on the new high speed reserved formation on the 6 km run to the villages of Heuchelhof and Rottenbauer (left)

with completion expected in the spring of 1998. A 600 m segment is being upgraded in the same way as in Frankfurter Strasse, with a reverse curve eliminated at Ehehaltenhaus. The tram stop here, along with that at Eichendorffstraße, will be relocated and redesigned. Tree planting is an important element of this work, which will cost DM13m.

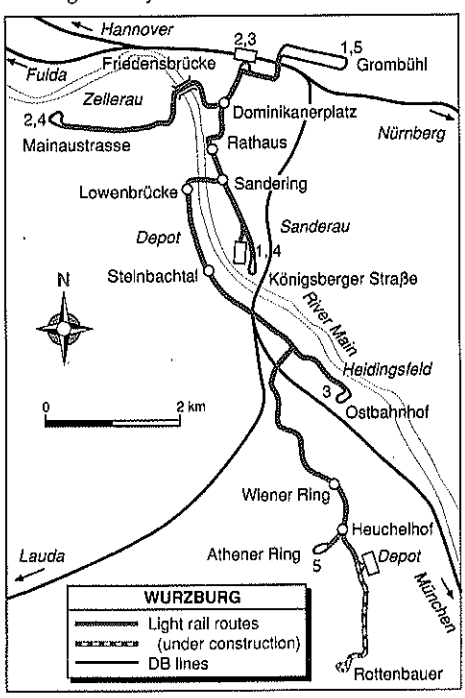
Other improvements

Also due to start in the near future is a DM20m redesign of the approaches to Hauptbahnhof, which will see the turning loop lengthened and construction of a new double track tram station with attractive covered waiting areas. Motor traffic, which at present still has to cross tram tracks in the station forecourt, will be routed elsewhere.

Future plans also include a central interchange in Juliuspromenade, which will be served by trams and buses, replacing stops at Dominikanerplatz and Barbarossaplatz. This plan has yet to be ratified by the local authority.

In contrast, a further 1·2 km extension of Line 5 from Heuchelhof to Rottenbauer is already under construction. Good urban planning will see the whole of this modern park-like residential area served by low-floor trams without the need for any bus routes. Barring unforeseen circumstances, the DM16m project will be completed this year.

During 1996 we also introduced automatic ticket vending machines at all stops, further speeding the operation of light rail services, which will give our city efficient public transport and an attractive environment for the coming century. ❑



Tramway upgrade presages metro plan

Eng Branko Mikinac
Traffic Manager
Zagreb Electric Tramways

OVER the next three or four years, several extensions will extend the reach of Zagreb Electric Tramways to the new suburbs springing up around the Croatian capital. As the former Yugoslav republic recovers from the ravages of war, economic growth is starting to take off, and major plans have been launched for the development of the capital's central business district. These include a heavy metro or S-Bahn which could interwork with or take over parts of the existing tram network.

Today the 1 000 mm gauge ZET network comprises 200 km of routes, linking the historic core of the city with districts south of the River Sava such as Utrine, Zaprude and Sopot. Services are provided on 15 routes from 04.00 to 24.00, and on four night routes from 00.00 to 04.00. Of the 15 daytime routes, 11 radiate from the city centre to outlying areas, whilst two are local suburban services which do not pass through the city centre. In the central area there are three focal points: the main railway and bus stations and Josip Jelacic Square.

Average route length is 9·1 km, with the longest 13 km and the shortest 2·7 km. During the week, the trams make 4 268 individual journeys. Average headway is 7 min at peak times, and 7 ½ min off-peak. Total capacity is around 29 000 passengers/h. Commercial speeds are 14 km/h on reserved track and 7 to 10 km/h on the street-running sections.

Rolling stock replacement

The ZET fleet comprises 250 motor and 172 trailer cars. There are seven types of motor car, both conventional and articulated, accommodating between 95 and 197 passengers per vehicle. The three types of trailer carry between 116 and 132 passengers each. Services are operated by one motor car and up to two trailers. On weekdays there are 170 motor cars in traffic, with 129 trailers. On Saturdays 124 motors and 87 trailers are deployed, whilst on Sundays this falls to 109 and 75.

The average age of the fleet is 22·1 years. The oldest motor cars are the 51 Class TKM 101 four-wheelers built by Duro Dakovic, which are now over 30 years old. It is likely that they will be scrapped in the next few years, as rebuilding is not a viable proposition for vehicles of this age. Nine of the original 60 cars have already been withdrawn.

Work is under way to rebuild the 30 Class 201 bogie motor cars built by Duro Dakovic as type TMK 1Z in 1975-76. The prototype TMK 2101 was rolled out by local supplier Konkar Engineering as a three-section eight-axle articulated car in the summer of 1994. Another five conversions are under way, and a further 24 sets of electrical equipment have been ordered from Adtranz to complete the process.

The core of the fleet are 51 Class 301 articulated cars from Tatra of the Czech Republic and 94 similar four-axle cars designated Class 401. These run with the 77 B4 trailer cars, which are more modern than the 115 locally-built TP1Z trailers supplied by Duro Dakovic.

A batch of 34 second-hand Duewag Type GT-6 articulated trams was purchased from Mannheim in 1994-95, and put into service on routes 1, 8 and 13. Designated TMK 901, these cars are expected to remain in service for a period of at least five to seven years, until new vehicles have been purchased to replace the remaining TKM 101 four-wheelers.

In addition to the purchase of new vehicles, ZET has also developed plans to expand its

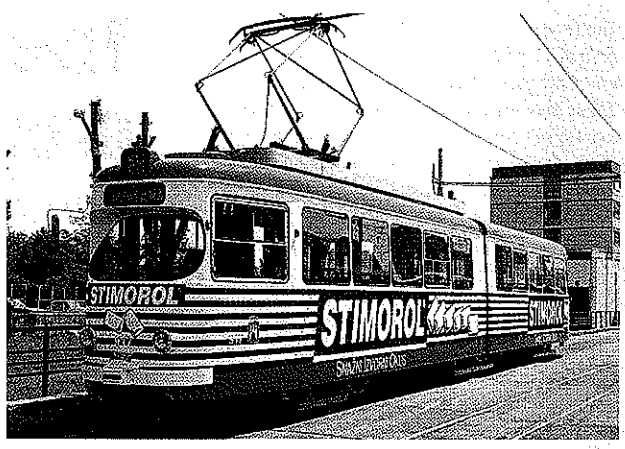
One of ZET's 30 Class 201 cars has been rebuilt by Konkar Engineering as a three-section articulated car designated Class 2101, and the remainder will be converted over the next few years

network by 2000. However, this timescale is becoming increasingly uncertain because of the high costs involved.

Dubrava Avenue is already one of Zagreb's principal east-west arteries across the city centre, carrying heavy tram traffic as far as a bus-rail interchange at Dubrava in the northeast. Plans are now being developed for a 7 km extension from the existing terminus at the end of Maksimirska Street to the new suburb of Dubec. To the northwest, an extension from Crnomerec along Ilica Street to Vrapce is also under consideration. In the city centre, a 1·8 km extension along Vukovar Avenue from Tratinska to Savksa is planned, together with 170 m of new alignment at Savski Gaj.

Substantial expansion is envisaged in the southwestern outskirts, where 4 km of new route is planned to serve the residential area at Precko. The first step is to extend the existing branch from Jadranski Most to Cankoviceva Street by 2·3 km along Horvacanska Street to Precko. Horvacanska Street is being widened to dual carriageway, and a wide median strip has been reserved to accommodate segregated tram tracks. The new junction of Horvacanska and Cankoviceva Streets has already been laid out with the future tram route in mind.

However, the existing route along Horvacanska Street from Savski Most to Jarun runs along the heavily-congested Savska Street, which is also used by the intensive feeder bus services which connect the traffic to the Ljubljanica tram terminus. ZET is studying an alternative alignment which would cut travelling times from the outskirts to the city centre, as well as relieving the Savska Street bottleneck. A 900 m cut-off would run north from Horvacanska Street alongside the Crnomerec Brook and through the yard of an existing tram depot to join the Ljubljanica Street branch.



Latest additions to the ZET fleet are these second-hand Duewag Class 901 cars from Mannheim.

We envisage that this cut-off would form the first stage of a 9 km north-south radial route, which would continue northwards along the Cronomerec Brook corridor to meet the existing line along Ilica Street. This would fill a chronic gap in the present network; ZET is particularly short of north-south links across the River Sava. Another north-south corridor is also being planned, which would head south from the main railway station to cross the river on the existing Most Slobode bridge. It would then run to the Novi Zagreb suburb of Velika Gorica, interchanging with the existing southern loop line at Sopot.

S-Bahn or metro tunnel

In the longer term, development plans for the city centre are expected to bring major changes to the tram network. New underground railway alignments are envisaged to ensure the future efficiency of public transport in the city centre. These could be operated either as heavy metro or S-Bahn routes or as a high-capacity light rail system worked with new LRVs. Outside the central area, the tunnel routes would be connected to new surface alignments built on dedicated rights of way.

Top priority will probably be a north-south route from Zrinjevac to Stjepan Radic Square and over the river Sava to Novi Zagreb, splitting there into routes to Velika Gorica and Pleso Airport. This route would be built to heavy metro standards, with 1 435 mm gauge and third rail power supplies. Some reserved track suburban sections of the tram network may be converted to standard gauge and connected to feed into the core tunnel section. ❑

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