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Minimetros miss the target

Anticipated savings from eliminating drivers through full automation have not materialised, finds Tom Parkinson, as capital and operating costs remain high. Greater benefits come from closer headways and flexible response to traffic surges

AUTOMATION of urban public transport has been a goal of operators ever since Frank Sprague demonstrated multiple-unit operation in 1897. During the 20th century, automatic acceleration became a feature of motor control systems, and coded track circuits provided signals and speed limits in the driver's cab. So it was not a large step to merge these to drive a train automatically.

The acronyms can be confusing. Automatic train control (ATC) combines automatic train protection (ATP), the signalling function; automatic train operation (ATO), the driving function; and automatic train supervision (ATS), the despatching or CTC function. ATO is often assumed to include ATP.

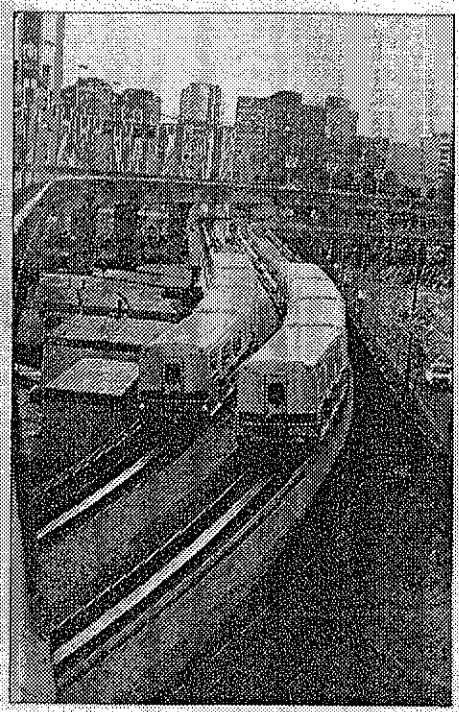
There are disputes as to who had the first 'automatic control'. There have been many demonstrations, and the Post Office railway has been busily moving mail under London for over 60 years. But the modern trend really took off in 1960, when two railways entered public service using automatic driving: NYCTA's Times Square shuttle and Barcelona's Horta line are clear candidates for the first full scale operation.

As these two lines entered service, Bart in the San Francisco Bay Area was starting development of an automatic train control system. Five quite different automatic train control concepts were developed and tested. These ranged from 'overlay' systems where ATO and ATS are added to conventional coded track circuit signal systems, to a novel General Electric scheme with moving blocks using radar in a wayside waveguide. There were even thoughts of having the radar detect obstacles in the roadbed.

Tenders were opened in 1967 and the contract awarded to the low bidder Westinghouse Electric Corporation with a system that deviated from the one tested on Bart's Walnut Creek test track. Aerospace engineers had displaced the conservative railway signalling engineers with claims of lower cost equipment. It was also lower performance equipment, and the many difficulties that befell Bart in its first decade of operation set back to ATC in North America, overshadowing the success of Patco's Philadelphia – Lindenwold line which quietly and efficiently ran under full overlay type ATC from 1969. Subsequently overlay ATC has dominated other North American installations.

Early ATC systems were complex, with bulky and expensive vehicle and lineside equipment. The advantages were questionable. ATC was hardly a prerequisite to one man train operation, headways were little or no better than conventional signalling, while reliability left much to be desired. Even so, by the beginning of this decade some 20 rapid transit lines around the world had been equipped with ATC. But all retained attendants in the driver's cab, most with door control and starting roles.

The attendant's job is boring, and it is difficult to sustain continual attentiveness. Patco even allowed attendants, on request, to assume manual control outside peak hours. Incidences of emergency braking on two North American systems showed that in a majority of cases there was either nothing there or the object spotted was within the train's braking distance and was struck. Meanwhile, increasing security concerns were adding staff to the trains to deal with fractious passengers and perpetual door problems.



First fully automated metro with steel wheels was BC Transit's 21 km line in Vancouver, which has carried up to 150 000 passengers/day since 1986

Westinghouse Electric's rubber-tyred airport shuttle has found an urban application as a downtown feeder for Miami's heavy metro line

Enter the minimetro

At about this time the dream of the perfect peoplemover evolved into a race to develop a driverless automated guideway transit system, or minimetro, for the mythical intermediate capacity market. Fortuitously, this coincided with the availability of low cost microprocessors, fibre optics and other control system advances. The concept of driverless operation was pursued by several minimetro developers following the success of driverless shuttle operations in airports and other sheltered locations. The goals were numerous: lower operating costs or the better use of staff to deal with passengers, closer headways, the ability to add trains to service rapidly, and freedom from staff shortages, absenteeism or concerns of alcohol or other substance abuse.

First off the starting block was the Westinghouse Electric Corporation with its rubber-tyred Transit Expressway, demon-

Portland's light rail was dramatically cheaper to build than an equivalent automated line

strated in South Park, Pittsburgh in 1964 but not installed as an airport shuttle at Tampa International Airport until 1971. There are now 10 Westinghouse shuttle installations, including two lines at London's Gatwick airport, opened in 1983 and 1988, and the 3·0 km double-track loop Miami Metromover, opened in 1986.

The Japanese proposed driverless operation for two minimetros with different technologies, both using rubber-tyred cars. The 6·4 km Kobe Portliner opened in February 1981, and the 6·6 km Osaka NewTram the following month. To their embarrassment, a combination of regulatory and social pressures have left the NewTram with a constant white gloved attendant while the Portliner carries an attendant in the front at limited times. Both lines carry some 15 million passengers each year. Other driverless minimetros are under construction in Yokohama, Kobe and Tokadai and may fare better. They are scheduled to open in 1989, 1989 and 1990 respectively.

In May 1983 BC Transit opened the 1·1 km Vancouver SkyTrain pre-build demonstration which carried some 250 000 passengers over the next six months. The UTDC ALRT technology operated flawlessly, helped by the lack of any curves. A survey revealed that the public were quite indifferent to the omission of drivers, only the politicians and railway inspectorate seemed worried.

The next driverless system to enter revenue service was Lille's VAL line in 1984, after lengthy public trials. This was the first fully fledged driverless urban transit system. It was an immediate success, attracting higher patronage than anticipated and demonstrating headways down to 60 sec with a fixed block ATC system. Its developer, Matra, is aggressively promoting the system and has made design changes to provide wider cars and a less bulky elevated guideway. Matra is also developing a moving block train control system. Short VAL lines are under construction at Chicago's O'Hare airport, and in Jacksonville, Florida (p673). VAL has been selected for urban lines in a further three French cities, in Taipei, and as an RER feeder to Orly airport in Paris.

The longest driverless minimetro, Vancouver's 22 km SkyTrain, opened in January 1986. Intense use during the Expo 86 world fair introduced rail corrugations and bogie problems resulting in high noise levels, since partially corrected. During the fair the system carried over 150 000 passengers per day on the main line and on an integrated express shuttle. The shuttle reversed on the main line some 50 sec ahead of a main-line train moving at 50 km/h. This remarkable feat continued without service delays for six months and would not have been possible without the driverless moving block ATC system.

Vancouver uses the German developed SelTrac, already in use on main-line railways and metros and subsequently selected as the control system for competing minimetro systems: M-Bahn, under construction in Las Vegas, the Bombardier Disney monorail, and a light rail line in Düsseldorf.

The Detroit Downtown People Mover, a 4·6 km single track loop, opened in 1987, without drivers or attendants, using the same technology as Vancouver. Later that year the Docklands Light Railway entered service (p664). Two routes, totalling 12 km, connect London's Underground and British Rail networks to major redevelopments along the now abandoned docks east of London's financial centre. Conventional standard gauge light rail vehicles with third-rail power collection use a hybrid overlay ATC developed by GEC. Data communication from central control to the trains occurs only at 'docking data links' in stations and ahead of junctions. There is no driver or cab but each train carries a 'train captain' who dispatches the train from each station by closing the doors.

Aims and objectives

Excluding small systems in controlled environments, there are now five full time driverless transit systems in the world. Table I compares these with typical light rail systems from the same countries: Canada, France and the United States. The differences between the driverless systems can be illustrated by looking at their aims and comparing operating results between the three major systems and new light rail lines.

Platform edge safety is a major concern of driverless systems. Lille has platform doors that open synchronously with the car doors. The additional cost is modest where the line is underground, but adds appreciably to the cost of at-grade or elevated stations.

Vancouver considered platform doors but felt that they may not meet the North American fire and life safety evacuation codes under certain circumstances. Instead an electronic surveillance system was developed which stops trains if any object over 5 kg falls from a platform. The detection and communication time taken to throw an approaching train into emergency brake is faster than the most alert driver. The surveillance remains in place when a train is stopped at the platform and has saved the life of a blind person who fell in front of a stationary train.

Docklands Light Railway has train captains to provide platform safety as the train departs but not as the train enters a station. In contrast Miami and Detroit have no special safety provisions at the platforms. This reflects a view that a driverless system is no different from a manned metro or the

Table I. A comparison of driverless minimetros and selected light rail systems

System	Year opened	Length km	Number of cars	Passengers per year million	Cost[2] per km US$m
VAL Lille	1983·5	13·5	76	27	24·3
Miami Metromover	1986	3·0	12	5	61·1
SkyTrain Vancouver	1986	22·5	114	25	28·7
Detroit Downtown PM[1]	1987	4·7	12	3·5	42·5
Docklands Light Railway	1987	12·4	11	7	11·5
Calgary Light Rail	1981·7	27·7	53	24	13·0
Nantes Light Rail	1985	10·6	20	12	10·6
Portland Light Rail	1986	24·3	26	7	8·7

1. Single track (all others double).
2. No allowance is made for inflation. Typically the costs reflect two years before opening.

edge of any street, where a person stepping in front of a train or motor vehicle is at great risk. Metro line D in Lyon is under construction and will become the world's first driverless Metro. Lyon is planning for Vancouver style platform edge protection using a different electronic detection system. Both Japanese minimetros were planned to be driverless with platform doors as in Lille.

Train frequency is regarded as a passenger attraction and is claimed as an advantage of driverless systems. VAL operates headways down to 60 sec, while Vancouver, Miami and Detroit have peak hour headways of 2 to 3 min. The Docklands Light Railway is currently limited to 7½ min headways due to both the train control and single track sections. Planned upgrading will allow headways of 2 min. Vancouver and Detroit have the capability of 60 sec headways. There is no evidence to suggest that headways closer than every 3 to 4 min attract additional patronage. At these frequencies the average passenger waiting time is already below 2 min. Passengers are as much concerned with regularity and appreciate the 'time of next train' information provided on several manned and driverless systems.

Other advantages of driverless systems show different design and marketing philosophies. The VAL system promotes reductions in labour costs while Vancouver claims a high human presence with as many roving attendants throughout the system as there would be drivers. This approach has been well received by passengers. Vandalism, graffiti and other crimes are low. Several lives may have been saved by the fast response to passengers with heart attacks by attendants trained in first aid.

Poor cost performance

Driverless minimetro operating costs as shown in Table II are disappointing. It appears that the management and maintenance complexity of the driverless systems and the costs of security staff have overwhelmed the savings in operating labour. This situation will change in favour of the driverless systems with higher passenger volumes. Two of the three new light rail systems tabulated show direct costs per passenger trip about one-third of the best driverless systems. The addition of amortised capital cost to the passenger trip cost again shows the advantage to two of the three light rail systems but the differences are not as great.

Table II. Comparison of minimetro and light rail operating costs

System	Number of staff[1]	Annual operating cost[2] US$m	Direct cost per passenger US$	Total cost per passenger[3] US$
VAL Lille[4]	195	21·9	0·80	2·30
Miami Metromover[5]	65	7·9	2·25	7·50
SkyTrain Vancouver	310	21·1	0·84	3·93
Detroit Downtown PM[6]	130	12·0	3·40	10·30
Docklands Light Railway	142	7·6	1·10	3·45
Calgary Light Rail	207	11·1	0·46	2·26
Nantes Light Rail	78	3·6	0·30	1·42
Portland Light Rail	115	6·5	0·93	4·65

1. May not include all contracted out staff
2. Annual budget is used where possible to allow for contracted out services
3. Total operating costs include 12% of capital as annual amortisation
4. Excludes 47 station security staff claimed by union in Reference 2
5. Includes 9 security staff
6. Includes 60 security staff

Data for 12-month period ending in 1987 or 1988. Undertakings account and assign overheads differently so cost comparisons can only be approximate

One goal of driverless systems has been met. All systems, except Docklands, are able to dispatch trains to meet special demands such as football games or heavy shopping nights rapidly, economically and without staffing concerns. This is particularly effective in Vancouver, Detroit and Lille where the yards are fully automated and stored trains can be dispatched at a single central control command.

There are insufficient statistics to confirm but it appears that the driverless minimetro systems and automated metros are accumulating a safety record equal to or better than conventionally driven systems. This is to be expected as many rapid transit accidents are attributed to human error.

In summary, the promises of driverless transit systems have not yet been fulfilled. The greatest prospective benefit appears to lie in the use of close headway automatic train control on metro and commuter railway systems in need of extra capacity. Train headways down to 60 or 75 sec have been effectively and safely demonstrated. The only limitation to passenger volumes at these headways is the entering and exiting capacity constraints at busy stations.

In the intermediate capacity market, the data suggests that the proprietary minimetro systems are rarely a match for well designed and executed light rail. The light rail systems used for comparison show convincing economic advantages in both capital and operating costs, which may explain the current dominance of light rail in the intermediate capacity market. It does not explain the persistence of so many competing manufacturers in the proprietary field, scrambling for so few pickings. □

References

1. Correspondence with individual undertakings
2. Étude Comparative entre Le Tram Nantais et le VAL Lillois, La Branche Urbain de la FGTE CFDT (French Public Transport Union), 1987
3. A Comparison of some new Light Rail and Automated Guideway Transit Systems. Gerald D Fox, Transportation Research Board Light Rail Conference, San Jose, California, May 1988

Les mini-métros ratent l'objectif. *La promesse de systèmes de transports publics sans agent de conduite n'a pas encore été remplie car les dépenses d'investissement et d'exploitation restent élevées. Au lieu des économies anticipées par l'élimination des agents de conduite la meilleure solution semble être la fréquence de passage étroite que les systèmes automatiques offrent aux métros qui ont besoin d'augmenter leur capacité. Des réductions d'intervalles entre trains, de 60 à 75 sec ont été démontrées efficacement et en sécurité, la seule restriction étant la limite du nombre de voyageurs aux stations très fréquentées.*

Sind Mini-U-Bahnen die Lösung? *Die großen Erwartungen, die in die fahrerlosen Transitsysteme gesetzt wurden, haben sich bisher nicht verwirklicht, da die Kapital- und Betriebskosteh weiterhin hoch sind. Anstelle der zu erwartenden Einsparungen durch das Entfallen der Fahrer, scheint der größte Vorteil nunmehr in den knappen Zeitabständen zu liegen, die auf 60 oder 75 Sekunden reduziert wurden, erwiesen sich in der Praxis als durchaus risikolos, wobei die einzige Beschränkung des Passagiervolumens in den beschränkten Ein- und Ausstiegkapazitäten in betriebsreichen Bahnhöfen liegt.*

Los minimetros no han alcanzado su objetivo. *Aun no se han cumplido las promesas de sistemas de transito sin maquinista, debido a que los costes de inversión y de explotación continúan siendo altos. Más bien que las economías previstas por la eliminación de conductores, lo más prometedor parece ser el corto intervalo entre trenes que los sistemas automáticos ofrecen a los metros. Ya se han demostrado de manera eficaz y segura intervalos entre trenes de hasta 60 o 75 segundos, siendo la única limitación respecto a los volúmenes de viajeros las restricciones de capacidad de las estaciones de mucho movimiento.*

Docklands prepares to expand

It was fortunate that Docklands Light Railway had train captains on all cars, for the automated train control package had a troubled start. Reliability has improved, traffic has exceeded the target, and work is in progress to quadruple capacity

GIVEN THE CHANCE of a fresh start in 1988, London's 12 km Docklands Light Railway would not be reproduced in the form that it opened on August 31 1987. For a start, the capacity of trains and stations would be far greater, and the automated train control system better suited to short headways. It is highly unlikely that there would be 40 m radius curves on running lines, and the network would certainly be more extensive with better connections to the Underground.

The fact is that none of these desirable attributes could have been achieved within the £77m limit set by government when the project was approved six years ago. In 1982, many people saw DLR as a white elephant with little prospect of carrying sufficient traffic to justify its construction. The need for economy was paramount.

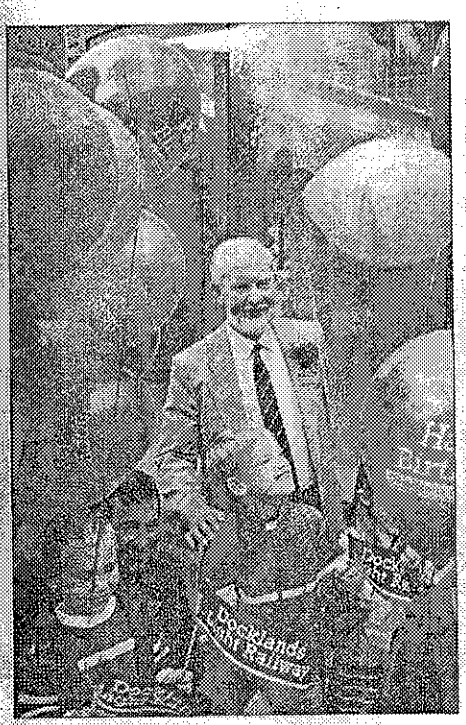
As built, DLR had many of the characteristics of a minimetro like Lille's VAL or Vancouver's Skytrain, including ATO. But London Regional Transport baulked at fully automatic operation, providing a train captain on every car to close the doors and check tickets — and drive it manually when the automation packed up.

It was just as well. There were numerous occasions on which the train control system failed to perform as it should, so that cars had to be manually driven. This was one reason why revenue service had to be delayed for a month after the royal opening on July 30 1988. Even today, under conditions of poor adhesion, cars can slide through a station, and thus fail to stop over the docking data link which is used to pass instructions for the trip to the next station from the central computers. The train captain then has to take over.

In fairness to turnkey contractor GEC-Mowlem, the extremely tight three year design-and-build contract awarded on August 22 1984 simply didn't allow enough time to eliminate software bugs.

Nonetheless, automation has not been a failure. According to DLR Managing Director Cliff Bonnett, delays exceeding 20 min have been cut from 8 to 13 per four-week period last autumn to between 5 and 7 today. Most months this summer have seen 98 to 99 per cent of scheduled trains operated.

If there have been rather too many technical problems — 'a collection of minor things', says Bonnett — DLR has certainly been popular with the customers. Weekday passenger-journeys predicted for the end of the first year were 20 000. On August 9, a typical Tuesday, the trains carried 28 300 passengers, compared with 16 100 on Tuesday December 15. While a lot of tourists were riding DLR in August, growth has continued — despite the need to close the railway down after 21.30 from May 9 to October 31, and take sections out of service at weekends, so that contractors can expand the capacity of the network.



Managing Director Cliff Bonnett led DLR's first birthday celebrations at Island Gardens on August 31

Rapid expansion

The reasons why DLR would be different if it were being planned today have to do with capacity rather than the choice of technology. When the government approved funding for DLR in October 1982, a nominal capacity of 2 000 passengers/h per direction appeared more than adequate in an area noted for poverty and industrial dereliction.

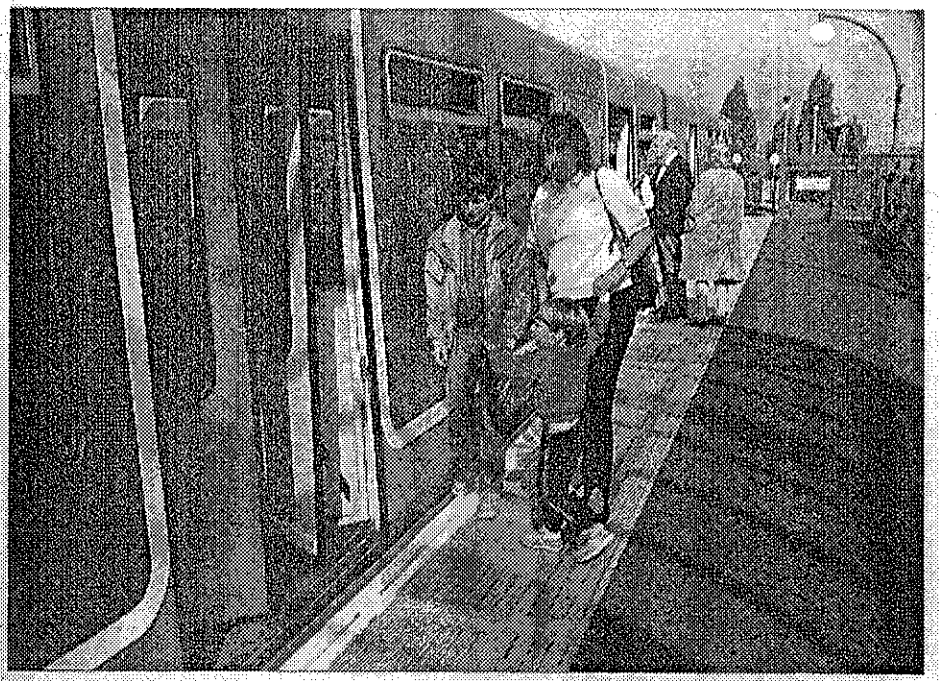
Six years later the Docklands scene is transformed as new buildings spring up, symbolised by the huge development on Canary Wharf where over 40 000 people are expected to be working in the mid-1990s. Already, work is in progress to upgrade DLR, virtually doubling frequency to 15 trains/h on much of the network, and doubling train length to two 28 m articulated cars. This will increase capacity to more than 7 500 passengers/h.

Station platforms are being lengthened to take two cars instead of one, and could be further extended to three cars if the need arises. However, if frequency were to be doubled again to 30 trains/h it would probably be necessary to replace the train control system completely.

Work began earlier this year on the first extension to DLR, a 1·5 km line in deep bored tunnel to Bank. This will bring Canary Wharf within 9 min of the heart of the City of London when the first single-track tunnel opens in 1990; the second track should be ready in 1991. The original 11 cars built by Linke-Hofmann-Busch in 1986 are being

DLR's automatically-driven cars have no cabs, offering passengers a clear view ahead (right). A locked control console allows the Train Captain to drive manually when necessary (opposite)

Inwards-swinging doors were chosen to combine level access from platform to train with a 75 mm gap, but they cause delays when the cars are crowded



supplemented by 10 almost-identical cars built under licence at Brel's York works, and 10 more will be ordered shortly.

Parliamentary powers to build a second 7½ km extension from Poplar to Beckton are likely to be granted soon, requiring 34 more cars. This will involve major reconstruction at Poplar to grade-separate Delta Junction where the three existing lines meet, and reconstruction of Poplar station to provide cross-platform interchange.

Further extensions are planned, notably to Greenwich and Lewisham south of the River Thames which would plug DLR into BR's Kent commuter services.

What went wrong?

Despite all the start-up difficulties, Bonnett insists that 'there is nothing basic that we would have done differently, given a fresh start in similar circumstances'. But he is clearly not entirely happy with fixed price design-and-build turnkey contracts which, for example, leave the contractor to decide what spares provision is appropriate.

One legacy of this is the 40 m radius curves at Delta Junction and elsewhere, round which the cars squeal and judder to the detriment of tyre and rail profiles. The specification allowed 40 m radii and 6·5 per cent grades, 'but if you're going to operate a railway, you don't use 40 m curves unless you have to', Bonnett points out. The contractors were under no such constraint, and were given no financial incentive to add to capital costs by easing curves, even if an analysis of whole-life costs had justified this.

Then there is the problem of learning how to maintain equipment which has been set to work by the contractor; as Bonnett puts it, 'how do you take over a railway designed by somebody else?' Had DLR staff been more closely involved at an earlier stage, such obvious traps as cars becoming 'gapped' if they pass too slowly through Delta Junction might have come to light.

One outcome is that the £150m extension to Beckton will be built on a more conventional basis, with consulting engineers supervising contractors and DLR staff more closely involved at the design stage.

One feature that has caused a lot of heartsearching was the selection of car doors that swing inwards, sweeping across an area of the vestibule floor. Closing or opening these doors is very difficult when the train is crowded, and this has caused delay.

These doors were preferred to external swing-plug or sliding doors so as to give easy entry for wheelchairs; the car floor is level with the platform, and the gap is only 75 mm. To avoid the problem, the second batch of 10 cars for the Bank extension and the 34 for Beckton will be slightly narrower, allowing space for external doors.

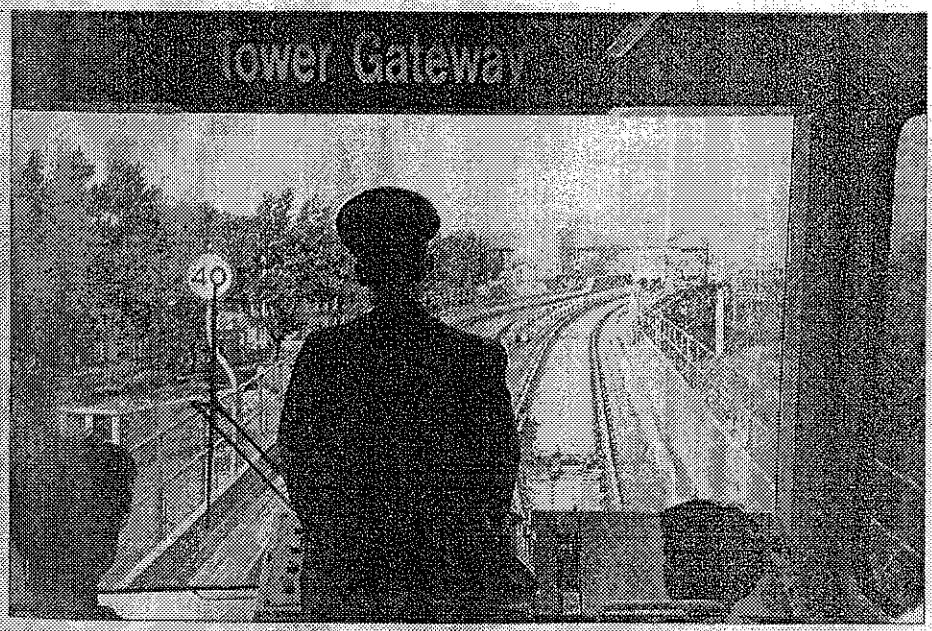
London's East End is traditionally a tough area, and problems with vandalism were anticipated in the design of the unmanned stations. With regular contract cleaning, and radio to direct cleaners quickly to stations or trains where graffiti artists have been busy, or somebody has vomited, this problem has been well contained. Potentially more serious are cases where the large windows have been smashed by stones thrown from the lineside. Clear polyester Llumar film is being applied to the glass to prevent it shattering and injuring passengers.

A major source of irritation — accounting for 85 per cent of passengers' complaints —is the automated fare collection system, which Bonnett says 'leaves a lot to be desired'. Most of the problems stem from the need to make DLR's ticket machines compatible with the Underground and British Rail, which introduces great complexity. But passengers have obviously been confused by the need to validate as well as purchase DLR tickets, a concept new to Londoners. Stations on the Beckton extension are likely to have much simpler machines selling tickets for 1, 2 or 3 zones; passengers making longer journeys will have to rebook at the interchange station.

Use of an old single-track viaduct between Mudchute and the southern terminus at Island Gardens (where both routes overlap and terminate) limits headways to 7½ min. In fact, 10 min headways were operated throughout the first year, but even so the single track sections at Island Gardens and Stratford slowed recovery from delays.

Bonnett feels performance has now improved to the point where 7½ min headways can be operated in peak hours; they were due to be introduced at the end of last month. The number of cars required to work this timetable is still nine, as layover and station dwells times are being reduced.

When frequency is stepped up after the Bank extension opens, turnback facilities at Crossharbour and the reconstructed Canary Wharf station will be used to avoid sending more than 16 trains/h to Island Gardens. In



any case, the layout of this station makes it impossible to accommodate two-car trains — yet Island Gardens has attracted far more traffic than expected because passengers come through a pedestrian tunnel under the Thames; a situation which will probably remain unresolved until DLR is extended across the river to Lewisham.

Flexible staffing

The total number of staff employed by DLR has built up gradually and now stands at 140, but this includes provision for supervising and protecting the heavy programme of engineering work required to increase capacity. The total of 124 which applied last February reflects more accurately the number needed to operate the railway as originally designed.

Policy is to use contractors for many routine tasks, such as cleaning and lift maintenance, but for safety reasons employees are used to maintain the signalling and track, as well as the cars.

Flexibility has been the aim on the traffic side — train captain describes a duty, not a job grade — and automation has been deliberately limited in certain respects to ensure that job satisfaction is maintained.

One place where the need for extra staff quickly became apparent was the control room at Poplar. Like most minimetros, DLR is designed to operate automatically with human intervention only when things go wrong. It became evident that a third person was needed in the control room just to handle some phone calls and keep a log at times of stress. This task is undertaken by one of the traffic assistants who is normally acting as train captain; thus there is movement of personnel between train crew and control centre.

With unemployment falling and a huge amount of construction going on all around, it is not easy to keep good technical staff. However, turnover among traffic assistants, few of whom were recruited from a railway background, has been remarkably low. Their salary covers a fixed working week with no extra payments for Sundays.

Problems with the electronic destination blinds have led to the installation of manually-operated indicators

Despite the problems, not all resolved, DLR is clearly popular with the public and has amply proved its worth as a catalyst for redevelopment. The fact that Canary Wharf developer Olympia & York is contributing £67m towards the £140m Bank extension and upgrading project, and the Beckton extension will effectively be 100 per cent financed through enhancement of land values, is proof of that. □