Light-Rail Developments in Great Britain

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Nearly all street railways in Britain had disappeared by the 1950s, but their resurgence as light rail is now well established. Tyne and Wear Metro brought light-rail technology to the United Kingdom in 1980. Manchester opened the first light-rail system with street running in 1992, and Sheffield followed in 1994. Outlined in this paper are light-rail schemes at various stages of planning and implementation in Great Britain. The efforts to secure private-sector funding to meet government objectives and the environmental concerns about congestion and pollution are described. A summary of the characteristics of schemes built, under construction, and planned is given, and the costs of construction for each system and proposed extension are compared. The characteristics of light-rail vehicles are summarized together with the benefits obtained from light rail.

Street railways, known as tramways in Britain, all but disappeared in the 1950s. Buses took over, as in many North American cities, in the belief that railed vehicles in the streets were a prime cause of congestion. Now the severe congestion in most large cities as a result of too many automobiles is causing a major reappraisal of transport policies.

Transit in the form of bus lines has been in decline in Britain for more than three decades as buses are delayed by congestion and become increasingly unreliable and unattractive. Efforts to provide protection through bus priority measures, including transit lanes, have met with limited success.

It has become clear that a step change is needed in the quality of urban transit and that this is extremely difficult to achieve with bus-based systems. The first new street running light-rail system in Britain, opened in Manchester in 1992, has demonstrated the ability of light rail to attract car users in substantial numbers.

The resurgence of the modern tramway is now gaining momentum in Britain, albeit with a struggle against central government reluctance to provide capital funding. A new government approach to funding, combining highway and transit expenditure in a single package, is encouraging local authorities to review their policies. It allows them to give high priority to light-rail schemes where costs and benefits meet specified criteria.

It has finally been accepted by the government's Department of Transport that new highway construction does generate additional traffic. It has also been recognized that there is no way that future growth in traffic can be accommodated by constructing more new or expanded highways. These fundamental changes have yet to be reflected in major changes to government policies for roads and railways or in spending priorities, but such changes are slowly emerging.

The emphasis is moving toward managing demand for travel, not trying to meet the demand. This is already having an effect on planning policies, which have re-

cently moved away from support for out-of-town shopping centers and business parks toward more centralized developments closer to existing town and city centers.

Private-Sector Funding

The government is, however, adhering rigidly to the belief that the role of the private sector is paramount and that private finance and private-sector operation are essential to the success of any scheme. Government policy is to maximize the involvement of the private sector, not just in funding but in transferring risks from the public to the private sector and in harnessing private-sector skills and enterprise. This policy is being encouraged through the Private Finance Initiative and is being applied to all forms of transport investment.

Although private-sector contributions must be sought by the promoter of any light-rail scheme, efforts to meet these demands for private-sector funding have so far had only limited success. Schemes like the Docklands Light Railway or Manchester Metrolink are often quoted as good examples of private-sector participation, but the proportion of capital investment from private sources is in fact very small.

New forms of procurement have been developed in an attempt to entice private-sector capital and to transfer risk from the public sector. Manchester was the first light-rail scheme to be built using a Design, Build, Operate, and Maintain (DBOM) form of contract. This enabled the bidding consortia to place a value on the 15-year operating concession, which could then be reflected as a capital contribution to the design and construction of the scheme. The mechanism devised was for a new company to be created that is owned by the companies forming the group that won the contract. The new company then subcontracted with its constituent companies for the design and construction of the light-rail system, including supply of rolling stock. The company itself became the operator of the system.

It should be noted that this approach works only if the operation of the system is predicted to be profitable. Profitability is a prerequisite for any proposed light-rail scheme in Britain. If its direct operating costs are not predicted to be profitable, it will not even be considered for any form of funding by the central government. No other source of capital funds exists, because there is no provincial or state government, and local government finances are strictly controlled by central government.

Other light-rail schemes in Britain are following the DBOM approach, including those in Birmingham and Leeds, but other variations are being developed. In every case a key objective is to maximize the private-sector role and financial contribution.

Environmental Concerns

Increasing congestion and atmospheric pollution from road vehicles has heightened public concern over their effects on health. There is a growing awareness that major policy changes are needed, and this is reflected in an increasing readiness to accept restrictions on private automobile use in cities. More people now want investment in transit rather than in expanded highways.

The Royal Commission on Environmental Pollution published its report in October 1994 (*1*). Over 100 recommendations were made, many of which affect urban transit systems. A key objective in the recommendations was to ensure that an effective transport policy at all levels of government is integrated with land use policy and that priority is given to increasing the proportion of trips made by less environmentally damaging modes, including walk, cycle, and light rail. Further, the Royal Commission recommended that the government make more resources available for light-rail systems so that they can be built within a reasonable time, provided they form an integral part of an overall transport strategy for the conurbation.

A string of recommendations related to improving air-quality standards, including government encouragement of the development of electric power for transit systems operating with frequent stops in urban areas. The Royal Commission's strong support for electric traction in general, and light rail in particular, has been welcomed, but it has yet to find expression in government policy on funding for light-rail schemes.

Environmental benefits are an important part of the evaluation of any light-rail scheme and an environmental impact assessment is now required for major projects under European regulations.

Existing Light-Rail Systems

Currently there are four operational "new generation" light-rail systems in Britain, the most recent of which, Manchester and Sheffield, include street running. There is also the Blackpool Tramway, which was the country's first electrified tramway system in 1885 and was the only one to survive the abandonment policies of the 1940s and 1950s. The Isle of Man also has its historic Manx Electric Railway and Snaefell Railway, which may be classed as light rail.

The principal characteristics and performance of the four new systems are given in Table 1, together with those for the next two systems to be built, Midland Metro and Croydon Tramlink. A brief outline is given for each system.

TABLE 1 Line Lengths, Car Fleets, and Productivity

System/City	Year open	Route length kms (mls)	No. cars	Annual rides (M)	Cars/km (cars/ml)	Rides/km (M) (rides/ml) (M)	Rides per car (M)
Tyne and Wear Metro Newcastle upon Tyne	1980	59 (36.9)	90	41	1.6 (2.4)	0.69 (1.11)	0.45
Docklands Light Railway London	1987	21.5 (13.4)	80	17	3.7 (6.0)	0.79 (1.27)	0.21
Metrolink Manchester	1992	30.9 (19.3)	26	13	0.8 (1.3)	0.42 (0.67)	0.50
South Yorkshire Supertram Sheffield	1994	29.0 (18.1)	25	17*	0.9 (1.4)	0.59 (0.93)	0.68
Midlands Metro Birmingham	1998*	20.4 (12.8)	15	14*	0.7 (1.2)	0.68 (1.09)	0.93
Croydon Tramlink London	1998*	28.0 (17.5)	22-30	22*	0.8-1.1 (1.3-1.7)	0.78 (1.26)	1.00-1.36

* estimated

Tyne and Wear Metro

Tyne and Wear Metro introduced light-rail technology to the United Kingdom in 1980. The Metro is fully segregated and has no street running and was the first "new generation" light-rail system in Britain. It was also the first, and so far it is the only, example of an integrated bus-and-rail network in the United Kingdom. The system was an immediate success and reversed the downward trend in ridership, which elsewhere in the country was still in decline.

The Metro replaced outworn suburban diesel multiple units on the north and south Tyne branch lines and linked them through new tunnels under the twin centers of Newcastle upon Tyne and Gateshead. Because the River Tyne is in a deep gorge at this point, the tracks emerge from the tunnels to cross the river on a high-level bridge, as in Edmonton.

The Metro was also the first transit system in Britain to provide level boarding from platform to car floor and hence offer mobility to those with pushchairs or in wheelchairs. All stations have either ramps or lifts. Initially the Metro was operated as a closed system with automatic barriers at each station entrance, but these were later removed and it is now an open system with increased levels of ticket inspection.

An extension to serve Newcastle Airport opened in 1991, and a second extension is planned to Sunderland that will entail joint running over the tracks used by Railtrack (the successor to British Rail as owner of the existing railway). Details of proposed extensions are included in Table 2.

Docklands Light Railway

The Docklands Light Railway (DLR) in London opened in 1987. It was conceived and developed by London Transport in close liaison with the London Docklands Development Corporation (LDDC), a public-sector entity set up to encourage new investment in the Docklands area. The system is now owned by LDDC and is to be privatized. It is fully automatic with no drivers, although each train carries a train captain, who inspects tickets, deals with any passenger concerns, and drives the train in emergencies. It is powered from a protected third rail pickup.

The initial system ran from Tower Gateway close to Fenchurch Street Station in the city of London to Stratford in London's East End and The Isle of Dogs, which was formerly the focus of London's docks. It was built primarily to encourage new development rather than because of any existing demand. In this respect it was almost embarrassingly successful, needing a major upgrade and reconstruction only a few years after opening.

TABLE 2 Capital Costs for Existing and Proposed Light-Rail Lines

System/Line or Extension	Year Open	Route length km (mls)	Capital Cost(a) £M	$M	Capital Cost(a) £M/km	£M/ml	$M/ml
Tyne and Wear Metro							
Initial System	1980	55 (34.4)	284	446	5.2	8.3	13.0
Airport extension	1991	3.5 (2.2)	12	19	3.4	5.5	8.6
Sunderland extension	1999*	19.2 (12.0)	56(b)	88	2.9	4.6	7.3
Docklands Light Railway							
Initial System	1987	12 (7.5)	77	121	6.4	10.3	16.1
Bank Extension	1991	1.5 (0.9)	276	433	184	306.7	481.1
Beckton Extension	1994	8 (5.0)	280	440	35.0	56.0	88.0
Lewisham Extension	1999*	4.5 (2.8)	140	220	31.1	50.0	78.6
Greater Manchester Metrolink							
Initial System	1992	30.9 (19.3)	145	228	4.7	7.5	11.8
Salford Quays/Eccles Ext.	1999*	7.5 (4.7)	85	133	11.3	18.1	28.3
Oldham/Rochdale Ext.	2001*	24 (15.0)	115	181	4.8	7.7	12.1
Airport/Wythenshawe Ext.	2003*	21 (13.1)	145	228	6.9	11.1	17.4
East Didsbury Extension	2003*	10 (6.3)	80	126	8.0	12.7	20.0
Trafford Park Extension	2001*	7 (4.4)	55	86	7.9	12.5	19.5
East Manchester/Ashton Ext.	2003*	10 (6.3)	100	157	10.0	15.9	24.9
South Yorkshire Supertram							
Initial System	1994/5	29.0 (18.1)	260	408	9.0	14.4	22.5
Midland Metro							
Birmingham-Wolverhampton	1998*	20.4 (12.8)	145	228	7.1	11.3	17.8
Birmingham-Airport	2001*	27.5 (17.2)	343	539	12.5	19.9	31.3
Wolverhampton-Dudley	2001*	31.4 (19.6)	228	358	7.3	11.6	18.3
Croydon Tramlink							
Initial System	1997/8*	28.0 (17.5)	154	242	5.5	8.8	13.8

[(a) price bases not consistent; (b) excluding rolling stock; * estimate;]

Two extensions have since been opened, to Bank in the heart of the city and to Becton via the Royal Docks. The former is in tunnel and at a cost of over $480,000,000 per mile may be the most expensive section of light-rail alignment anywhere in the world. The latter is also expensive by light-rail standards because of the need for total segregation, which is essential for a fully automated railway.

A third extension, under the River Thames to Greenwich and Lewisham, is in the advanced planning stages; construction is expected to start in 1996. An initial 7-year franchise is expected to lead to full privatization.

Greater Manchester Metrolink

Manchester became the first city to bring back trams (streetcars) running on the streets in 1992. The concept is very similar to Tyne and Wear Metro in that two former suburban railways have been converted to light rail

and linked through the city center. The key difference is that although Tyne and Wear Metro runs in tunnels, Manchester's Metrolink runs through the streets. An earlier plan to build a tunnel for suburban rail services, similar to Philadelphia's city center regional rail link, had to be abandoned because of the high cost.

The light-rail plans were formulated by the Passenger Transport Executive (PTE) in the early 1980s, although some light-rail proposals had been made in the early 1970s. Parliamentary powers and approval for funding were obtained in 1988, and construction began at the end of 1989. The first section opened in March 1992 with the whole first phase system complete by July.

Peak traffic grew more slowly than expected, but off-peak traffic grew much faster. The private-sector operating company, Greater Manchester Metro Limited, decided to double the off-peak frequency between the peaks on purely commercial grounds. Peak capacity has now been reached without the addition of more rolling stock. One car has been modified experimentally with a lower number of seats and more standing space to increase total capacity. This has also been done on Tyne and Wear Metro and the DLR.

One more existing rail line is proposed for conversion to light rail and a number of further extensions are planned to serve other parts of Greater Manchester that are not served by the commuter rail network. Parliamentary powers have already been obtained for four lines, including one for Salford Quays, which is the old Manchester Docks and similar in character to parts of London's Docklands. Powers are currently being sought under the new Transport and Works Act procedures for two more lines to serve the airport to the south and Ashton to the east.

South Yorkshire Supertram

Sheffield is the largest city in South Yorkshire and was the last city in Britain to operate streetcars in 1960. The first section of a three-line light-rail network opened in 1994, and the last section was completed in October 1995. Most of the system is street running, with extensive sections of side and central reservation.

Sheffield's hills demanded a vehicle specification that could cope with 10 percent gradients in the snow. The Siemens Duewag eight-axle double articulated cars have all axles motored and are probably some of the most powerful light-rail vehicles built, having a power-to-weight ratio of 24 kW/t. They proved their worth in snowstorms early in 1996 when all other traffic in the city stopped.

Although Manchester introduced street running, Sheffield claims to have the first new street tramway system, given its very different character. One line, to the out-of-town shopping mall at Meadowhall, is entirely on reserved track and uses some former freight rail alignments. Sheffield is also the first British system to adopt low-floor cars, and like the other three systems is fully accessible.

A condition of the government grant was that the system be privatized when fully operational. However, the revenues have been well below predicted levels, and the operation currently falls far short of profitability. The future structure for the company is still under debate.

Light-Rail System Under Construction

The next system to be built will run on a former rail alignment between the center of Birmingham in the West Midlands and the town of Wolverhampton. The first 4.5 km (2.8 mi) from Birmingham is shared right-of-way with a recently reopened suburban rail line, but with no shared track, and the last 1.8 km (1.1 mi) into Wolverhampton is street running.

The project was developed by the West Midlands PTE and is being funded by the Passenger Transport Authority (PTA), a government grant, European grants, and the private sector. A contracting consortium was selected for the DBOM contract in 1993, but funding from the government was not finally secured until July 1995. The private contribution is in return for a 23-year concession, 3 years to design and build the line and 20 to operate it. It is still hoped to open this first phase in 1998.

Two more phases are planned and with Parliamentary powers will take the network to Walsall, Dudley, and Birmingham Airport, giving a total network of 80 km (50 mi). An eventual network of 200 km (125 mi) is envisaged.

Proposed Light-Rail Systems

Croydon Tramlink

The other system that is close to realization is Croydon Tramlink in south London, developed jointly between London Transport and the London borough of Croydon. It is similar in concept to Manchester: Croydon also has two railway stations on opposite edges of its town center. Tramlink will take over two lines from Railtrack, serving Wimbledon, Beckenham Junction, and Elmer's End, and link them through the center with a street-running loop. A third line is entirely on new light-rail alignment to serve the large suburb of New Addington, which has been the subject of new rapid transit proposals for more than 25 years.

Low-floor cars will operate over the 28-km (17.5-mi) network at speeds up to 80 km/hr (50 mph) with a very

high proportion of segregated running. The operation is expected to generate substantially more revenue than the operating costs.

An unusual method of procurement was adopted that involved setting up a project development group (PDG) after a brief contest between a number of consortium bidders. The PDG developed the design to what in effect is tender stage and then becomes one of the tenderers. Thus the PDG, which has been paid for its design development, had to bid in competition with other consortia.

Government approval was obtained in December 1994 subject to a satisfactory private-sector contribution. A short-list of tenderers was published and final bids for the 99-year DBOM franchise were due in January 1996. The preferred bidder, Tramtrack Croydon, was announced by London Transport in April 1996 and is a consortium including Bombardier Eurorail, civil engineering contractors Amey and Robert McAlpine, London bus company CentreWest, and the Royal Bank of Scotland. It is hoped that construction will start in 1996, with completion by 1998.

Leeds Supertram

Plans are well advanced in Leeds for the first phase of a light-rail line to the south of the city serving a major housing area at Middleton and a large park-and-ride lot at Stourton at the northern end of the M1 motorway from London. Part of the route incorporates a tramway alignment that was originally built in 1948 only to be abandoned in 1958. It should reopen by 1999.

Parliamentary powers were obtained and approval in principle has been given by the government. A DBOM form of contract is proposed and a short-list of bidders has been prepared. The promoter, West Yorkshire PTE, is hopeful that it may be possible to start construction in 1996. A further two lines are planned, serving Headingley in the northwest and Seacroft in the northeast, both with major park-and-ride lots.

Nottingham

A 14-km (9-mi) line has been authorized from Nottingham city center to Hucknall in the north. It may be the first in Britain to involve shared track between heavy-rail trains and street-running light-rail vehicles. Work undertaken by British Rail Research at Derby has investigated in detail the technical options for solving a number of issues on shared track (2). There are a number of potential applications in British cities that could considerably expand the future role of light rail.

The project is being promoted by Greater Nottingham Light Rapid Transit Limited, a company owned jointly by the City Council, the County Council, and the private-sector Nottingham Development Enterprise. As with most schemes, funding will be the major hurdle, but construction could possibly start in 1997.

South Hampshire

The unique geography of the Portsmouth Harbour area would benefit from a planned light-rail scheme linking Fareham with Gosport and then running by tunnel under the harbor into Portsmouth city center. At present there is no road link and the quickest route for many commuters is by cycle using the ferry. The light-rail vehicles will have to be adapted to carry large numbers of cyclists.

The project is out for public consultation, and a draft order under the new Transport and Works Act procedures will be sought in 1996. Planned extensions would serve Portsmouth to the north and Southampton to the west, the latter requiring shared track with the existing electrified railway.

Glasgow

Britain's last city to have a tramway should see it return in the form of light rail early next century. Powers are being sought under the Scottish legal system to construct and operate a light-rail line from Maryhill in the northwest through the city center to Easterhouse in the east.

The first line is 24 km (15 mi) long and will cost £180,000,000 ($270,000,000). Further extensions are being planned to create a 40-km (25-mi) network, which will complement the extensive suburban electrified railway network.

Bristol

The proposed light-rail network for the city of Bristol, promoted by Avon County Council, has been called Westway and will run from north of the city through the principal shopping area to a loop around the southern suburbs. The 32-km (20-mi) first phase will cost over £400,000,000 ($600,000,000) and a number of extensions are planned.

A wholly private-sector scheme was proposed some 10 years ago but was abandoned. The current scheme has been well received at public consultation. Avon is to be reorganized, and the County Council will be replaced by a number of single-tier authorities, including Bristol City Council. It is hoped that this reorganization will not delay the light-rail scheme.

Cardiff

The Welsh capital city may see light rail on its streets. A project is well advanced to operate a line from the city center to the former docks area, sponsored by Cardiff Bay Development Corporation and supported by local authorities. Later phases would see the initial line extended northward up the valleys over existing railways, another example where track sharing could result in an extensive network. The line will be street running through the city center but on reserved track elsewhere.

Medway Towns

The Kentish towns in the Medway Valley include Maidstone, Strood, Rochester, Chatham, and Gillingham. An existing suburban railway line does not serve the town centers. Plans are progressing to convert the line to light rail but retain some heavy-rail use, at least for freight. The line would be extended at each end to run on street into the town centers. It would also serve major park-and-ride lots on the M2 and M20 motorways. Public consultation on this scheme is currently in progress.

Liverpool

The most recent city to announce that it is planning light rail is Liverpool, which once had one of the most extensive streetcar systems in Britain, with many miles of reservations. At a launch last week it was indicated that the first line would run from the newly rebuilt dockside area through the main pedestrianized city center shopping streets to suburbs to the north at Page Moss. A former central reservation will be used for about half the route.

Another proposal for a light-rail line has already been announced by a private-sector group to link the city center with Liverpool Airport.

Small-Scale and Heritage Tramways

Interest is growing in the possible role of heritage tramways in smaller towns and cities. An established narrow-gauge line has operated in Seaton, Devon, for many years, and a new line opened this year in Birkenhead, using new trams built in Hong Kong. In addition to providing tourist facilities, some could play important park-and-ride roles. A proposal for a seafront line has been made by a private company in Margate, Kent.

Low-cost, small-scale tramways could also benefit a number of smaller towns that could not afford conventional light rail but that need more attractive transit than the bus. Historic cities like Chester and Bath have been studying the potential for light rail to tackle local traffic problems by linking fringe park-and-ride lots with the center city. The key is to create a segregated right-of-way that can ensure reliable, speedy operation.

A flywheel-powered minitram known as the Parry Peoplemover is being developed by a small private company and has been demonstrated in a number of towns, including Brighton and Swansea.

Costs of Light-Rail Systems

One of the advantages of light rail over metro or underground systems is light rail's much lower capital costs. However, substantial investment is still needed for even the more modest schemes, and most of this has to come from the public sector. It is therefore crucial to the progress of any scheme to ensure that its capital costs be kept to a minimum.

Capital costs of the light-rail lines already built or under construction, including extensions where planned, are set out in Table 2. The initial systems or first phases are in the range of $11 million/mile to $22.5 million/mile. The lowest costs are for those lines that utilize former railway rights-of-way, such as Manchester and Croydon ($11.8 and $13.8 million/mile, respectively). The higher cost of the Sheffield system reflects the much greater proportion of street running and the fact that it is a new system throughout, with no reuse of track. It also reflects a higher vehicle specification, which costs nearly twice that for the Manchester cars.

The most notable differences can be seen in the costs for the DLR. Although the initial system was within the same range and made use of some existing railway infrastructure, subsequent extensions have proved extremely expensive. The Bank extension may be regarded as a special case, involving some of the most difficult tunneling and underground station construction to be found anywhere, but the Becton and Lewisham extensions are also very costly. Lewisham does include a tunnel under the River Thames, but Becton could have been constructed at much lower cost if it were not an automated system. Grade separation of all intersections has resulted in long sections of elevated track where at-grade running would have been feasible with manual operation. This is an added cost, which is not always considered when the benefits of automation are evaluated.

The low costs for Tyne and Wear extensions again show the benefits of being able to use existing rail alignments and track. Manchester's Oldham/Rochdale extension is a conversion of an existing railway with a similar cost to the initial system, but other extensions that generally involve new construction are up to twice this cost. The Salford Quays line includes bridges over the

Bridgewater Canal and the River Irwell and a higher proportion of civil engineering works.

One concern is the high cost of diverting public utilities plant and equipment, averaging between $2 million/mile and $5 million/mile, with some city center streets costing even more. This high cost has prompted the proposal of a new form of track construction that would not require excavation for a trackbed. It would use the strength of the highway structure to spread the rail loadings. Laboratory tests have been carried out, and field trials are planned.

Another concern is the high cost of light-rail vehicles—at least 10 times the cost of a bus. Another project is developing a lightweight low-cost vehicle using a high proportion of standardized components from the automobile industry. Both projects are being carried out by Lewis Lesley at John Moores University in Liverpool.

A number of smaller towns and cities are considering lower-cost, fixed-track systems such as busways or guided busways. A guided busway operated in Birmingham in the 1980s, and the first section of a new guided busway has recently opened in Leeds.

The strong financial discipline demanded by the Department of Transport in the evaluation and justification of light-rail schemes has encouraged promoters to seek cost-effective solutions. The British light-rail schemes built so far demonstrate how effective projects can be achieved within a reasonable budget.

Benefits of Light-Rail Systems

When Britain's first light-rail system opened in Tyne and Wear, some were skeptical of its value in a car-dominated era. Although demand for transit was decreasing everywhere else in the country, in Tyne and Wear it grew despite population loss, unemployment, declining economic activity, and growth in car ownership. After only 5 years of operation, Metro was carrying 61 million passengers per year, half from car-owning households and one-third with driver's licenses. The current patronage of only 41 million is the result in part of the deregulation of bus services and in part the dismantling of the integrated bus-rail network.

A key benefit of light rail is the ability of travelers to go into and through busy congested cities without delay or disruption, whether during peak or off-peak times. Manchester's Metrolink achieves excellent levels of reliability and is the only transit system to practice timed transfer. Metrolink has also shown the power of light rail to attract car users. About half of the 13 million passengers per year have a car available for the journey but have chosen to use Metrolink. Up to 15 percent of passengers formerly made the journey by car. There is also some evidence that car ownership levels have been influenced: car ownership continued to increase in Greater Manchester as a whole but has stabilized or even decreased in the Bury and Altrincham corridors (*3*).

Both Tyne and Wear Metro and Metrolink have proved particularly attractive for shopping and leisure trips and have strengthened shopping centers along their routes. There was less evidence of significant changes to land use patterns although in the longer term there is a trend for new development to locate near the Metro.

The movement was not all inward to the regional center of Newcastle. Businesses in towns at the outer ends of the line, South Shields and Whitley Bay, also benefited. Two-way flows also occur in Manchester; Altrincham and Bury, at the extremities of Metrolink, have seen increased shopping activity. Traders believe this to be a direct result of light rail.

The ability of the DLR to act as a catalyst for new development was greater than any expectations. When construction started on the Isle of Dogs, there were acres of derelict land and abandoned dock areas and industrial sites. Today it is a new city with massive investment in offices and leisure activities. The DLR threads through the new development, forming a spine route. This pattern has not been repeated along the Becton extension, where the property market has been depressed and little investment has followed construction of light rail. This difference illustrates how difficult it is to predict real estate movements: light rail is no guarantee.

One of the greatest benefits of British light-rail systems is their accessibility. They all offer level boarding without the need for platform lifts or on-vehicle lifts. Where stations are not at grade, elevators or ramps are provided to allow access between platforms and street level. Although level boarding is invaluable for wheelchair users, it benefits a large proportion of the population, including those with pushchairs or luggage and those who have difficulty climbing steps.

Environmental benefits continue to advance in importance and have been the subject of a European Communities study (*4*). The low noise and pollution levels of light rail contrast starkly with those of the deregulated bus services. This benefit has influenced both Manchester and Sheffield city councils to seek to reduce the number of bus movements through the main shopping streets. Constructing light rail creates opportunities for improvements by extending pedestrian zones, building more hard and soft landscaping, and enhancing the urban environment. Examples can be found in Newcastle, Manchester, and Sheffield, although much more could be achieved with the level of funding that French cities have enjoyed.

The benefits from the investment made in building light rail can be greatly enhanced if a comprehensive approach is adopted. Light rail is much more effective as part of a package, which may include traffic manage-

TABLE 3 Characteristics of Light-Rail Vehicles on British Light-Rail Systems

System	Newcastle	Docklands	Manchester	Sheffield	Birmingham	Strasbourg
Builder	Metro Cammell	Bombardier	Firema	Siemens	Firem	ABB (York)
Length	27.8m	28.8m	29.0m	35.0m	24.0m	33.1m
Width	2.65m	2.65m	2.65m	2.65m	2.65m	2.40m
Articulations	1	1	1	2	2	6
Axles	6	6	6	8	6	8
Floor height	960mm	1025mm	915mm	420/880mm	350/850mm	350mm
Seats	84	66	86	90	58	66
Standing(4p/m²)	125	145	120	160	102	144
Total capacity	209	211	206	250	160	210
Max. speed	80km/h	80km/h	80km/h	80km/h	75km/h	70km/h
Acceleration		1.1m/sec²	1.3m/sec²	1.3m/sec²	1.4m/sec²	-
Braking	1.0m/sec²	1.3m/sec²	1.3m/sec²	1.3m/sec²	1.4m/sec²	-
Emergency Braking	1.6m/sec²	-	3.0m/sec²	1.3m/sec²	4.0m/sec²	-
Max. gradient	4%	6.5%	6.5%	10%	-	-
Min. radius	70m	38m	25m	25m	18m	-
Line voltage	1500Vdc	750Vdc	750Vdc	750Vdc	750Vdc	750Vdc
Weight (empty)	39.0t	36.0t	48.0t	46.5t	-	40.5t

ment, bus priority measures, some highway construction, pedestrian streets, and parking controls. In the future it may include road pricing.

Technical Comparisons

The principal technical characteristics of the light-rail vehicles for the first five British light-rail schemes are shown in Table 3. Comparable data for Strasbourg are included as an example of a new European system and the only one to have British-built vehicles.

The only common features are the gauge—all are 1435-mm (4-ft 8½-in.)—and the width. The levels of performance are generally similar. Discussions between promoting authorities and representatives of manufacturers on standardization have not produced any form of standardization that could potentially reduce costs. The essential competitive-bid procedures and the move toward all-embracing DBOM forms of contract make any attempt at commonality very difficult.

It is likely that any future systems will adopt low-floor cars, and a preference is emerging for the narrower gauge width of 2.4 m (7 ft 10 in.) in place of 2.65 m (8 ft 8 in.) where narrow streets have to be negotiated such as in Croydon and Portsmouth.

The specification for vehicles and for the track, power supply, and signaling have to meet all safety requirements or recommendations of Her Majesty's Railway Inspectorate. A completely revised set of documentation incorporating a new section dealing with street running has just completed the consultation stage and will be published in 1996 (*5*).

Prospects for Light Rail

A substantial number of light-rail schemes are in various stages of planning and may eventually be added to the four operational schemes and the one under construction. There is great concern over the rise of traffic congestion and environmental pollution, and light rail is seen by many as one way to attract car users onto transit.

However, the relatively high capital costs do not make it a popular choice for government. The Minister of Transport indicated recently that only the systems in Leeds and Nottingham and the extension of Manchester's Metrolink to Salford Quays had any chance of funding in the foreseeable future. Any other authorities considering light rail would be better advised to examine cheaper alternatives such as guided buses. This situation does not bode well for light rail in Britain, but the implied policy may not last too long. It is not discouraging a number of authorities from progressing with their light-rail projects. They realize that most attempts to make buses attractive to car users have not had great success. A step change in quality is needed, and this is difficult to achieve with any type of bus-based system. However, hard factual data on the effects of light rail are not always readily available. More effort is needed to monitor and document the changes in travel patterns when light rail is introduced so that justification of new schemes can be related more closely to actual experience.

One positive effect of the government's pessimism is to further encourage development of lower-cost, light-rail vehicles and systems, exemplified by the work of Lesley at John Moores University. Major vehicle manufacturers are responding to the need to drive down the capital costs although not many examples are in production as yet. But the future of light-rail systems will depend more on the funding mechanisms devised for their implementation than on the technical development of their specifications.

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