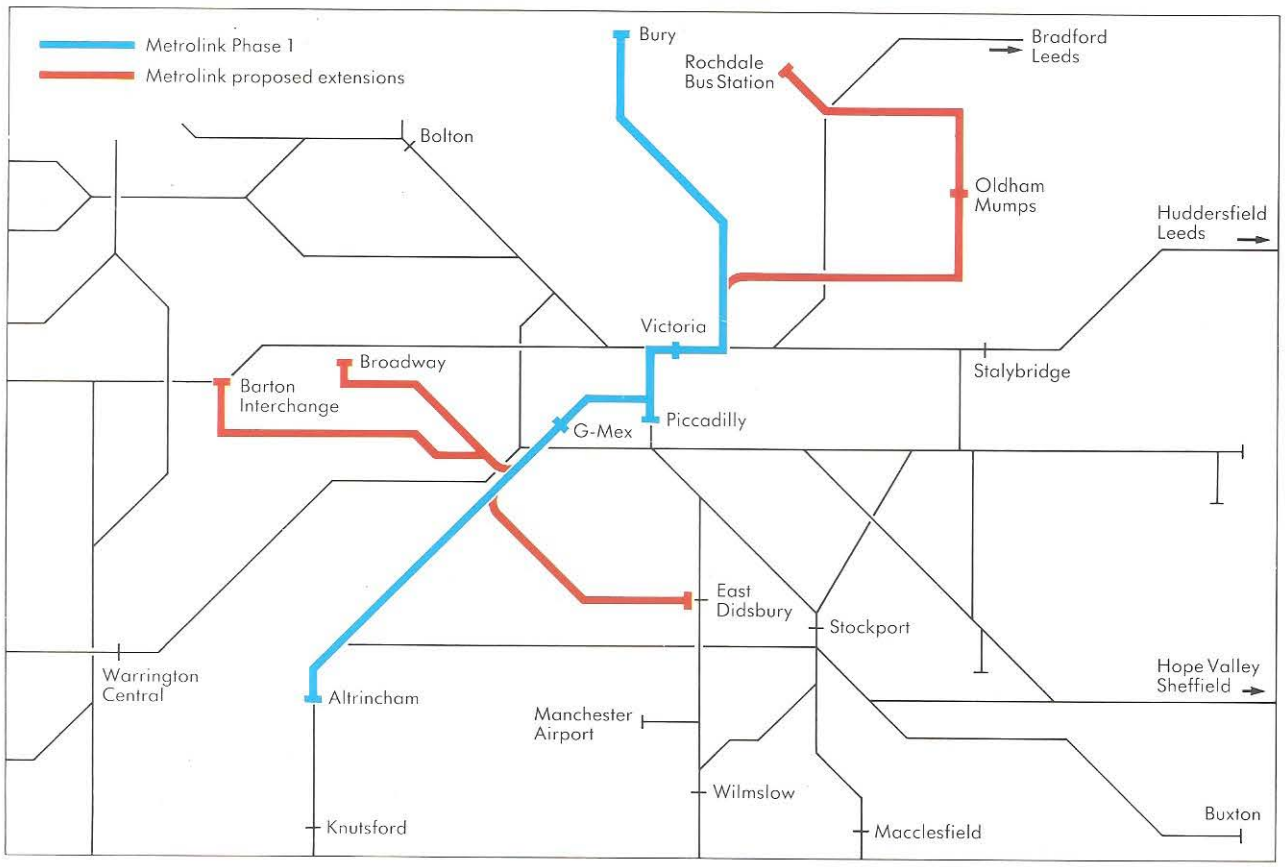
Manchester Metrolink

GEC ALSTHOM

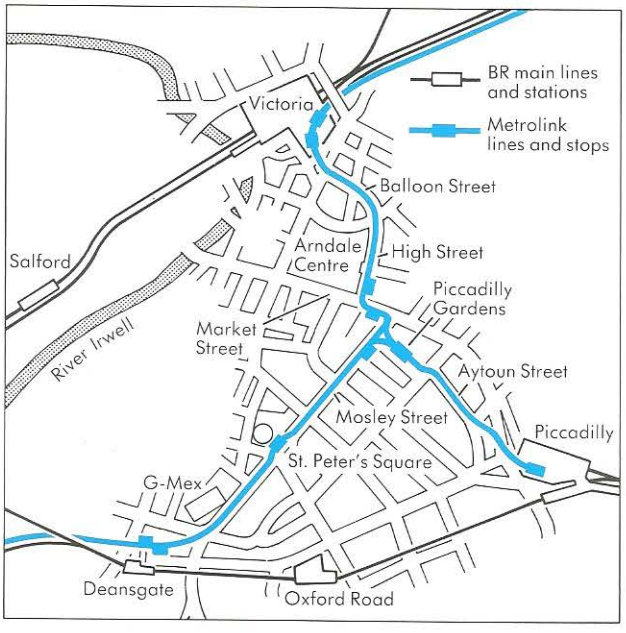
TRANSPORT

Introduction



The Manchester passenger railway system with Metrolink highlighted.

The Metrolink street section (right) links Piccadilly and Victoria Stations with G-Mex.



Metrolink is the name given to the new light rail system in Manchester. It is, in fact, the first street-running light-rail (or tram) system to be built in the UK for over 40 years; as such it has pioneered new procedures for street running in the UK and the project has also pioneered a unique form of contract.

Phase 1 of the Metrolink project involved the conversion of two existing suburban heavy-rail routes to light rail, together with new track through the city streets to link them together.

The initial contract covered the first phase of the proposed network of light rail routes in Manchester and its surrounding districts. This first phase was designed to cater for a specified level of traffic but the system can be upgraded to cope with much higher traffic levels with relatively minor changes to the signalling and power supply systems. The street section will be the core of the proposed network and the potential vast increase in traffic on this section has been taken into account in the design.

The project was covered by a turnkey contract which also included a franchise to operate the system for a 15 year period. The Metrolink contract was believed to be the first of its type in the world, although it is expected that it will become the norm - certainly for UK light rail projects. The form of contract is commonly known by the anacronym DBOM (Design, Build, Operate and Maintain).

The contract was initially let to the GMA Group, a Joint-Venture partnership of GEC ALSTHOM, Mowlem and AMEC. The GMA Group then set up a new company in which each of the partners had a substantial shareholding and this Company, known as Greater Manchester Metro Limited (GMML), subsequently undertook all the obligations of the whole DBOM contract.

Metrolink itself was preceeded by a demonstration - Project Light Rail. For this three week demonstration, a Docklands vehicle was borrowed and run on a 1¼ mile length of British Rail track in east Manchester. The Transport Minister is seen waving off the first service prior to many local and national politicians, transport professionals and several thousand members of the public, sampling the service.
This demonstration undoubtedly convinced many people of the advantages of Light Rail.

GEC ALSTHOM was responsible for all electrical and mechanical aspects of the project (including the vehicles), Mowlem was responsible for new works and conversion work along the line of route whilst Fairclough Civil Engineering, part of the AMEC Group, constructed the Operation and Maintenance Centre (OMC) at Queens Road. GM Buses brought to the Group its expertise and experience of many years of operating a public transport service in the region.

Collectively the Group had international railway construction experience, including the Docklands Light Railway in London, as well as experience of operating public transport services.

Finance

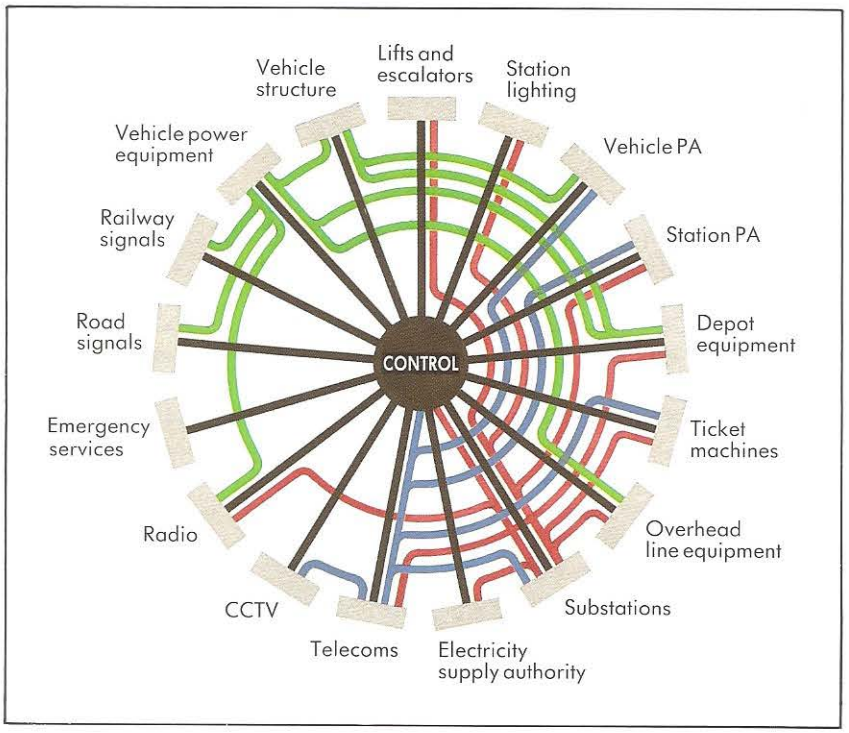
The capital cost of the project was paid jointly by central government and local government but day-to-day responsibilities for *operating* the system rest with GMML.

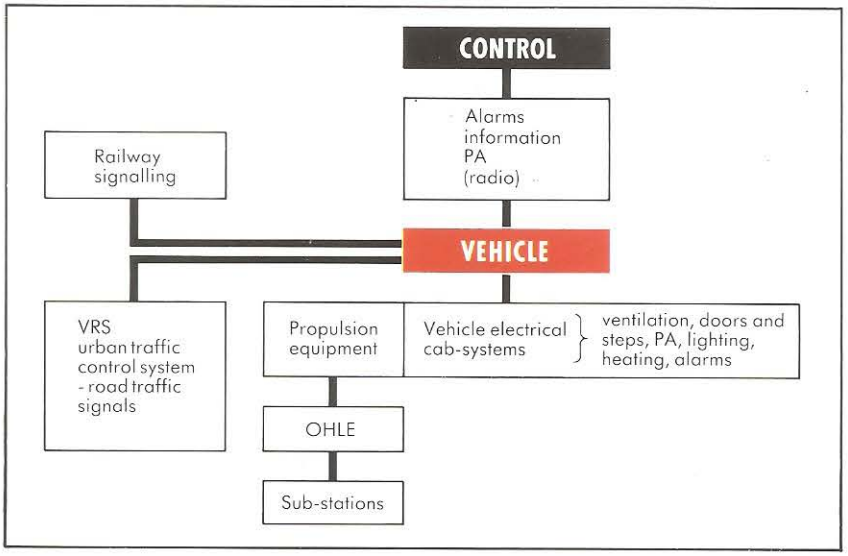
The level of service is specified in the DBOM contract (hours of service, frequency, etc) and so operating costs can be readily calculated. The main source of revenue is from the farebox and the level of fares has been carefully calculated so as to give a reasonable return to the shareholders. Advertising on the vehicles will increase the net revenue slightly but station advertising brings in no revenue to GMML as the advertising contractor keeps all that revenue in return for keeping the stations clean and tidy.

GEC ALSTHOM's involvement in Metrolink

Woodlands Road station showing the station equipment room, a sub-station, ticket vending machine, passenger alarm/call point, lighting and the new graded approach for disabled passengers.

Some of the system *interfaces, the satisfactory solution of which was GEC ALSTHOM's responsibility.*





GEC ALSTHOM Transportation Projects Limited was the joint-venture partner responsible for all electrical and mechanical aspeets of the project.

This work included:-

- the vehicles
- their propulsion equipment
- their electrical sub-systems
- sub-stations
- overhead line equipment
- signalling
- communication - radio
  - telephone
  - video (CCTV)
- ticketing
- the control centre
- depot equipment

These specialist subjects are dealt with briefly in the following pages and in detail in other publications.

In addition, of course, the company liaised with the civil engineering joint-venture partners, with British Rail, the Railway Inspectorate, statutory services bodies (such as electricity, gas, water) and local authorities (such as City planning departments, and the urban traffic control centre).

Some of the numerous inter-relationships are illustrated in the diagrams.

The vehicles also have interfaces with many other disciplines as is illustrated by this diagram.

Vehicles

The vehicle easily negotiates a 25m radius curve on the street section.

The initial system is operated with a fleet of 26 vehicles. Up to 23 vehicles are in service in the peak periods with the remaining 3 on standby or under maintenance, whilst 14 vehicles are required for the off-peak service. Phase I is operated by single vehicles but they can be coupled in tandem to provide extra capacity and, in fact, four vehicles can be controlled by a single driver in an emergency.

The vehicles are articulated units carried on three bogies. Each of the outer bogies is powered by two, separately-excited direct-current traction motors whilst the centre bogie is not powered and supports the articulation gangway. The weight balance is such that under full-loaded conditions, almost 70% of the weight is on the powered bogies, which assists the hill-climbing ability of trains.

Each vehicle is 29m long. The normal seating capacity is 82 and when crush-laden the vehicle can accommodate 270 (although in normal service the load is unlikely to exceed about 200).

Two areas (adjacent to the centre doors) have been specially set aside for wheelchairs and a further two areas are allocated for parcels/luggage. Fold down seats are provided at all four locations for use by other passengers if the areas are not immediately required for their prime purpose.

Four doorways are provided each side, each 1.22m wide, with externally-hung sliding door leaves. To facilitate access with prams, wheelchairs, etc the nominal platform gap is 75mm with the floor height maintained nominally constant relative to the platform by means of the air suspension system.

The areas allocated for wheelchairs, etc are adjacent to the two middle doors and the articulation gangway is wide enough to allow wheelchairs to move freely from one section to the other.

The vehicle bodies are of a welded steel construction employing steel sections and sheets. The floor consists of composite wood sheets mounted on stainless steel with an abrasion-resistant rubber covering.

The saloon walls are lined with laminate materials which are moulded to form window recesses. The ceiling is lined with light alloy panels which are shaped to accept two rows of semi-recessed fluorescent light fittings and to provide central air distribution ducts.

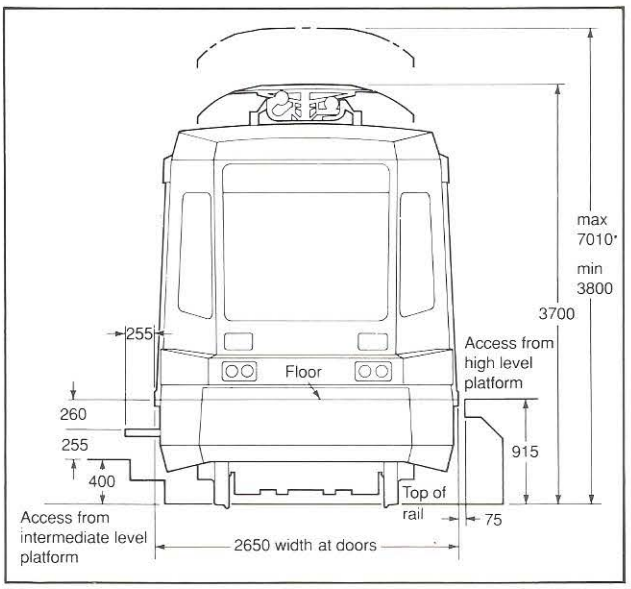
Thermostatically-controlled heaters are provided at floor level along the side walls of the vehicles. The main saloon windows include a hopper-type opening section at the top of the window with sealed windows next to the articulation and in the doors.

Although release and closing of the doors is under the driver's control, the *opening* of individual doors is initiated by passenger-operated push buttons mounted at each doorway. At low level platforms a sliding step operates in conjunction with the doors; the step being automatically activated when a passenger-operated pushbutton is pressed.

(Left) The cab layout showing controls and instruments conveniently arranged around the driver. The combined power/brake controller incorporates a deadman device and the horn control.

(Below) Saloon interior showing a passenger alarm and door controls.

(Right) At stations with low-level platforms a step will project below the doors to ease passenger access.



The vehicles are bi-directional with a full-width cab at each end. The cab has a deep windscreen and long side windows to give the driver excellent vision all round. In addition there are self-retracting mirrors on each side of the vehicle allowing the driver to see the length of the train when it is in a station. These mirrors are heated and adjustable from the cab.

The driver is seated on the centre line of the cab with a wrap-around console carrying the various controls (radio, public-address, heating, ventilation, lighting etc). Control of brake and acceleration is by means of a joystick-type controller with integral emergency brake and horn controls.

To provide the necessary clearance between vehicles passing on 25m curves the ends of the vehicles are tapered for almost the length of the cab.

Propulsion equipment

The power for the two driven bogies is provided by four separately-excited dc motors, a pair for each bogie, each motor group being fed from independently controlled choppers utilising gate turn off (GTO) thyristors.

The choppers are controlled by a microprocessor and operate at an interlaced chopping frequency of 600 Hz whilst a frequency monitoring circuit ensures that the chopper frequency does not deviate into signalling frequencies.

The separate field control is also provided on a per bogie basis, and is achieved using four-quadrant inverters with insulated gate bipolar transistor (IGBT) technology reducing the overall component count and weight.

A third, four-quadrant IGBT inverter provides an ac source to a reduction transformer for rectification into the 110V dc supply used for charging the battery and providing control and auxiliary supplies.

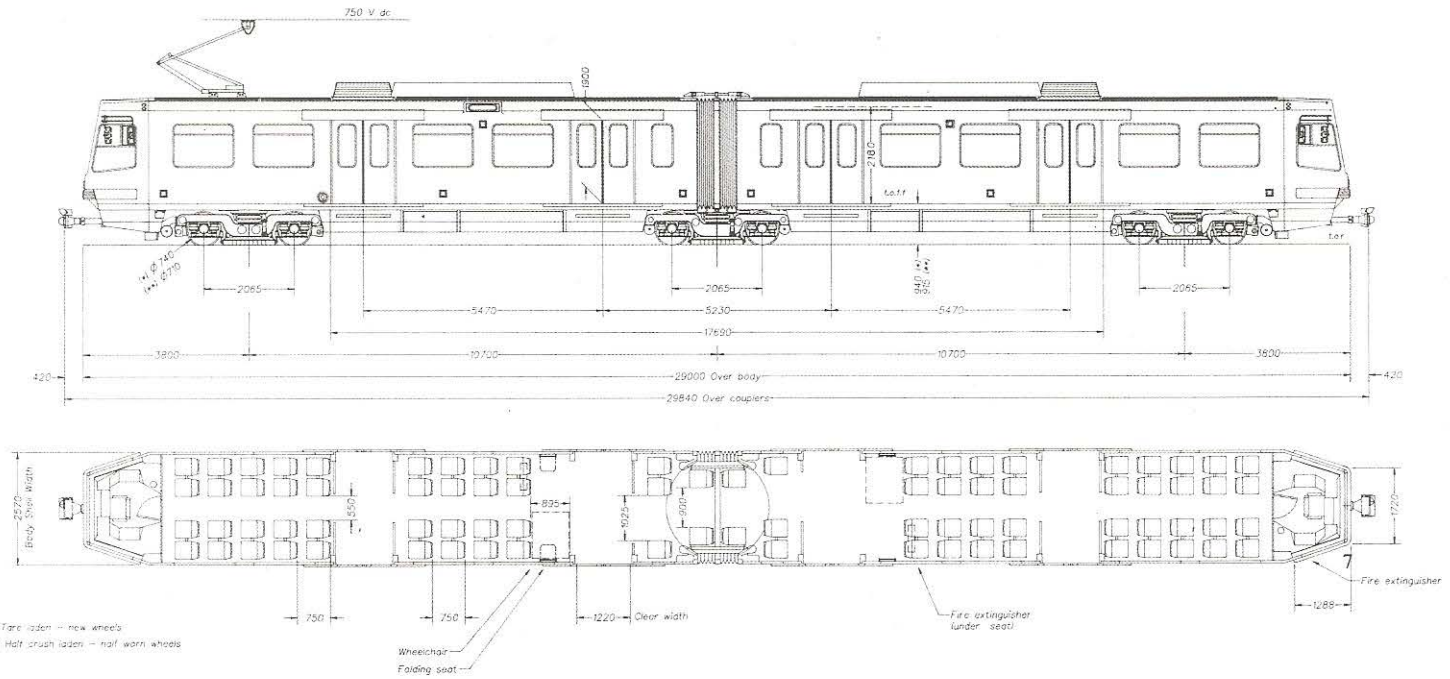
A programmable logic controller (PLC) is used to reduce the number of control relays, thus providing space savings and giving greater flexibility of operation.

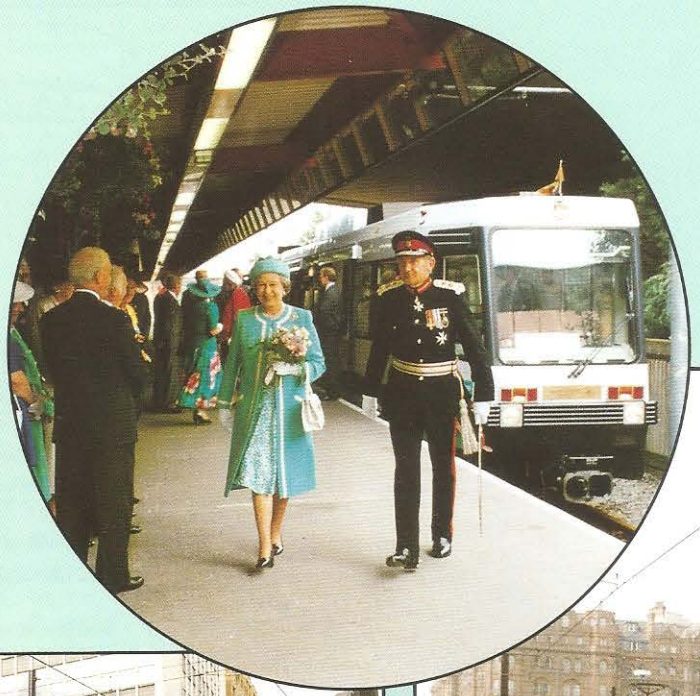
The LRVs are braked using a fully-blended braking system, which employs regenerative/rheostatic electric and pneumatic brakes on the motored bogies and pneumatic brakes on the articulation bogie. Also fitted to all bogies are electric track-brakes, which provide a significant additional braking force, allowing the LRV to operate safely with normal road traffic.

The LRVs can be driven from either end, or coupled together in multiple. The driver has full control of all vehicles connected via the autocoupler from one cab, while the PLC provides such facilities as automatic door closing during the winter months.

Data

Maximum speed (off highway)	80km/h
Maximum speed (street running)	48km/h
Acceleration rate	1.3m/s²
Braking (normal)	1.3m/s²
Braking (emergency)	2.6m/s²
Jerk rate	0.8m/s³
Maximum gradient	6.5%
Minimum curve radius	25m
Voltage	750Vdc



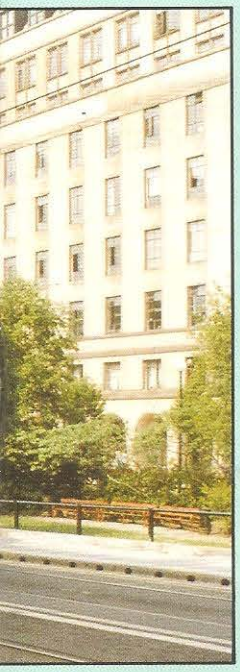


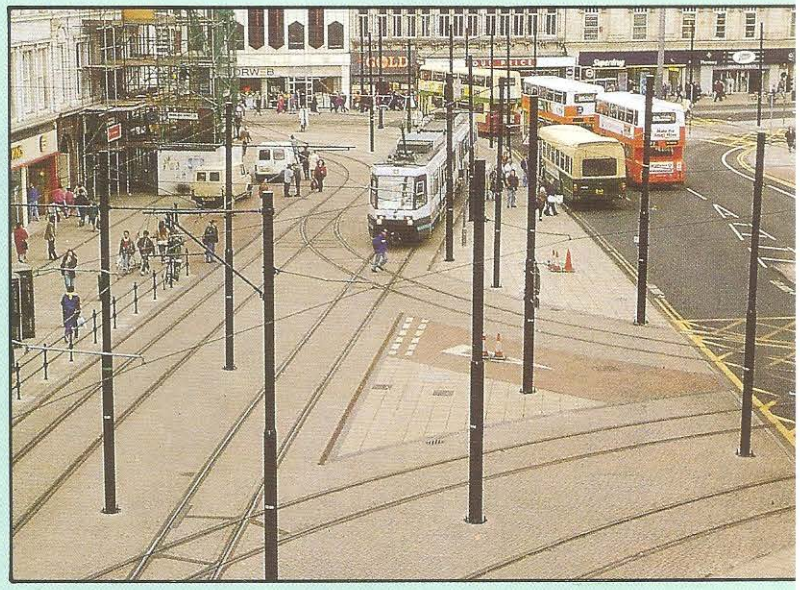
Her Majesty, Queen Elizabeth II, formally opened Stage 1 of Metrolink on 17th July 1992.
(Below) The openness and greenery in St Peter's Square surprises many visitors to Manchester.

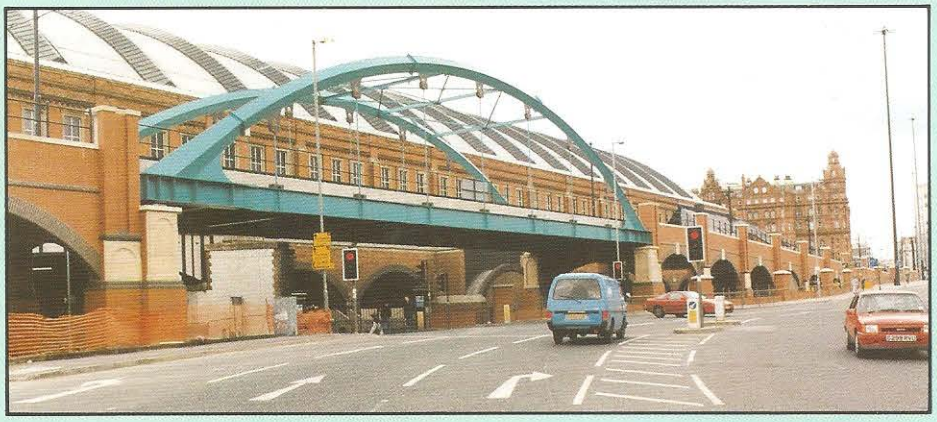
A busy scene in the City centre.
(Below) Great care was taken to restore (and to improve) the environment after construction work was complete as can be seen from this newly created ground cover at a suburban station.

The line runs through pleasant urban areas such as Radcliffe (right) and Stretford (far right).

The Altrincham section comes "on-street" in front of the G-Mex exhibition and conference centre.



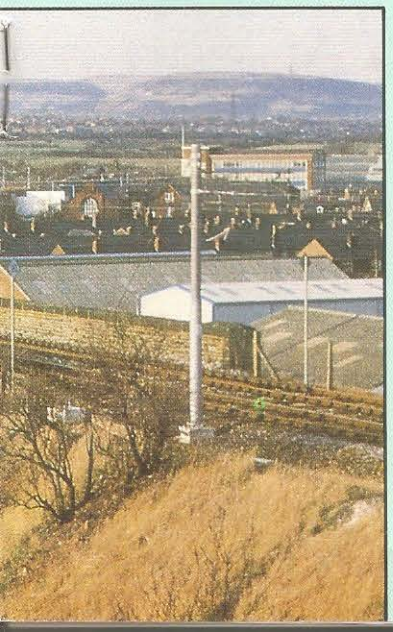




The "delta-junction" in Piccadilly is the focal point for Phase 1 of Metrolink and also for the planned extensions.

(Left) Piccadilly Undercroft station is built below the British Rail main-line station to give good interchange.

(Above) The Bow-string bridge was designed to complement the style of the nearby G-Mex Centre. The adjoining viaduct is actually of concrete construction but is faced with factory-assembled brick facing panels - again to match the G-Mex architecture.



Maintenance

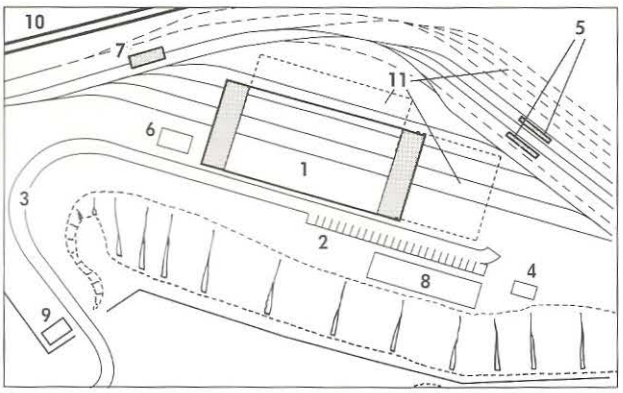
Metrolink maintenance is carried out at a purpose-built maintenance centre at Queens Road (2km north of Manchester City Centre). The site is ideally placed as, not only is it approximately at the mid-point of the present route between Bury and Altrincham (Phase 1), but it is also exactly where the route to Oldham & Rochdale (the next phase) will leave the present main line.

As with so many aspects of the Phase 1 contract, the maintenance centre has been designed to be extended. The workshop area at present can accommodate 6 LRVs on 3 undercover roads but, by extending sideways and endways, it will be possible to maintain 11 vehicles under cover. Similarly there is space to more than double the capacity of the storage sidings.

Queens Road provides routine "maintenance" ranging from daily cleaning (both internal & external) to wheel-turning. Vehicle lifting is by a suite of hydraulic jacks and there is also a crane, spanning the two non-electrified roads, for lifting components. The depot area has its own substation (both for traction and domestic supplies) which is supported by an emergency diesel generating set.

(Left) All vehicles pass through the cleaning plant every day.

(Right) Layout of the Operations and Maintenance Centre (with proposed extensions shown dotted).



1 Workshop
2 Car park
3 Access road
4 Emergency generator
5 Cleaner access points
6 Sub-station
7 Washer
8 Offices and control room
9 Gatehouse
10 Metrolink's main line
11 Future extension

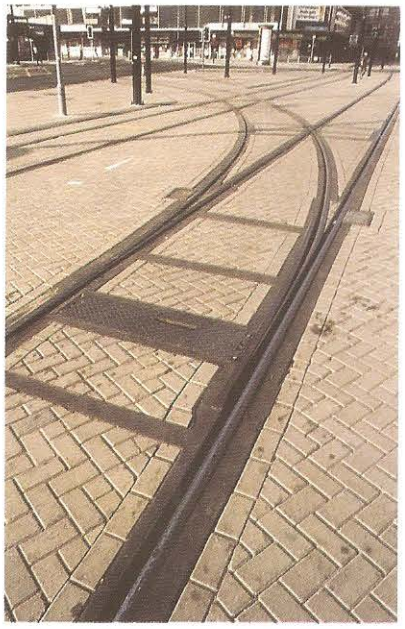
Power supplies

Power is supplied to the LRVs at 750Vdc from an overhead catenary. There are eleven substations - at the Queens Rd Depot itself and a further ten to feed the line at: Altrincham, Timperley, Dane Road, Trafford Bar, G-Mex, Victoria, Woodlands Road, Prestwich, Radcliffe and Bury. There is also a track parallelling and switching hut serving the Piccadilly Gardens area.

The incoming supply voltage is either 11kV or 6.6kV. For Phase I the substations' rectifier transformers are all rated at 600kW but space is provided such that, where necessary in subsequent phases, they can be uprated to 1500kW.

A system of inter-tripping of dc circuit breakers is employed between substations such that in the event of a fault on the line, all feeds to that section of the line are automatically broken. The SCADA system (System Control and Data Acquisition) at the control centre continually monitors system parameters (currents, voltages) to ensure correct operation.

The power system is designed to minimise electrolytic corrosion of public services by stray currents. The rails provide the return path to the substations for vehicle traction current, and are insulated from earth (apart from in the depot where the rails are earthed for safety reasons).

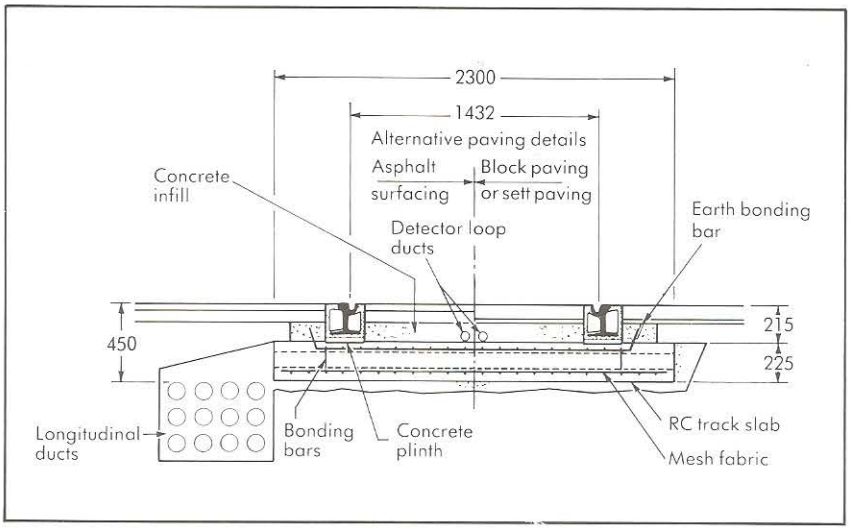


Metrolink's on-street sections use R59 grooved rail secured in position and encapsulated in a poured polymer, whilst the reinforced concrete earthing mat collects any stray current. None of these details, however, are visible in the shot of the completed paved track.

In addition, the rails are bonded together at regular intervals, and bonded or welded at joints, to provide as low a resistance path as possible for the return current. At the substations, the rails are connected to the rectifier negative. Additional protection is attained in the City Centre (where there are complex networks of pipes, sewers, cables, etc) by a reinforcing earth mat set below the rails. The earth mat is connected at short intervals to a continuous cable back to the substations. If any stray leakage current were to occur, it would be collected in the earth mat and flow back to the substations along this cable, which is connected via a leakage return diode (which prevents current flow of the opposite polarity) to the rectifier negative.

Overhead line equipment

The 750V overhead line equipment is an unearthed system with either double insulation (consisting of two physically separate insulators between live and earth) each rated for the full system voltage, or reinforced insulation insulators with electrical characteristics which are far in excess of the system requirements. These configurations comply with the prime power system objective of minimising electrolytic corrosion of public services by stray currents and, in addition, the appearance of the equipment is enhanced since the use of aerial wires is eliminated.



Communications

Every platform has a combined staff telephone and passenger emergency calling point.

The telecommunication system on Metrolink, provides a comprehensive package of communication sub-systems including:-

- radio
- telephone
- station public address
- passenger information
- passenger emergency call
- closed circuit television
- vehicle public address

and by careful consideration and design it has been possible to provide sub-systems which allow all groups of personnel on the railway to communicate with each other.

In communication terms, there are three groups of personnel to provide facilities for; the **control centre,** the **drivers** and last, but by far the largest group, **the passengers.**

Controller to passenger to controller

At the heart of the telecommunication system is an optical fibre transmission network which provides a communication link between the Control Centre and stations. Each station is provided with two types of transmission equipment, the first being capable of multiplexing telephone and data circuits, and the second for video signals. The optical fibre cable link transfers this multiplexed information to the Control Centre, where it is de-multiplexed and presented to the appropriate control equipment.

The infrastructure enables the controller to speak directly to the passengers at any station using the station public address system and in addition, at key interchange stations, he can update passengers with the latest train movements by displaying text on a television-style monitor using the passenger information system.

Each station platform has a passenger emergency call unit which consists of a pushbutton for requesting the attention of the controller together with a microphone and loudspeaker. In the

event of an emergency, a passenger can press the pushbutton which causes the closed circuit television camera picture monitoring that station platform, to be displayed in front of the controller, together with a signal indicating to the controller which passenger emergency call pushbutton has been pressed. The controller can then speak directly to the passenger. During this time the picture is being recorded on to a video cassette recorder.

Closed circuit television monitoring is also used for general surveillance of stations including the TVMs and subways (where they exist) at Hagside level-crossing and the railway tunnels at Heaton Park and Collyhurst. Normally the camera pictures from each camera will be cycling on the bank of monitors at the control centre in front of the controller. However, at any time, the controller can hold a particular camera picture for close scrutiny or record the picture on to a video cassette recorder.

Controller to driver to controller
Each LRV is equipped with a radio unit in each cab. This is linked via a network of base-stations to the Control Centre equipment where the controller is equipped with a handset and control unit. Each radio channel uses separate frequencies for transmitting and receiving and incorporates address codes, to allow the controller to select individual drivers. Trains can be called selectively or a "fleet-call" can be made.

In the event of failure of the radio system, a driver's telephone is provided at each station and at other key positions along the track for communication to the controller.

Driver to passenger to driver
Each LRV is equipped with a public address system which enables the driver to pass information to the passengers.

In an emergency, passengers call the attention of the driver by pressing the pushbutton on the passenger emergency call unit. This unit is similar in function and operation to the station passenger emergency call unit in that the driver is able to respond to the passenger's call by communicating directly and discreetly with the passenger.

Disabled persons intercom-call units are provided on the vehicle, which allow a disabled passenger to communicate with the driver to ask for assistance or information under non-emergency conditions. These are located where space is provided for wheelchairs and are at a height where a passenger in a wheelchair can easily use them.

A CCTV camera (alongside the lift) scans the platform.

Signalling

The Metrolink signalling system is monitored and controlled from the Operations Centre also located at Queen's Road. Metrolink, of course, is the first modern UK light rail system to combine street running with operation on segregated track and as a result a number of new control concepts have been introduced.

On the former British Rail lines, traditional two-aspect (red/green) signals are used with full track-circuit block working supported by an automatic train-stop system. On the street section there are no signals (except the new displays at road junctions) and vehicles are driven on sight - *defensively* as it is described in the rule book.

Flashing amber signals warn pedestrians of the approach of a tram.

Precision stopping is very important on Metrolink as all stations (both suburban and city centre) have the platform edges extended towards the track over the length adjacent to the centre two doors of the vehicle to facilitate access for passengers with impaired mobility.

Transition from street-running mode to segregated (and vice-versa) is made when vehicles are stationery in either G-Mex or Victoria stations. Changing to "street" mode brings in additional lighting to conform with the Road Traffic regulations and the horn changes to a chime. In this mode the vehicle is limited to a maximum speed of 30 mile/h.

The Vehicle Recognition Sytem (VRS)
Every vehicle has a pair of VRS transmitter coils mounted below the centre bogie which transmit a continuous modulated carrier signal (a different frequency for each vehicle/route combination) which is picked up by detector loops buried between the rails.

A number of systems tap into this VRS data, for example, the SIGNET signalling data network users it for Automatic Train Reporting. It is also used to seek clearance of road traffic signals and for route setting at junctions.

Ticketing

All stations are "open" and passengers are required to have a valid ticket before boarding a train. A comprehensive range of tickets is available both pre-purchased and purchased at-the-time-of-travel. Tickets purchased at time-of-arrival are sold through Ticket Vending Machines (TVM's).

TVM's issue a range of tickets for cash (they accept most denominations of coins) and give change, and all ticket-issuing transactions are recorded centrally giving the operator daily information on the numbers and type of tickets sold at each station and by time period.

The performance of all TVM's is continually monitored at the Control Centre and a vandal attack will immediately cause action to be taken by the police or the company's own security staff. TVM's which run low on tickets or change also alert Control with, in this case, the problem being dealt with by maintenance staff.

Good Accessibility

The whole Metrolink system has been designed to make it easily accessible to all people with impaired mobility. This group, includes mothers with prams and people carrying luggage or heavy shopping - not just those who are confined to wheelchairs. It also includes those with no *apparent* disability such as sufferers from arthritis, vertigo and angina. Taken together it is estimated that this group accounts for approximately 20% of the current UK population.

On the vehicles two spaces have been set aside specifically for passengers in wheelchairs (equipped with low-level emergency call/communications panels) plus a further two spaces for luggage/pushchairs.

Platforms at suburban stations have been raised to give level access to the LRV's at all doors whilst at the centre doors (nearest to the wheelchair/luggage spaces inside) the platform edge has been extended to give level access across a very narrow gap. Access to the platforms is, wherever possible, by very gentle sloping ramps but at some locations there is not sufficient space. In these cases hydraulic lifts are provided.

In the city centre, profiled platforms have been adapted to minimise visual intrusion but here also the length adjacent to the centre doors gives level access and is approached by a gentle ramp.

The close fit between the vehicle doorway and the platform is clearly visible, a design feature of the whole system to make it readily accessible to the disabled.

Victoria Station showing TVM's, passenger call point, passenger information VDU, telephone kiosks and, of course, an LRV.

Spaces with pull-down seats cater for mothers with push-chairs and for passengers with luggage.

The low-level passenger alarm in the area designed for travellers in wheel-chairs.

Security

Manning levels on the system are minimal (a single person on each vehicle and unmanned stations) but there is an extensive back-up security organisation.

The Operations Centre includes a bank of video monitors which display pictures from the CCTV cameras located so that they cover all platforms, subways and lifts. The pictures normally "scroll" every few seconds but the Controller can select any one for continuous observation (and possible recording).

Every platform is equipped with a passenger call facility to be used both for general assistance and in an emergency. Once the call button is pressed the Controller can speak directly to the caller and also can see the caller on the appropriate video screen. Both the conversation and the video picture are automatically recorded. Line-side and station equipment rooms and the TVM's are fitted with alarms to protect against intruders and vandalism.

On the vehicles there are a number of emergency call points which enable the passengers to speak to the driver (and at the same time alert Control to the existence of an emergency). Low-level call points are located in the special wheelchair locations.

Response to emergency calls anywhere on the system can be dealt with either by the Company's own security staff or by the police. Both organisations ride the system on a regular basis and also have their own road transport as back-up. A dedicated squad from the Greater Manchester Police is actually based at Metrolink headquarters.

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TRANSPORT

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