Warwick University/Lanchester Polytechnic
URBAN TRANSPORT RESEARCH GROUP

University of Warwick,
Coventry CV4 7AL,
Warwickshire,
England.

Telephone number 0203 24011 extension 2075

WORKING PAPER 21

Advanced Urban Transport

2447

I.G. Black, R.F. Gillie, C.J. Longley,
T.H. Thomas

December 1973

Contents

1 Introduction

The working paper describes a number of advanced transport systems currently under development. The systems, listed in Appendix A, have several elements in common:-

- They are automated systems. None of the vehicles need or are intended to carry a driver (although manual operation may be an option). Stations may or may not be manned depending on individual circumstances.

- They use a reserved track for safety and operational reasons.

- Their vehicles are generally smaller than those used in conventional urban transport. The largest vehicle described is 2.5 m wide 3.1 m high and carries about 50 passengers, while the smallest is 1.5 m wide 1.8 m high carrying 2-3 passengers.

- They are under serious development by or in association with large companies often with government assistance. The only exception is Cabtrack which was being developed by the U.K. Government, but whose development has now stopped. Chauvinism persuaded us to include it. A full list of all ideas and innovations, many of which have not reached the prototype stage is given by "Unconventional Passenger Transportation Systems" U.I.T.P. 1973 (306p)

Chapters 2 to 7 describe some of the technical and economic features of the 24 systems included in the review.

2 Service Potential under Automation

Automation offers a number of different opportunities in the provision of transport services. The most sophisticated service is provided by the 'autotaxi' type systems. 'Autotram' type systems can offer a 'line-haul' service similar to current public transport practice but numerous suggested variations may lead to service improvements.

Autotaxi

Autotaxi - sometimes referred to as 'true PRT' - provides a non-stop personal on-demand service for passengers. Intending passengers arriving at a station board a waiting vehicle, or, if one is not available, an empty vehicle is directed to the station by computer control. The passenger, having made his destination known to the computerised controller is automatically carried to his desired destination without stopping at intermediate stations. The passenger has exclusive use of his vehicle which he may, of course, share with his friends and associates. The carrying capacity of the vehicles is unlikely to exceed 6 passengers.

The transport system will contain a number of stations connected by a track network ensuring journeys between any two stations do not require changing vehicles. Stations will be situated on short loops off the mainline (offline station) to enable passenger-carrying vehicles to by-pass stationary vehicles. Main lines may be one-way to avoid complicated junctions and keep visual intrusion to a minimum. Sophisticated control systems will be required to monitor vehicle movements. Close headway operation (<5 seconds) will be required to cater for typical flows found in urban areas. Methods must also be evolved for the merging and routing of the automatic vehicles. Systems A1 - 10 demonstrate examples of the autotaxi variety.

Autotram

The simplest autotram system operates as a line haul service. Vehicles operate on a 'fixed' route stopping at all stations which are on the main line. Different services use different tracks and for certain trips this will involve passengers changing vehicles at intermediate stations. Numerous variations on this well known type of service have been evolved attempting to approach that offered by autotaxi without incurring the extra cost.

Changing vehicles can be avoided by designing a system of routes which connects all stations to all stations. In extended networks this may involve a prohibitively complicated (from the passenger's as well as the operator's viewpoint) set of services. The time spent waiting for a direct vehicle may eventually outweigh the disadvantages of changing vehicle. Average trip speed might be increased by the use of different services along the same route (express services, intermittently stopping or perhaps more complicated patterns not involving changes). Another widely canvassed alternative is to provide defined services in the peak hours stopping at all stations, when high levels of passenger flow and high vehicle occupancies are necessary, and an 'on-demand' service in the off-peak period, which may be of the pure autotaxi type - a non-stop journey for each travelling party. Alternatively it may provide a jitney-type service where a central computer faced with various journey demands from passengers maximizes an objective function which may allow cab-sharing and limited stopping to pick up and put down passengers. This type of operation requires sophisticated vehicle marshalling techniques together with a significant information exchange between passengers and the system.

All these improvements to the basic pattern involve off-line stations (to avoid stationary vehicles 'blocking' the line) and more sophisticated control techniques to allow route selection. Systems of the autotram variety are demonstrated in A11 - 24. In most instances the exact type of service to be offered is not determined.

3. Support, Propulsion Guidance and Switching of Vehicles

The principles of support, propulsion, guidance and switching for an automatic vehicle need be no different from the methods already familiar on railways. However, the operating conditions of an automated urban transport are sufficiently different to have encouraged alternative solutions to the basic problems of supporting and moving a vehicle.

The conditions that are different from normal railway practice and encourage (or do not discourage) change are:

- The envisaged reductions in scale of the track and vehicles means that continuity with existing systems is not an important issue.
- The importance attached to routes in streets and near buildings necessitates quiet vehicles able to negotiate the tight curves and steep gradients found in urban streets.
- Close headways between vehicles and short distances between stations increase the advantages obtained from high rates of acceleration and deceleration.

Both the steel wheel of a railway and a road vehicle's pneumatic tyre assist in the functions of supporting, guiding and propelling a vehicle. There is a tendency in the development of automated systems to separate the equipment fulfilling these functions, but the system developed at Morgantown by Boeing uses pneumatic tyres to achieve all three. Several other systems use wheels for traction and braking, but only the magnetic levitation methods being developed by Krauss-Maffei and Rohr Corps. combine guidance and support with a separate means of propulsion. (It cannot yet be decided whether systems that combine these functions have any superiority over those where they are separate)

3.1 Methods of Support

Many means of support for guided vehicles have been suggested - some ingenious such as sliding on a block of ice - but the principal methods being developed for use in cities are:

- Steel wheels on steel rails
- Rubber tyres on concrete or macadam surfaces
- Magnetic levitation by controlled magnets
- Air cushion suspension; the cushion being created by air jets generated either on the vehicle or track.

All these methods have their own advantages and disadvantages. Sometimes however these are confused by claims that some item is a unique advantage, when the item could in practice be added to any system, but happens to be essential to the example in question.

3.1.1 Wheel Systems

A wheel permits motion along one-axis and resists motion perpendicular to that axis, i.e. in the axis of the axle. This is usually beneficial for guided vehicle applications where movement is only desired along one axis. It has been suggested that a mechanism enabling lateral movement would be desirable for docking purposes in stations. This could be arranged with wheels, but would necessitate wheels that castor, a moveable section of track, or a second set of wheels.

A vehicle with wheels does not consume energy while stationary. Lower energy consumption may therefore result on systems with short distances between stations by using vehicles with wheels, as a high proportion of journey time will be spent at stops.

Wheels do, however have the disadvantage of giving a vehicle a high unsprung mass which can make suspension design more difficult and owing to their admittedly low rolling resistance consume some power when in motion.

Steel wheels on steel rails

Conventional coned wheelsets have been used for urban rapid transit for over 100 years. They have lately been compared with systems using pneumatic tyred wheels and air cushions in amongst other places, Paris, Manchester and California

In spite of the universal acceptance of the steel wheel for use with 'metros' there is only one proposal (Pullman GlideRide A9) to use them for automated transport. However, they were considered during the early development of Cabtrack and were being developed by Demag for their Cabinentaxi at one time.

Three disadvantages of steel wheels are usually advanced ;(a) It is difficult to design a switch for steel wheels operated from on-board the vehicle, (b) steel wheels are limited in the adhesion they can provide, and (c) they can be noisy. In addition a less frequently considered drawback (d) is their limited ability to negotiate tight curves.

(a) On-vehicle switching mechanisms have been designed for steel wheels but they do not have the simplicity of some of the alternatives. If track switching is used, the system is unlikely to be applicable to a dense network with close headways.

(b) Steel wheels provide less adhesion than pneumatic tyres except under icy conditions. The coefficient of friction employed for determining the starting load for rail locomotives is 0.24 and rail adhesion in Britain very rarely falls below 0.2 even with the threat of oil on the track from diesel locomotives. Therefore the adhesion required for an acceleration of 0.15g usually specified for vehicles with standing passengers can probably be reached, whereas the higher accelerations of about 0.25g used in most taxi systems could not be guaranteed.

(c) Although existing steel wheeled vehicles are generally noisy, it has been shown that well designed trams can be as quiet as rubber tyred vehicles. This can be greatly assisted by a suspension design that reduces flange contact and incorporates some resilience into the wheel itself.

(d) Existing designs of standard guage vehicles usually have heavy flange contact when negotiating curves with radii less than about 200m. It seems likely that this can be greatly reduced by using a narrower gauge, a carefully designed wheel profile and a means of keeping the vehicle axles as near as possible radial to the curve: but there is no knowledge of how small a curve could be easily and noiselessly negotiated.

Rubber Tyres on Concrete or Macadam

Rubber tyre suspension has been extensively developed for road-vehicles and several developers of automated vehicles have adopted very similar techniques using largely the same components (L.T.V. Airtrans, Boeing-Alden P.R.T., Hawker Siddeley Minitram). Others rely on rubber tyred wheels but have made major adaptations in use (e.g. Rohr Monocab, Demag Cabinentaxi, Aerospace P.R.T.)

Rubber tyres have more resistance to motion than steel wheels and therefore have not been favoured for high speed railways or heavy goods haulage by rail. In urban transit other factors than traction economy become significant. Tyres are probably superior to steel wheels in conditions where tight turns, steep gradients and frequent switching are encountered. They do however, usually incur penalties of about 8 times as large a rolling resistance compared to steel wheels, at least one set of wheels must usually be steered or allowed to castor on curves and guidance and switching equipment also tends to be larger than for steel wheel vehicles.

A balance can be obtained between the rolling resistance of a tyre and its adhesion and quietness. At one extreme is the policy pursued by Demag of using separate tyres for support and guidance. Their tyre is solid and runs on a smooth steel surface. The coefficient of adhesion, the rolling resistance and noise are all small while traction, braking, guidance and switching all have to be supplied by other means.

At the other extreme the Boeing vehicles for Morgantown use their rubber tyred wheels for support, traction, braking, guidance and switching. The tyres need to be able to supply sufficient adhesion for the fore-and-aft accelerations incurred in traction and braking and the lateral accelerations experienced in guidance and switching. As these characteristics must be maintained in all weathers, the tyres need to have a tread pattern in addition to being of reasonable diameter, pneumatic and constructed of high hysteresis rubber. To complement this the track must be constructed of a material such as concrete or macadam that can give good adhesion under various weather conditions.

Between the extremes mentioned above there is spectrum of designs some with linear motors for traction and braking, some with arms giving lateral guidance and switching independently of the wheels and some which bias the steering, but rely on an alternative means of guidance for switching.

The general trend is to use separate equipment for each function on systems with more sophisticated control requirements and to combine the functions mentioned above in instances where the headways and routes are less demanding. This seems logical since methods that combine these functions tend to have lower performance.

The Demag Cabinentaxi and Aerospace P.R.T. systems have some of the highest performance requirements and have the functions of support, guidance and propulsion completely separated, but the Matra Aramis system, although employing very close headways, has propulsion and support combined and relies on wheel adhesion.

3.1.2 Magnetic Levitation

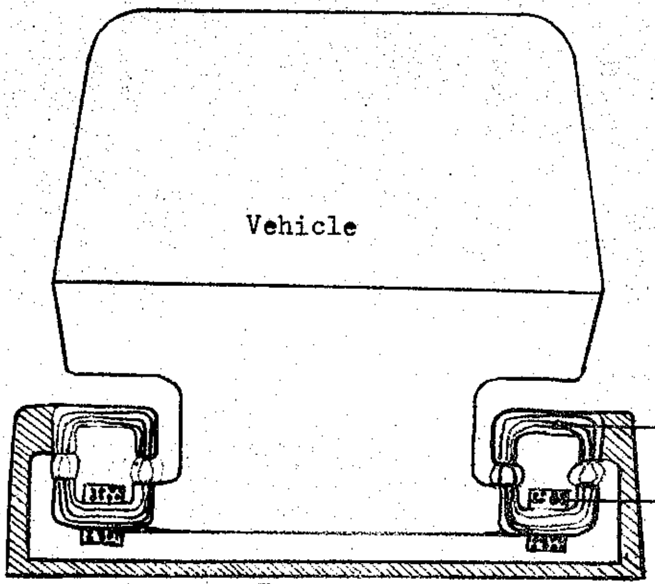
Interest in magnetic levitation has developed very recently and has centred on methods that use electro-magnets that are attracted to steel rails(see: Krauss-Maffei, A16;Rohr 'Romag',A19). Other magnetic and electro magnetic methods have been considered, but are mainly applicable to high speed vehicles.

The magnets can either be used purely for support or for both support and guidance. For support, in which control is required in the vertical axis, servo control of the electromagnets is necessary as they are unstable (the attractive force increases the closer the two surfaces are to one another). Laterally the magnets are stable and they tend to centre themselves over the steel in the track. Some systems use this characteristic to give lateral guidance (e.g. Krauss-Maffei TAKT). The electromagnets may be either in the track or on the vehicle. The passenger compartment may be above or below the track. Both the systems under serious development (Rohr's 'Romag' and Krauss Maffei's 'TAKT') have electromagnets on the vehicle and the passenger compartment is above the track. The vehicle is also mechancially prevented from severe lateral or vertical movement which might remove it from the track. There are developments which combine support and propulsion, but in its most usual form a magnetically suspended vehicle would need a separate propulsion system such as a linear electric motor.

Magnetic levitation, of the form described, relies on an active suspension, to retain a gap between vehicles and track and give a smooth ride to passengers. The suspension depends on a complex electronic system, which must measure the vehicle-to-track gap and probably also the velocity and acceleration between the two, then translate this into a stabilizing fluctuation in the magnetic attractive force. It still remains to be seen whether electronic equipment can be made to operate reliably on a public service vehicle. In other situations such as railways and buses electronic equipment has not been found very reliable at least initially, but the unreliability has mainly been caused by vibration which hopefully would be absent in this type of system.

The power requirement for magnetic levitation has not been definitely established. The D.C. power to levitate a vehicle without disturbing forces can be relatively easily calculated and gives a power requirement of about 1 kW per tonne. Fairly complex simulation is required to assess the power required when there are also perturbations in 2-axes (vertical and horizontal).

The A.C. component that is needed to cope with these force transitions necessitates very much higher peak voltages (about 10 times) which in turn need heavier insulation and possibly longer flux paths.



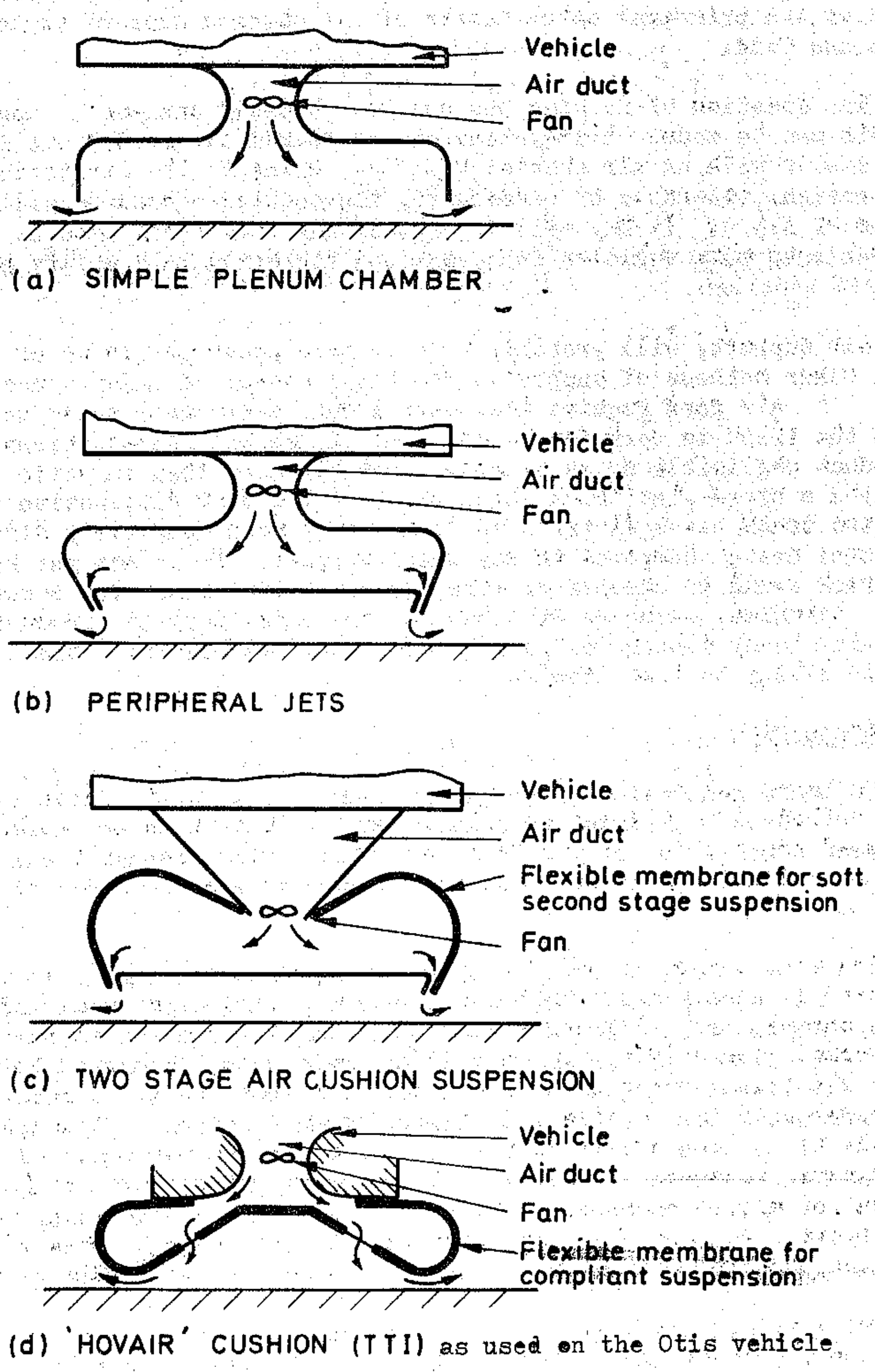
Magnetic levitation is likely to be considerably quieter than wheel support or air support and the major noise source on an electric vehicle may be the current collectors and possibly any necessary cooling fans. This is one of the major advantages of magnetic levitation. In addition it provides a method of support that is not seriously affected by small radii curves and steep gradients.

Its disadvantages, apart from its lack of development, are not easy to be precise about. Its power consumption will be, it is expected, up to twice as much as an equivalent pneumatically tyred vehicle depending on whether support is to be maintained in stations. Maintenance will not entail any standard replacements such as tyres, air cushion skirts or rails, but it remains to be seen whether replacement of failed electrical components amount to a significant cost. General reliability, as mentioned above is unknown. Switching by magnetic means will probably always involve a second set of magnets, which will increase vehicle weight. Non magnetic methods of switching would be less elegant, but may well be cheaper.

3.1.3 <u>Air Support</u>

Many forms of air supported vehicles have been constructed in the last ten years. However, the layout that appears to have emerged as most popular for guided urban vehicles uses a flexible skirt or bellows on the vehicle to increase the amplitude of permissible suspension movement.

The vehicles being developed by Otis (A21) feed their air-cushion from the vehicle: the vehicle being developed by Uniflo (A22) feeds the cushion from the track. Both vehicles can be moved laterally when the normal guidance walls are absent. This is claimed as an asset by the



Alternative forms of air-cushion suspension.

developers, as it makes lateral docking in stations easier. Station docking is one of the principal extra assets of air cushion support exploited by Uniflo and Otis.

The question of docking has not been closely analysed. However, certain comments can be made. All systems can be docked laterally, but it is likely to be easier with an air cushion vehicle. Owing to the limitations on acceleration, tolerable by passengers, the docking manoeuvre will take a minimum of 3.5 s. It may well be that if any docking is used it would be preferable to move vehicles in a vertical direction to simplify passenger access to stations.

Air support, will probably require more power per tonne of load than any of the other methods of support. The final answer to this is unclear. Although small air gaps require low power input, skirt wear tends to be high unless the track is very smooth and clear of debris. Air-cushions are likely to produce negligible noise although probably more than magnetic levitation. They need a broad flat track which provides the most distinctive features. Since the track has a distributed load it may need completely different structural design compared to say wheel support. It is not yet known whether this track would be cheaper or more expensive than track for concentrated loads. Likewise, although Otis have demonstrated that an air-cushion vehicle negotiates track debris well, air cushion vehicles require a track of a form which is likely to trap debris.

3.2 Propulsion

On board generation of propulsion power from fossil fuels is one of the oldest methods of supplying propulsive energy, but it is not normally considered acceptable for new forms of urban guided transport owing to the noise and pollution generated and poor economics when used for high density flows.

The most common means of transmitting propulsive energy to vehicles now considered is electrical. Mechanical methods (cableways, rack and pinion, helical screws) are still under consideration, but are not easily applicable to networks. The only system that is actively being developed but does not rely on electrical propulsion is Uniflo. Air from the track reacts against vanes underneath the vehicle and imparts forward motion. Although this method is likely to be less efficient than electrical means per tonne of vehicle for thermodynamic reasons, it permits a lightweight vehicle with no power collection equipment or motors on-board to be used. This may provide an economic solution to transport corridors that have high flow densities, but in many urban situations the high cost of the track will make the system uneconomic.

One developer (L.T.V. A5, A6) also has developed a system with the major propulsion component in the track. This is a system using a linear induction motor drive with the motor stator coils in the track. It has similar advantages and disadvantages as those mentioned above for Uniflo. Aerospace have used a stepper linear motor in their model vehicles partly, it is believed, to assist headway control. However, it is not known whether they are efficient in full size vehicles.

Electrical propulsion by means of rotary or linear electric motors has become the most popular form of drive, because they both avoid the complications of on-board prime movers and offer the most efficient and convenient means of utilising centrally generated power.

3.2.1. Propulsion by means of wheel adhesion and rotary electric motors

If wheels are employed to convert the torque of an electric motor into thrust a whole range of types of electric motor can be considered. However, the propulsion is dependent on adhesion being maintained; either by the weight of the vehicle or by means of two wheels clutching a rail (the Fell system).

Rotary motors are, in general more efficient, lighter and cheaper than existing linear counterparts. At the speeds in question, rotary motors are lighter because they can be geared with the relative speed between rotor and stator being faster than that of the vehicle. However, rubber tyred vehicles would probably also need separate motors either side, or a differential, in order to negotiate curves.

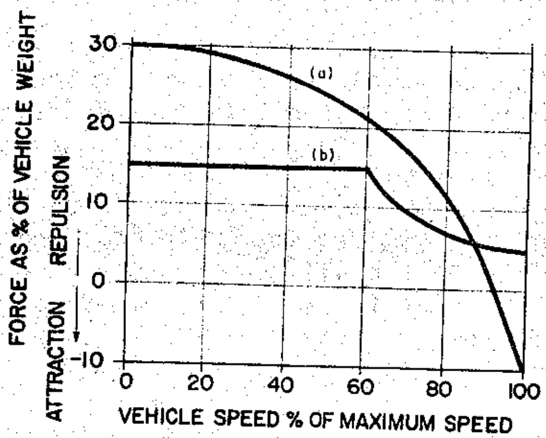
Although the electrical concepts in linear and rotary motors are the same, some layouts are successful in the one form and not the other. Gramme-ring wound motors and transverse flux motors are not viable in rotary form. D.C. linear motors are rare, but are the best known form of rotary traction motor.

The use of rotary motors and wheel propulsion in the future will largely depend on developments in control methods and of linear motors, as these are progressing faster than the development of rotary motors. If linear machine efficiency and costs continue to improve the rotary motor-gearbox-wheel combination might be outclassed while developments in D.C. motor control methods might favour rotary machines and developments in variable frequency A.C. control favour linear machines. At the moment the rotary motor is a cheaper, lighter and more reliable drive than the linear motor.

3.2.2 Linear machines

The serious development of linear electric motors has occurred in less than ten years, thus their final potential is not yet known. Unlike a rotary motor the relative speed of the rotor and stator is determined by the speed of the vehicle. The most economic relative speeds are likely to be over 200 km/h for normal A.C. electrical frequencies. Most urban vehicles will travel well below ideal motor speeds and will therefore incur a weight penalty. In addition all types of linear motor suffer from endlosses which do not occur with rotary machines. As the two main components of the motor are split between the vehicle and the track and need to remain in close proximity for efficient operation, the suspension of the vehicle needs to cater for opposing demands: a motor that must follow the track with some precision and a passenger compartment that must be given a smooth ride. This has meant in some instances that the motor and cabin must be provided with separate suspensions. Nevertheless the gap between rotor and stator on linear motors is usually about 12 mm compared with about 2 mm for rotary motors. These problems also apply to the L.T.V. Lectravia that has the main motor windings on the track.

Most early development of linear motors was concerned with double sided machines in which two stators (on the vehicle) sandwiched a reaction rail (on the track). This provides a most efficient form of motor, but has largely been superseded because the rotor rail, which is usually made of aluminium about 5 mm thick, is fragile and hinders track switching. The single sided motor is now more usual. There is one set of stator coils on the vehicle suspended above a flush reaction rail on the track. Although this layout is a little less efficient it has been adopted by many developers for its simple track configuration. The forces between reaction rail and stator



(a) Vertical force

(b) Thrust force

are in this design unbalanced and vary from an attractive force to a repulsive force as the vehicle speed increases. This will further complicate suspension design and may necessitate either a separate support structure for the motor or an active suspension.

A linear motor drive enables electric propulsion to be used on non-contact vehicles and means that wheeled vehicles can operate without reliance on adhesion for propulsion. The motor is simple and avoids mechanical drives. However, its disadvantages should be recognised -

(a) The track must include a reaction rail (or, in the case of Lectravia stator coils).

(b) The motor and power control system are more difficult to design than for rotary machines. A cheap design gives poor performance in one of the following areas: power factor, vertical forces, motor/control weight, vehicle performance.

(c) The suspension of the vehicle is complicated by the gap and force problems mentioned above.

(d) The power factor of the motor is poor (about 0.5 compared to about 0.9 in rotary motors) this can either cause more expensive power equipment to be needed or require heavy power rectification equipment.

Table: Some types of electric motor applicable to traction purposes.

Rotary Motors	Linear Motors
Series Field D.C.	Longitudinal flux 3 - phase A.C.
Series/Parallel field compound D.C.	Transverse flux 3 - phase A.C.
{ 3 - phase, low frequency A.C.	Gramme-ring wound 3 - phase A.C.
{ 3 - phase variable frequency A.C.	

Table: Some methods of power supply to automated urban vehicles

		1	2	3
Grid to track supply		Transform to 400 V and Rectify	Transform to <6kV separate phases	Transform to <6kV 3 - phase
Track supply carries		400 V D.C.	0 → 6kV single phase A.C.	0 → 6kV 3 - phase A.C.
Vehicle Equipment				
Vehicles with D.C. rotary motors	a)	Voltage control by resistors	Supply voltage reduced (transformer): rectified: control by transformer tapping	Supply voltage reduced (transformer): rectified: control transformer tapping
	b)	Pulsed supply (D.C. chopper)		
Vehicles with A.C. linear or rotary motors		Supply inverted to variable frequency 3 - phase A.C.	Supply triplicated and fed via voltage control	Supply fed directly via voltage control

3.2.3 Energy Consumption

The primary causes of energy dissipation by a vehicle in motion are air resistance, braking and suspension losses. For a typical urban vehicle, the following table shows how the losses are distributed for different forms of suspension.

Table: Energy losses in kWh/tonne km

Cruise speed 13 m/s

Distance between station 1 km

1.	To overcome air resistance and supply kinetic energy (dissipated during braking)	0.033
2. a)	To overcome tyre drag (typical)	0.035
b)	To overcome steel wheel drag (typical)	0.004
c)	To supply air pads	0.05
d)	To supply electro-magnets	0.04

2(c) and 2(d) will vary with air gap height (figures shown relate to clearances of a few millimetres) and contain no allowance for use of active suspension while the vehicle is stationary.

The values given above are estimates of energy output; the input must account for inefficiences. For a tyre supported rotary-motor-driven vehicle, efficiency will be about 80%. The total output of 0.068 kWh/tonne km tabulated above would require an input of about 0.084 kWh/tonne km. Extra losses may occur during acceleration. Using series resistors - the most inefficient method - the required input might be raised to 0.103 kWh/tonne km giving an overall efficiency of only 66%. Linear motors are generally less efficient than rotary motors.

3.3 Guidance

Vehicle-guidance solely by a signal has not been favoured, and some form of physical barrier is usually provided. The form of guidance in the vicinity of a switch may differ from that elsewhere in the system.

A common form of control employs an arm which locates on a rail or in a slot and directly restrains lateral movement of the vehicle. There may be two alternative rails or slots and the vehicle can, by a simple mechanism, latch on to either and thereby be made to take either of two routes at a track switch. (The L.T.V. Lectravia is an example of this method). In a simple extension of the method the vehicle sits in a trough or straddles a beam and a guiding arm is only used at switches. This approach is used, for example, by: Matra Aramis, L.T.V. Airtrans, Hawker Siddeley Minitram.

Other forms of guidance allow some latitude in vehicle movement. Steel coned wheels return a wheelset to a central path by means of the difference in rolling diameters of an offset wheelset. Finally, if a lateral oscillation becomes too large, lateral movement is restrained by the wheel flange. A similar situation occurs with vehicles that employ biased steering of pneumatic tyres. Instead of following a central path, a normal Ackerman steering is biased to seek either the left or right wall of a channel. An arm neutralises the steering bias when near the wall. The bias towards either wall can be employed as a method of choosing two at a junction (Boeing, Morgantown). This form of guidance relies on wheel adhesion and is thus less suitable when high rates of lateral acceleration are contemplated.

The Krauss-Maffei TAKT system, relies as mentioned in Section 2.1.2 on the natural stability of its support magnets.

3.4 Switching

Methods of switching are usually divided into two groups: those in which a change in attitude occurs on the vehicle and those in which a change occurs on the track. Virtually all developments in guided transport relied, until the last few years, on switches in which the track changed. However, closer headways can usually be obtained by changes in vehicle attitude. A track change must occur in the time interval between vehicles following one another while a vehicle change must occur in the time taken to travel from one switch to another. On a network system vehicle headways will generally be less than switch spacing and hence vehicle switch operation is usually preferred. On line haul systems the choice is less critical and both methods are often proposed.

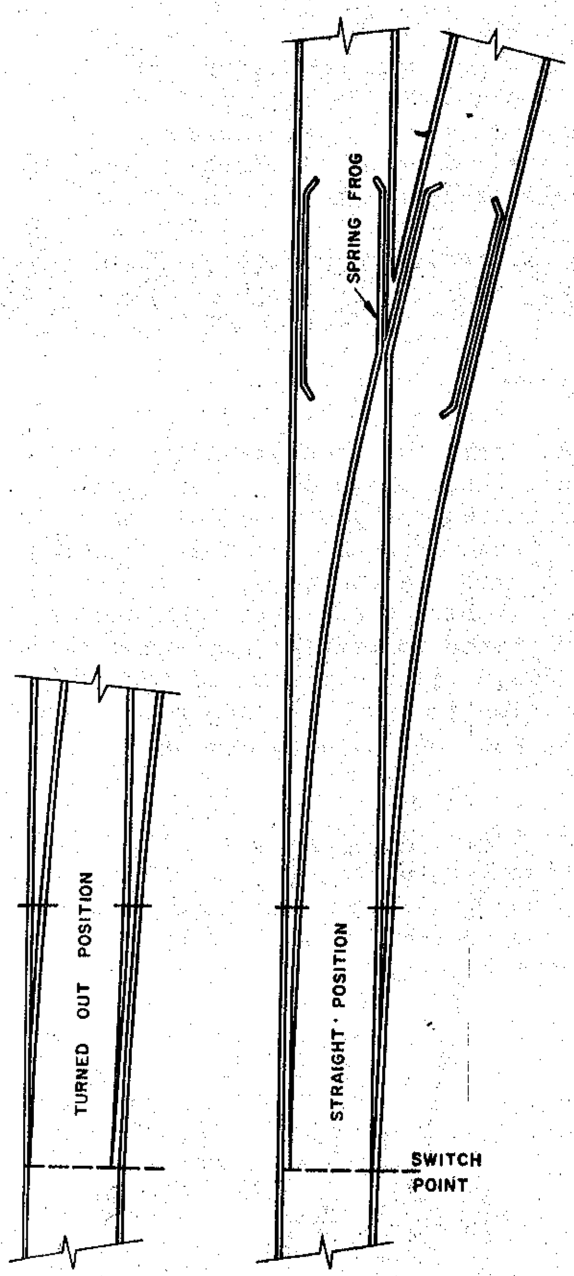
The cost and speed of actuation of a switch are usually closely related to the size of element that moves. The Westinghouse Skybus uses a particularly large portion of moving track and has been criticised for this limitation in its design. A conventional railway uses a small moving element. Hence, junctions and sidings can be built quite cheaply.

In cases where switching is carried out by changes on-board the vehicle, the mechanism is usually small, comprising wheels that can be moved to engage channels either side of the track. However, a few of the proposals are large. The L.T.V. Lectravia has a cumbersome mechanism stretching the whole length of the bottom of the vehicle. The Krauss-Maffei TAKT uses extra electromagnets for switching. This avoids moving components but entails additional weight and switchgear for large currents on the vehicle.

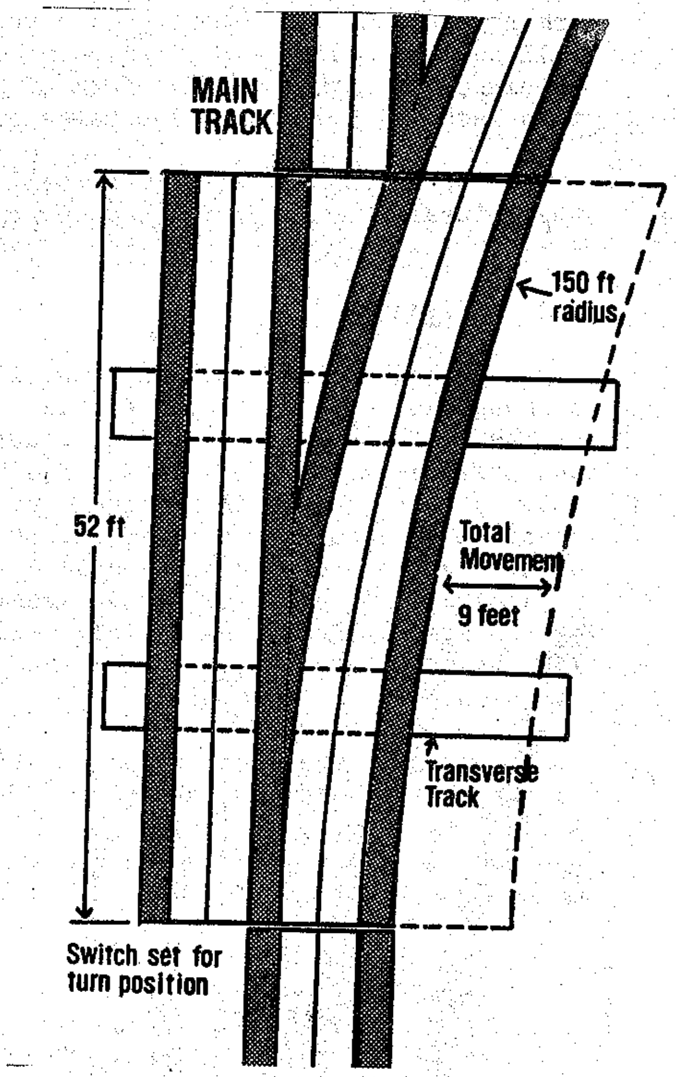
4 Track Characteristics

The support track for automatic reserved track urban transport may represent 50% of the capital cost of the whole system and be also the most visible portion.

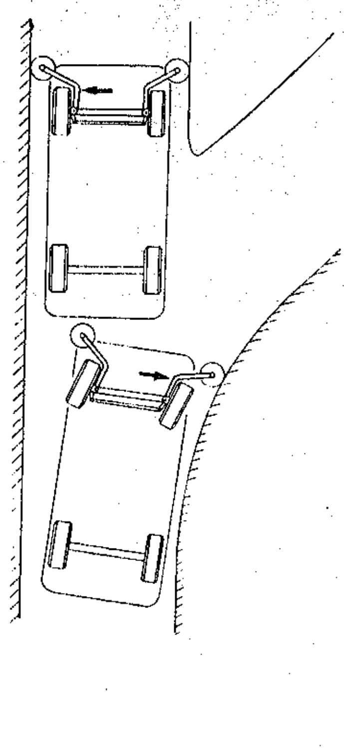
Attempts to improve the physical appearance of the track may have a great influence on the design and cost of track above ground, some on surface track and almost none at all on tunnelled track. Since most schemes proposed envisage a high proportion of overhead track, the problems associated with track and vehicles above ground have been most influential in



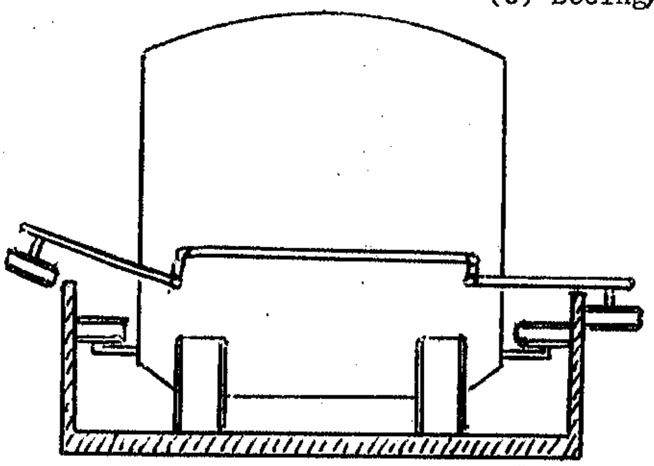
(a) Conventional rail switch.



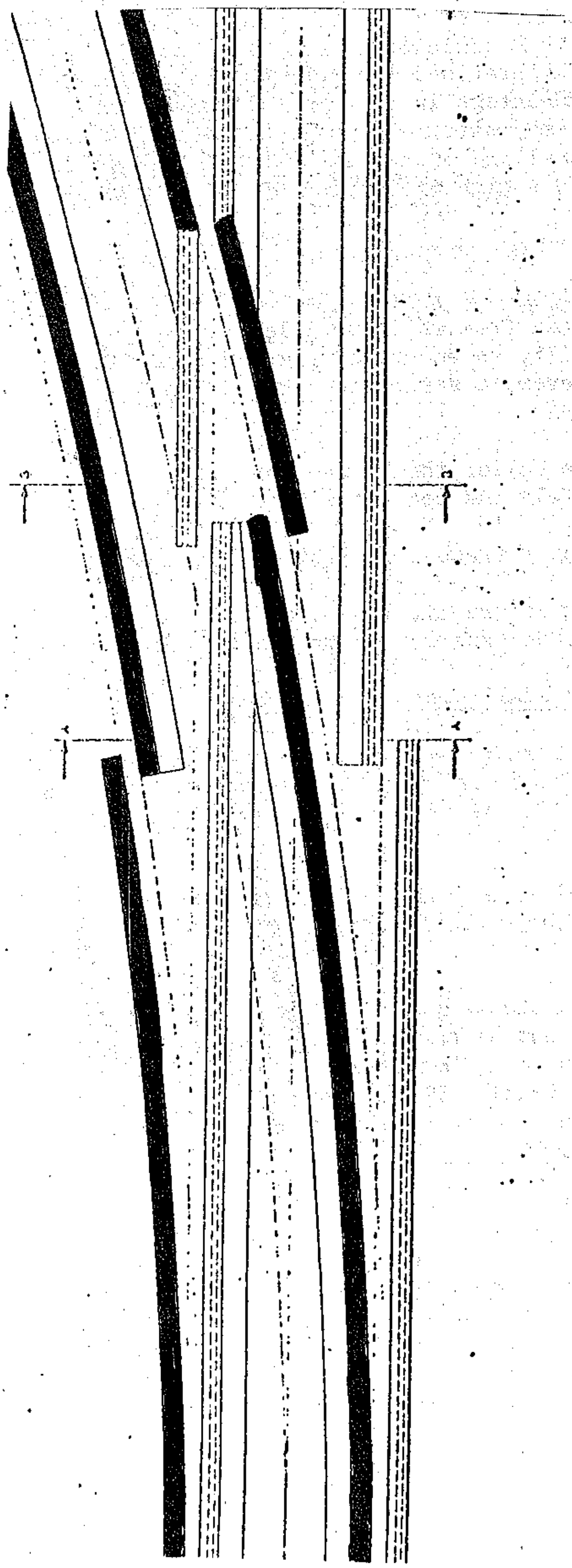
(b) Westinghouse Skybus switch.



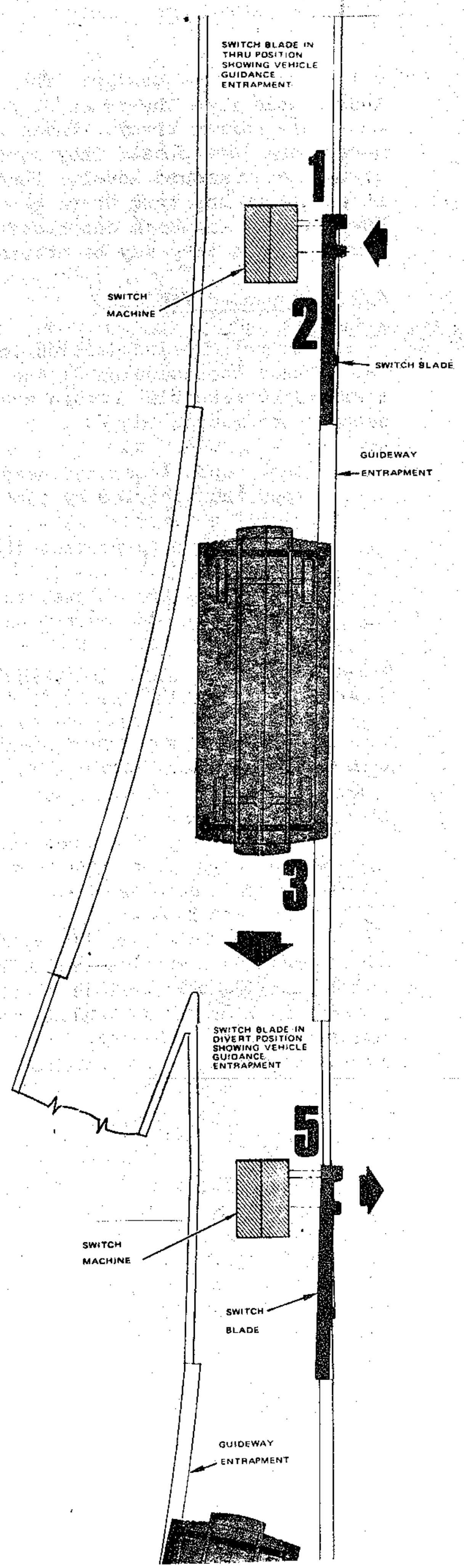
(c) Boeing/Alden switch.



(d) Common method of switching



(f) Krauss-Maffei switch (2 sets of magnets are necessary to negotiate the rails shown).



(e) L.T.V. Airtrans switch.

determining track design. The most extreme of these are schemes that suspend the vehicle from the track or ensure that vehicles can run in a stable manner on a very narrow track. These are characterised by: Rohr Monocab, Siemens H-bahn and Aerospace. They give no advantage in a tunnel and are a disadvantage at ground level. Thus they may carry a significant economic disadvantage in any town where ground level and tunnelled track is preferable. However for a network cab system where a high proportion of track must be above streets they may be attractive.

4.1.1 Suspended Vehicles

The principal objection to a track from which vehicles are suspended has already been mentioned: the inability to economize where surface level track is permissible. There are, however, a series of other factors that need to be considered.

- Track support columns need to be taller than those for bottom supported vehicles by approximately the height of the vehicle.
- It is easier to protect the track surface from weather and debris.
- If vehicles are allowed to swing laterally, the track does not need to react to overturning forces experienced by the vehicle.

4.1.2 Vehicles supported underneath by small cross section beams

Only Aerospace propose to operate vehicles that rest on beams of similar size to suspended vehicles. Their scheme employs a vehicle undercarriage that fits in a deep slot in the track and is stabilized by wheels pressing on the sides.

This proposal overcomes the problems of tall columns encountered by suspended vehicles, but does not gain their advantages of a protected track with no torsional loads.

The Krauss-Maffei TAKT system and the very compact Demag Cabinentaxi use reduced track cross-sections, but not as small as those mentioned above. In both systems the vehicle straddles a beam, but Demag have vehicles both above the track and suspended from the track. These designs promise a less intrusive track. They may be more expensive to construct and, owing to the straddle vehicle, make switching difficult.

4.1.3 Track for bottom supported vehicles

The majority of system proposals suggest a track underneath the full width of the vehicle. This configuration simplifies the design of guidance, switching, power supply and vehicle access at the expense of the factors mentioned above, probably the most important of which are the intrusiveness of the track and the lack of protection to its surface. Most systems use sidewalls for guidance and switching but even these may be eliminated (Westinghouse Skybus).

4.2 Methods of Construction

(See U.T.R.G. Working Paper No. 16).

4.2.1 Overhead Track: Foundations

Foundation methods are likely to be similar to normal civil engineering practice. Methods can be broadly divided into: spread footings where a column rests on a flat lump of concrete about 1 m below the surface and 3 m square; and piled foundations where piles - usually concrete in towns - are driven up to 20 m deep.

: Superstructure

Both steel and concrete construction are suitable for track structures. The cheapest track can usually be constructed from standard steel beams, but this rarely looks attractive. Track that is acceptable in urban surroundings is usually made from concrete, as special sections are expensive in steel. Two alternatives that are sometimes favoured are.

- A simple steel structure covered by lightweight steel panelling. This plan was adopted in Morgantown and is proposed by Messerschmitt-Bolkow-Blohm for their Cabinentaxi system.

- A composite steel and concrete structure has recently become favoured for road and pedestrian bridges. This may offer a cheap means of building track that incorporates vertical and horizontal curves, but it has not yet been adopted for an automated system.

Column spacing varies between 10 and 30 metres.

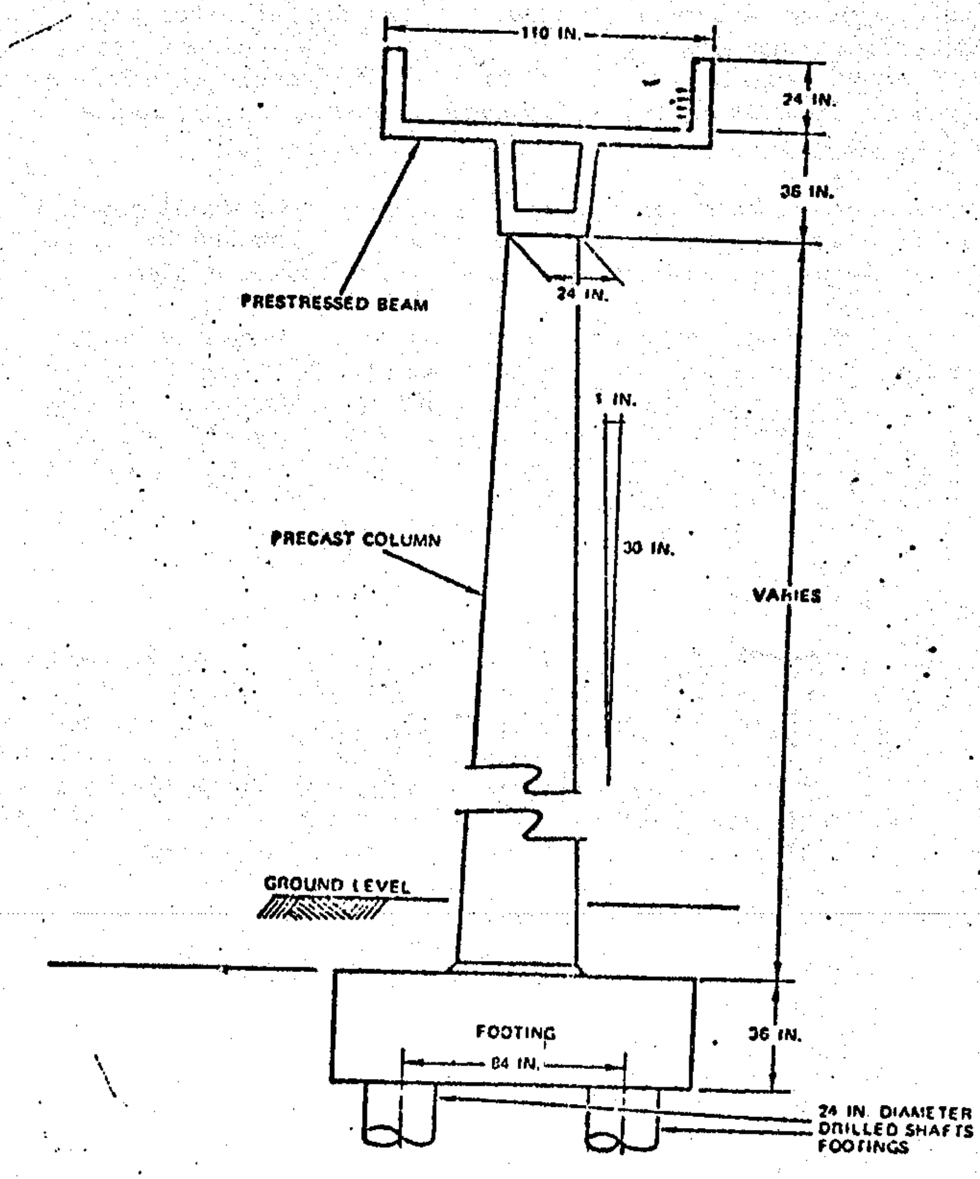
4.2.2 Ground level track

Although ground level track is not frequently discussed as an alternative, both systems that exist at present, Morgantown and Dallas/Fort Worth use long sections of ground level track. A considerable proportion will probably be used in most future proposals. Systems with intricate methods of support such as the Krauss-Maffei magnetically levitating vehicle and the Aerospace vehicle gain very little from surface level construction as the same form of structure is still needed at a lower level. However, bottom supported vehicles using wheels and air cushions can easily use conventional road-beds made from tarmacadam or concrete. These have been extensively developed and are much cheaper than overhead structures. Lateral restraints can be also simply constructed from concrete or steel.

4.2.3 Tunnelled Track

Like ground level track little emphasis has been devoted to tunnelled track by developers. Although many towns might demand sections of tunnelled track, many vehicles are built in a shape that does not use the cross section of a typical tunnel economically.

The sizes of tunnel needed for automated systems (2 - 5m in diameter) are frequently used for other purposes and thus constructional techniques are well understood. Tunnels can either be bored or constructed by covering in a trench that is initially dug. Whereas the trench or cut and cover method is usually cheaper in open ground, in a city where it is difficult to obtain temporary possession of the ground above a tunnel and there are many services under streets, both methods are similar in cost.



TYPICAL GUIDEWAY BRIDGE SECTION

5 Automatic Control Techniques

Control is the regulation of energy in response to information. Driving a car involves the processing of a large amount of information, some of it acquired en route and some memorised at the start of a journey. Because a driver makes mistakes during this processing, and because certain information is not available (e.g. future positions of other vehicles), his performance falls short of the ideal. When the driving function is transferred to automatic equipment, it is not usually convenient to place all the equipment, like the driver, on board the vehicle. This is partly because there is no communication system available as versatile as human sight, so that vehicles may need to communicate with each other via a trackside intermediary. It is also because control equipment in a central location is well placed to handle widespread phenomena like congestion and queueing.

Automatic vehicle systems consequently have their control functions distributed between vehicle-borne and trackside devices. Indeed a three tier heirarchy is common, comprising vehicle, local and central controllers, linked together by a communication network. The vehicle controller handles active suspension, steering, motor control and the control of ancilliaries such as heating. The local controller regulates the progress of vehicles along the track or through stations, and also monitors the safety of their motion. The central controller or computer is concerned with authorising the despatch of vehicles, of foreseeing and preventing movement conflicts, of regulating the supply of empty vehicles and of handling a range of system disturbances.

5.1 Longitudinal control

The longitudinal motion of an automated vehicle (as opposed to lateral or vertical motion) is determined by the commands received by vehicle motors and brakes. In a few cases the driving motors are not on board vehicles, (see LTV's Lectravia, Uniflo), but generally it is easier to transmit variable commands to a vehicle than to transmit a variable force. These are often two control systems working simultaneously, one giving 'normal' commands, and the second giving commands only in an emergency as for example when the first develops a fault. Of the many possible ways of effecting longitudinal control, three have been particularly favoured, namely block control, marker-following control and vehicle-following control.

Block control as traditionally used on railways is well-suited for emergency signals. The track is divided into sectors, and the presence of a vehicle in a sector causes an 'emergency stop' command to be displayed at the entry to that sector (or to the preceding sector). Other less restrictive signals can be located in the preceding blocks, warning any vehicle there what lies ahead. The smaller the block length, the more finely graded can be these advance warnings - for example each block can be allocated a maximum speed based on the distance to the next vehicle ahead (and also on permanent speed restrictions due to track curvature). Fixed block control is not ideal for normal running, partly because it leads to rather inefficient junction control. Fixed block control is used by LTV at Dallas Fort Worth airport and as an emergency back up system by Boeing-Alden at Morgantown.

Marker-following control, like fixed block, requires no direct vehicle-to-vehicle communication. It is a form of position control, insofar the future position of all vehicles is known within a small error; it therefore permits simple yet efficient control at junctions. The markers that vehicles follow are conceptual rather than mechanical: the whole transport network is provided with track signals that define an endless chain of moving points. At junctions two points coalesce into one, or one branches into two. Vehicles are so launched from stations as to 'attach' themselves to one of the points. The term synchronous control is often given to this system and is the method favoured at Morgantown.

Vehicle-following control, also known as asynchronous control requires direct communication between vehicle, for example by some form of radar. If a vehicle is running on empty track it obeys speed commands from the track. When it approaches the rear of another vehicle it adjusts its speed to be some function of spacing. This technique will not work when vehicles are on merging routes, where other measures have to be taken. The behaviour of platoons of vehicles each using vehicle-following control has been studied by road traffic engineers, some of their findings can be helpful in the design of automatic controllers. The Matra Aramis system employs vehicle following-control to form and maintain tight platoons ('trains') of 4 seater vehicles. MBB's Cabinentaxi employs the method for all normal operation.

5.2 Merging control

Where two tracks converge or cross, it is not usually necessary to give vehicles special steering commands, but it is necessary to regulate their longitudinal motion to prevent collisions. There are two alternative philosophies for achieving this. Under deterministic control, a vehicle's entire journey is so planned as to avoid conflict with other vehicles at merges. Under stochastic control, vehicles present themselves at merges and a local controller sorts out potential conflicts.

The deterministic approach is associated with marker-following longitudinal control. Advance booking tables are used to effectively reserve part of a junction's capacity. With appropriate refinements a high usage of merge capacity (merges are often the main system bottlenecks) can be obtained. The schedules of a conventional railway are an example of deterministic control: however the ability and practice of a railway system to revert to local control following loss of schedule, makes the term quasi-deterministic more appropriate. Quasi-deterministic also describes systems wherein the task of local controller at merges is limited to rearranging the order of a few vehicles, the longer term arrival rate at the merge having been kept within its capacity by means of careful regulation of journey starts.

Stochastic or ad hoc control of merges is most simply achieved using 'traffic lights', allocating the merge for alternating periods of time to the two incoming tracks. The consequent queues result in journey delays, and special arrangements are needed to prevent the queue at one merge growing back through some previous junction. Both vehicle-following control and fixed-block working are compatible with queue formation. Delays at merges can be reduced if approaching vehicles are individually interleaved. This is possible with block control and possible but very difficult with vehicle following control.

5.3 Routing control

In contrast to the situation at merge points, at diverge points special longitudinal control is not required but special lateral control is. The means of effecting choice of branch at a fork is discussed elsewhere: the making of the choice itself is called routing. Four general methods of routing can be distinguished representing the range from total to zero vehicle autonomy. Then can be called route memory, destination memory, vehicle identity and passive vehicle methods.

If a vehicle commences a journey carrying a set of instructions that will lead it to its destination, no participation in routing is required from trackside equipment. The vehicle is, for routing purposes, autonomous like a car in a city street. In order to work through its route memory, the vehicle only requires notification that it has passed a diverge point. The method has three weaknesses, viz. it is not easy to load the vehicle with the routing instructions, its route cannot be altered once it has set off, and any error in execution sends it to the wrong destination. Otis vehicles incorporate a route memory.

A vehicle can be loaded, at the start of its journey, with a record of its destination. On approaching a diverge point the vehicle 'reads' the trackside signpost, compares it with its destination memory and routes itself appropriately. Alternatively, the vehicle communicates its destination to a trackside controller which employs a look-up table to determine a switching instruction back to the vehicle. This method of routing still requires that data be loaded into the vehicle's memory at the start of the hourney, however it is flexible insofar as the signposts or routing tables can be altered while the vehicle is in motion.

A vehicle that carries only an identity number can be so labelled during manufacture - there is no need to load data at the start of a journey. However to route such a vehicle requires a trackside controller at every diverge that is expecting the vehicle and has been informed what to do when it arrives. This vehicle identity method entails much more elaborate central control than the two previous methods; indeed the track-side and central computers need to contain an 'image' of the vehicle. This is sometimes called model reference control - the model of the vehicle being a mathematical one. Most control systems use one of these methods. Boeing employ the vehicle identity variation and Flyda the destination identity alternative.

A more extreme form of model reference control is involved in the passive vehicle method. Here the vehicle carries no identification - only its presence is detected by trackside equipment from time to time, and is used to confirm that the vehicle is progressing through the network in step with its image's progress through the central computer's memory.

Each of the methods above has its advantages, and of course in a simple line-haul transport system none of them is required. Making the vehicle autonomous protects the service from disruption due to communication breakdowns and central computer failures, but requires a vehicle sophistication that makes the service vulnerable to other types of failure.

6 ECONOMIC COSTS

Considerable uncertainty attaches to estimates of the economic costs of urban automatic transport systems. Many are still under development, and detailed designs of track, stations, vehicles and control systems have not been made, thus precluding anything beyond general indications of cost. In cases where finalised designs do exist, for reasons of commercial secrecy cost estimates are only rarely made available to outside organisations not directly involved in associated contract work.

Even if detailed designs were completed, uncertainty would remain nonetheless because of the significant proportion of new and sometimes untried techniques incorporated in a number of the advanced systems under consideration. The construction and running of prototypical systems will undoubtedly provide valuable initial information on costs, and such published costs will, it is expected, include an element of the expense incurred in the development process (see below for comment on the costs of vehicles for the Morgantown PRT system). Costs incurred in the sustained building of vehicles and track for a "production-run" system will be much lower.

Accurate estimates of operating costs can only be made after a period of passenger carrying service. Overseas data, especially from the USA, is interesting and helpful, but of limited value to UK researchers because of such difficulties as the reconciliation of variations in wage and salary scales, as well as manufacturing and urban conditions. Lastly, it is considered possible that manufacturers, successful or unsuccessful in their contract bids, may be prepared to tender at prices which incorporate only minimal profit components or no profit at all in order to obtain the prestige of an order or a degree of market ascendancy - a trend perhaps encouraged by the generosity of governmental contributions to R and D expenses.

The estimates which follow refer to two distinct types of system - a 'linehaul' autotram-type system and a system using smaller (although not very small) vehicles providing a demand-actuated service akin to 'Cabtrack' or 'Autotaxi'. Cost estimates, it is emphasised, depend upon both the level of service contemplated and upon the particular design features and technology chosen: vehicle suspension, for example, may incorporate wheels, air pads or perhaps magnetic levitation. Lack of reliable information prevents any attempt to cost all the available permutations in design which suggest themselves. The actual systems to which the costs below refer are described in more detail in the original sources. At present, the limited amount of information available does not suggest that any of the novel technologies under development are likely to lead to significant savings in capital or operating expenses in the forseeable future.

A AUTOTRAM COSTS

'Autotram' represents a line-haul system using 15 to 40 passenger vehicles at headways of the order of 10 seconds or more. It might incorporate either on-line or off-line (D-loop) stations and operate in a passenger-demand actuated rather than a scheduled mode at certain off peak periods. Major sources of information on costs used here are the UTRG Working Papers (16, 19, 20) about a route in Coventry, "An Aid to Pedestrian Movement" (2) (See Appendix B) and a paper (1) given by M.H.L. Waters of Advanced Vehicle Systems Division of TRRL to the conference 'Moving People in Cities' in April 1973. Figures given in the paper by Dr. Waters refer to a route-system in Birmingham. A comparison shows that a wide range of estimates still exist for various components, and consequently complete systems in different contexts. Track and station costs depend critically on the types of structure and station under consideration. The estimates from sources (1) and (2) relating to track costs contain an unknown proportion of overhead track but even taking account of this possibility UTRG estimates seem substantially higher. UTRG station costs on the other hand are lower.

Evidence from the Morgantown demonstration project in the USA tends to suggest that some estimates of capital costs for vehicles, including those of UTRG, may be optimistic. The cost of the first five experimental prototype 21 place vehicles for Morgantown was $860,000 each and reflects some proportion of development costs. It is necessary to emphasise that these Morgantown vehicles are highly sophisticated research and monitoring exercises capable of functions not required by the run of the mill 'Autotram', and though technically instructive, are likely to be wholly unrepresentative financial "one-offs". It is envisaged that this figure will be reduced to $60-70,000 per production batch vehicle, a figure nonetheless twice the cost of a high quality 25 passenger bus of USA make.

There is a similarly wide range of operating cost estimates. The high estimates in source (1) may be due to the different type of operation contemplated: distance between station stops is only 200-300 m compared with an average of 1600 m in (2) and 750 m estimated in UTRGs urban area study. 10p/km and 20p/km seem to be the extremes of estimated individual vehicle operating costs.

Table 6.1 Cost Estimates for 'Autotram'

Category	Unit of measurement	Estimates (Source in brackets)	UTRG estimates (WP No 20)
Track	£/km	250,000 (1) 223,000 (2)	150,000 ground level 550,000 overhead 650,000 tunnel
Station	£/station	150,000 (1) 108,000 on-line (2) 156,000 off-line (2)	40,000 overhead on-line island 65,000 overhead on-line 115,000 overhead off-line
Control	£/km	59,400 including power distribution (1)	50,500
Depot	£/vehicle	1000 (1) 1400 (2)	1800
Vehicle	£/vehicle	8333 (1) 20 place 9600 (2) 14 place	12000 20 place
Operating Costs (including all vehicle costs)	p/vehicle km	19 (2) 32300 km/vehicle/year 16 (1) (3)	12 59000 km/vehicle/year
Track Maintenance	p/vehicle km	1.1 (1) (3)	0.7
Station operation	p/vehicle km	)	1.2
Control system operation	p/vehicle km	) 3.2 (1) (3)	0.6
Central management	p/vehicle km	)	0.2
Vehicles			
Initial Cost	p/vehicle km	2.7 (1) (3)	3.4
Maintenance	p/vehicle km	5.2 (1) (3)	3.5
Power	p/vehicle km	3.6 (1) (3)	2.0

(1) 'Minitram - the TRRL Programme' M.H.L. Waters 5/6 April 1973

(2) 'An Aid to Pedestrian Movement' March 1971. Note: Inflation correction +20%

(3) No estimate of km/vehicle/year is given in the paper. The above figure is based on 50000 km/vehicle/year. Alternative figures and their implication for total operating costs are 35,000 (23p/vehicle km) 59,000 (14p/vehicle km) 75,000 (11p/vehicle km).

Operating costs are closely related to the number of vehicle/km run per accounting period, whereas Capital costs - track, stations and control - are largely independent of vehicle/km run. As a result capital costs/vehicle km will vary with changes in track/station configurations and the level of service provided. Table 6.2 compares various cost estimates in the three studies cited.

Table 6.2 Comparison of Cost Estimates 1973 prices

Study	Operating Costs (1)	Capital Costs (1) (2)	Total Costs	Number seats/vehicle	Cost/passenger (3)
	pence/vehicle km			seats/vehicle	pence/pass. km
Westminster	19	12	31	14	6.6
Birmingham	16	13	29	20	4.4
Coventry	12	9	21	20	3.2
Bus	-	-	25	60	1.3

(1) Capital costs of the vehicles are included in operating costs. A vehicle life of 10 years is assumed.

(2) Discounted at 10% over 25 years.

(3) Occupancy = 0.33

All three studies estimate that cost per passenger/km will be greater than the cost of travel by bus (the bus figure is an average for all Municipal Authorities in 1973). The conclusion is that if fares charged were expected to cover only operating costs, they would exceed present bus fares. Whether the introduction of an 'Autotram'-type system is justified on economic grounds will depend on the trade-off between 'Autotram's' increased money costs and its inherently superior service of smaller, more comfortable vehicles operating at very frequent predictable intervals.

B 'AUTOTAXI' COSTS

The major UK source of economic and technical information on 'autotaxis' is the cabtrack report (Appendix B, ref. 1). Cost estimates for 'autotaxi' have also been made by UTRG. 'Autotaxi' systems incorporate 4/5 seat vehicles, usually powered by rotary electric motors driving sprung wheels and carrying their passenger(s) non-stop between origin and destination stations over complex trackwork at the close headways which are achieved by on-board direction selection mechanisms and sophisticated control.

Table 6.3 Cost Estimates for Autotaxi

1973 prices

Category	Unit of measurement	Cost Estimates	
		Cabtrack Report (1)	UTRG
Track	£/km	247000	119000 ground level 379000 overhead 399000 bored tunnel
Transfer lane	£/lane	24000 including control	
Station	£/station	520000 major station 100000 minor station 2400 track side 133800 average	240000 average
Cab	£/cab	1600	3000
Passenger km total cost operating cost	p/km p/km	3.75 (2)	4.9 (3) 3.5

1. Inflation correction +60%

2. London context p. 180

3. Coventry context

7 EXISTING AND PROPOSED INSTALLATIONS

During the last 12 months two important automated transport installations have been opened. A prototype vehicle first ran on a track in Morgantown, West Virginia during December 1972; and at the opening of the Dallas/Fort Worth Regional Airport an automated passenger/cargo distribution system went into revenue service. Two contracts have been awarded for the construction of automated systems: in Toronto (to Krauss-Maffei) and Lille (to Engins-Matra). The Transport and Road Research Laboratory in the UK have revealed their plans for a demonstration project in Sheffield.

7.1 Dallas/Fort Worth Regional Airport

LTV Aerospace were awarded the contract for an automated distribution system to serve the new Dallas/Fort Worth Regional Airport in May 1971. 2½ years later in October 1973 the service was in operation carrying passengers, cargo, refuse and baggage. The contract, worth $33.3 m for 20.6 km of guideway ($1.6 m/km), was a commercial venture initially receiving no government assistance, although USDoT belatedly made a contribution to the project. The Airtrans system provides 11 routes connecting 53 stations in the airport. The services are segregated for passengers, employees and cargo. They use, however, the same lengths of track which, with permitted intervehicle headways as low as 18 seconds, require off-line stations on certain heavily used sections. According to LTV "the basic vehicle and systems represent a new application of proven equipment to resolve a specific transportation problem". The vehicles are of conventional design using well tried, mainly automotive, components, and the longitudinal and routing control is based on conventional railway signalling techniques, and was designed, built and installed by General Railway Signal Corporation. The most important innovation incorporated in 'Airtrans' is probably the switching and guidance mechanism. The only previous major installation of an automated vehicle system was the Westinghouse 'Skybus' (A23) in Pittsburgh (also at Tampa Airport and Seattle-Tacoma Airport) in 1965. Its lack of further applications since that date seems to have been due to the cumbersome switching mechanism (costly and time consuming) and non-steering axles employed which meant a large minimum radius of curvature (about 60 m). The switching device used on 'Skybus' places limitations on headway and a complicated route structure (as at Dallas/Fort Worth) would necessarily require a large number of costly and space consuming switches. The radii of curvature limitations imply strongly that complex geometric layouts in confined areas are difficult to achieve. Airtrans' two steered axles permit radii of curvature as low as 10 m and its track switching mechanism still allows headways as low as 18 seconds.

The services are scheduled but a human central controller may alter schedules or, re-route vehicles to cater for unusual passenger demand

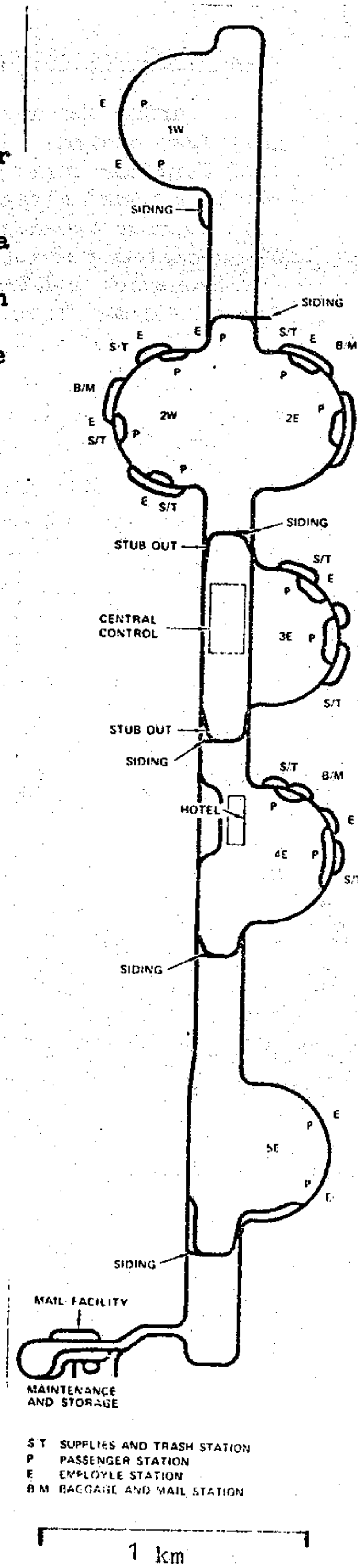
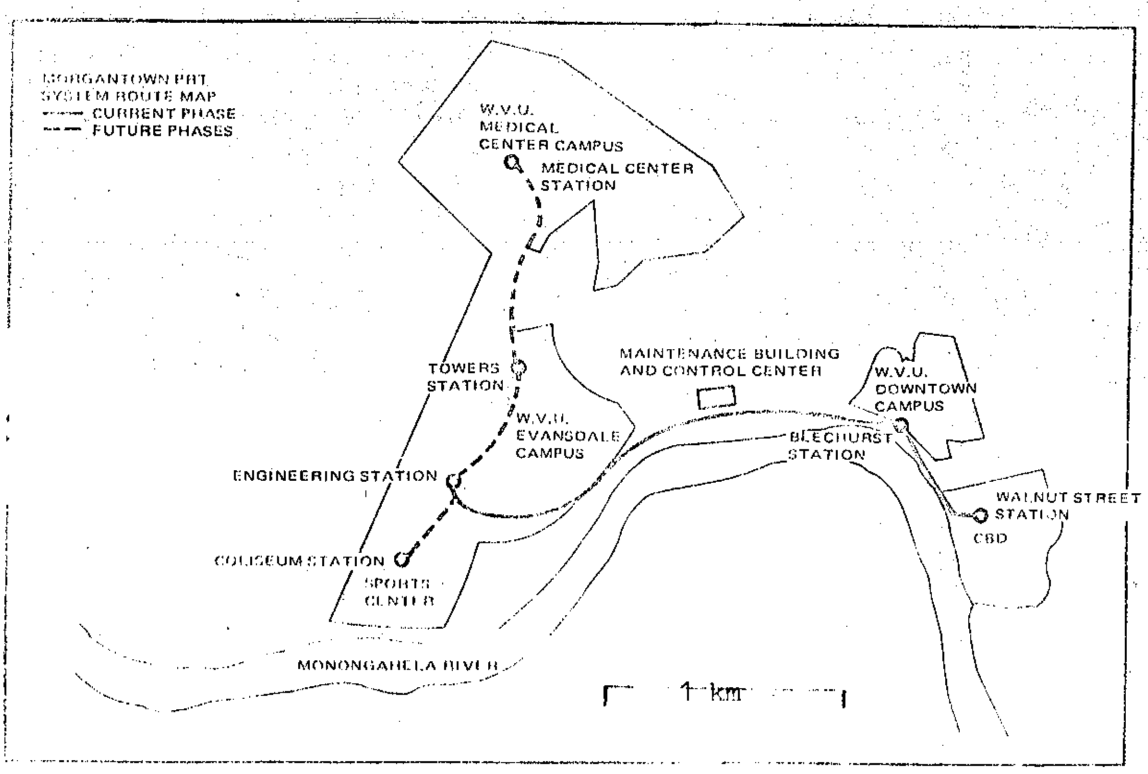


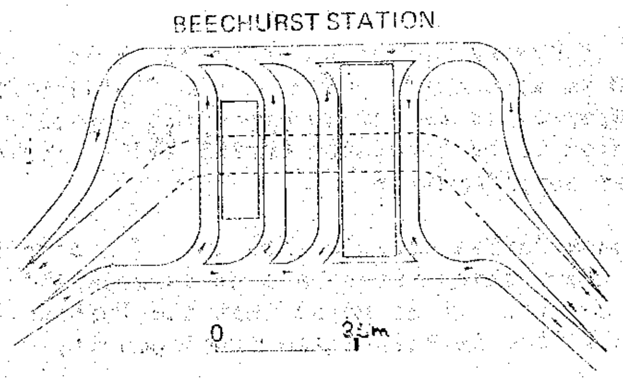
Table 7.1 Comparison of two U.S.A. Installations

	Dallas/Fort Worth	Morgantown
Prime Contractor	Ling Temco Vought	Boeing
Source of finance	LTV DOT/UMTA	DOT/UMTA
Contract Cost ($m)	33.3	63.0
Area of operation	Airport	University/town
Revenue service	Jan. 1974	Jan. 1975 (est)
Length of single track (km)	20.6	6.4
Stations	53 (43 off main line) (14 passenger 14 employees 25 cargo)	3 (3 off main line)
No. services	11 (5 passenger, 2 employees, 4 cargo)	No specific routes
No. vehicles	68 (43 + 8 + 17)	45
Type of operation	Scheduled	Scheduled and On demand
Track width	2.79 (single) m	3.66 (s) m 6.96 (double) m
Vehicle passenger capacity	40 16 seated	21 8 seated
weight (tonne)	6.5	5.4
width (m)	2.24	2.03
length (m)	6.76	4.72
height (m)	3.15	2.67
floor area/pass. (m^2)	0.38	0.46
normal operating speed (km/h)	27.4	44
normal acceleration/deceleration (m/s^2)	1.14	1.25
emergency deceleration (m/s^2)	2.74	3.0
normal jerk not to exceed (m/s^3)	0.76	1.0
emergency jerk not to exceed (m/s^3)		4.0
lateral acceleration not to exceed (m/s^2)		1.25
motor	Compound wound D.C. shunt motor 80 kw at 2736 rev/min Phase delay rectifier	107 kw D.C. shunt motor sc rectifier
switching	off-vehicle	on-vehicle
minimum headway (secs)	18	15 (7½ on one section)

7.2 Morgantown, West Virginia, U.S.A.

Morgantown is a small town with a resident population of 50,000 and a student population of over 20,000. A contract was awarded to Jet Propulsion Laboratory in 1968 (Replaced as systems manager by Boeing in 1970) to build a 6.4 km long track to connect various parts of the university campus and the town centre. The track was opened for testing in December 1972 and is expected to open for revenue service in early 1975. The estimated cost of $63.0 m to date is provided by the US Department of Transportation Urban Mass Transportation Administration (DOT/UMTA) who have a separate office to administer the project. The objectives of the project are several. As a demonstration programme it is expected to demonstrate the technological, operational, and economic feasibility of a fully automated transport system. It is also expected to provide information to help determine the potential applicability of PRT to national needs. It is also expected to help in solving Morgantown's traffic problems. The 6.4 km of 'PRT' track connect two parts of the University Campus with the town centre (see map). Further connections with other parts of the University are proposed (see map). The unique feature of the system employed in Morgantown is its on demand service. In off-peak periods, passengers will be able to call a vehicle by pressing a button at their departure station. A vehicle will be assigned to the station (if there is not already one present in the station) and carry the passenger(s) without intermediate stops to their destination station. Only in exceptional circumstances will this lead to personal vehicles in the sense of one passenger (and perhaps his companion) having exclusive use of one vehicle. The level of demand at each station together with the limited number of destinations will ensure a steady demand for the various journey possibilities. The level of service provided and the average occupancy of the vehicles is a function of the total number of vehicles available on the system (given set performance and demand characteristics). With a vehicle carrying capacity of 21 passengers, it appears uneconomic and wasteful to operate with average occupancies lower than 7 people even in off peak periods.





In order to achieve on-demand service, off line stations and termini are required (In certain circumstances the latter may be required at all stations). The size of these stations may be quite large (see Beechurst). A number of comments have also been made concerning the visual intrusion of the track structure itself. The width of a single track catering for a single 2.0 m wide vehicle is 3.7 m. More thoughtful design with more emphasis on visual aspects and the non-passenger would lead to a more acceptable structure. For example, the 'Airtrans' single track width is only 0.55 m greater than the vehicle width. The Westinghouse Skybus, using no sidewalls, has a track narrower than the vehicle (2.6 m) but the absence of sidewalls leads to limitations on the methods available for switching.

The Morgantown system incorporates two important technical innovations. It is the first application of synchronous control techniques (see p 21) Using the deterministic method it is claimed to allow headways on a limited section as low as 7.5 s although normal operations will be at 15 s headways. Secondly the vehicle (built by Alden Self Transit Corp.) incorporates a form of on-vehicle switching.

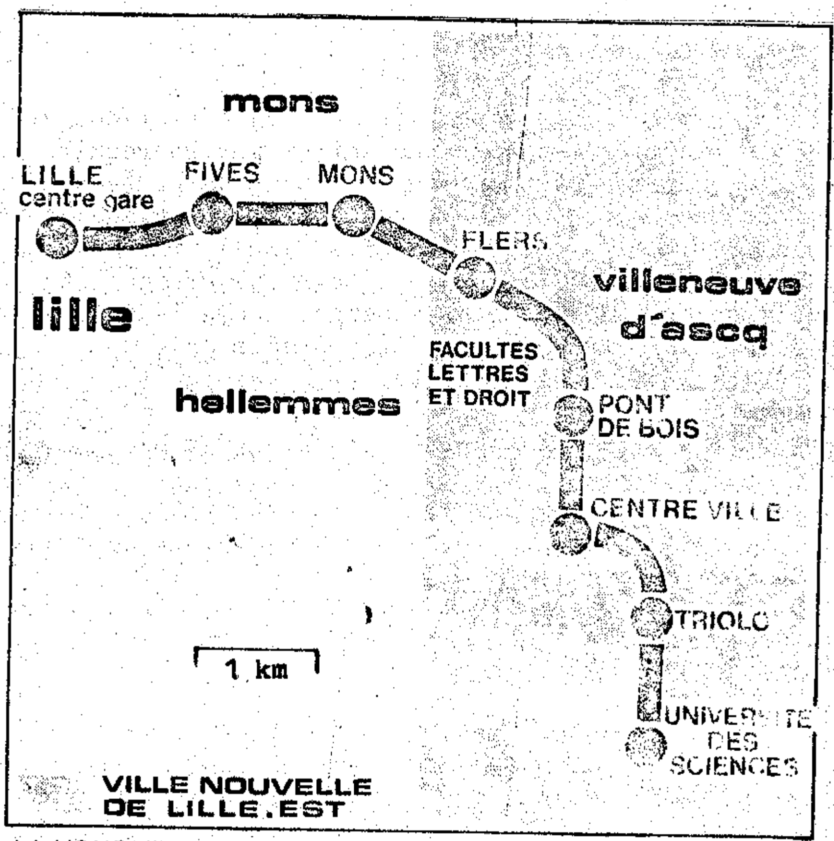
Detractors of the Morgantown system claim that a system of the Airtrans variety would have sufficed, at much less cost and little reduced level of service. To the extent that Morgantown's travel problems required solution, this view may be justified. But Morgantown is more than "just another solution"; it is intended to be a testing ground for a number of concepts (of which on-demand service, synchronous control, and on-vehicle switching are the most important) probably vital to future American developments in automated transport. Results from Morgantown will be carefully examined and the emphasis accorded to different aspects of development will no doubt be critically affected.

It should also be emphasised that Morgantown is just one example - one design - of automated transport. Ten years hence it might conceivably be considered old fashioned and outdated. Different vehicles, different guideway structures and different types of operation which emerge over the next decade will lead to better and more acceptable automated transport systems. It is therefore particularly important to distinguish between comments about Morgantown and comments about automated transport in general - present and future.

7.3 <u>Toronto, Ontario</u>

The German firm of Krauss Maffei was awarded on 1st May, 1973 the contract to build an 8 km automated system at the Canadian Exhibition Centre in Toronto. Referred to as "an intermediate capacity transit prototype" it is expected to be completed during 1975. Proposals for a further 90 km are under consideration.

The proposed Krauss Maffei vehicle (see A16) incorporates two important technical innovations about which there is considerable discussion, magnetic levitation and linear motors. It is hoped that the Toronto project will demonstrate the possibilities in both these developments.



LA LIGNE VILLENEUVE D'ASCQ - LILLE

7.4 <u>Lille, France</u>

During 1973 a contract was awarded to Matra Engins to construct a 16 km stretch of track incorporating 8 stations and connecting Lille with the new town of Villeneuve d'ascq (see map). The VAL system (see A17) employs quite large vehicles - 2m wide, 3m high, 13 m long - compared with other system manufacturers. It uses conventional technology and headways greater than 30 s.

7.5 Sheffield

TRRL/DOE proposals for the development of Minitram culminate, it is hoped, in a public demonstration project in Sheffield. Consultants (Robert Matthews Johnson - Marshall and Partners) are currently examining the civil engineering and architectural implications of 4 km of route and 5 stations in Sheffield. Essentially a Central Area distribution system, the £8-12 million project is hoped to be in operation around 1980. The date is considered to be a 'prudent and realistic estimate of the time taken to get full public and planning approval for a scheme' but 'the system development could be accelerated if this were required'.

The technical details of the vehicle, track and control system will be decided after completion of the project definition studies. These are currently being carried out by Hawker Siddeley Dynamics Ltd. and Easams Ltd. (a subsidiary of GEC Ltd) and should be completed by the end of 1974.

CITY WIDE SYSTEMS

1. Aerospace Corporation (U.S.A.) "PRT" **
2. DEMAG-Fordertechnik (W. Germany) "Cabinentaxi" ***
3. Flyda Ltd. (G.B.) "Flyda C.10" ***
4. Hawker Siddeley Dynamics Ltd. (G.B.) "Cabtrack" *
5. L.T.V. Aerospace (U.S.A.) "Minimover" **
6. L.T.V. Aerospace (U.S.A.) "Lectravia" *
7. S.A. Engins Matra (France) "Aramis" ***
8. Mazda (Japan) "CVS" ***
9. Pullman-Bendix (U.S.A.) "Glide-Ride" *
10. S.I.G. (Switzerland) "Elan" *

Line-Haul/Corridor Systems

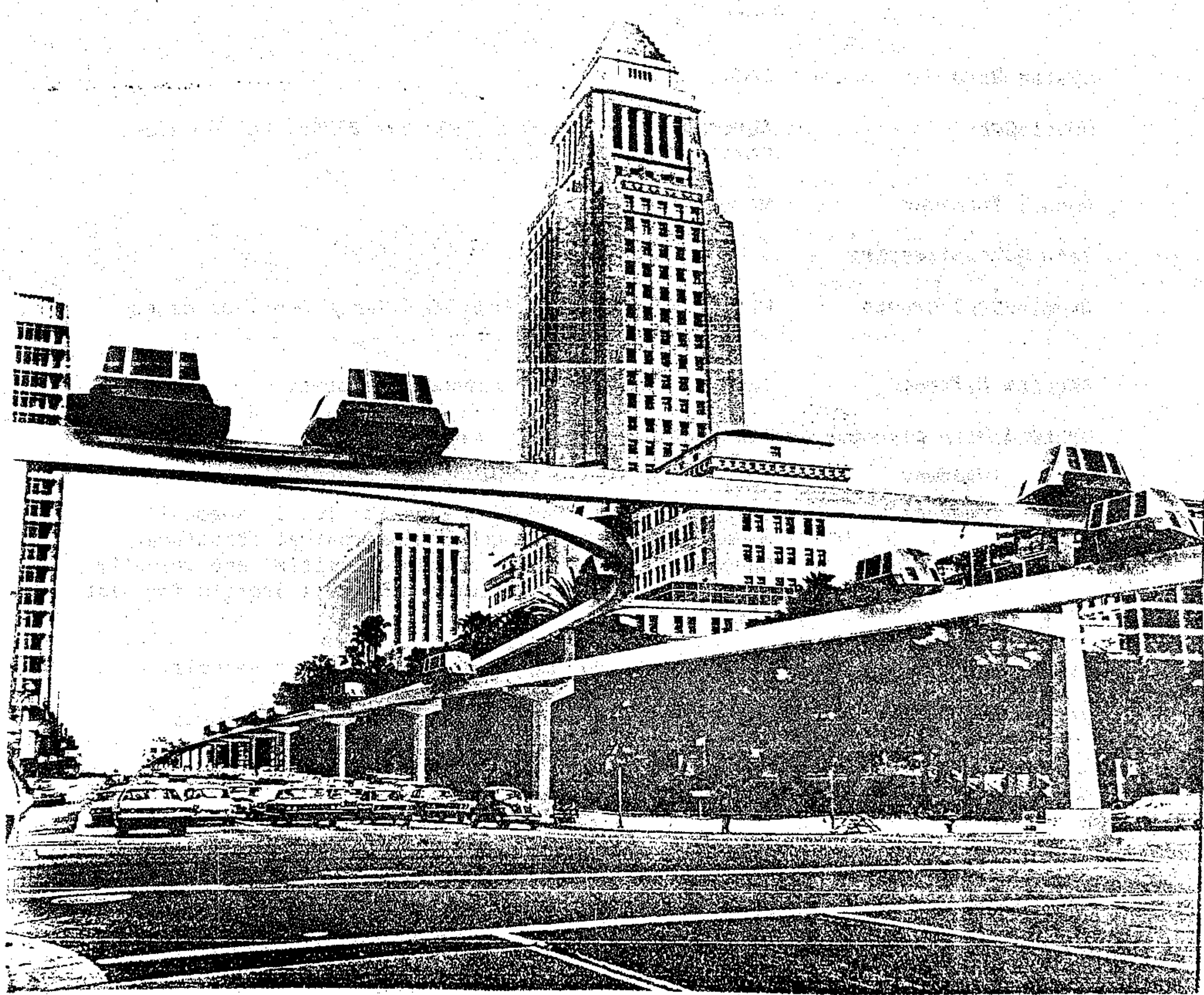
11. Bendix Corporation (U.S.A.) "Dashaveyor" ***
12. Boeing/Alden (U.S.A.) "Morgantown PRT" ***
13. Ford (U.S.A.) "ACT" ***
14. Hawker Siddeley Dynamics (G.B.) "Minitram/Slimway" *
15. L.T.V. Aerospace Corporation (U.S.A.) "Airtrans" ****
16. Krauss-Maffei A.G. (W. Germany) "Transurban TAKT" ***
17. S.A. Engins Matra (France) "VAL" ***
18. Rohr Industries Inc. (U.S.A.) "Monocab" ***
19. Rohr Industries Inc. (U.S.A.) "Romag" ***
20. Siemens A.G. (W. Germany) "H-Cabinen" **
21. OTIS Elevator (U.S.A.) "TTI-OTIS Hovair" ***
22. Uniflo Inc. (U.S.A.) "Uniflo" ***
23. Japanese Consortium "VONA" ***
24. Westinghouse Electric (U.S.A.) "Skybus" ***

**** in revenue operation   *** fullscale prototype

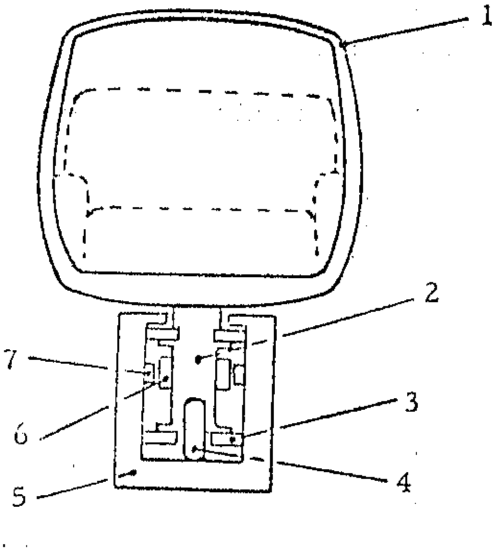
** model operating   * design study, no models operating

as at Dec. 1, 1973.

Most turnover figures are from 'Fortune' magazine. Numbers in brackets are U.S.A. ratings (with '*' non U.S.A.). Some figures from 'Times 1000'.

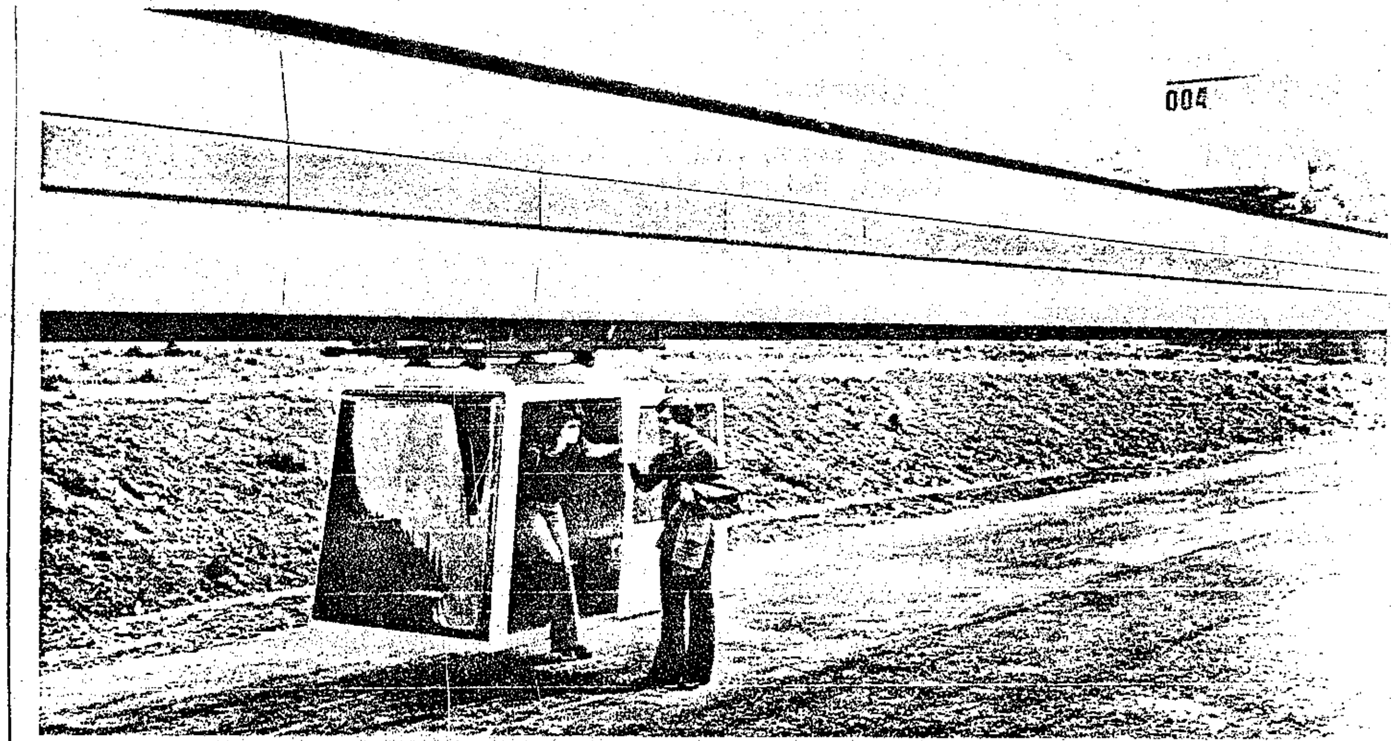


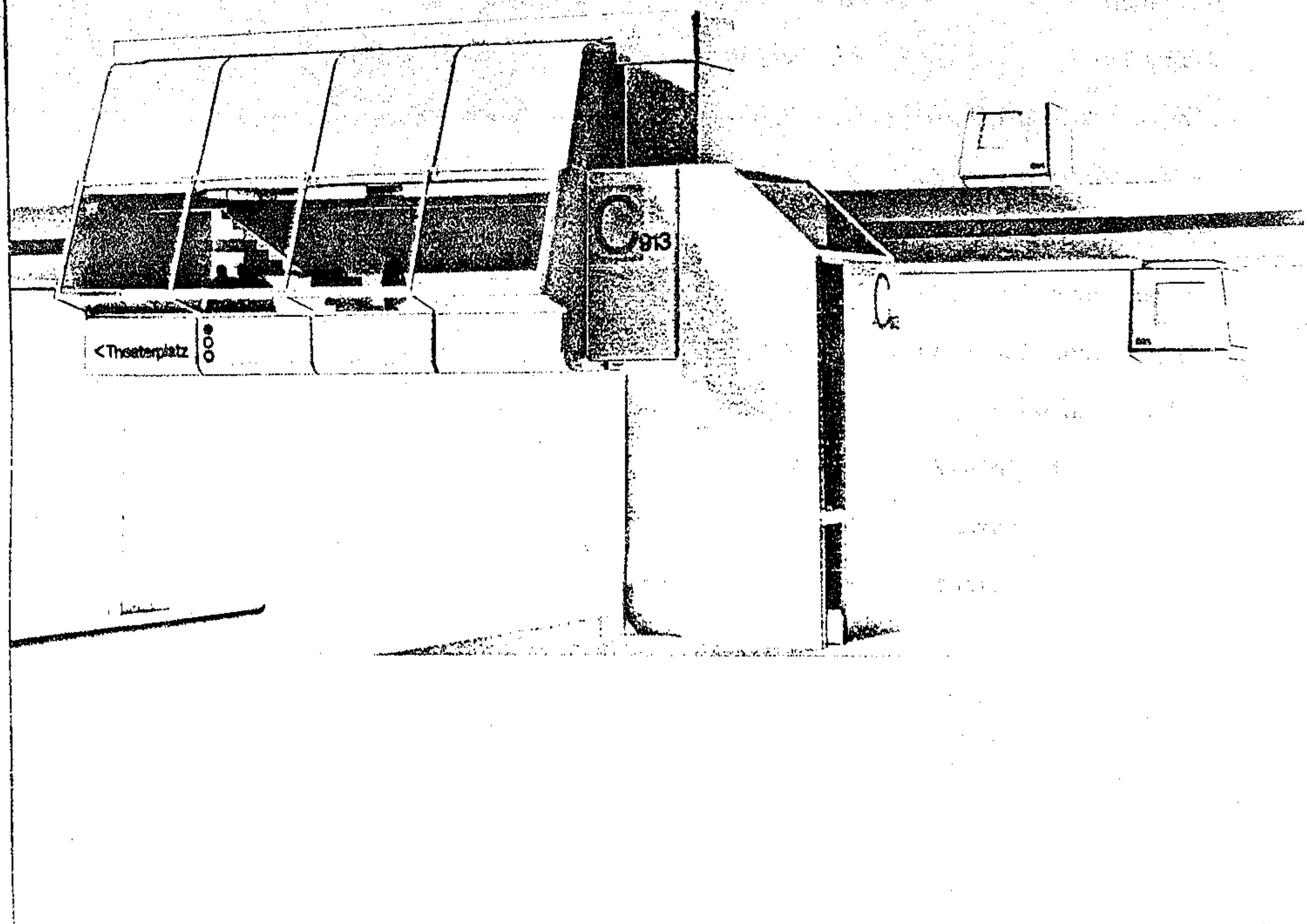
OVERRIDING
MONORAIL
CONCEPT



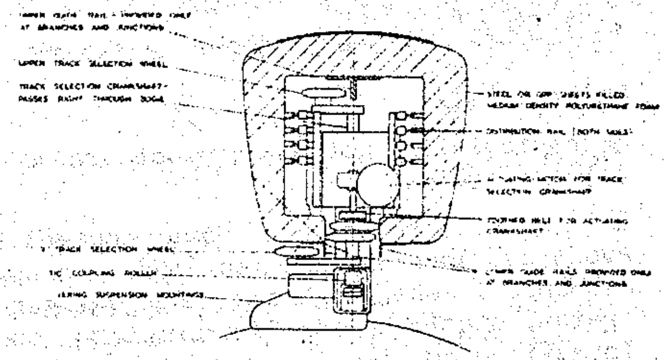
1 -- VEHICLE BODY
2 -- VEHICLE CHASSIS AND SUSPENSION SYSTEM
3 -- LATERAL SUPPORT AND GUIDANCE WHEELS
4 -- MAIN VERTICAL SUPPORT WHEELS
5 -- GUIDEWAY BEAM
6 -- LINEAR ELECTRIC MOTOR PRIMARY
7 -- GUIDEWAY MOUNTED PERMANENT MAGNETS

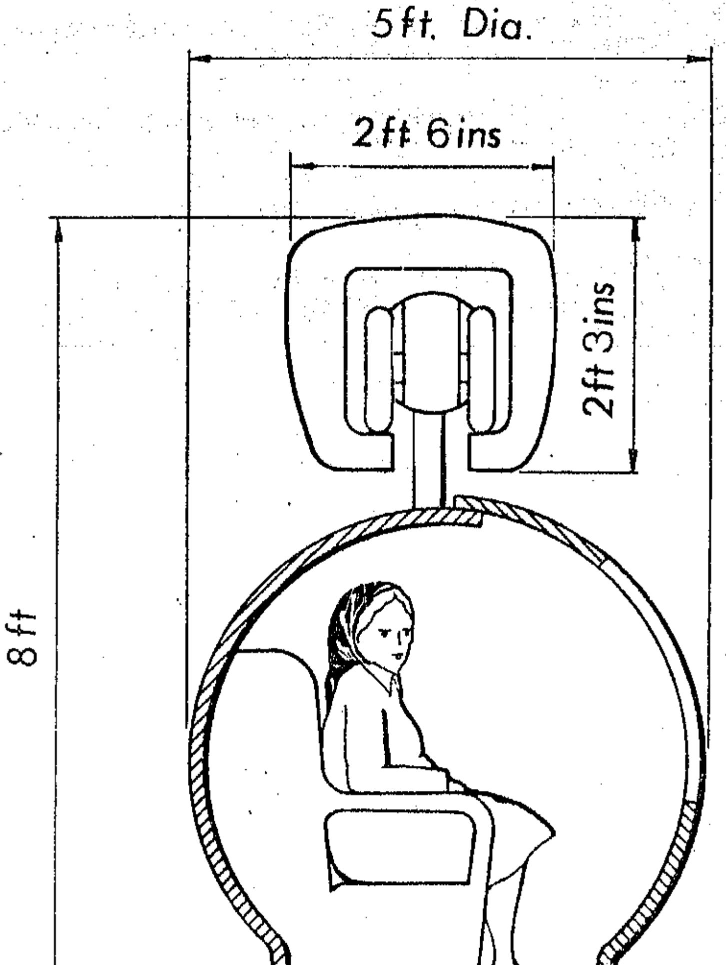
System Name	PRT
Developer	Aerospace Corporation, P.O. Box 95085, Los Angeles, California 90045, U.S.A.
Annual Turnover	No information.
Main Subcontractors	-
Development Grants	Proportion of funds from US Defence Dept. diverted to civilian use.
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Stochastic.
:Headway	Synchronous (slot slipping incorporated).
:General	Vehicles manoeuvred from slot to slot in special management zones through a hierarchical structure. On-vehicle closed loop absolute position and velocity subsystem, including stored manoeuvre profile for slot slipping.
Propulsion	Pulsed DC linear machine - secondary on vehicle.
Braking	Primary braking by reversal of propulsion thrust; secondary by mechanical friction brake.
Support	'Bicycle' main support wheels.
Guidance	Horizontal wheels against guideway sidewalls.
Switching	Electromagnetic attraction to one guideway sidewall.
Single track width(m)	0.75 (full scale)
Normal accn/decn(m/s^2)	2.23
Emergency decn (m/s^2)	8.94
Cruise speed (km/h)	120
Vehicle capacity(pass)	4-6 seated
Minimum headway	1.52m between vehicles at 96km/h
Line capacity(pass/h)	7050 (at 32.2km/h and 1.5 pass/vehicle)
Stage of Development	1/10th scale model constructed and simulated operations. Film available.
Place of Development	Los Angeles, U.S.A.



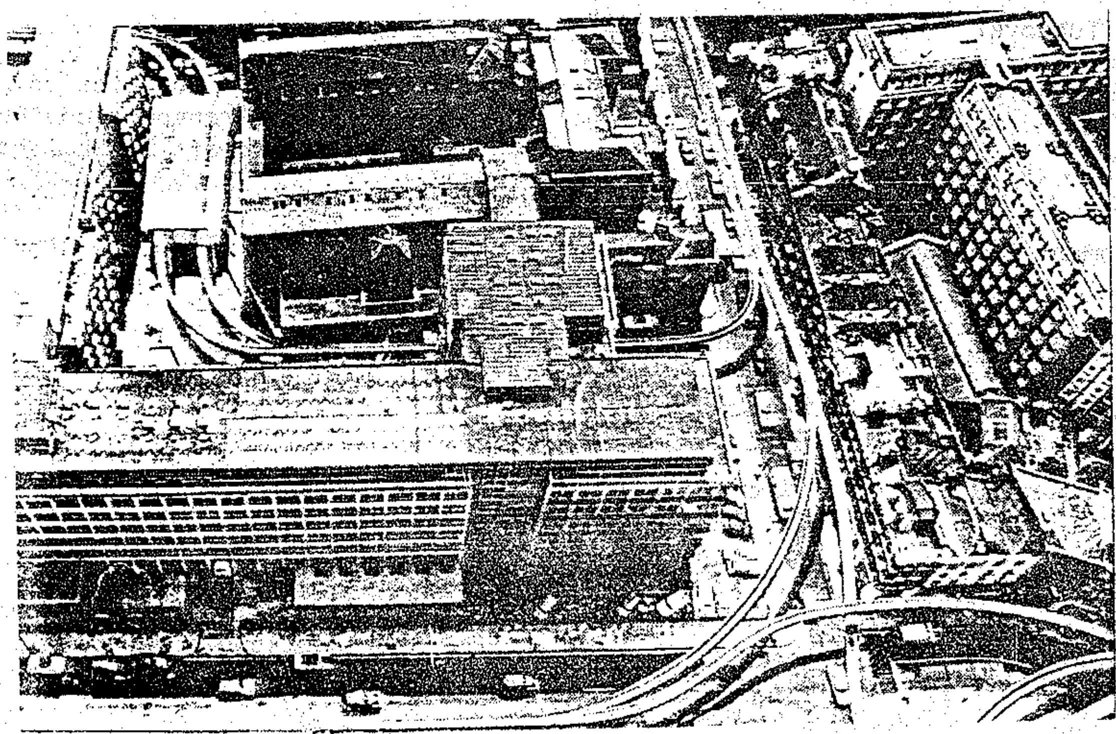

<Theaterplatz
C913

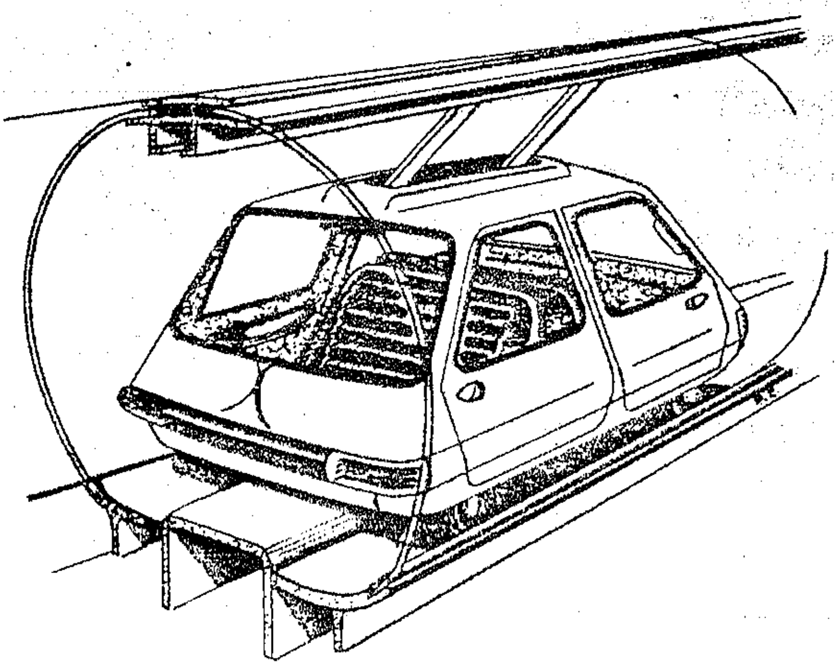
System Name	Cabinentaxi
Developer	Demag Fordertechnik, Produkneventwicklung, 5800 Hagen, Heinitz Strasse 28, W. Germany.
Annual Turnover	$417mil. (216*)
Main Subcontractors	M.B.B. System, 8 Munchen 80, P.O. Box 801/109, W. Germany.
Development Grants	No information.
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Stochastic
:Headway	Asynchronous
:General	Hierarchical control system. First level - local section vehicle control. Second level - station vehicle demand/supply and switching/merges. Third level - optimisation of empty vehicle dispatch. Failure of third level produces reduced efficiency, not shutdown.
Propulsion	Twin linear induction motors, windings on vehicle, reaction member on track.
Braking	Linear motor thrust reversal.
Support	Sprung rubber tyred wheels running in guideway.
Guidance	Wheels retained by guideway.
Switching	On-vehicle selection by rubber wheels.
Single track width (m)	1.5 (vehicles run both above and below beam)
Normal accn/decn (m/s^2)	2.5
Emergency decn (m/s^2)	5.0
Cruise speed (km/h)	36
Vehicle capacity (pass)	2-3 (all seated)
Minimum headway	0.5 - 1.0 s.
Line capacity (pass/h)	6000-10000 at 36 km/h
Stage of Development	300m test track built.
Place of Development	Hagen, W. Germany.


AT BRANCHES AND JUNCTIONS
UPPER TRACK SELECTION WHEEL
TRACK SELECTION CRANKSHAFT -
PASSES RIGHT THROUGH BOGIE
AT BRANCHES AND JUNCTIONS

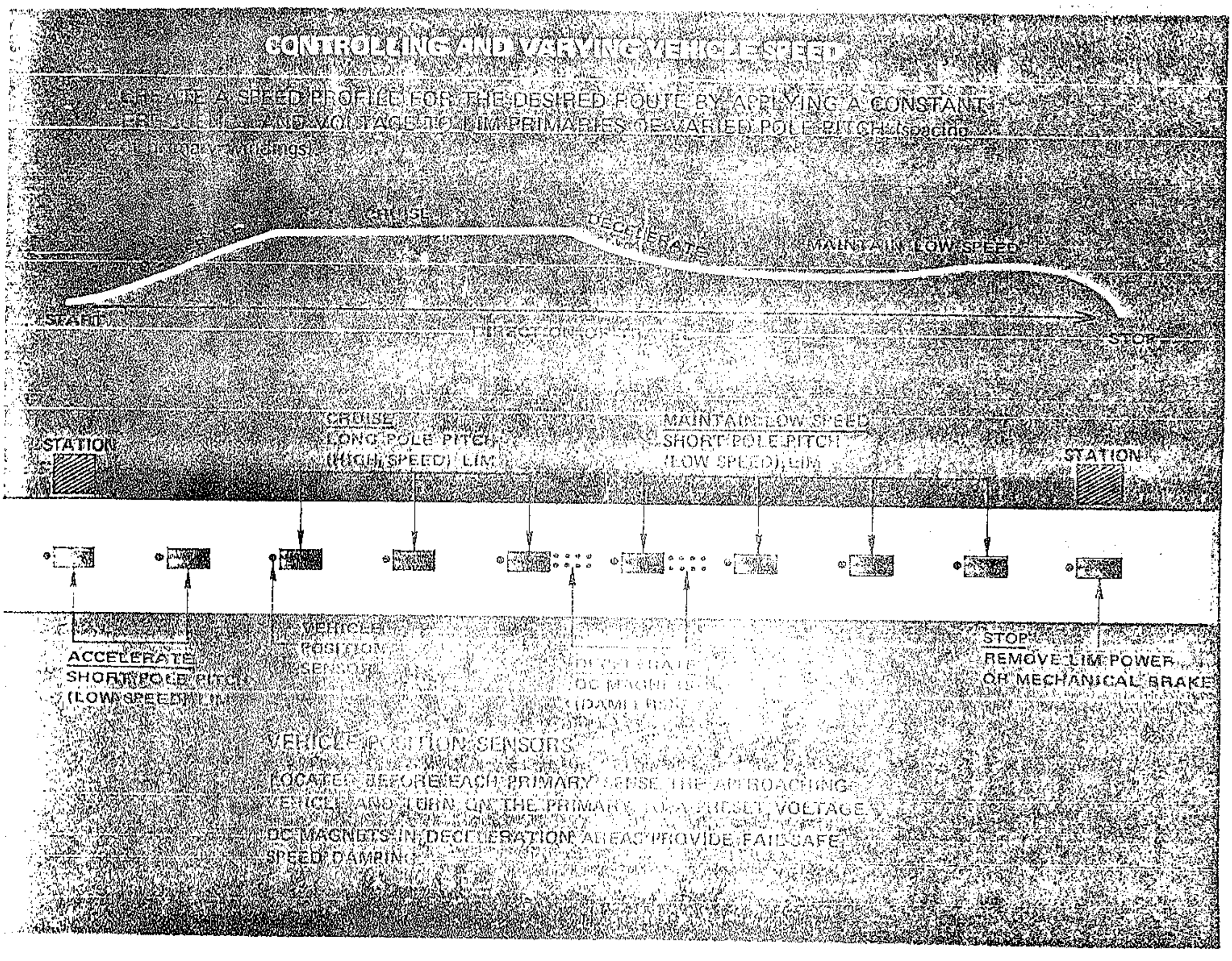

5ft. Dia.
2ft 6ins
2ft 3ins
8ft

System Name	Flyda C10, C30
Developer	Flyda Ltd., South Cerney, Cirencester, Gloucestershire, England.
Annual Turnover	No information.
Main Subcontractors	-
Development Grants	No information.
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Deterministic
:Headway	Mechanical link within 'contact trains', block between trains.
:General	Individually routed cars form 'contact trains' to avoid overloading specific links. A combination of mechanical make/break couplings between vehicles in trains, static blocks for formation, control-formation and dissolution of trains between and by-passing stations, and hierarchical for dispatch and rostering of individual vehicles over desired routes, surveillance and general monitoring (inc. empty vehicle redirection). On-vehicle routing, with automatic speed control by block power supply regulation.
Propulsion	3 phase AC rotary asynchronous bogie-mounted electric motor.
Braking	Regenerative braking for normal service; emergency by caliper application of friction brakes.
Support	'Metalastik' sprung polyurethane tyred wheels; pneumatic tyres on C30.
Guidance	Horizontal wheels against guideway sidewall.
Switching	Patented positive on-vehicle moveable wheel brake selection. (GB Patent No. 1213453) (USA Patent No. 3777667, 3780666)
Single track width(m)	0.62 (overhead)
Normal accn/decn(m/s^2)	1.21
Emergency decn (m/s^2)	2.42
Cruise speed (km/h)	16 (C10); 49 (C30)
Vehicle capacity (pass)	3 (C10); 12 (C30)
Minimum headway	30 (C10); 18 (C30)
Line capacity(pass/h)	6000 (C10); 1200 (C30) (at 50% load factor)
Stage of Development	Full scale C10 prototype bogie built, design information and assembly drawings for C10 available.
Place of Development	Flyda Ltd., England.

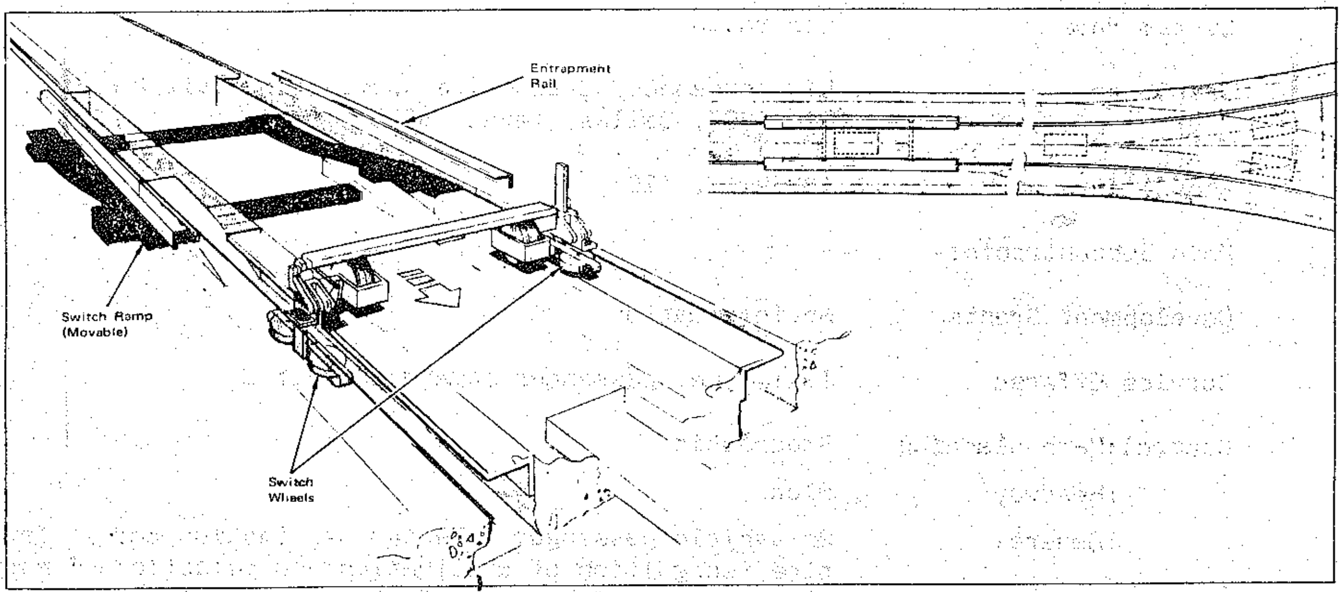


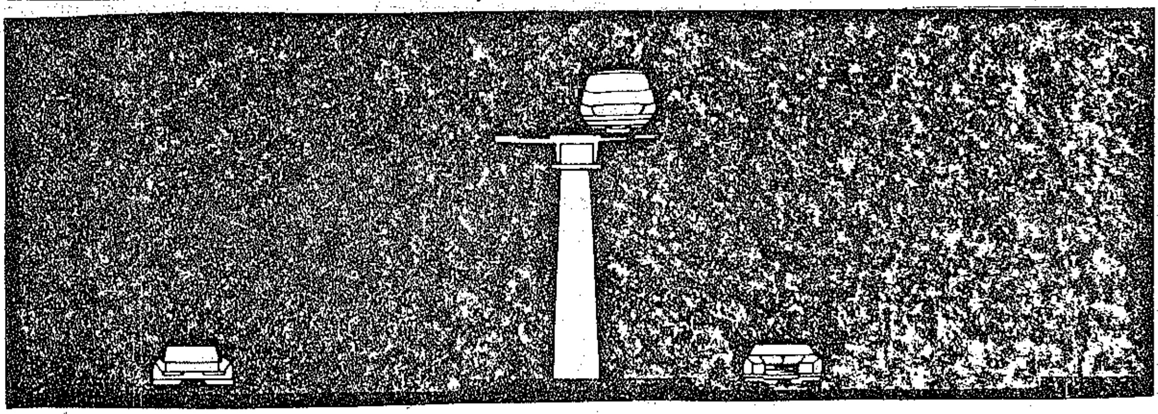


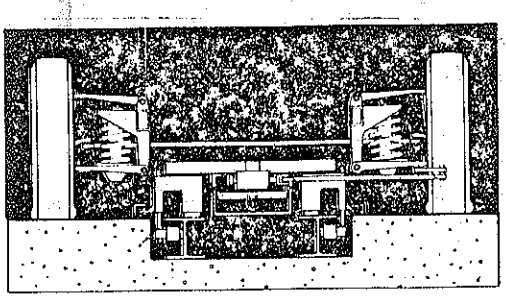
System Name	Cabtrack
Developer	Hawker Siddeley Dynamics Ltd., Manor Road, Hatfield, Hertfordshire, England.
Annual Turnover	$1151mil. (73*)
Main Subcontractors	Concept developed at various times in association with: Brush Ltd., (UK), Dr. L. R. Blake, Transport and Road Research Laboratory (UK), Royal Aircraft Establishment, Farnborough (UK), (RAE).
Development Grants	Considerable work undertaken at RAE, TRRL and Brush Ltd. NRDC assistance.
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Deterministic
:Headway	Synchronous
:General	Hierarchical 1. Basic headway control to maintain intervehicle spacing. 2. Local strategy - in stations and at junctions. 3. Overall - empty vehicle routing, metering of passengers onto system, link overload prevention, diversions to avoid breakdown, cab performance/ maintenance log.
Propulsion	Rotary electric motor.
Braking	-
Support	-
Guidance) Switching)	Horizontal wheels against guideway sidewall.
Single track width(m)	1.7m. approx.
Normal accn/decn(m/s^2)	2.42
Emergency decn(m/s^2)	No information
Cruise speed(km/h)	72
Vehicle capacity (pass)	4 - all seated
Minimum headway	0.9 s. (4000 cabs/h)
Line capacity (pass/h)	1600 (at 4 persons per cab and 10 m/s speed)
Stage of Development	(a) Test track at RAE; (b) Architectural study commissioned by TRRL; (c) Control studies at AVS, TRRL; (d) Study on Central London (AVS); study on Birmingham (AVS); development ceased 1972.
Place of Development	Advanced Vehicle Systems Division (AVS), TRRL.

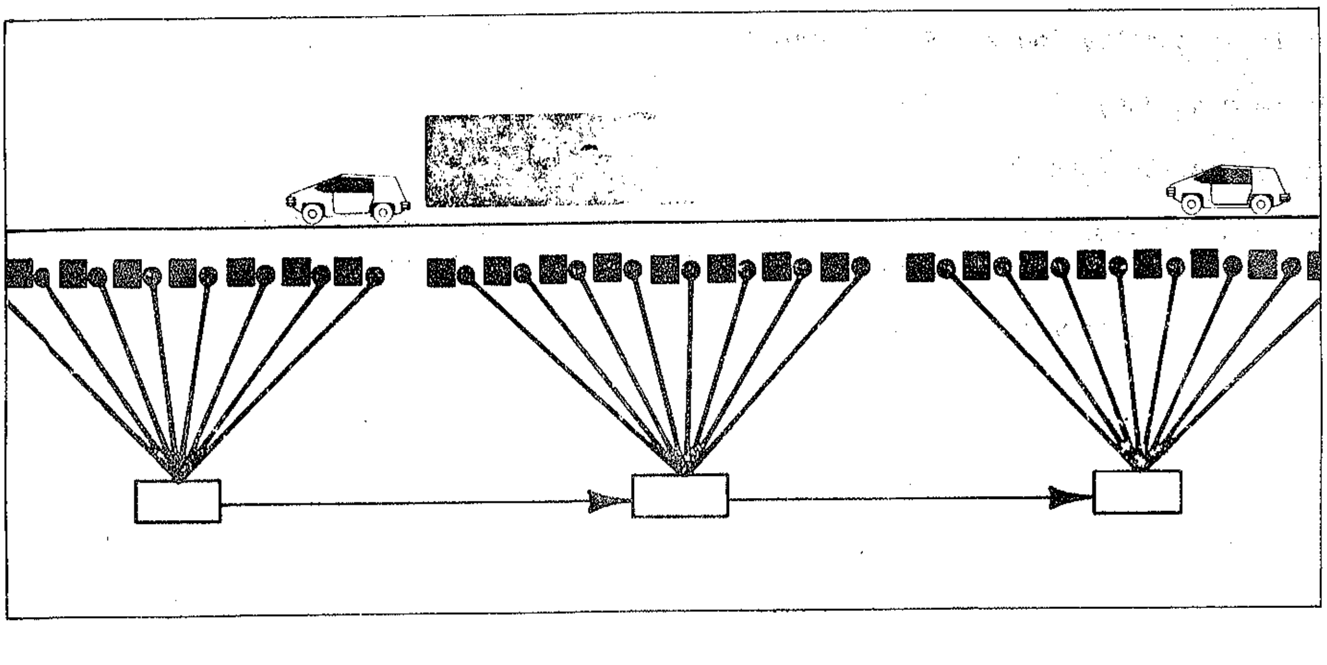

CONTROLLING AND VARYING VEHICLE SPEED
CREATE A SPEED PROFILE FOR THE DESIRED ROUTE BY APPLYING A CONSTANT
AND VOLTAGE TO LIM PRIMARIES OF VARIED POLE PITCH
CRUISE
DECELERATE
MAINTAIN LOW SPEED
START
STOP
CRUISE
LONG POLE PITCH
(HIGH SPEED) LIM
MAINTAIN LOW SPEED
SHORT POLE PITCH
(LOW SPEED) LIM
STATION
STATION
VEHICLE
POSITION
SENSOR
ACCELERATE
SHORT POLE PITCH
(LOW SPEED) LIM
STOP
REMOVE LIM POWER
OR MECHANICAL BRAKE
VEHICLE POSITION SENSORS
LOCATED BEFORE EACH PRIMARY SENSE THE APPROACHING
VEHICLE AND TURN ON THE PRIMARY TO A PRESET VOLTAGE
DC MAGNETS IN DECELERATION AREAS PROVIDE FAILSAFE
SPEED DAMPING

System Name	Minimover
Developer	LTV Aerospace Corporation, Ground Transportation Division, P.O. Box 5907, Dallas, Texas 75222, U.S.A.
Annual Turnover	$3359mil. (20)
Main Subcontractors	UK agents: Trinity International Ltd., 8 Upper Phillimore Gardens, London W8, England.
Development Grants	No information
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Stochastic
:Headway	Block
:General	1. Guideway sensors permit windings energising/thrust reversal to ensure headway maintenance. 2. Detail on route selection for individual vehicles and overall system management not published.
Propulsion	Linear induction motor windings in track; reaction member under-vehicle on secondary 'truck'.
Braking	DC magnets at stations; LIM reverse thrust on track; friction brakes for emergency use.
Support	Sprung rubber-tyred wheels.
Guidance	Horizontal wheels against rails in the guideway.
Switching	Selection of appropriate guideway rails by on-vehicle wheels.
Single track width (m)	"A slim profile is exhibited to the casual observer" (LTV)
Normal accn/decn (m/s^2)	No information
Emergency decn (m/s^2)	No information
Cruise speed (km/h)	16.38
Vehicle capacity (pass)	6 to 12
Minimum headway	No information
Line capacity (pass/h)	No information
Stage of Development	1/5th scale model of the system including 3 cars and a continuous track loop with off-line station. Possibly superceded by 'Lectravia' (qv).
Place of Development	Dallas, U.S.A.

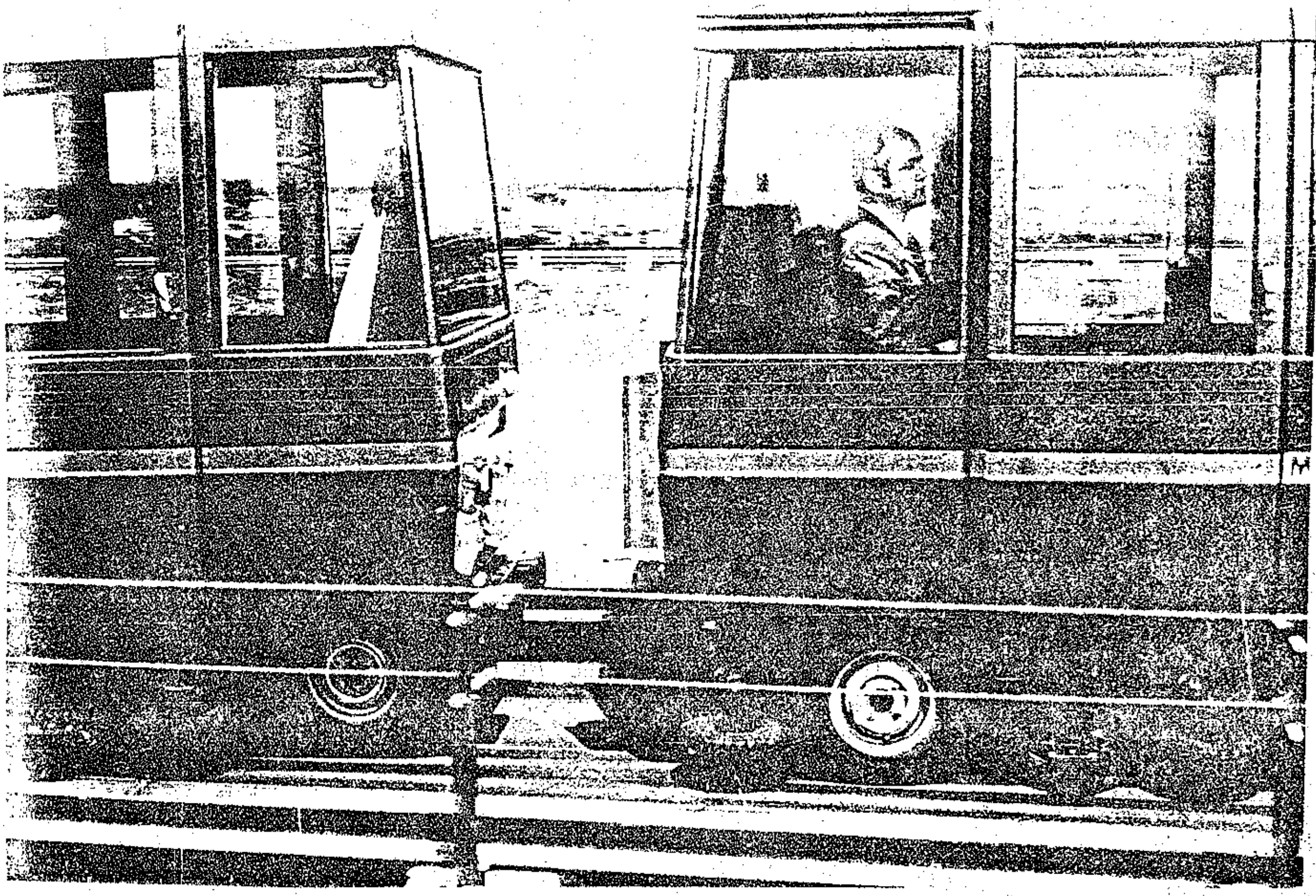

Entrapment Rail
Switch Ramp (Movable)
Switch Wheels

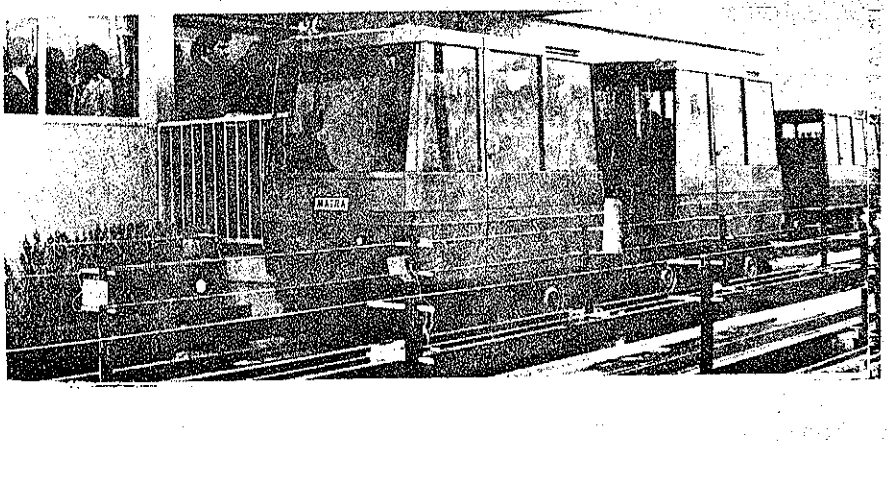




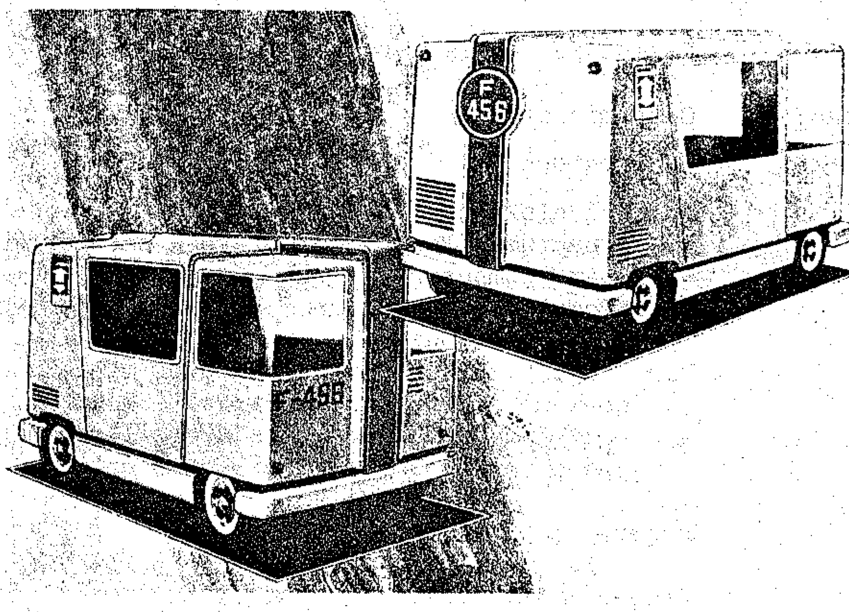


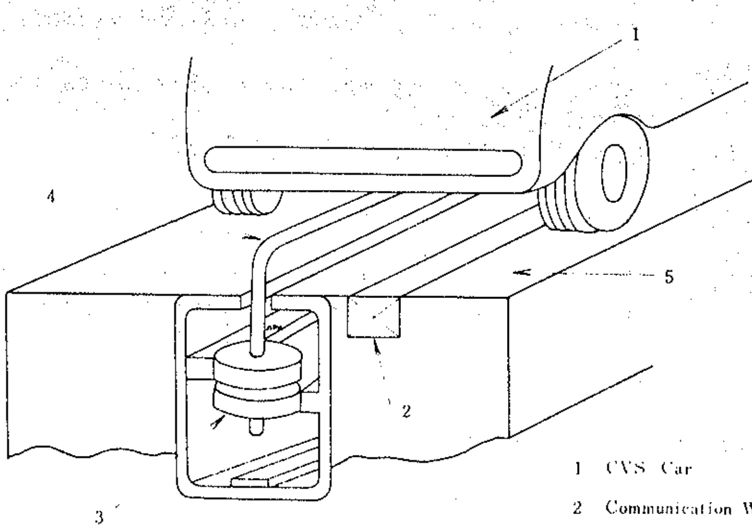
System Name	Lectravia
Developer	LTV Aerospace, Ground Transportation Division, P.O. Box 5907, Dallas, Texas 75222, U.S.A.
Annual Turnover	$3359mil. (20)
Main Subcontractors	-
Development Grants	No information
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Stochastic
:Headway	Block
:General	On-vehicle passenger selected destination code. Track-side recognition of destination and selection of path at switches. Central control is for reallocation of spare cabs; does not normally influence cabs in service.
Propulsion	Reaction member on vehicle with own suspension system, LIM windings in track.
Braking	LIM thrust reversal, DC magnets in stations, mechanical friction emergency wheel brakes.
Support	Sprung pneumatic tyred wheels on guideway.
Guidance	Horizontal wheels on vehicle LIM carriage control vehicle four wheel steering.
Switching	Guideway guidance-wheel entrapment mechanism moves in response to vehicle orginated stimulus.
Single track width (m)	1.52
Normal accn/decn (m/s^2)	2.58
Emergency decn (m/s^2)	5.8
Cruise speed (km/h)	56
Vehicle capacity (pass)	4 - 6 seated
Minimum headway	3 s
Line capacity (pass/h)	4800
Stage of Development	Design study, partially in context of Las Vegas, U.S.A. (appears to be an advanced 'minimover')
Place of Development	Dallas, Texas, U.S.A.




MATRA

System Name	Aramis
Developer	S. A. Engins Matra, Directions de Relations Exterieur, B.P. No. 1, 78 Velizy, France.
Annual Turnover	$62mil.
Main Subcontractors	-
Development Grants	No information
Service Offered	Taxi-type, passenger demand activated, or peak hour scheduled.
Control:Path planning	Stochastic
:Headway	Asynchronous in "trains"; block between trains
:General	Hierarchical system for dispatch, routing of individual vehicles over desired routes, the surveillance of vehicles and general monitoring.
Propulsion	Rotary electric motors.
Braking	Friction brakes.
Support	Sprung rubber-tyred wheels.
Guidance	Horizontal wheels against guideway side.
Switching	Selection of appropriate guideway by on-vehicle wheels.
Single track width (m)	1.75
Normal accn/decn (m/s^2)	No information
Emergency decn (m/s^2)	No information
Cruise speed (km/h)	50
Vehicle capacity (pass)	4 to 10 seated
Minimum headway	30cm within "trains"; 55s between trains.
Line capacity (pass/h)	11000
Stage of Development	1 km test track, 3 vehicles, one on line station, one off line station.
Place of Development	Test track at Orly Airport, Paris, France.





1 CVS Car

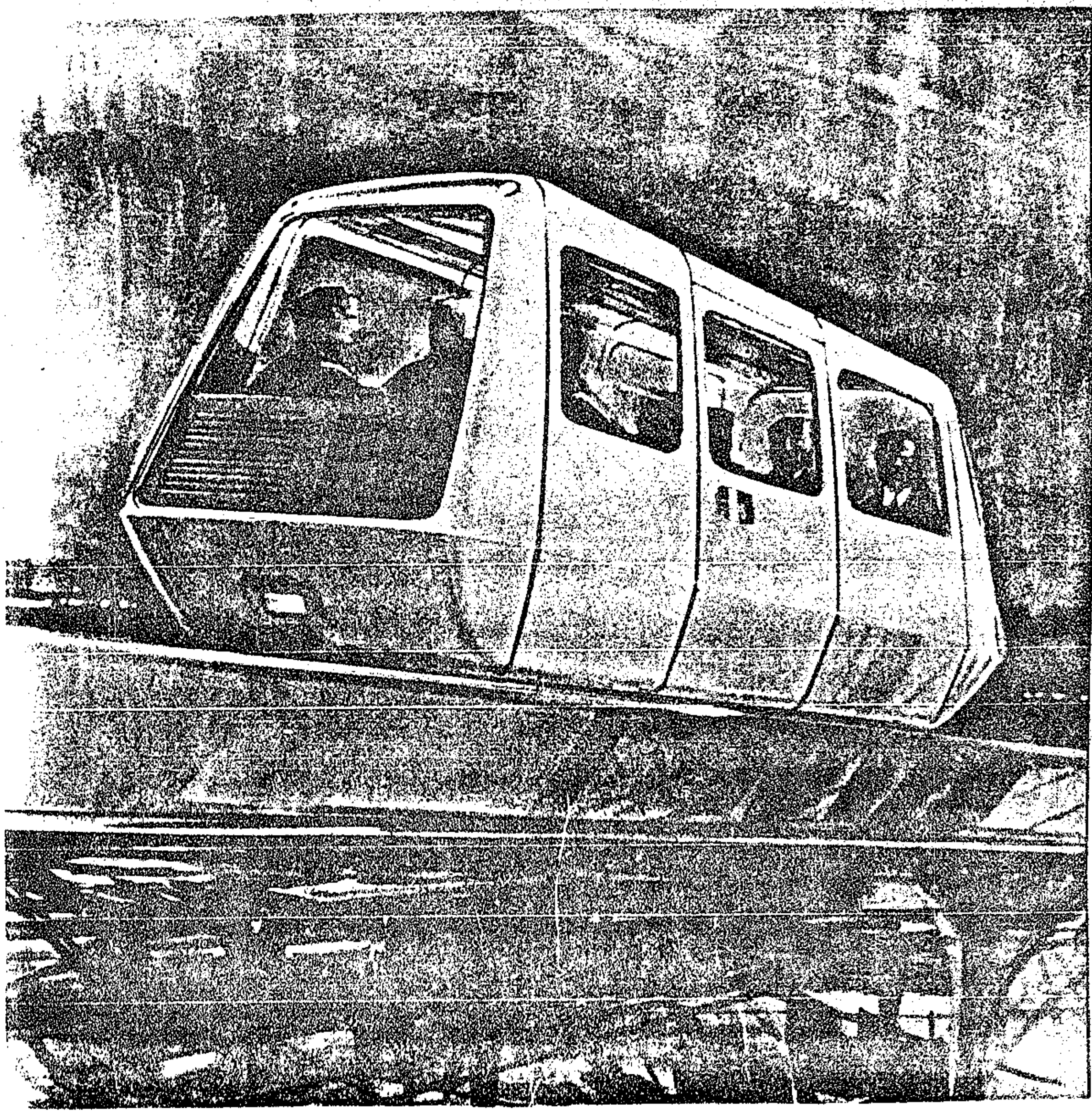
2 Communication Wire

3 Guide Wheels

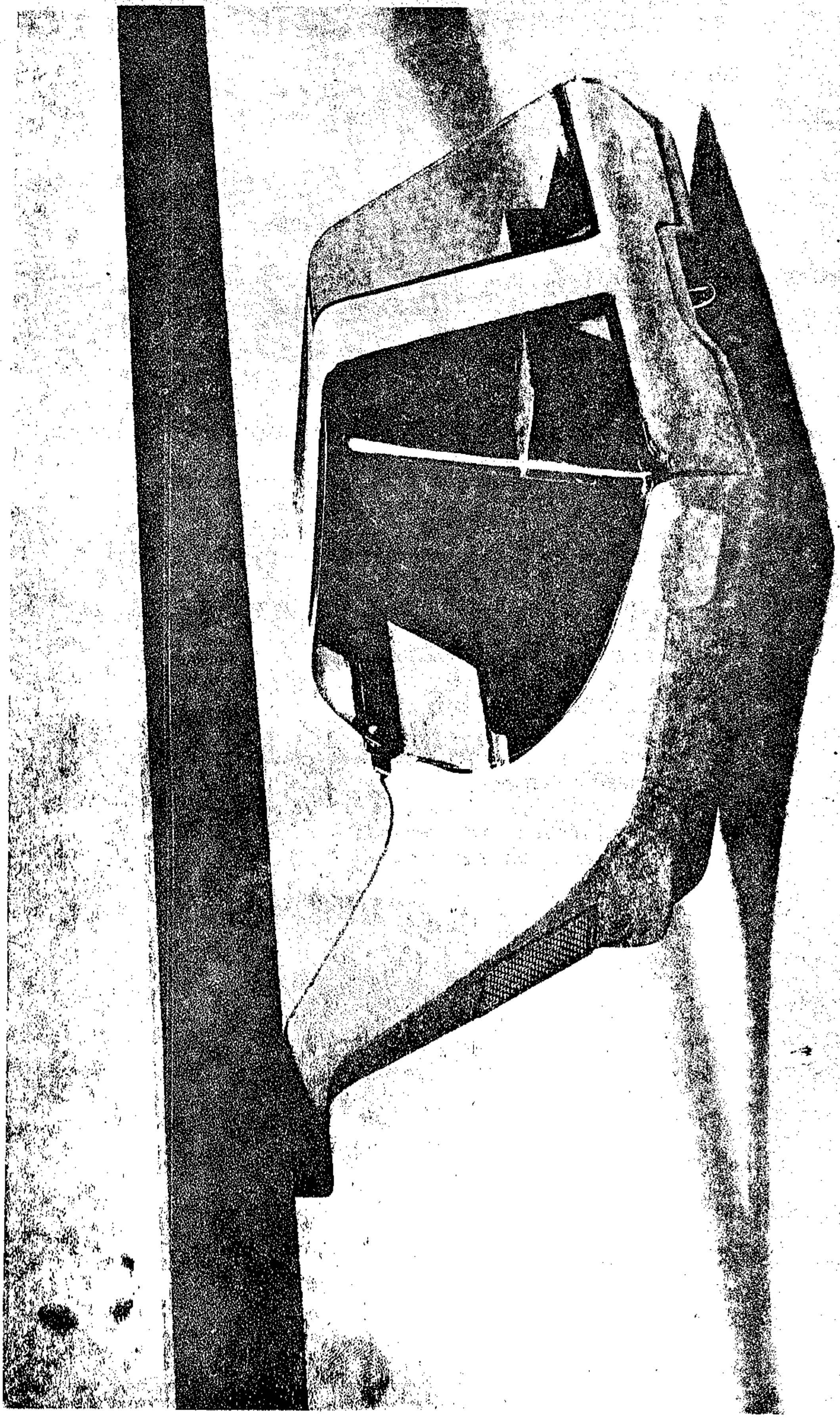
4 Guide Rod

5 Road Surface

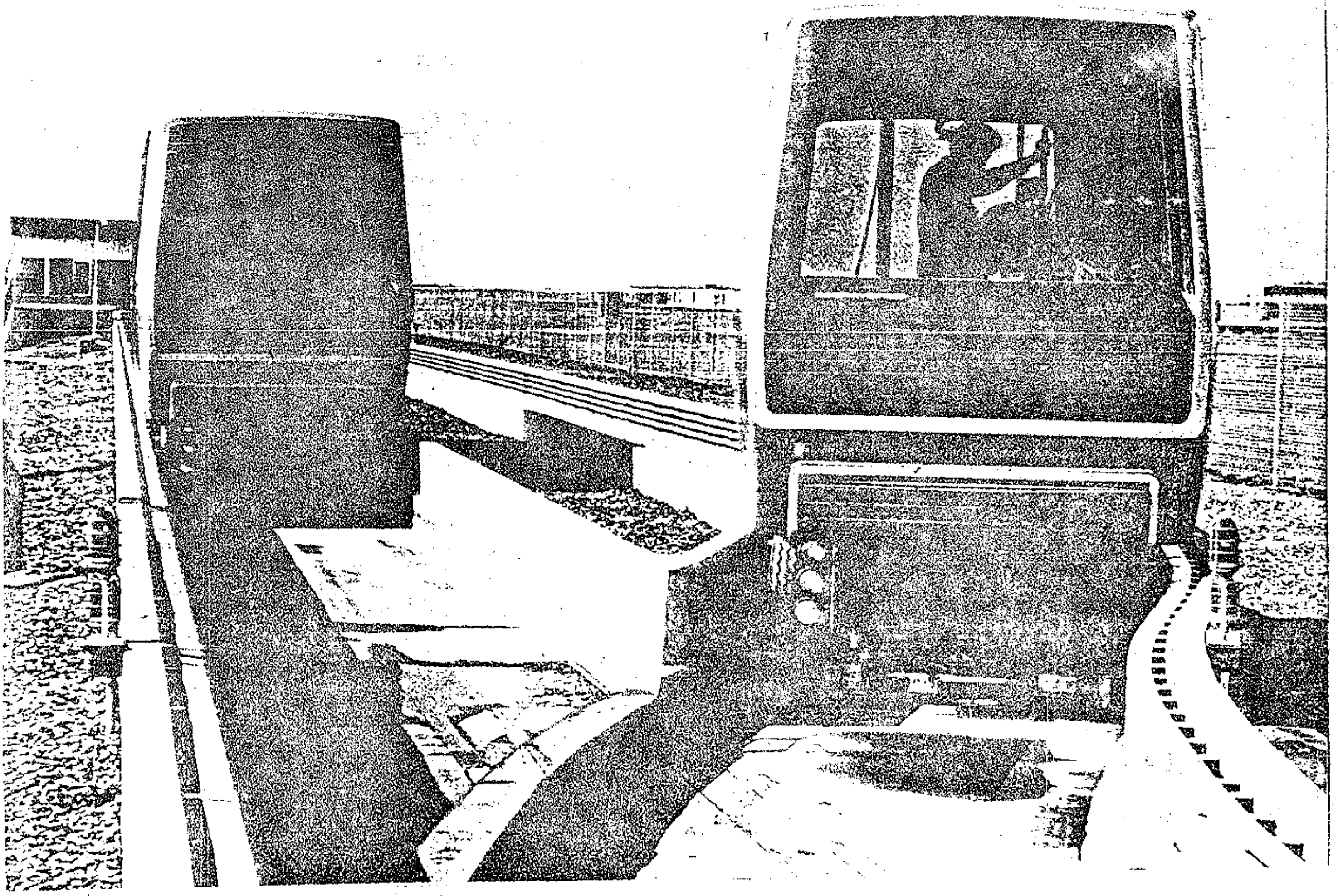
System Name	CVS
Developer	Japan Society for the Promotion of Machine Industry, 3-5-8 Shiba Koen, Minatoku, Tokyo, Japan; also, Jetro, Baker Street, London.
Annual Turnover	$2553mil. (26*)
Main Subcontractors	-
Development Grants	Ministry of International Trade and Industry (MITI) involvement.
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Deterministic
:Headway	Synchronous
:General	Control hierarchy has 4 levels: 1. "Quantum" (local) computers - one per 200 m of track; spare computer to every 5 or 6. 2. "Module" computer coordinates quantum computers, supervise routing. 3. "Super" computer controls over of 1 km^2 including control of high speed travel (60 km/h). 4. "City" computer controls overall routing on high speed routes and monitors movement.
Propulsion	Rotary electric motor.
Braking	Regenerative brake and disc brake (normal service); friction shoes pressing guide rails to obtain 2g. emergency deceleration.
Support	Sprung rubber-tyred wheels.
Guidance	Guide wheels and rod held by groove in centre of right of way, steering front wheels of vehicle.
Switching	On-vehicle selection (no moving parts in the track).
Single track width (m)	Not exceeding 1.7
Normal accn/decn (m/s^2)	1.96
Emergency decn (m/s^2)	19.6 (system has all passengers facing rearward in special seating with restraint systems).
Cruise speed (km/h)	80
Vehicle capacity (pass)	2 - 4 seated
Minimum headway	0.6s at 40 km/h.
Line capacity (pass/h)	24000 @ 100% occupancy of cabs at 40 km/h.
Stage of Development	Prototype cars and track built; full-size dummy car built; 1/20th scale models operated.
Place of Development	MITI - Higashi-Murayama, Tokyo, Japan.

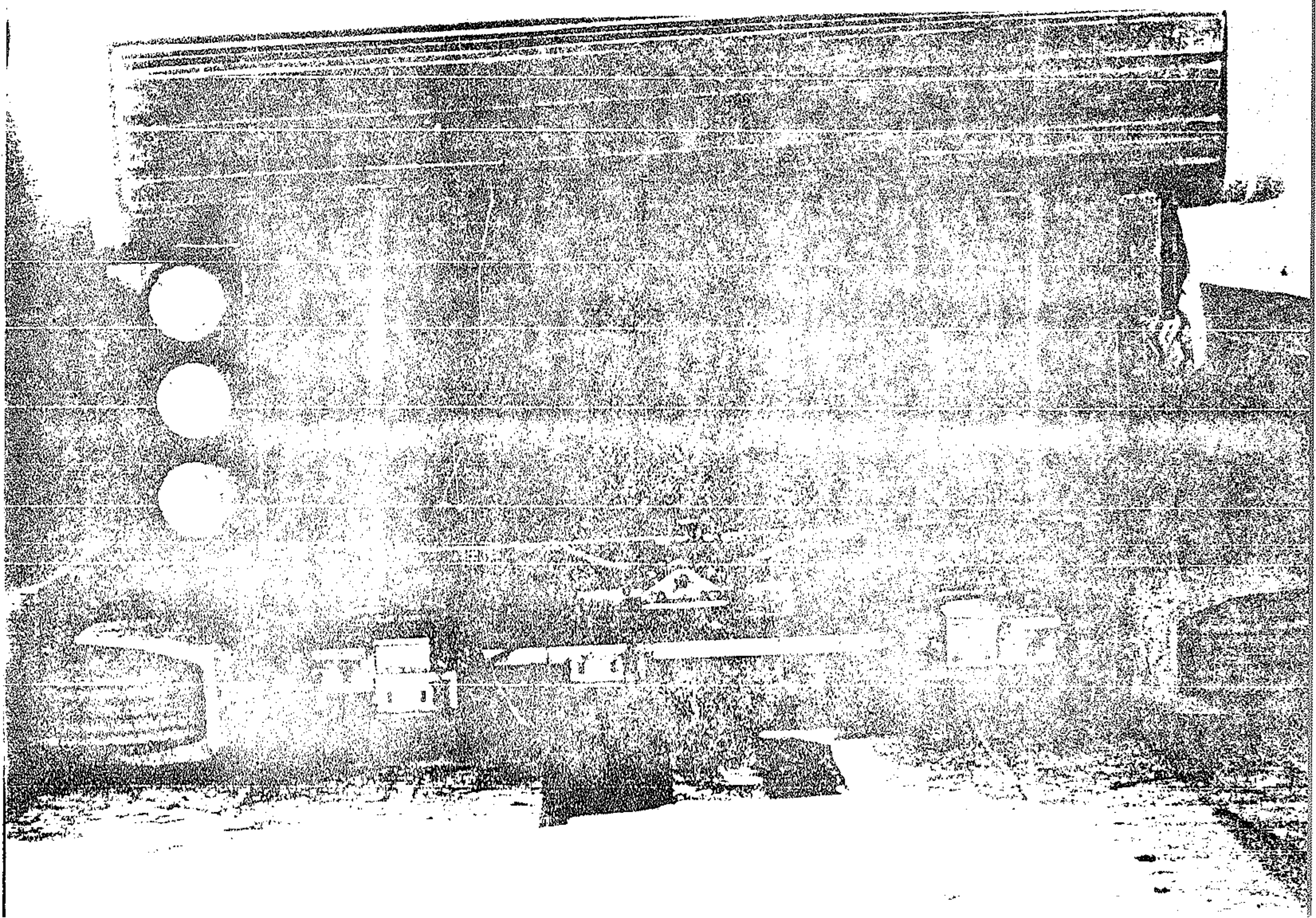


System Name	Glide-Ride
Developer	Pullman Incorporated, Transportation Systems Center, 441 Smithfield Street, Pittsburgh, PA, U.S.A.
Annual Turnover	$694mil. (Pullman 183)
Main Subcontractors	Bendix Transportation Systems, 3300 Plymouth Road, Ann Arbor, Michigan 48107, U.S.A.
Development Grants	No information.
Service Offered	Presumed to provide a level of passenger demand activation.
Control:Path planning	No information.
:Headway	No information.
:General	"The control hardware will be similar to that being employed by Bendix in the Morgantown, W. Virginia Peoplemover project". No further information provided.
Propulsion) Braking)	No information (but see Bendix Dashaveyor which may be a guide.
Support	Flanged steel wheels on rails.
Guidance	Vehicle retained by wheel coning and wheel flanges.
Switching	On board switching mechanism.
Single track width (m)	2.42
Normal accn/decn (m/s^2)	No information provided
Emergency decn (m/s^2)	No information provided
Cruise speed (km/h)	40 - 48
Vehicle capacity (pass)	6 "a typical people mover"
Minimum headway	5.5s
Line capacity (pass/h)	Not stated
Stage of Development	Conceptual design collection; prototype vehicle built and demonstrated to Las Vegas PRT study, U.S.A.
Place of Development	Being designed for possible employment in Las Vegas, Nevada, U.S.A.

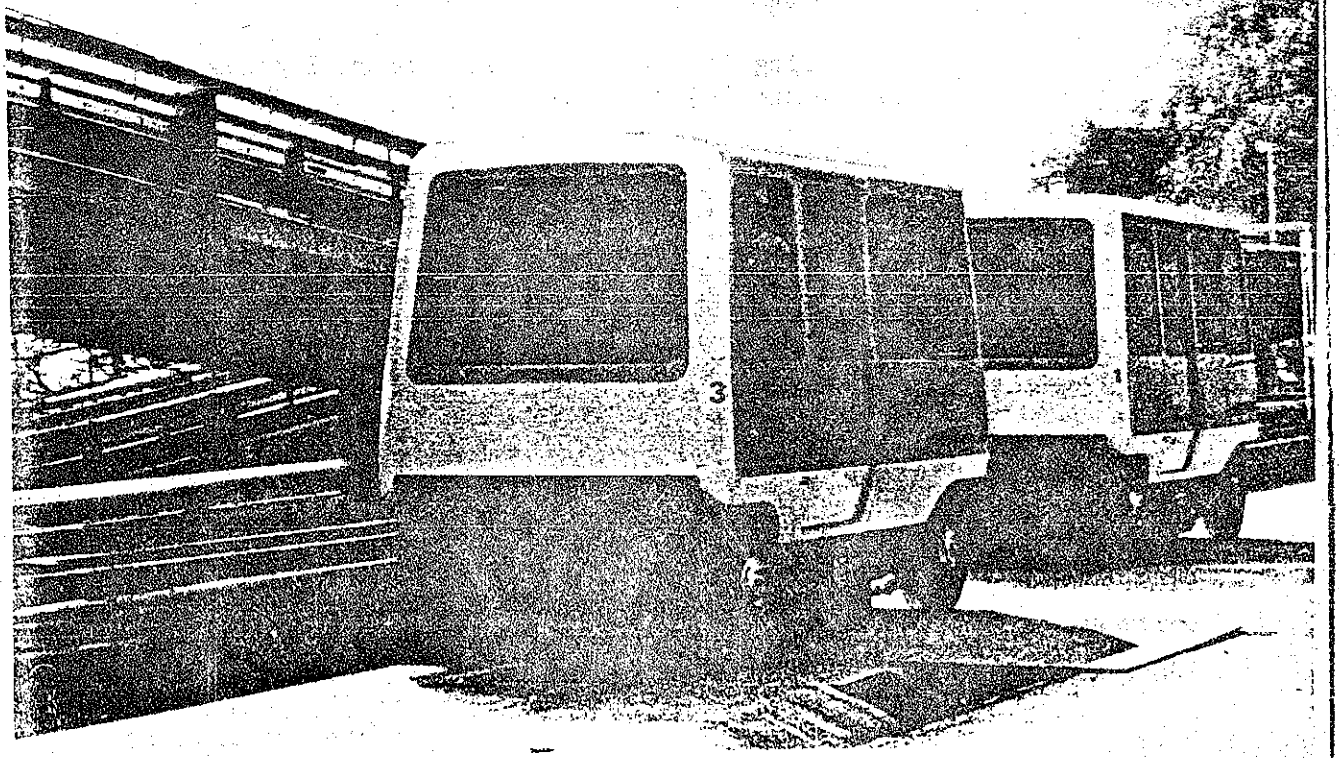


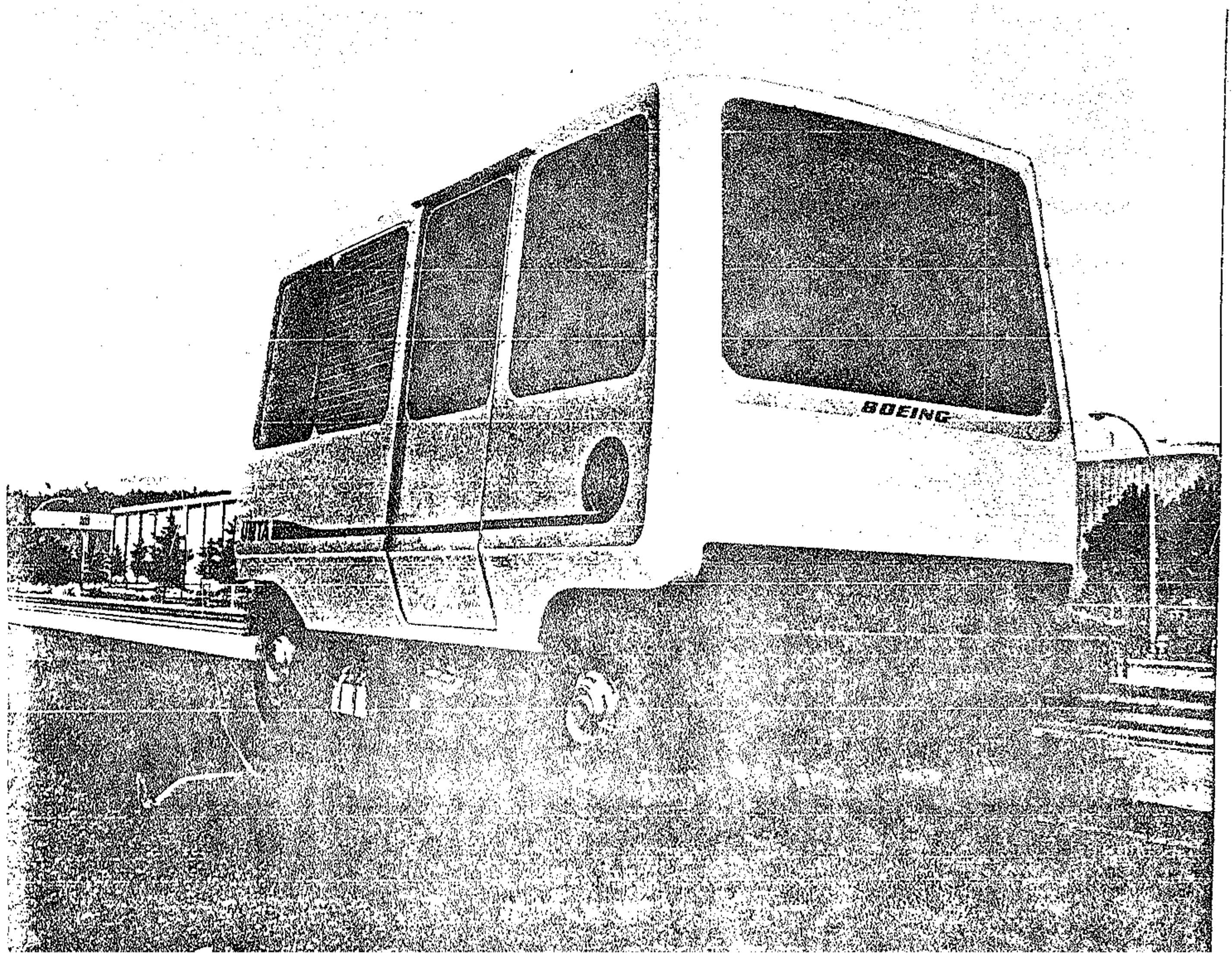
System Name	'Elan'
Developer	SIG Swiss Industrial Company, CH - 8212 Neuhausen Rhine Falls, Switzerland.
Annual Turnover	No information.
Main Subcontractors	-
Development Grants	No information.
Service Offered	Taxi-type, passenger demand activated.
Control:Path planning	Deterministic
:Headway	Synchronous, permitting slot-slipping.
:General	Four hierarchics of control are envisaged: 1. Moving slots with en-route slot-slipping permitted; centrally generated. 2. On-vehicle destination, speed regulation, emergency stop, doors control. 3. Line-sector/stations control acceptance/exit of cabs, switching, speed change and stopping. 4. Centrally - spare vehicles, destination, co-ordination of general demand/supply of cabs.
Propulsion	DC rotary electric motor on a single central car axle.
Braking	Mechanical friction wheel brakes.
Support	Car axle with rubber tyres.
Guidance	Assymetric - positioned overhead guidance arm restrained by overhead guideway.
Switching	Moving switchblade in overhead guideway and moving selection wheel on vehicle.
Single track width (m)	2.27
Normal accn/decn (m/s^2)	2 - 2.5
Emergency decn (m/s^2)	3.5
Cruise speed (km/h)	58
Vehicle capacity (pass)	4 seated
Minimum headway	0.7s
Line capacity (pass/h)	7200
Stage of Development	Concept, and static models built.
Place of Development	SIG, Switzerland.



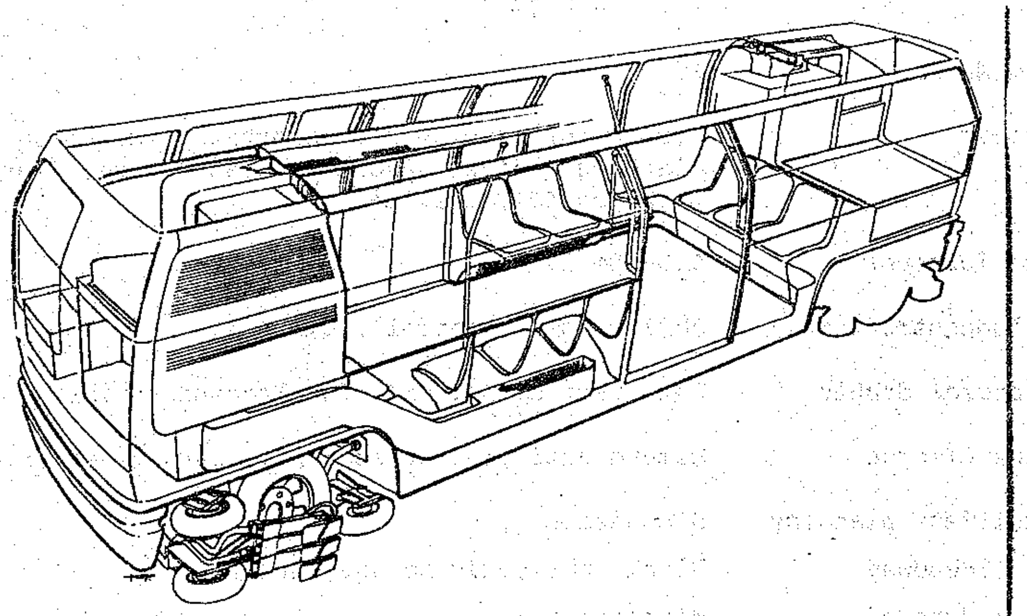


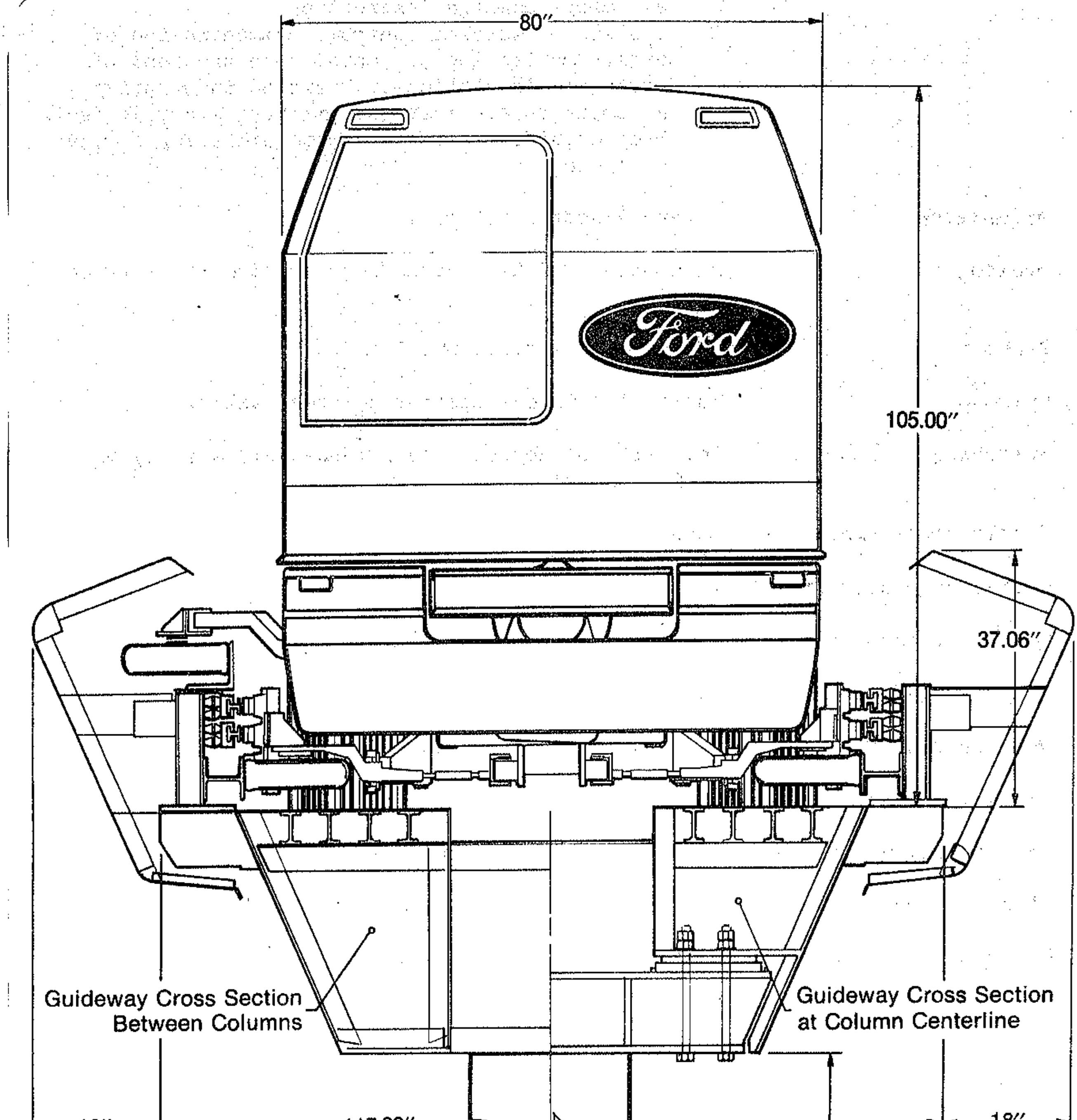
System Name	Dashaveyor Transpo '72 exhibit
Developer	Bendix Transportation Systems Centre, Bendix Aerospace Systems Division, 3300 Plymouth Road, Ann Arbor, Michigan 48107, U.S.A.
Annual Turnover	$1163mil. (71)
Main Subcontractors	-
Development Grants	USA Dot $1.5mil. grant for Transpo '72.
Service Offered	Scheduled.
Control:Path planning	Stochastic
:Headway	Block
:General	1. Automatic train operation (ATO) - speed regulation, programmed stopping, doors, direction control. 2. Automatic train protection (ATP) - vehicle detection, signalling, speed. 3. Line supervision - local and central supervision, strategic control.
Propulsion	DC series wound rotary motors.
Braking	Disc brakes for service; spring activated emergency disc brake.
Support	Air coil spring, pneumatic tyred wheels.
Guidance	Horizontal wheels against guideway wall.
Switching	Moveable guideway diverters provide continuous guidance.
Single track width (m)	2.48
Normal accn/decn (m/s^2)	1.12 (accn) 0.914 (decn)
Emergency decn (m/s^2)	3.03
Cruise speed (km/h)	32
Vehicle capacity (pass)	12 seated, 20 standing.
Minimum headway	No information.
Line capacity (pass/h)	No information.
Stage of Development	Prototype operation at Transpo '72 exhibition.
Place of Development	Dulles Airport, Washington DC, U.S.A.


3
1

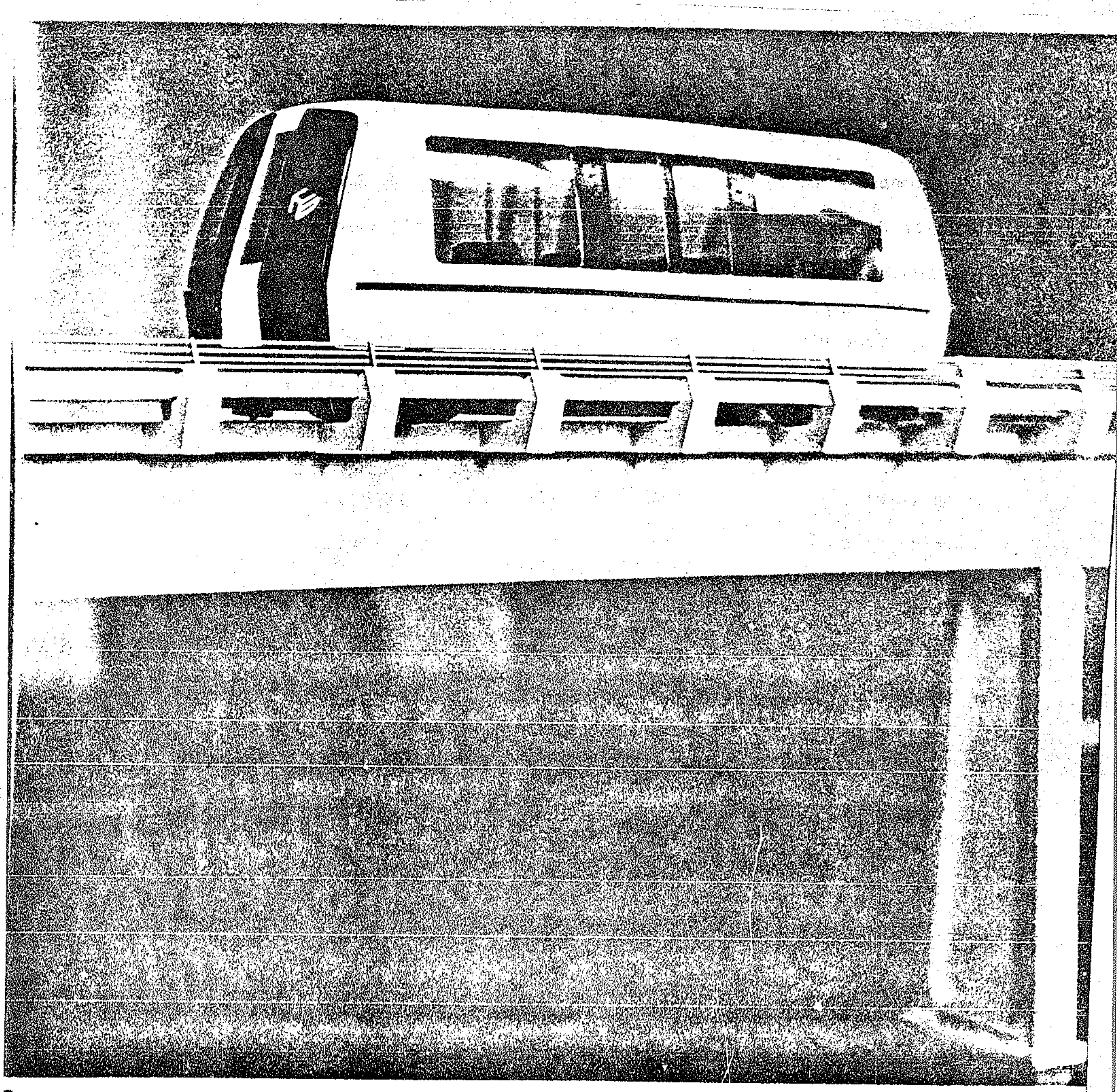

BOEING
UMTA

System Name	Morgantown 'PRT'
Developer	The Boeing Company, Aerospace Group, Seattle, Washington 98124, U.S.A.
Annual Turnover	$3040mil. (24)
Main Subcontractors	Alden Self Transit Corporation (vehicles), 64 Summer Street, Milford Massacheusetts 01757, U.S.A. Bendix Corporation (qv) and for software Systems Development Corporation, 2500 Colorado Avenue, Santa Monica, California 90406.
Development Grants	$63mil. contract from UMTA.
Service Offered	Passenger demand activated; peak hour scheduled service.
Control:Path planning	Deterministic
:Headway	Synchronous
:General	Hierarchical control including the following levels: 1. Synchronous slot control centrally generated. Vehicles not permitted onto system unless path clear all the way to the destination. Central computer "hands vehicles on" from local computer to local computer. 2. Local station control over dispatch manoeuvering. 3. Multiple control monitoring functions; speed level controls, vehicle separation centrally monitored.
Propulsion	Rotary electric motors.
Braking	Friction brakes on wheels.
Support	Air/coil sprung, rubber tyred wheels.
Guidance	Horizontal sensing wheels steer to either side of guideway.
Switching	Horizontal sensing wheels follow appropriate guideway wall.
Single track width (m)	3.66 (single), 6.96 (double)
Normal accn/decn (m/s^2)	1.32
Emergency decn (m/s^2)	3.0
Cruise speed (km/h)	48.3
Vehicle capacity (pass)	13 seated, 8 standing
Minimum headway	15s.
Line capacity (pass/h)	5040
Stage of Development	Full scale experimental system due for revenue service January, 1975.
Place of Development	Morgantown, West Virginia, U.S.A.



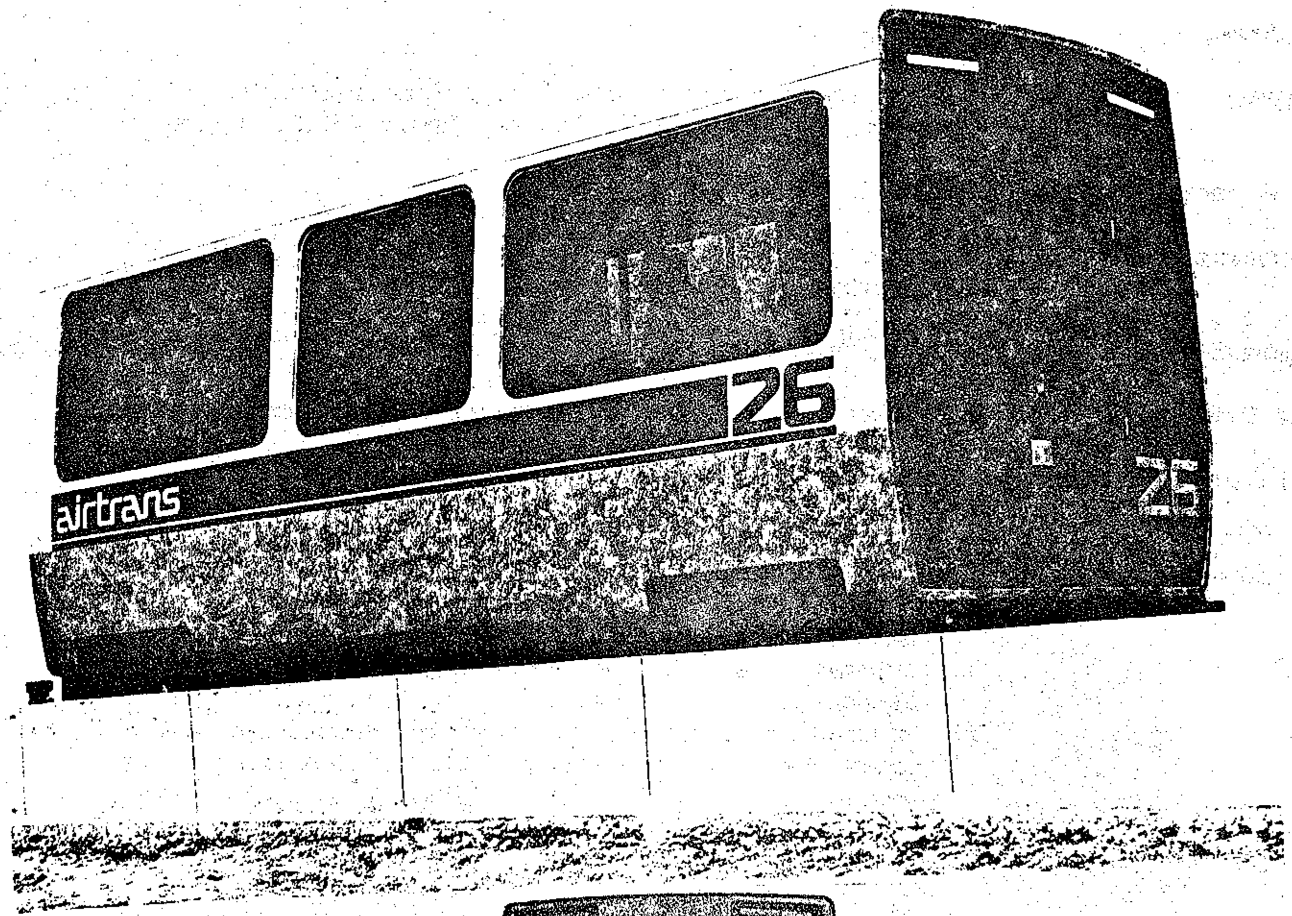

80″
105.00″
37.06″
Guideway Cross Section
Between Columns
Guideway Cross Section
at Column Centerline
18″
117.00″
18″

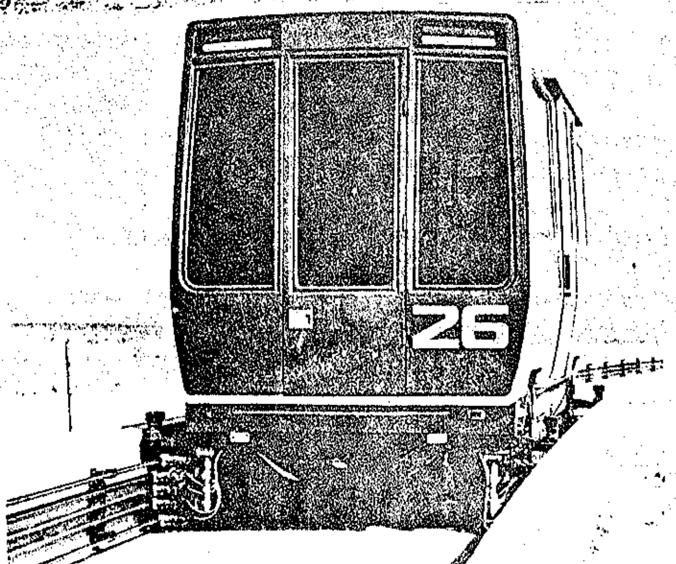
System Name	ACT
Developer	Ford Motor Company, Transportation Research & Planning Office, 23400 Michigan Avenue, Dearborn, Michigan 48124, U.S.A.
Annual Turnover	$16433mil. (3)
Main Subcontractors	Philco-Ford (control), U.S.A.
Development Grants	Dot grant of $1.5mil. for Transpo exhibit.
Service Offered	Demand activated or scheduled service at Transpo.
Control:Path planning	Stochastic
:Headway	Block, but could be asynchronous
:General	Hierarchical 1. Central control: fleet management, routing of vehicles, interfacing of local controller, and all merge/demerge instruction. 2. Station or wayside control: communication of orders/monitoring to vehicles on sections of route and in stations. Position information accurate to 4.4 feet with markers every 44 feet. Each wayside controller responsible for 1 mile of route.
Propulsion	Rotary electric motors
Braking	Automotive friction brake/regenerative for service braking.
Support	Sprung rubber tyred wheels.
Guidance	Horizontal wheels against guideway walls.
Switching	Selection of appropriate guideway sidewall by on-vehicle wheels.
Single track width (m)	3.86
Normal accn/decn (m/s^2)	1.32
Emergency decn (m/s^2)	3.0
Cruise speed (km/h)	48.30
Vehicle capacity (pass)	24 passenger vehicle at Transpo.
Minimum headway	2s.
Line capacity (pass/h)	43200 (theoretical maximum)
Stage of Development	Fullscale prototype operated in 1972.
Place of Development	Dulles Airport, Washington U.S.A.

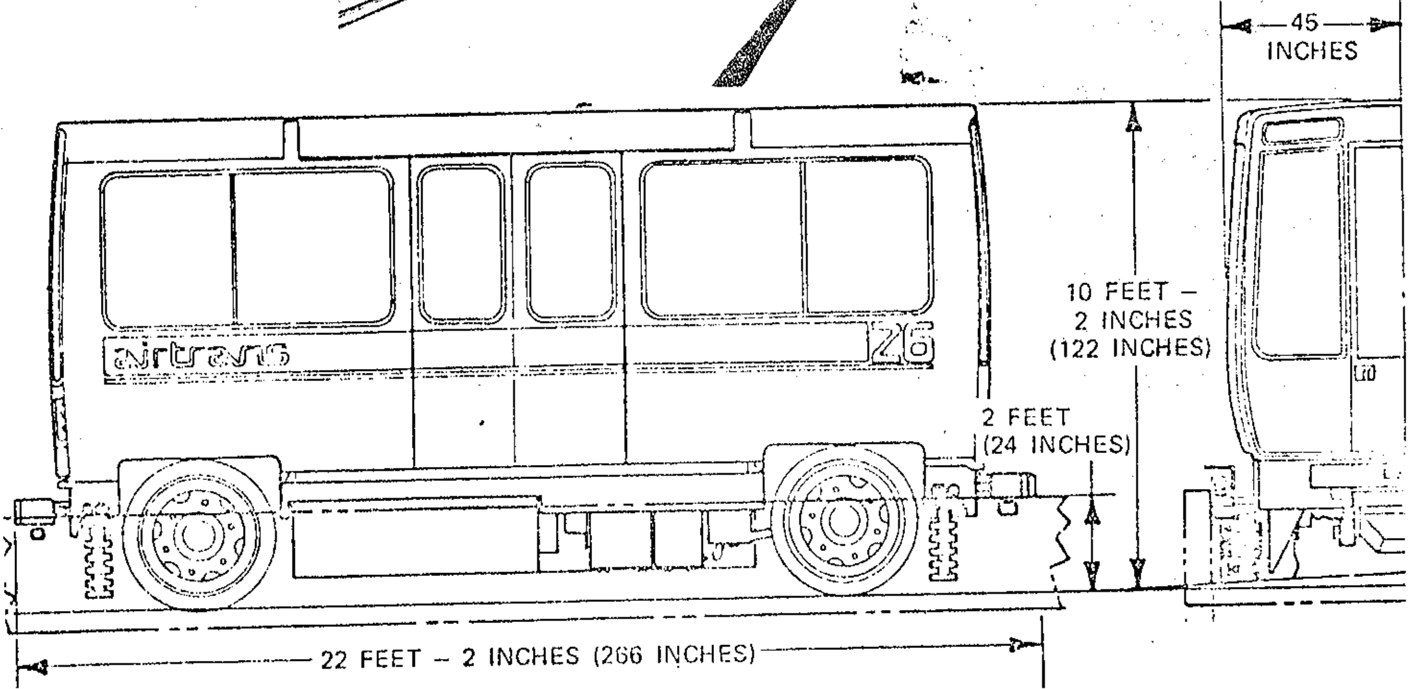


System Name	Minitram/Slimway*
Developer	Hawker Siddeley Dynamics Ltd., Manor Road, Hatfield, Hertfordshire, AL10 9LL, England.
Annual Turnover	$1151mil. (73*)
Main Subcontractors	-
Development Grants	Various forms of aid from UK DOE
Service Offered	Various (MESD/UTG/104/Mar'73/Page 3)
Control:Path planning	No information
:Headway	No information
:General	Control (longitudinal separation of vehicles): hierarchical (MESD/UTG/104/Mar'73/Page 3) 1. "vehicle speed profile and safe headway" 2. "control at branches, merges and stations" 3. "overall strategy, start-up and shut-down" No information as to exact nature of control system.
Propulsion	Rotary or linear electric machine* on a carriage.
Braking	"Blended" (-motor braking, wheel/friction drum, guideway caliper).
Support	Pneumatic rubber tyred wheels.
Guidance	Horizontal wheels against guideway sidewall.
Switching	"On board".
Single track width (m)	3.2
Normal accn/decn (m/s^2)	1.45
Emergency decn (m/s^2)	3.86
Cruise speed (km/h)	exceeds 72
Vehicle capacity (pass)	10 seated, 14 standing
Minimum headway	5s. at 72 km/h
Line capacity (pass/h)	"4-20000" (MESD/UTG/104/Mar'73/Page 2)
Stage of Development	Tender for application in Toronto April 1973. Exercise in Sheffield context for DOE study.
Place of Development	Hatfield, U.K.

*Slimway uses linear electric machine.

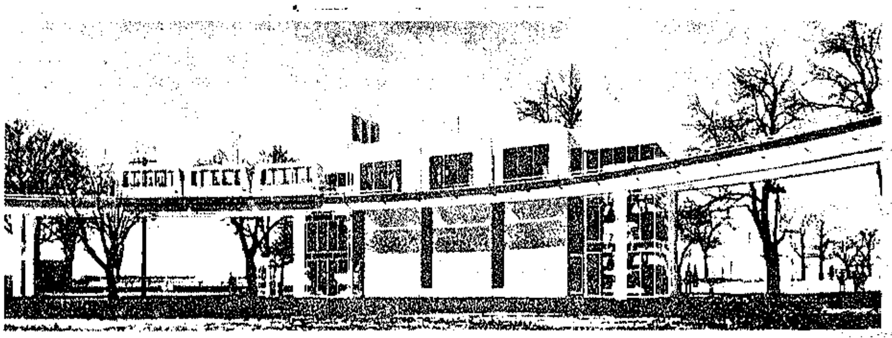

airtrans
26
26


26


45
INCHES
airtrans
26
10 FEET –
2 INCHES
(122 INCHES)
2 FEET
(24 INCHES)
22 FEET – 2 INCHES (266 INCHES)

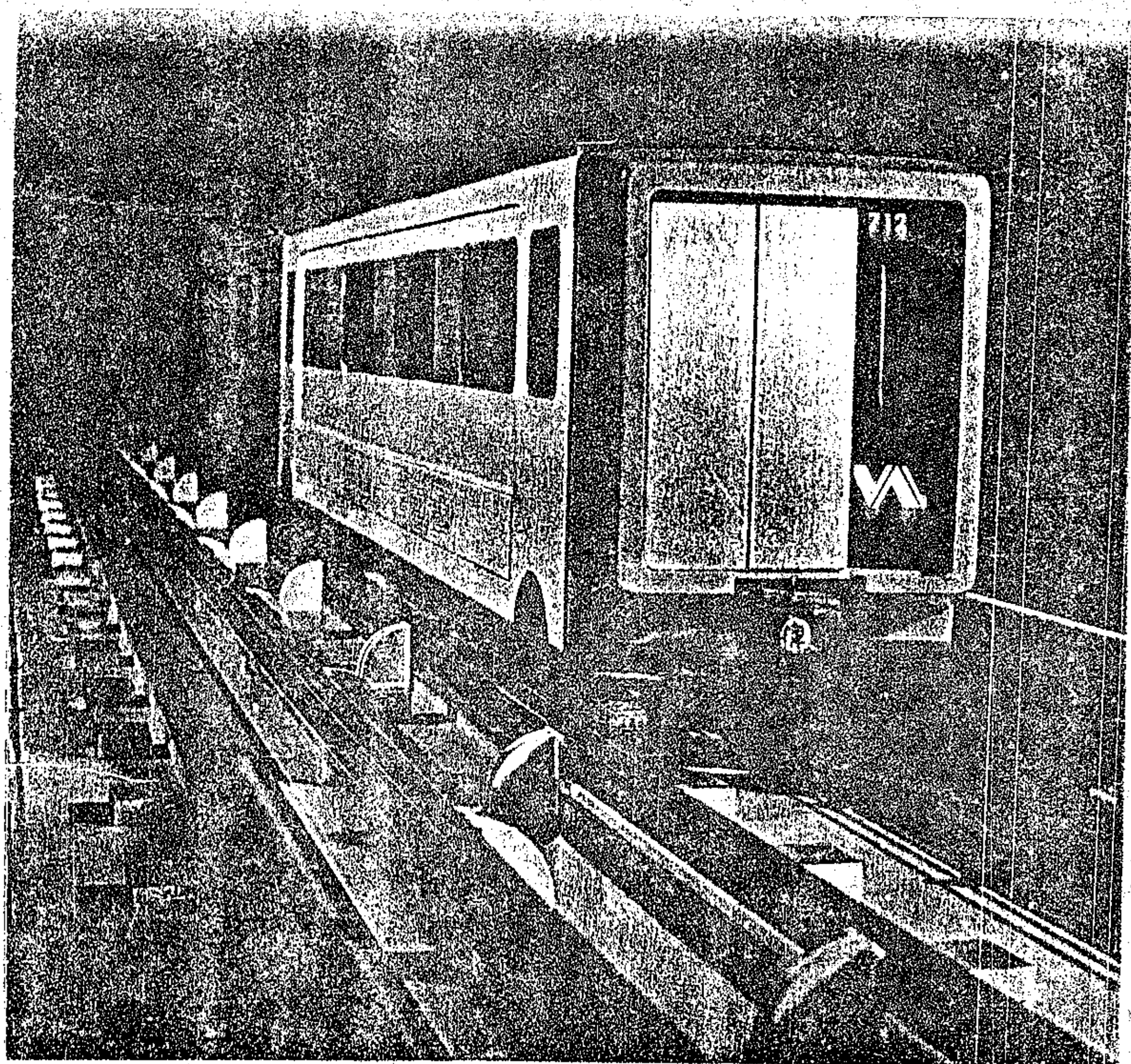
System Name	Airtrans
Developer	LTV Aerospace Corporation, Ground Transportation Division, P.O. Box 5907, Dallas, Texas 75222, U.S.A.
Annual Turnover	$3359mil. (20)
Main Subcontractors	Texas Bitulithic (track), General Railway Signal Corporation, (control system).
Development Grants	$7mil. grant Dot, 1973.
Service Offered	Scheduled. Single vehicles or train formations.
Control:Path planning	Stochastic
:Headway	Block
:General	Hierarchical automatic train control. 1. Automatic vehicle protection (AVP): headway, switching, speed limits, vehicle safety systems. 2. Automatic vehicle operation (AVO): route control, stopping, doors, speed. 3. Central; monitoring, supervisory (speed, switches, route changes, "bunch"control), station monitoring power.
Propulsion	Rotary electric motor.
Braking	Friction brakes mechanically activated (service); spring emergency supplement applied to discs.
Support	Pneumatic tyred wheels, pneumatic springs, shock absorbers and levelling devices.
Guidance	Horizontal wheels against guideway walls.
Switching	Positive entrapment of horizontal wheels by moveable guideway-side switch device.
Single track width (m)	2.79
Normal accn/decn (m/s^2)	1.14
Emergency decn (m/s^2)	2.74
Cruise speed (km/h)	27
Vehicle capacity (pass)	16 seated, 24 standing
Minimum headway	18s. at 27 km/h
Line capacity (pass/h)	8000
Stage of Development	20.6 km of guideway, 51 passenger vehicles, 17 cargo vehicles in revenue operation.
Place of Development	Dallas Fort Worth Regional Airport, Texas, U.S.A.


KM KRAUSS MAFFEI
TRANSURBAN

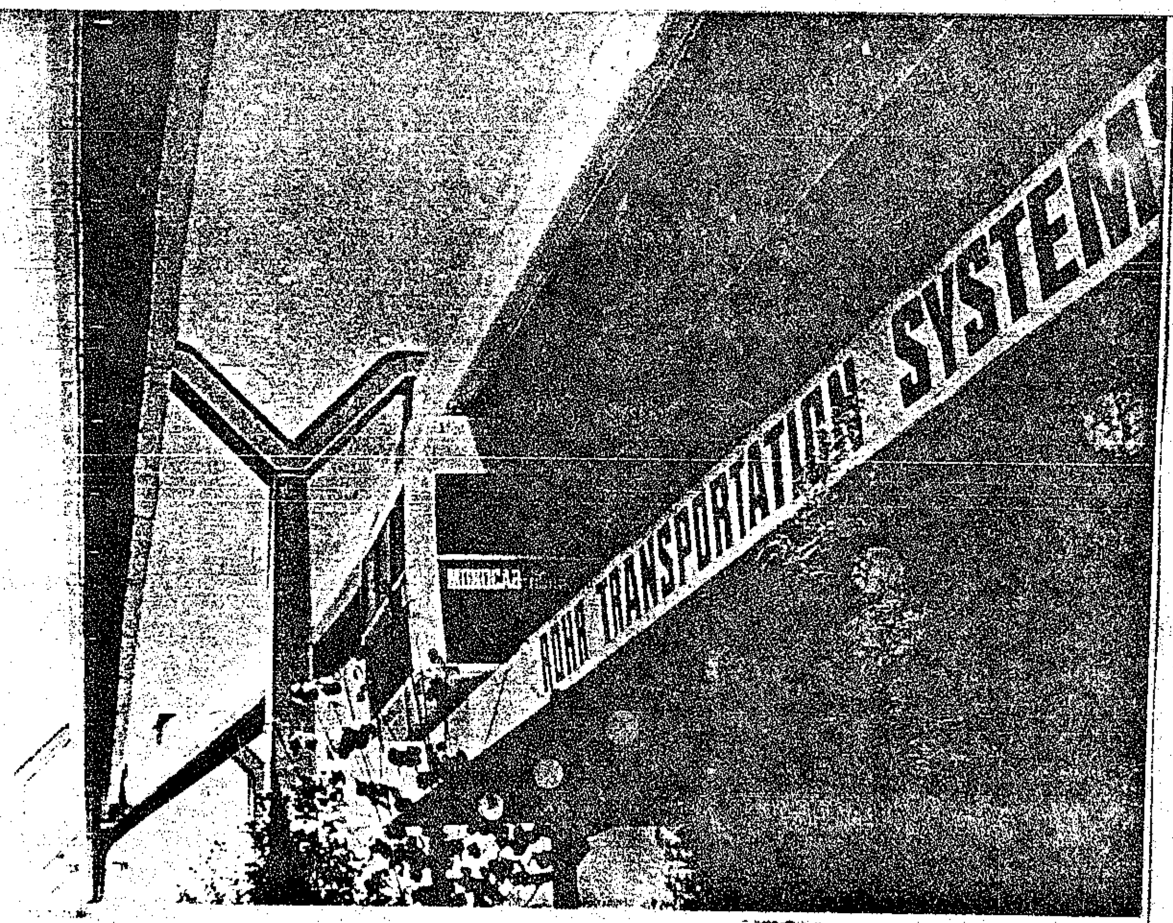


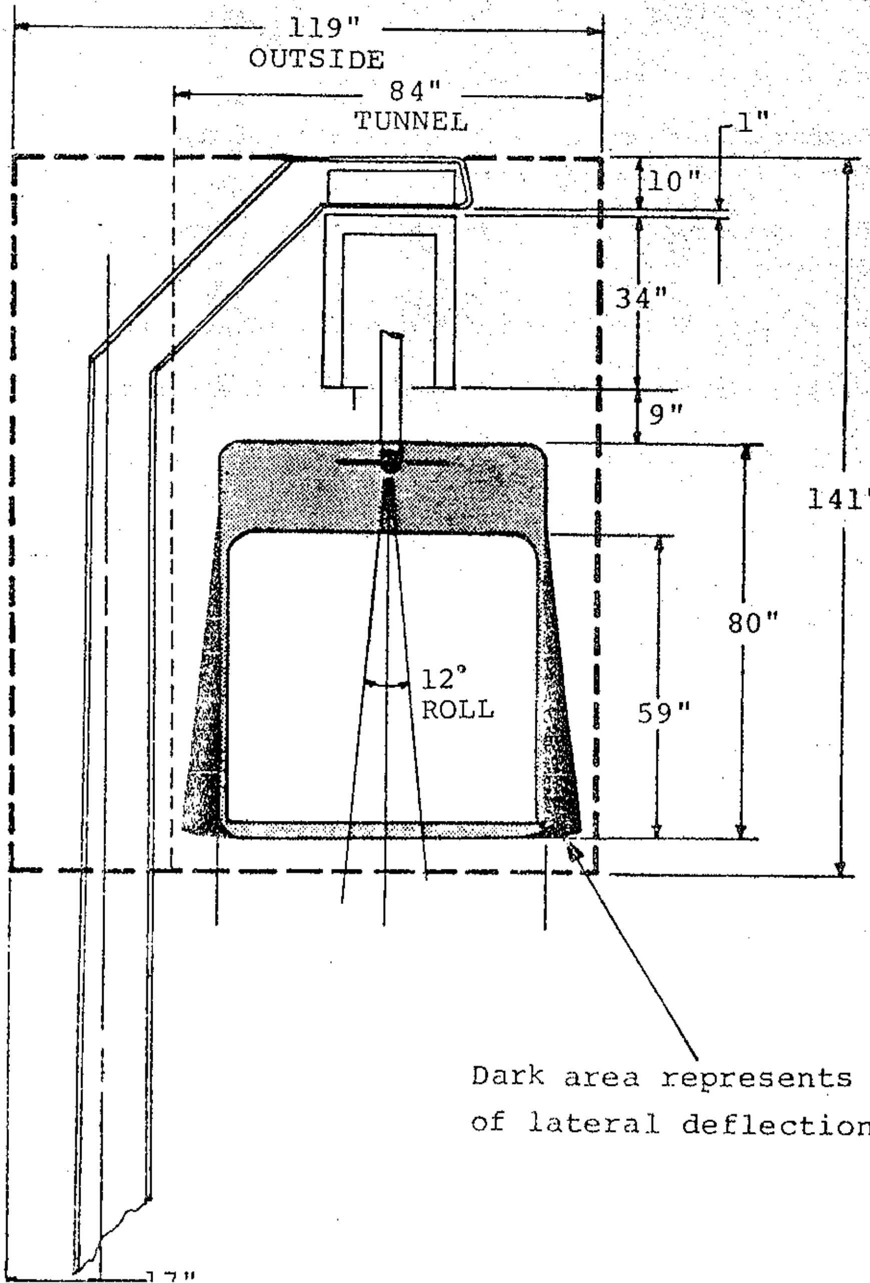

KM
TRANSURBAN
TU 02
KRAUSS
MAFFEI

System Name	Transurban TAKT
Developer	Krauss-Maffei AG, 8000 Munchen 50, Krauss-Maffei Strasse 2, W. Germany.
Annual Turnover	KM:$212mil. ITT:$7345mil. (9)
Main Subcontractors	Control - SEL AG, (a subsidiary of ITT).
Development Grants	W. German Ministry of Transport.
Service Offered	Scheduled.
Control:Path planning	Stochastic
:Headway	Block
:General	Hierarchical 1. Vehicle operations - headway, doors, acceleration, stopping in stations. 2. System operations - disposition of vehicles, coupling/decoupling, routing detours.
Propulsion	Linear electric machines.
Braking	Linear motor thrust reversal (service); pneumatic brake (stopping and emergencies).
Support	On board electromagnets.
Guidance	Support magnets provide stable lateral guidance.
Switching	Selection of appropriate sequence of on-board magnets.
Single track width (m)	1.45
Normal accn/decn (m/s^2)	No information
Emergency decn (m/s^2)	No information
Cruise speed (km/h)	40
Vehicle capacity (pass)	20 seated, 8 standing
Minimum headway	30 - 40 s. between trains
Line capacity (pass/h)	3360
Stage of Development	Prototype in operation; contract to build 8.0 km system in Toronto by 1975.
Place of Development	Munich, W. Germany.


712

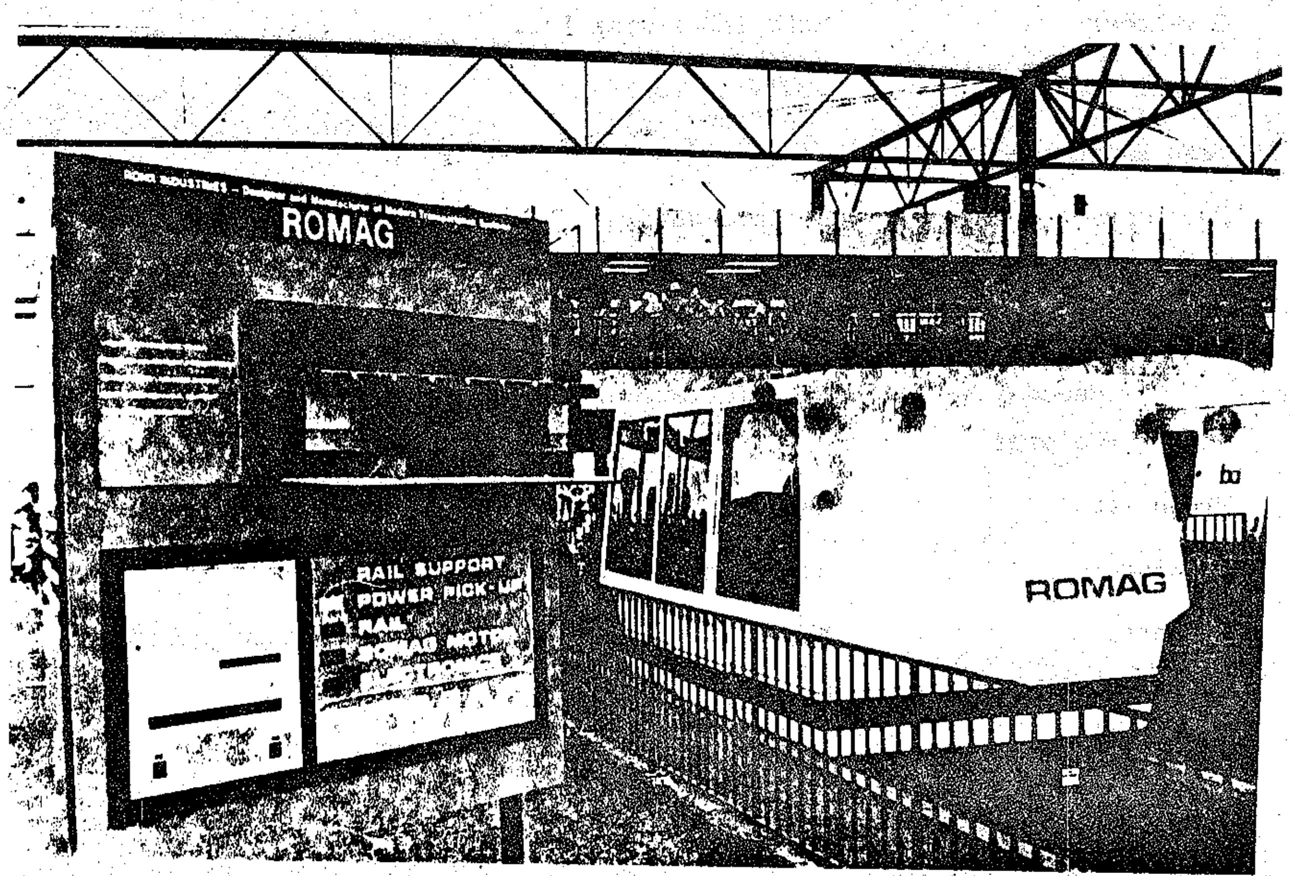
System Name	VAL
Developer	S.A. Engins Matra, Directions de Relations Exterieures, BP No. 1, 78 Velizy, France.
Annual Turnover	$62mil.
Main Subcontractors	Metropolitan Cammell Weymann Ltd., (bodies); CIMT-Lorraine (vehicles); Transexel (development); BET-SETEC/MATRA (civil).
Development Grants	French Ministry of Transport.
Service Offered	Scheduled.
Control:Path planning	Stochastic
:Headway	Synchronous
:General	Logic circuits on the train compare time checks (from central control) with actual progress along track, as measured by passive markers consisting of aluminium plates. Failure to keep to 'timetable' causes entire train service to stop. Separate anti-collision block system.
Propulsion	Rotary electric motors.
Braking	Regenerative braking with air-operated disc brakes in reserve.
Support	Sprung pneumatic tyred wheels.
Guidance	Horizontal wheels against guideway side.
Switching	Guideway moves to provide continuous sidewall.
Single track width (m)	3.25
Normal accn/decn (m/s^2)	1.3
Emergency decn (m/s^2)	1.3
Cruise speed (km/h)	80
Vehicle capacity (pass)	36 seated, 17 standing.
Minimum headway	60s.
Line capacity (pass/h)	9540 (trains of three vehicles)
Stage of Development	Prototype test track built.
Place of Development	Lille, France.



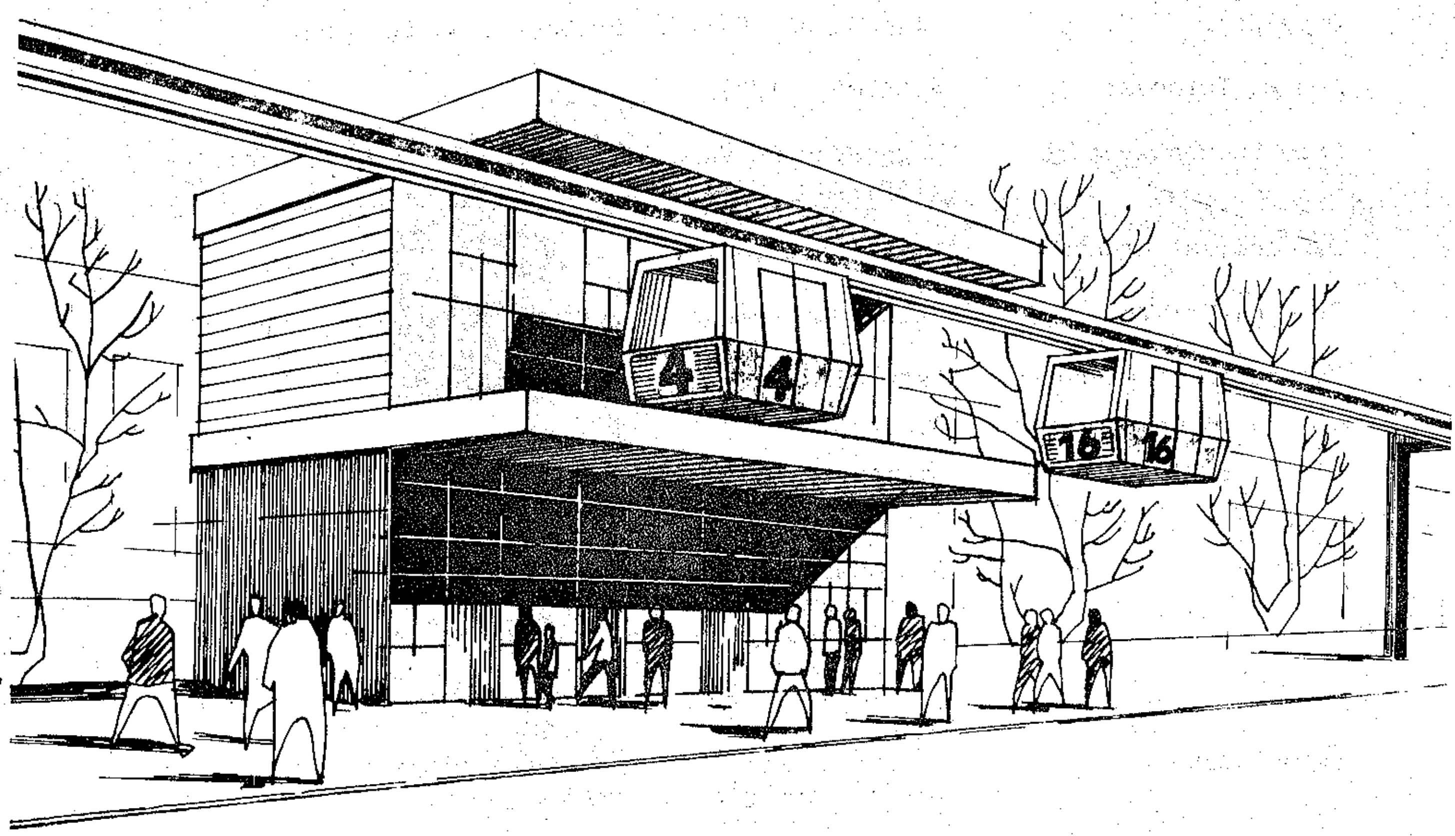


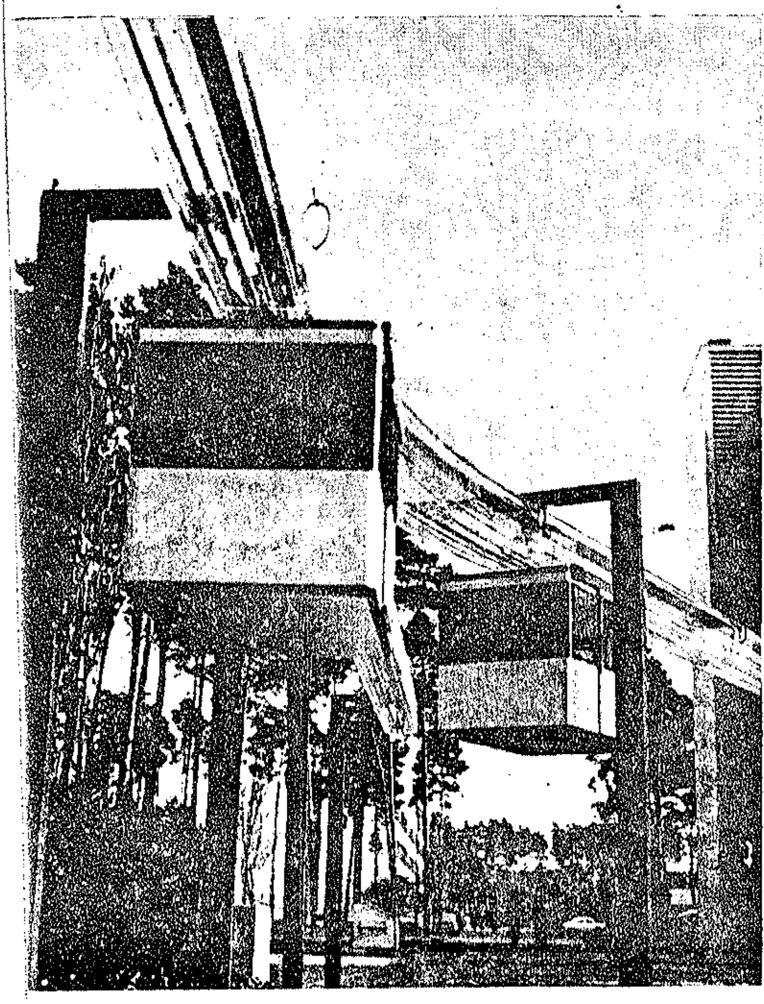
Dark area represents limits of lateral deflection.

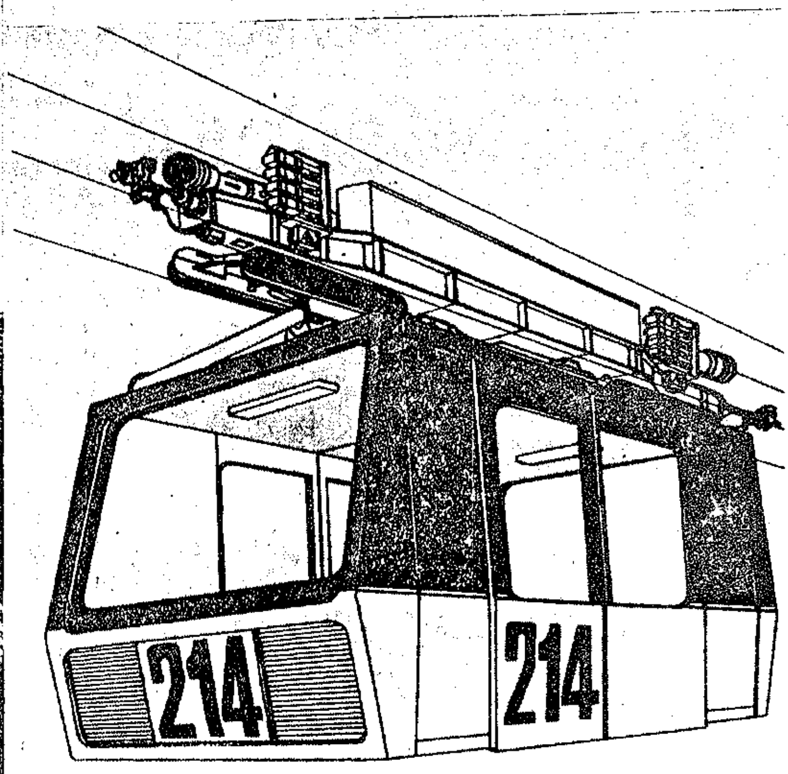
System Name	Monocab
Developer	Rohr Industries, (Monocab Inc.), 2700 Oakland Avenue, Garland, Texas 75041, U.S.A.
Annual Turnover	$336mil. (325)
Main Subcontractors	General Railway Signal Corporation, Box 600, Rochester, New York, N.Y. 14602, U.S.A. (control system).
Development Grants	$1.5mil. for Transpo exhibit from DOT.
Service Offered	Demand activated by passengers, or scheduled mode.
Control:Path planning	Deterministic
:Headway	Synchronous
:General	Hierarchical at the following levels: 1. Velocity, acceleration, headway. 2. Automatic docking and door operations. 3. Spare vehicle routing and routing of vehicles to destination, including switching. 4. Safety control of system operation and monitoring.
Propulsion	Rotary D.C. electric motor.
Braking	Regenerative service braking; spring release emergency friction braking.
Support	Pneumatic tyred wheels running within overhead guideway.
Guidance	Horizontal wheels against overhead guideway side.
Switching	Wayside-controlled switchblade movement of track.
Single track width (m)	0.75 actual overhead track; 2.42m swept envelope width.
Normal accn/decn (m/s^2)	1.21
Emergency decn (m/s^2)	3.02
Cruise speed (km/h)	94
Vehicle capacity (pass)	4-6 seated.
Minimum headway	10s.
Line capacity (pass/h)	2160
Stage of Development	Prototype operation.
Place of Development	Transpo 72 at Dulles Airport, U.S.A., and at Garland Texas, U.S.A.


ROMAG
RAIL SUPPORT
RAIL
ROMAG

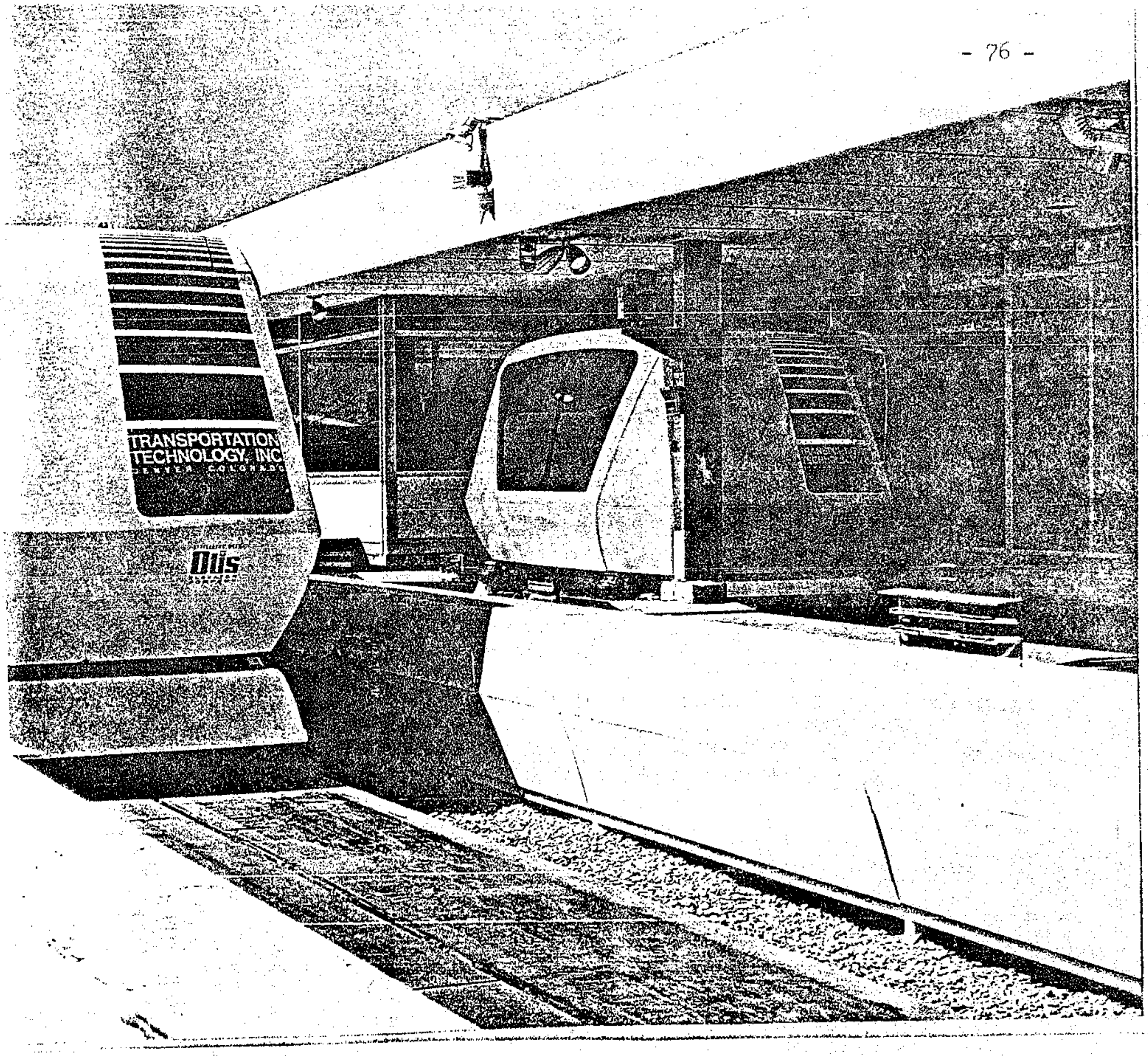
System Name	ROMAG
Developer	Rohr Industries Inc.
Annual Turnover	\$335mil. (325)
Main Subcontractors	-
Development Grants	No information.
Service Offered	No information available.
Control:Path planning) :Headway) :General)	No information.
Propulsion	Linear induction motor - windings vehicle mounted.
Braking	No information.
Support	Magnetic attraction.
Guidance	No information.
Switching	No information.
Single track width (m)	No information.
Normal accn/decn (m/s^2)	No information.
Emergency decn (m/s^2)	No information.
Cruise speed (km/h)	No information.
Vehicle capacity (pass)	No information.
Minimum headway	No information.
Line capacity (pass/h)	No information.
Stage of Development	Prototype or dummy full size vehicle.
Place of Development	Above exhibited at Transpo 72 (static model).

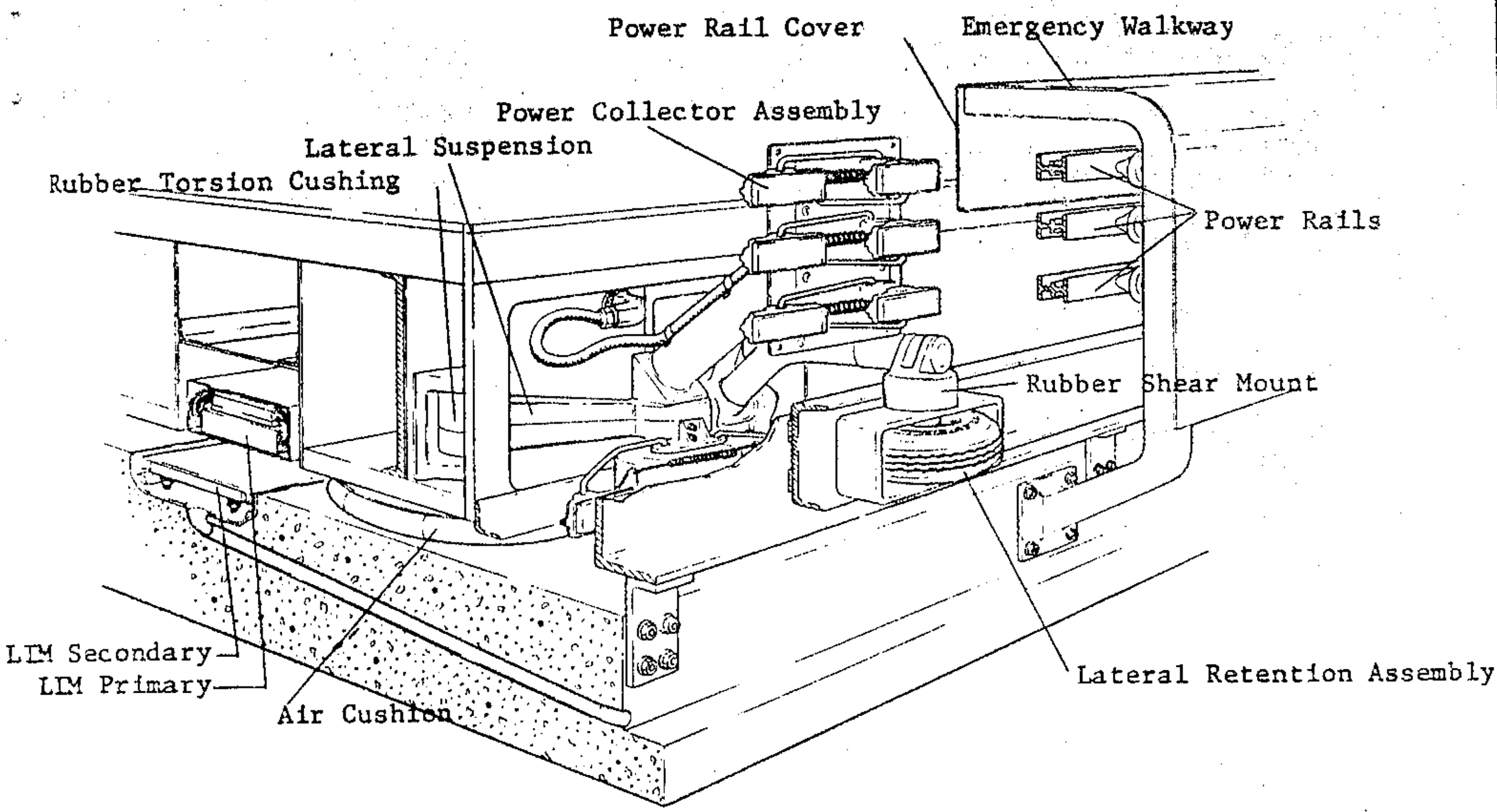

4
4
16
16



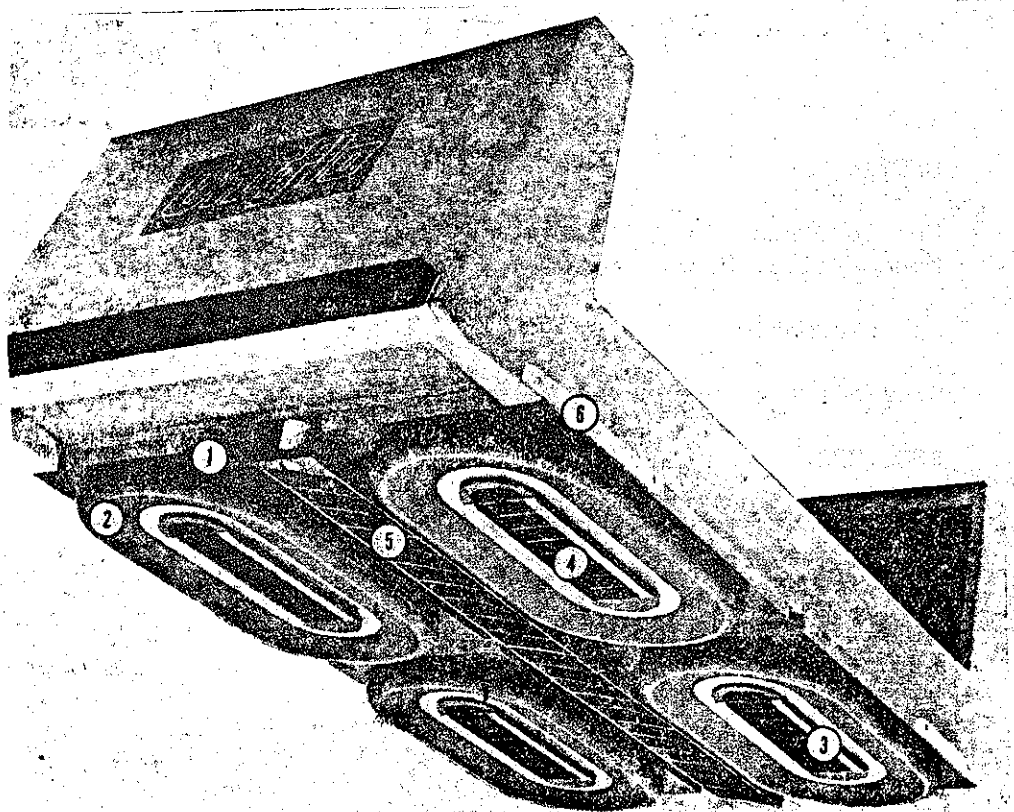

214
214

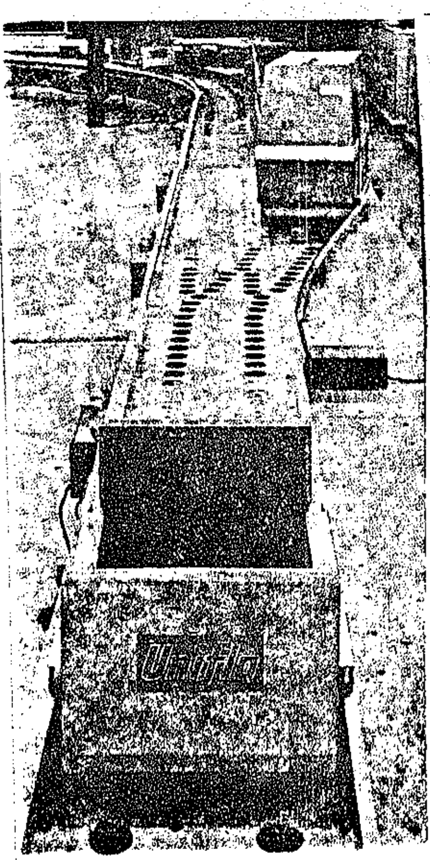
System Name	H-Cabinen
Developer	Siemens AG, D 8250, Erlangen, W. Germany.
Annual Turnover	$3815mil. (7*)
Main Subcontractors	Waggonfabrik Verdingen AG (DUVAG), D4150 Krefeld-Verdingen, W. Germany. (vehicles).
Development Grants	No information.
Service Offered	Passenger demand activated, scheduled in peak hours.
Control:Path planning	Deterministic
:Headway	Synchronous
:General	Hierarchical at the following levels: 1. Cabs are allocated exclusively to a unique destination without intermediate stops. 2. Headway maintenance is by "synchronisation" (Siemens). 3. Central computer surveillance of the circulation of cabs adapting numbers of cabs to demand. 4. Separate cabin security/safety system is envisaged.
Propulsion	Linear synchronous motors, windings on the vehicle, one at each side of overhead bogie.
Braking	Linear synchronous motor reversal with friction emergency.
Support	Wheels on rails, for both support and guidance.
Guidance	Horizontal wheels against overhead guideway side.
Switching	Alternate activation of linear synchronous motors, supplemented by mechanical traps in case of power failure.
Single track width (m)	Not known accurately but unlikely to exceed 1m.
Normal accn/decn (m/s^2)	No information available.
Emergency decn (m/s^2)	No information available.
Cruise speed (km/h)	35
Vehicle capacity (pass)	8 seated, 8 standing.
Minimum headway	12s.
Line capacity (pass/h)	12000
Stage of Development	Experimental stub track to be built by late 1973.
Place of Development	Duvag, Dusseldorf.

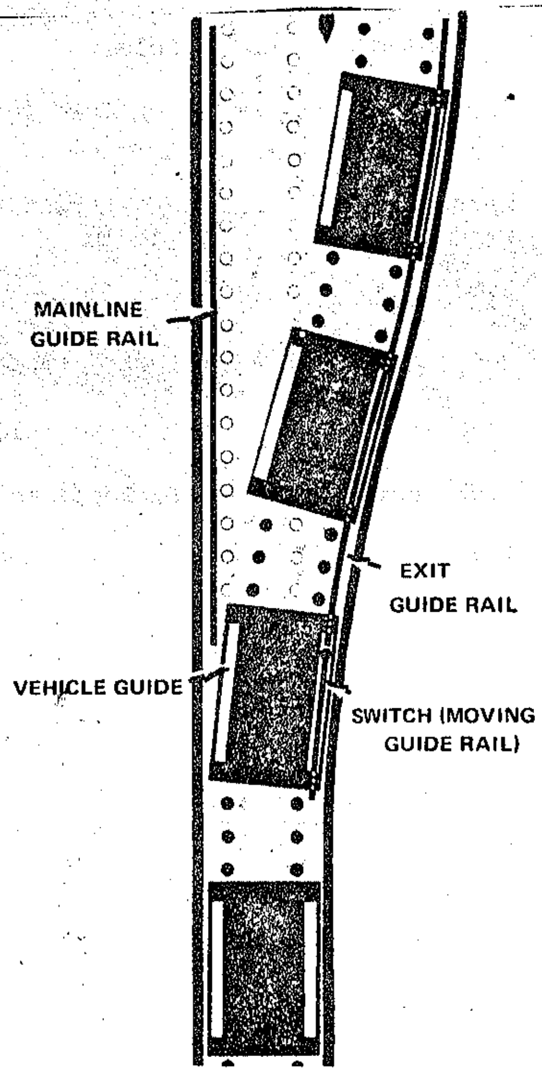

TRANSPORTATION
TECHNOLOGY, INC
DENVER COLORADO
Otis

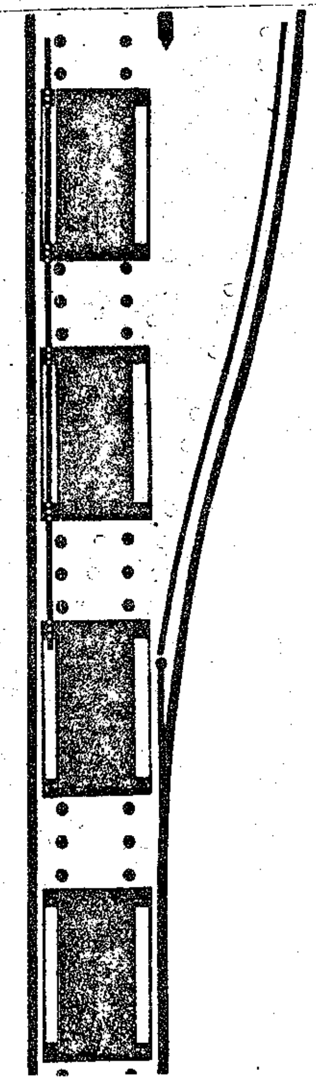

Power Rail Cover
Emergency Walkway
Power Collector Assembly
Lateral Suspension
Rubber Torsion Cushing
Power Rails
Rubber Shear Mount
LIM Secondary
LIM Primary
Air Cushion
Lateral Retention Assembly

System Name	TTI-OTIS 'Hovair'
Developer	Transportation Technology Inc., (a subsidiary of OTIS Elevator Co.), P.O. Box 7293, Park Hill Station, Denver, Colorado, 80207, U.S.A.
Annual Turnover	$789mil. (159)
Main Subcontractors	-
Development Grants	$1.5mil. from DOT for Transpo exhibit.
Service Offered	Off-peak demand activated, peak-hour scheduled service.
Control:Path planning	Deterministic.
:Headway	Synchronous
:General	Hierarchical at the following levels: 1. Central administrative function. 2. Station/Merge control, including in-station 'docking' procedures. 3. On vehicle control of switching per sequence/trip.
Propulsion	Linear induction motor, windings on vehicle.
Braking	LIM reverse thrust; "grounding" by deflating hover-pads in emergency.
Support	Air pumped from base of vehicle through rubber flexible pads.
Guidance	Horizontal wheels against vertical walls of guideway.
Switching	Horizontal wheels select appropriate guideway sidewall.
Single track width (m)	3.12 in switch areas.
Normal accn/decn (m/s^2)	0.96 (Transpo)
Emergency decn (m/s^2)	2.68 (deadstop from 6.7 m/s in 2.5s.)
Cruise speed (km/h)	47
Vehicle capacity (pass)	6 - 12
Minimum headway	2.5s. at 24 km/h
Line capacity (pass/h)	6150 at 24 km/h.
Stage of Development	Prototype operation.
Place of Development	Transpo 72, and 11380 Smith Street, Denver, U.S.A.

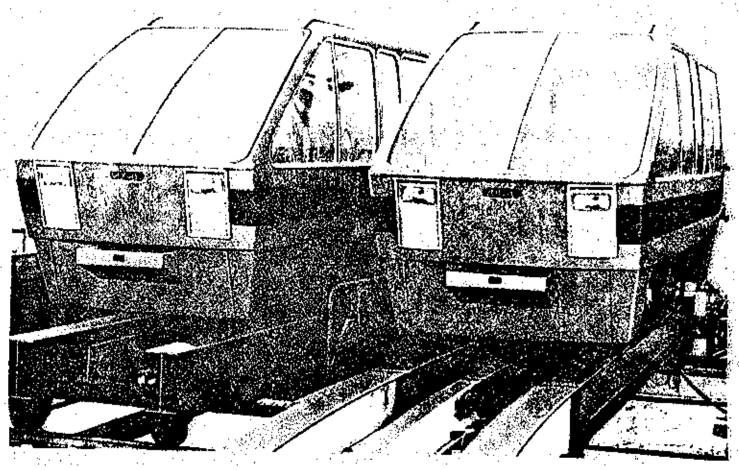

1
2
3
4
5
6
① LEVITATION ASSEMBLY
② LEVITATION SEAL
③ BRAKE SHOE
④ REACTION VANES
⑤ VORTEX THRUST UNIT
⑥ SIDE GUIDE UNIT

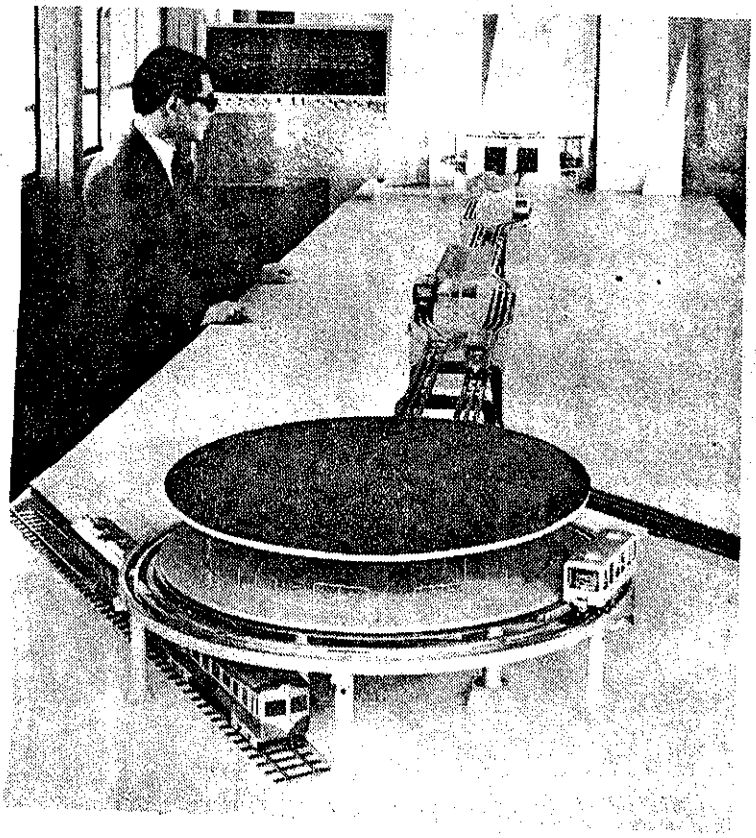



MAINLINE
GUIDE RAIL
EXIT
GUIDE RAIL
VEHICLE GUIDE
SWITCH (MOVING
GUIDE RAIL)

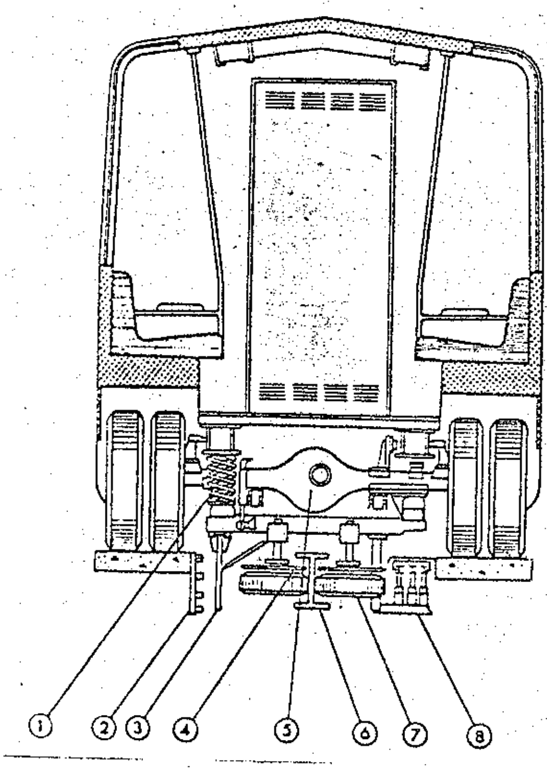


System Name	Uniflo
Developer	Uniflo System Co., 7401 Washington Avenue S, Minneapolis, Minnesota 55435, U.S.A.
Annual Turnover	No information.
Main Subcontractors	Subsidiary of Rosemount Engineering Inc. U.S.A.
Development Grants	$300,000
Service Offered	Demand activated or scheduled.
Control:Path planning	Stochastic
:Headway	Block
:General	Hierarchical. 1. Central control: monitoring, shutdown in emergencies, all alteration of berthing policies. 2. Station control: berthing policy and vehicle destination addrawing, door closure, docking, input of adjacent track condition. 3. Headway control: by adjustment of air pressure or by shutdown of air supply following disabled or slow vehicle.
Propulsion	Air pumped from track against vanes on the bottom of a passive vehicle.
Braking	Pneumatic from guideway (thrust reversal)/friction with guideway in emergencies.
Support	Air pumped from track.
Guidance	Horizontal wheels against guideway walls.
Switching	Trackside arm captures on-vehicle wheels.
Single track width (m)	2.57 (guideway is fully enclosed).
Normal accn/decn (m/s^2)	1.41
Emergency decn (m/s^2)	2.93
Cruise speed (km/h)	32-80
Vehicle capacity (pass)	8 or 12 all seated.
Minimum headway	5s. at 33 km/h.
Line capacity (pass/h)	5800-21600
Stage of Development	$300,000 test track built 1973.
Place of Development	Minneapolis, U.S.A.

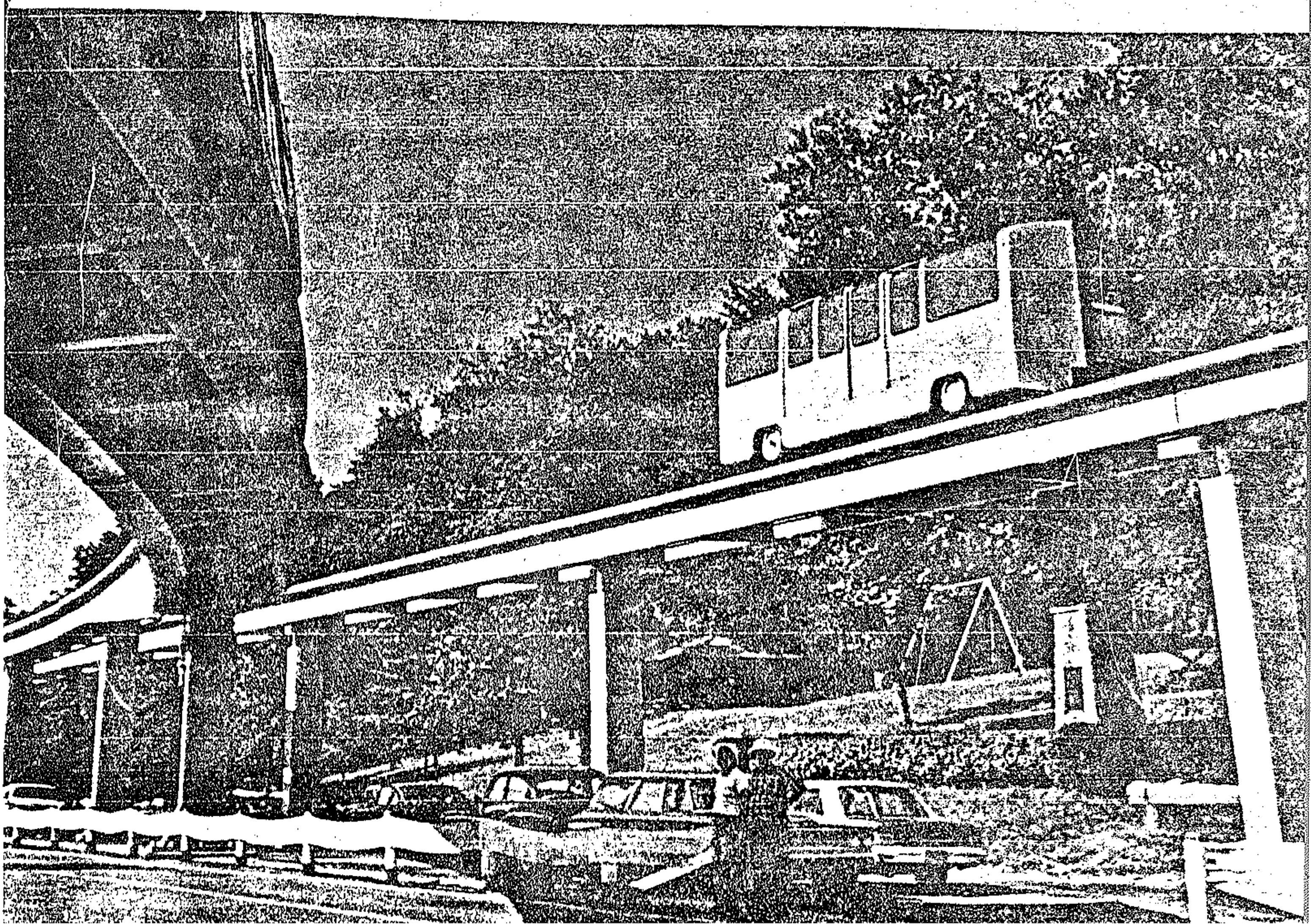




System Name	VONA
Developer	Nippon Shayo Seizo Kaisha Ltd., New Transportation System Division, 1-1 Sanbonmatsu-Cho, Atutu-ku, Nagoya, Japan.
Annual Turnover	$1294mil. (14*)
Main Subcontractors	Mitsui, Transportation Machinery Dept., 2-9 Nishi Shinbashi Itchome, Minato-Ku, Tokyo, Japan.
Development Grants	No information.
Service Offered	Scheduled.
Control:Path planning	Stochastic
:Headway	Block
:General	Automatic train control and train protection - no details available.
Propulsion	Rotary electric motor.
Braking	No information.
Support	Pneumatic-tyred wheels running on steel. I-beams with bitumen surface.
Guidance	Horizontal pneumatic wheels bear against beam central below track and thereby retain the vehicle.
Switching	Track section moved out of alignment and new section moved in to preserve continuous running surface and central guidance.
Single track width (m)	Unlikely to exceed 2m.
Normal accn/decn (m/s^2)	No information.
Emergency decn (m/s^2)	No information.
Cruise speed (km/h)	60
Vehicle capacity (pass)	30
Minimum headway	60s.
Line capacity (pass/h)	15000
Stage of Development	Prototype operation.
Place of Development	Precise location not known.



1 Air and steel spring comb.
2 Signal wire system.
3 Receiving and transmitting antenna.
4 Safety disk.
5 Differential and hypoid drive.
6 3 Phase collector system.
7 Pneumatic guide tire.
8 Steel guide rail.



System Name	Skybus/Vehicle Distribution System
Developer	Westinghouse Electric Corporation, Transportation Systems Division, Pittsburgh, 15235, U.S.A.
Annual Turnover	$4630mil. (14)
Main Subcontractors	Bethlehem Steel Inc., U.S.A. (track); St. Louis Car Co., (vehicle bodies).
Development Grants	Fed Housing $28mil.; Allegheny County $8.6mil.; Pennsylvania State $.2mil.; Westinghouse $1.042mil.
Service Offered	Scheduled.
Control:Path planning	Stochastic
:Headway	Block
:General	Train control - not hierarchical in prototype. Wayside or central monitoring of progress block to block, speed, acceleration of each vehicle - central control commands each vehicle according to "rules" of separation, station spacing, known speed limits. Headway maintained by one vehicle per inductive loop of 1760 feet.
Propulsion	Rotary electric motors.
Braking	Friction wheel brakes.
Support	Sprung pneumatic tyred rubber wheels.
Guidance	Horizontal guide wheels against central beam below track retain vehicle on track.
Switching	Transfer switch or table involving the movement of complete segment of track aside or realigned to preserve continuity of running surface. Takes 20 seconds per transfer cycle.
Single track width (m)	2.57
Normal accn/decn (m/s^2)	1.25
Emergency decn (m/s^2)	No information.
Cruise speed (km/h)	80
Vehicle capacity (pass)	28 seated, 42 standing.
Minimum headway	120s.
Line capacity (pass/h)	2100
Stage of Development	2.86 km of single track in a loop format with one transfer table at South Park, (Airport shuttles elsewhere.)
Place of Development	South Park, Pittsburgh, Penn., U.S.A.; Tampa and Seattle Tacoma Airport, U.S.A.

APPENDIX B

SELECTED BIBLIOGRAPHY

This bibliography (in chronological order) contains the major sources of information on automated systems. All the publications contain references to other sources.

1. Future Urban Transportation Systems: Descriptions, Evaluations, and Programs. (Final Report 1).
Stanford Research Institute, Menlo Park, California
March 1968 426pp PB-178265

The contract awarded to SRI for a "... study and report of ideal technological futuristic solutions to urban transportation problems, solutions available in from 5 to 10 years" was an important step in the analysis of urban transportation and the beginning of serious research into automated public transport. The report (which is the major one produced by the contract) provides a cogent analysis of urban transportation needs followed by an evaluation and integration of the various alternatives examined. The report naturally limits its analysis to American cities. The optimism found between its covers has not been justified by later research and events.

2. Cabtrack Studies Assessment of Autotaxi Urban Transport Group.
Technical Report 68287 Part 1, Part 2
Royal Aircraft Establishment, Farnborough, Hants.
December 1968 204pp and 90pp

A detailed, mainly technical report describing and evaluating the autotaxi system i.e. a small 4 seat cab under automatic control giving a non stop trip from origin to destination. An economic assessment of autotaxi in Central London provided only limited justification for its installation. Still a valuable source of information on vehicle design and performance, control systems, passenger handling, structure design.

3. Transportation System Candidates for Urban Applications. A.L. Handman et al. Mitre Corporation, McLean, Virginia, U.S.A. Under UMTA TR052.70, DOT UT 00007 contract. 289pp.

Useful review of many systems originating in U.S.A., Europe and elsewhere. A comparison with this working paper (December 1973) demonstrates the changes that have taken place in the urban transport field since 1970.

4. An Aid to Pedestrian Movement. A Report by a Working Party on the Introduction of A New Mode of Transport in Central London. Westminster City Council, Victoria St. S.W.1. March 1971 61pp

An evaluation of the Minitram concept as a short distance (0.5 - 3 km) people mover in Central London. The operational, economic and to a lesser extent environmental implications of twenty seater vehicles operating a line-haul service were examined. The study concluded 'a new system could not be justified on financial grounds. Its construction would need to be justified on its contributions to the broader planning problems as a whole'.

5. Cabtrack.Robert Matthew Johnson-Marshall and partners.
Article in Architects' Journal 19 May, 1971 21pp

The first comprehensive study of the environmental implication of cabtrack using Central London as a scenario. Relevant factors included safety, obstruction, privacy, visual scene, daylight and sunlight, noise, microclimate, air pollution and vibration.

6. Personal Rapid Transit. A Selection of Papers From the First National Conference on PRT - November 1971, Minneapolis, Minnesota ed: J.E. Anderson et alia December 1971 circa 250pp

A collection of 38 papers mainly on the small vehicle PRT concept. The papers are mainly technical examining the problems of vehicle and system performance. A few papers on economic and planning aspects concentrating on American conditions.

7. Planning for Personal Rapid Transit. Centre for Urban and Regional Affairs. University of Minnesota December 1972 347pp

A detailed and well balanced source of information for engineers, planners and students interested in the PRT concept. Chapters on architectural impact, economic aspects, design of stations and interchanges, design of control systems for vehicle management. The most persuasive and comprehensive single report on PRT (in USA) to date.

8. Opportunities in Automated Urban Transport. B.E. Grant. W.J. Russell Prepared under contract to the Transport and Road Research Laboratory March 1973. 46pp

"This publication is intended to familiarise people interested in transportation with what can be achieved in automatic, urban, public transport".opens the preface. A glossy, easy to digest publication for those wishing to know and see the type of systems under discussion. Not for those wishing a deeper understanding of the technical, economic and environmental implications of advanced systems.

9. Advanced Systems in British Cities. Proceedings of Symposium 21-23 March 1973 University of Warwick, Coventry, England. December 1973

A collection of 11 papers addressed to a British audience. The main papers were 'The Evolution of Modern Urban Transport', 'A New Era in Transportation', 'The British view of Urban Automatic Transport Systems', 'Experience with the Morgantown PRT System', and 'The Case for Reserved Track'. Specialist papers examined control, impact on city from, problems of fitting systems into the urban fabric and operational aspects.

10. Progress, Problems and Potential. International Conference on Personal Rapid Transit 2-4 May 1973. University of Minnesota Minneapolis, Minnesota.

A collection of 50+ papers covering the whole spectrum of PRT development - technical economic and environmental - from a wide body of contributors. A more detailed look at some of the problems reviewed at the first Conference.

11. A Technology Description of High Capacity Personal Rapid Transit. T.J. McGean. Mitre Technical Report. MTR 6498 (controlled distribution). Under DOT - TSC - 434 contract (Transportation Systems Centre), 11 July 1973. 94pp (Project 0910)

A well balanced description of 'PRT - like' vehicles and their characteristics addressed to the US market. An exploratory examination of their economics and the delineation of some 'key technical problems' form useful additions to information on PRT.