

**R**AIL-BASED TRANSIT is expensive to buy, and the expense is highly visible. All of the costs incurred in creating a metro appear in the balance sheet, and where tunnels are required, those costs have risen sharply in the 1970s.

In contrast, buses are mass produced and therefore cheap, while the operator is seldom charged for highway improvements, even when these include dedicated bus lanes. Likewise, the economic and social costs which the private car imposes on the community are widely accepted, but difficult to quantify and recover from the user.

Yet developments which have taken place around the world in the last 20 years clearly show that the role of rail transit is actually increasing, and at an accelerated rate. Why is this.

The two factors that have had the strongest influence on transit ridership in general—growth of cities and increase in car ownership—have also influenced the use of rail modes in recent decades. These factors have had a negative impact on one rail mode—the streetcar (SCR) or tram—but they led to a major increase in the development of light rail transit (LRT), rail and rubber-tyred rapid transit (RRT) systems usually known as metros, and regional rail (RGR) networks which link suburbs with the urban core.

Observing urban transport trends in different countries, it can be easily seen that growth of a city increases the total volume of travel. How much of that increase goes to public transport modes depends on car ownership, the quality and quantity of transit service, and transport policies at local and national levels.

When rapid increase in car ownership occurs, major efforts are focused on road construction, parking and related facilities. Transit usually suffers at this stage, modernisation getting much less attention than highway construction. In many cases transit is totally neglected, or its rights-of-way are taken over for street widening—a very costly mistake in the long run.

These developments have eliminated SCR from many cities, thus decreasing the role of rail transit. Only in cases where SCR rights-of-

# Designers widen the urban rail options

**Far from being rendered obsolete by car and bus, or squeezed out by rising costs, the pace of metro construction has accelerated dramatically through three decades—and this trend is continuing. Once categorised by planners as suitable only for the most densely travelled corridors, urban rail is now appreciated as offering a continuous spectrum of choice from fully segregated metro and regional rail systems through to the streetcar or tram. Provided large and medium-sized cities have sound transport policies, there will usually be an important role for rail transit**

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way were preserved and extended so that the system could be converted into LRT, rail transit retained its role, if in a somewhat different form.

As increased use of the private car leads to chronic congestion, even with expanded highways and streets, the fact that the car alone cannot satisfy the transport needs of cities for physical, social, economic, and environmental reasons is eventually recognised. The only solution to congestion relief and the provision of service with adequate capacity and acceptable quality is through creation of independent transit rights-of-way. Although partial and temporary separations can be achieved through provision of various types of bus lane, the most effective permanent solution is to construct rail systems.

It is these developments that have led to the accelerated construction of RRT or metro systems which has taken place since the mid-1950s around the world (Fig 1). During the 26 year period beginning in 1955, the number of cities with RRT increased from 19 to 58, and the total length of RRT networks almost doubled.

Much recent RRT construction (nearly 40 per cent) has taken place in Western Europe and Canada, but an increasing share is appearing in newly-urbanised countries such as Mexico, Brazil, Hong Kong and Korea. In the United States, following a period of serious neglect of public transport—particularly rail modes—the number of cities with RRT has increased from four in 1954 to eight today, with two more metros under construction.

In recent years, extensive construction of LRT has also taken place. Tunnels for downtown sections of LRT and extensions of lines in suburbs have been built in some 15 West German cities as well as several Dutch, Swiss and East European cities. New LRT systems have been planned and constructed since mid-1970s at a dramatically accelerating pace. Two cities in Canada have opened new LRT systems since 1978 (Edmonton and Calgary), one each in Great Britain (Newcastle) and the US (San Diego), while some 12 other cities in countries from the Netherlands to Brazil and from Tunisia to the Philippines (with particularly intensive activity in Canada, United States and France) are either constructing or planning LRT.

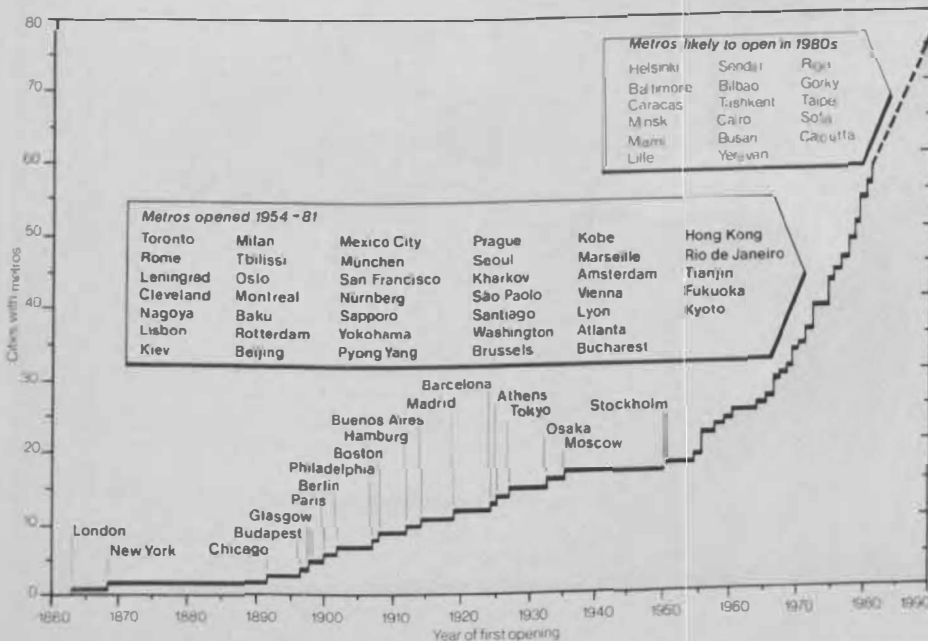
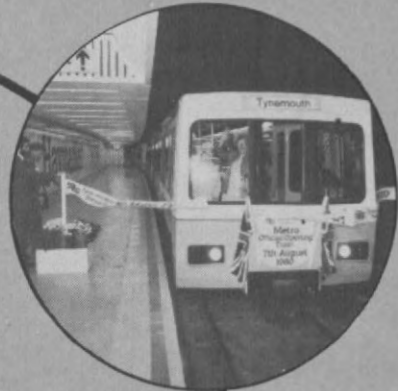


Fig 1. In the 1970s new metros were being opened all over the world at the rate of two a year, a trend that will continue through the 1980s

# Transit family tree

a  
b c d  
e f g  
h i j



**a Heavy metro:** massive investment underground brings mobility to America's capital

**b Regional rail:** RER in Paris is without doubt the classic example of the regional metro

**c Rubber-tyred metro:** elegant and quiet in Lyon, but of modest capacity

**d Light metro:** Tyne & Wear, partly underground, is about as heavy as light rail can get

**e Electric suburban:** almost a regional metro but still part of New South Wales' railway

**f Peoplemover:** fully automated, though Osaka's New Tram carries a crew member for safety

**g Light rail:** Toronto's new tram on Boston's green line, a former railway right-of-way

**h Railbus:** bus body on a rail chassis may be used around Britain's smaller cities

**i Guided bus:** equipped with guidewheels, this O-Bahn bus runs on a concrete track in Essen

**j Street tram:** even in East European cities the tram is retreating from the streets

Major RGR modernisation, and construction of entirely new lines, has been undertaken in numerous countries. Particularly interesting developments are found in Paris (RER); München, Frankfurt, Stuttgart and the Ruhr (S-Bahn); and in Brazilian, Canadian, and many Japanese cities.

### Immediate objectives

The decision to build a metro, the dominant representative of rail modes, has several objectives. In some cases, one or a few objectives dominate this decision, but they are usually supported by a number of others. A brief review of the objectives and goals in building RRT, which can be classified into three different categories, is quoted here with examples of cities in which each goal was particularly emphasised. LRT and RGR are usually based on similar considerations. Specific and defined immediate objectives include:

- increase in speed of travel (Brussels, Moscow, New York);
- provision of adequate capacity (London, Mexico, Moscow, Tokyo, Toronto);
- decreased operating cost through higher staff productivity (Hamburg, München);
- relief from street congestion (Boston, London, Montreal, Sao Paulo);
- avoidance of excessive parking requirements (Cleveland, San Francisco);
- higher reliability, safety and comfort than surface transit can offer (Berlin Philadelphia-Lindenwold, Vienna, Washington).

Some of these goals can be expressed and their achievement evaluated in quantitative terms—speed, capacity and so on—but that evaluation should not be considered as comprehensive and sufficient, as in most cases high-level goals are important and often dominant reasons for metro construction.

### Specific goals

A number of specific goals may also be pursued through building RRT such as:

- strengthening of the central urban area through improved transit service (Boston, Philadelphia);
- tying together a region split by geographic barriers (Rotterdam, San Francisco);
- stimulating development of an outlying area through improved connection with the city (Amsterdam, Stockholm);
- high-quality service on a special link, such as a line to an airport, stadium, or office complex (Cleveland and Chicago airports, Frankfurt-Nordweststadt).

Clearly, these goals cannot be precisely quantified, and their direct economic and performance evaluations are usually a minor part of the overall justification of investment.

### High-level goals

The highest-level goals in building RRT are, in the majority of cases, to:

- increase transit ridership, improving mobility of population;
- provide a high level of service in individual corridors or throughout an urban area, stimulating economic efficiency;
- attract passengers away from private cars and provide conditions in which the application of disincentives to car use in cities is politically possible;
- create a better balance between public and private transport which results in a system with physically, economically, and environmentally superior performance than is achieved by relying on one mode only;
- provide greater permanence of service to assist long term integration of land use and transport planning;
- shift travel to the most energy-efficient modes, thus reducing energy consumption in transport and, indirectly, for other purposes through better organised land use;
- influence urban development and create well-organised, efficient, and attractive urban forms, which are a precondition for high-quality urban living and the creation of great cities.

Since these goals are mostly qualitative there is a tendency to underestimate them. However, they should represent an integral part of RRT planning, and no evaluation of a rail transit project can be complete without a full recognition of its potential in terms of these goals. Neglect of these aspects in planning will result in under-utilisation of the potential interaction of rail transit with overall urban planning.

This diversity of objectives and goals in building RRT shows that a number of factors can favour its introduction in individual cities. The most significant are the city's size, form, and density. These factors govern travel volumes along individual corridors or throughout the city and determine whether investment in RRT is justified.

The condition of transit and traffic in the city also has a major influence. Narrow streets, traffic congestion, and an inability to provide any preferential treatment to surface transit are factors in favour of introducing transit on separate rights-of-way, usually RRT or LRT.

Geographic features represent another important element. Hilly terrain, narrow valleys, bodies of water, and so on, make construction of transport facilities very costly, so that application of high-capacity modes such as RRT becomes the logical choice. This factor played an important role in Rotterdam (metro under the Maas river), in San Francisco (Twin Peaks tunnel and the Bart tube under the Bay), and Hong Kong (RRT under Victoria Harbour).

Finally, an important element is the existence of a long-range transport policy enhancing co-ordinated planning and financing of transport facilities. Historically, RRT has always been constructed more intensively when there was a long period of peace, as well as in cities and at times when rational long-range planning of transport improvements existed. Without these two conditions improvements tend to be short range in character involving minimum investment, but often with limited and temporary impact.

There is a widespread belief that rail transit can be economically justified only in very high density corridors. This stems from an opinion prevailing during the 1950s and 1960s that rail vehicles could operate only on fully separated rights-of-way.

Developments since the mid-1960s have proved this thinking to be fundamentally incorrect. Light rail transit, operating largely—but not exclusively—on separate rights-of-way, has been proved as an efficient mode offering a superior performance/cost package for many alignments where RRT cannot be justified. Use of modern traffic engineering methods to give preferential treatment to rail vehicles has made even SCR an efficient mode for many cities.

At the heavy end of the spectrum there has been a trend towards converting suburban railways to transit-type operation. With shorter headways, electric traction and improved network coverage in the city centre, this mode has become for many cities an integral component of multi-modal transit systems. Therefore its most appropriate name is 'regional rail' (RGR).

A review of technical, operational and

**Les concepteurs élargissent la portée des options du rail urbain.** Bien loin d'être rendue surannée par les voitures et les autobus, la évincée par l'augmentation des coûts, la construction des chemins de fer urbains s'est accélérée de manière sensationnelle pendant trois décennies — et cette tendance ne fait que de se poursuivre. Classés naguère dans la catégorie convenant uniquement aux itinéraires de trafic-voyageurs les plus intensément utilisés, les voies ferroviaires dans toutes leurs formes différentes—métro entièrement séparé, réseau express régional, métro léger ou tramway— sont maintenant appréciées par les planificateurs comme convenant à un éventail continu d'applications. A condition qu'une ville fasse preuve de principes judicieux de transport, une place y sera généralement réservée convenant au rail, sous une forme ou sous une autre

**Konstrukteure erweitern die Reihe der spurgeführten Bahnsysteme in den Großstädten.** Nicht nur wurden sie weder durch Kraftfahrzeuge oder Autobusse Außer Gebrauch gesetzt, noch durch steigende Kosten verdrängt, sondern der Bau von U-, S- und Stadtbahnen wurde in den vergangenen drei Jahrzehnten dramatisch gesteigert—und dieser Trend bleibt auch weiterhin bestehen. Früher einmal, als nur für die Korridore mit dem

dichtesten Verkehr als geeignet klassifiziert, werden alle verschiedenen Formen der spurgeführten Bahnsysteme in den Großstädten, d.h. als U-Bahnen, S-Bahnen oder Stadtbahnen und Straßenbahnen von den Planern als bedeutend für ein kontinuierliches Anwendungsspektrum angesehen. Solange eine Großstadt eine gesunde Transportpolitik betreibt, finden Bahnsysteme in der einen Form oder anderen einen Anwendungszweck

**Los proyectistas aumentan el número de opciones del ferrocarril urbano.** La construcción de ferrocarriles urbanos incrementó su ritmo asombrosamente a lo largo de tres decenios y está prosiguiendo con la misma intensidad, prueba patente de que este medio de transporte no ha quedado anticuado frente al automóvil y al autobús ni excluido a causa de la subsidia de los costes. Clasificado en otro tiempo como medio adecuado sólo para los pasillos con mayor densidad de tránsito, el ferrocarril urbano, en todas sus formas diversas, metro totalmente separado, red ferroviaria regional o tranvía, es considerado hoy día por los planificadores como un medio apropiado a una gama continua de aplicaciones. Si es sólida la política de transportes de una ciudad, por lo general habrá en ella un lugar destinado al ferrocarril en una forma o en otra

system characteristics of the four rail transit modes SCR, LRT, RRT and RGR—is given in Table I. Actually, the trend has been toward development of a nearly continuous family of rail transit modes from low-performance, low-cost SCR at one extreme to RRT and RGR with high performance but also high investment requirements. The range of applications is thus much broader than many urban transport planners believe.

It is not necessarily true that all rail transit requires very high investment. Actually, if the goal in introducing a transit system is to attract car users by a high level of service, rail modes are often the cheapest option.

To provide an optimal rail system, the most appropriate mode must be carefully designed. Over-design, a more common problem than under-design in recent years, has often resulted not only in excessive costs, but also in fewer benefits to the city.

### Other guided modes

The natural advantages of guided modes—high reliability, safety, labour productivity and passenger attraction through system identity—have stimulated various inventions with both promising and disappointing results.

**Monorails**, promoted as highly promising modes around 1960, have proved to be suited to very special alignments (Schwebebahn in Wuppertal, Haneda airport line in Tokyo) but not for wide use.

**Automated guided transit (AGT)** modes, sometimes known as peplemovers, are increasingly used for short hauls, primarily within limited areas such as airports, fairgrounds, and as distributors for metros. Although they are used as transit lines in a few cities (Morgantown, Lille, Kobe, Osaka), these are still experimental applications.

In all comparative analyses with rail modes for regular transit lines, the latter have been found superior. A major benefit which rail transit may get from AGT is fully automatic operation (crewless trains) which rail operators have been reluctant to develop.

**Guided buses**, marketed recently in West Germany as the O-Bahn, feature simple physical or electronic guidance of buses. This allows specially-equipped buses to run on streets as well as on special guideways creating a bimodal operation with very simple transition between the two. Guided buses can therefore combine the advantages of serving low-density suburbs with a few advantages of guided operation on trunk sections in high-density corridors.

The main advantage is that in the guided mode buses require less guideway width. However, they do not have other advantages which rail transit has: electric traction with superior performance, ability to operate in tunnels due to absence of exhaust, high capacity (large vehicles, operation of trains), and high comfort (spacious, better-suspended vehicles).

Consequently, O-Bahn can extend applications of buses in some special cases where a narrow right-of-way is needed, but as long as the basic bus designed for street running is used, it will be constrained by diesel propulsion and small size. Although the O-Bahn offers a considerably lower perfor-

**Table I. Typical technical and operational characteristics of rail transit modes**

	SCR	LRT	RRT	RGR
Cars per train	1-3	1-4	1-10	1-10
Car length <i>m</i>	14-23	14-30	15-23	20-26
Seats per car	22-40	25-80	32-84	80-125
Capacity per car	100-180	110-250	140-280	140-210
Segregated route <i>per cent</i>	0-4	40-90	100	90-100
Driving	visual	visual/signal	signal	signal
Fare collection on/off train	on	on/off	off	on/off
Ticket barriers	no	yes/no	yes	yes/no
Platform	low	high/low	high	high/low
Maximum speed <i>km/h</i>	60-70	60-120	80-100	80-130
Commercial speed <i>km/h</i>	12-20	18-40	25-60	40-70
Trains/hour <i>peak</i>	60-120	40-90	20-40	10-30
<i>off-peak</i>	5-12	5-12	5-12	5-12
Passengers/hour <i>thousands</i>	4-15	6-20	10-40	8-35
Reliability	low-medium	high	very high	very high
Station spacing <i>m</i>	250-500	350-800	500-2000	1200-4500

mance/cost combination than LRT, it may be competitive only if the superiority of LRT in terms of level of service, permanence and passenger attraction are overlooked.

**Electric guided bus**, recently developed by Mercedes-Benz, represents a strange combination of concepts. Designed basically as a bus, this electrically-powered four-axle articulated vehicle can operate on guideways only. Thus it represents an awkwardly-designed rubber-tyred guided vehicle rather than an innovative concept.

**Rubber-tyred metros**, operated in six cities, have some features superior to rail: better adhesion for traction (therefore ability to negotiate steeper grades), lower noise in curves and on aerial structures. However, these advantages are outweighed in most cities by disadvantages in comparison with conventional rail technology. Inability to operate under ice and snow conditions makes expensive tunnelling necessary even in suburban areas (Montreal); smaller vehicles aggravate congestion on heavily travelled lines (Mexico); heat production in tunnels creates problems.

### Future role

It is increasingly recognised that provision of a transit system largely or fully independent from congested streets is an absolute necessity for contemporary cities. Only the existence of such a system—insulated from the spiral of declining revenue and rising operating costs that afflicts buses locked in traffic jams—can assure economic progress and re-establish a human-oriented environment.

With the broad variety of physical and operational characteristics developed in recent years through advances in LRT and RGR, rail transit is being used in a much greater variety of forms than its stereotyped definition as a 'high-cost high-capacity mode suitable for high-density corridors' implies.

The polarisation of transit modes to low performance buses on streets and high performance metros left a large gap for medium performance services without a suitable mode. Yet the vast majority of cities need such 'medium' systems: transit services much better than buses can offer on streets, for an investment much lower than RRT requires. This gap is now being filled by upgrading bus

and SCR services from one side, and by constructing a great variety of new LRT, RRT and RGR modes from the other.

The rapidly increasing cost of building metros represents a serious problem, but construction of rail transit continues for several reasons. First, the cost of other travel modes, particularly the car, is also increasing. Second, reducing dependence on oil has become explicit policy in many countries. Third, many cities find that the cost of not constructing independent transit systems (incurred by congestion) is higher than the cost of construction. Fourth, continuing construction of highways and parking is not acceptable in most cities due to environmental considerations.

Nevertheless, simpler and cheaper rail modes and facilities, such as LRT, are being used increasingly; efforts to reduce over-design should intensify if a slowdown in their construction is to be avoided.

The need for rail transit in the cities of developed countries is primarily aimed at providing a superior alternative to the car; service quality is therefore important. In cities of developing countries it is quantity—the ability to carry large volumes of passengers—that is the dominant factor.

Both needs will grow. With their unique advantages over similar transit technologies, rail modes are likely to be increasingly in demand not only in large but also in many medium-size cities.

Another major factor in the future of rail is transport policy as part of the urban planning process. Cities without a clear transport policy may regard transit as a supplement to the car, provided out of charity for those too poor to own one. Here the chances for construction and success of rail transit are weak indeed.

But in cities which pursue a policy of co-ordinated planning of urban development and transport, and which plan efficient transport systems consisting of co-ordinated public and private transport, rail transit will always have an important role. □

*Readers who wish to explore in more detail questions of rail transit design are recommended to obtain the author's recent work on this subject, 'Urban Public Transportation Systems and Technology', from the publisher Prentice-Hall, Englewood Cliffs, NJ 07632, USA.*