Light Rail: Making Urban Transport More Attractive

Pierre Laconte

Introduction

This introductory article provides some glimpses of the historic background of urban mobility. It describes the rise and decline of market-led urban rail transport operators, the rise of market-led individual modes, and the shift to public transport owned by the public sector (or operated on its behalf). Good examples of the increasing attractiveness of urban passenger transport through surface light rail include Manchester, Karlsruhe and the lesser-known expansion of surface light rail in France, Turkey, Japan, etc. The accounts are based on the experiences of UITP members and personal visits and interviews with people involved.

Urban Rail Markets of Yesterday and Today

In 19th century, most interurban road network was private and operated under concession. Contractors were in charge of building and maintaining roads and collecting tolls. In the UK around 1820, an estimated 20,000 miles of roads were operated under concession agreements.
Starting with the interurban link between Liverpool and Manchester in 1830, railways gradually expanded worldwide and, in addition to interurban services, opened suburban areas to the urban middle class. Private businesses were entirely responsible for determining routes, acquiring land, and investing in tracks and operations. They are naturally concerned with marketing and segmentation by classes of potential passengers.
Suburban land development became a key objective for rail operators and combined the creation of property values and urban passenger markets. Probably the most adventurous and successful combination of passenger transport and urban development was the extension of Cairo planned by the Belgian banker, Edouard Empain (1852–1929). Empain bought a huge tract of plateau desert land some 10 km from the centre of the city and a tiny corridor through the desert on which he built a tramway line and utilities (water supply, sewage, etc.). He subdivided the desert land according to a simple, high-density low-rise street grid and public services master plan and thus created a huge suburban passenger market between Cairo and the new settlement called Heliopolis.
The success of the market-led Heliopolis transport and land-use project later enabled Empain to repeat it on a larger scale in Paris where he financed the metropolitan railway network. He again combined property development and electricity generation with investment in public transport. The project was entirely private. No elected officials attended the opening in July 1900. The new Metro was an immediate market success—helped by the 1900 Paris Exhibition—with more than 16 million passengers during the first 5 months of operations.

Rise of motor vehicles and dawn of market-led railways

Electricity and the combustion engine were possibly the two most important transport-related technical innovations of the late 19th century. The telephone also played a role as a substitute for travel but even more as an incentive to additional physical mobility. Generation of electricity on an industrial scale facilitated the rise of new urban transport operators backed by a modern industrial sector.
Steam-locomotive hauled commuter trains boosted interurban travel and suburban travel into the countryside, while electric tramways allowed convenient short-distance urban transport in towns. In very large towns, the gap between the two modes opened the mobility services market to the electric-underground metropolitan railways; the first lines in London, New York, Paris, and Budapest appeared exactly when surface traffic had reached a peak of congestion and pollution caused mainly by horse-drawn carriages.
Since neither steam-locomotive hauled carriages nor horse-drawn carriages could be put underground easily, the market was open to building long underground tunnels for electric railways. This meant the acceptance of daily underground mass travel by city dwellers, leaving the street to individual transport. Paradoxically, a delay of a few years would have permitted building tunnels for cars, leaving the streets to the city dwellers.

Combustion engine vs urban rail

The invention of the combustion engine opened the market to the new, glamorous, convenient and street-friendly (at least initially) individual vehicles. At the turn of the century, the oil industry was on the verge of collapse because electricity was replacing oil lamps but it adapted quickly to the new market created by the advent of the mass-produced automobile.
The combined forces of the oil, the automobile and the road construction industries created an even mightier lobby than the rail barons at the peak of their strength. Roads financed entirely by taxpayers replaced the earlier user-financed toll roads, designed, built and maintained by the private sector. The 'automobile' welfare state was to go much further.
While the tramway companies had to pay for their track investments and maintenance and charge their passengers accordingly, the automobile used the space it consumed to run and to park without specific charges. Meanwhile, the commercial speed of trams was jeopardized because they had no segregated right of way and automobile traffic clogged their tracks.
At that point, the automobile industry in America and elsewhere did what would be expected—it bought up the ailing tramway companies, closed services and

replaced them with its buses. In many places, the ailing tramway companies were taken over by government, becoming part of the public sector and subject to the management style of subsidized public services. In most cases, the tram tracks were pulled up and services replaced by buses that were slower, noisier, less comfortable, and more polluting than the replaced trams.

In Paris, the transport authorities were heavily influenced by a well-orchestrated media campaign and abandoned the entire tram fleet of more than 3000 cars—many brand new—in just 5 years between 1932 and 1937. The trams were replaced by a fleet of buses produced by the national automobile industry.

This historic reminder helps us understand that the rise of 'automobility' was the result of a coherent and broad-ranging multi-sector marketing strategy as much as it was the result of spontaneous individual preference. 'Preference for space' occurs when space becomes available at less than full cost. This was indeed the case. Not only were the streets and roads made available free of charge but a wide range of market incentives were made available to buyers of individual detached homes. The most famous incentive was the postwar GI Act in the USA that offered vast home-buying subsidies and generated the Levitt Towns and thousands of suburbs. The standard form of urban growth in the USA became leapfrogging—land developers buying up tracks of cheap agricultural land ever further from built-up areas. However, instead of providing the connection to the city at their own cost as Empain did in Cairo, they only had to ensure that the government-financed road programmes (under the Federal Highway Act, etc.) guaranteed the connection. Consequently, land plots and homes could be sold at bargain prices assisted by the Federal and State subsidies.

These mechanisms were copied worldwide. In Europe, several countries even went so far as to introduce tax deductions for commuting by automobile. In terms of transport markets, this low density form of urban development favoured the automobile and excluded public transport from most of the market. More importantly, it maximized kilometers travelled and fuel consumption. As a result of this deeply unequal competition, public transport services gradually gave way to reliance on the automobile. The private sector left the realm of public transport which became a government-provided bare-bones service that was affordable by all but far less attractive, giving the automobile the largest modal share.

This explains why statistics for 1980 to 1995 in the OECD countries show that vehicle-km travelled by car increased by 65% while car ownership increased by 50% and population by 13%. In other words, vehicle-km increased five times faster than population and there were four times more new cars than new babies.

Trains and trams sharing same track at Karlsruhe Central Station, used for high speed rail (Author)

Improving Attractiveness of Public Transport

A growing number of citizens—not only mobile older people—are more sensitive to comfort and ease of use rather than to time gains. Metropolitan underground railways are fast but rarely achieve optimal ease of use. As an example, a return trip on the Paris Metro with one change each way requires the same total effort as climbing the stairs of an eight-storey building. Escalators have been installed in a number of stations but they are still far from widespread. Buses are usually slow because of traffic congestion. These are powerful reasons why surface light rail enjoying right of way could capture a large market.

New opportunity for public transport

Interest in the example of Manchester in the UK goes beyond the new *Metrolink* system (see pp. 22–25). Very soon after deregulation when on-street competition was introduced, the Greater Manchester Passenger Transport Executive (GMPTE) and Public Transport Authority (PTA) took measures to integrate transport supply by offering the *Travelcard* unlimited-use pass accepted by all operators (rail and bus) in the Manchester area.

The uniqueness of *Travelcard* is in how passenger revenues are allocated to different operators. A continuous sample survey covering all the operators is performed by an independent team according to a stochastic model accepted by all parties and the revenues are shared according to actual daily use (demand) rather than by seat kilometers (supply). Although the cost of the permanent survey sample is relatively high (about 2% of income), it has been a remarkable success in terms of user attractiveness and marketing. It has allowed identification of passenger profiles by asking three simple questions: point of entry, point of exit and passenger fare category (child, adult, concession). The results allow neutral assessment of the daily evolution of patronage level to the benefit of each operator. In addition, they allow independent assessment of the number of subsidized concession riders. Integration of *Metrolink* with its own tariff structure has proved compatible with *Travelcard.*

The market niche specifically generated by *Metrolink* was a direct result of its commuter rail–urban rail interoperability concept. In 1989, the GMPTE decided to link two disused heavy rail commuter lines via on on-street tram (see pp. 22–25). To implement this idea, they launched a European-wide call for consortia ready to design, build, operate and maintain (DBOM) the new network for 15 years. The winning consortium committed itself to taking the full risk of the construction investment while providing 5% of the total cost (about $200 million) and to take the full commercial risk of operation (no operation subsidies).

The niche effect was obtained through several operating innovations, especially:

- Very simple fare structure
- Simple timetable with one tram every 6 minutes (later changed to every 5 minutes) from 07:00 to 19:00, and every 12 minutes at other times
- 50% fare discount for travel outside peak hours, targeted at housewives shopping and leisure trips
- Staff hired according to service criteria (no previous transport experience needed) and trained to perform any job when necessary

High- and low-speed, heavy and light rail interface

High-speed railways have created a renaissance for interurban journeys of less than 3 hours. As an example, the Paris–Brussels *Thalys* service (300 km in 80 minutes) has already achieved a market share of more than 50% with business travellers forming 53% of traffic. As a result, Air France abandoned all flights on the route from 2001, replacing them by direct trains with airline-style on-board service from Brussels to Paris Roissy Charles de Gaulle Airport. The first direct *Thalys* service between Paris-Nord and Brussels Airport started in 2003.

Urban stations for high-speed trains unquestionably offer a market niche for urban and suburban public transport. The taxi ranks and parking at stations often have insufficient capacity to cope with the sudden mass of passengers. Consequently, passenger interfaces between such stations and the local rail network should be a priority investment area. Timetable information to main urban and suburban destinations, convenient ticketing, and unmissable signs checked by 'undercover passengers' are some possible tools that are too rarely used. Moreover, from the viewpoint of sustainable urban mobility, the recent construction of several high-speed rail stations in exurban areas with poor public transport services reflects the old attitude of mono-modal rail plus car. It eliminates rather than takes advantage of intermodality developing the public transport niche, and also increases dependence on cars in the areas. Examples are found in Florence (Italy) and Avignon (France).

Some connectivity best practices are found at: Madrid's Atocha Station (high-speed rail, commuter rail, and metro); Antwerp-Central (high-speed rail, commuter rail and tramways); and Düsseldorf Hauptbahnhof (high-speed rail, commuter rail and tramways).

Karlsruhe dual-current *Tram Train*

Interoperability between heavy and light rail is the most important passenger rail interface from the viewpoint of attractiveness, because the vehicle moves from one track to another instead of the passenger changing trains.

This requires track sharing between high- and low-speed trains and between heavy and light-rail rolling stock. Sharing the same electrified tracks has benefited all modes involved in the Karlsruhe urban and suburban *Tram Train* network, which started in 1995, 3 years after Manchester. The suburban tram operator succeeded in convincing Deutsche Bahn AG (DB AG) to allow heavy and light-rail rolling stock to use the same tracks. As a result, the same light-rail stock is running alternately on central city streets and traditional railway track.

For passengers, remaining on the same train for the entire trip removes all negative perceptions of changing mode and waiting. (see p. 10)

Track access issues

Copying the examples of Manchester and Karlsruhe in other cities could create a promising niche for public transport. However, it requires bridging the cultures between traditional railway operating staff and urban rail operators. It would mean putting more emphasis on active safety (avoiding collisions) than on passive safety (collision resistance) and adapting safety standards accordingly. Some engineers have suggested a compromise standard of 600-kN compression resistance.

The Karlsruhe experience presents a realistic case for encouraging the establishment of a body in charge of both tracks and operations to open up infrastructure to third parties while ensuring safety. In Karlsruhe, this happened by persuasion; in Japan it happened by regulation.

Opening track to third parties should not be confused with total separation of infrastructure and operations. A useful comparison can be made between the reportedly successful privatization and division of Japanese National Railways into the regional JR companies and the somewhat less-successful British Rail privatization with a split into a monopoly track owner (Railtrack) and various franchised operators.

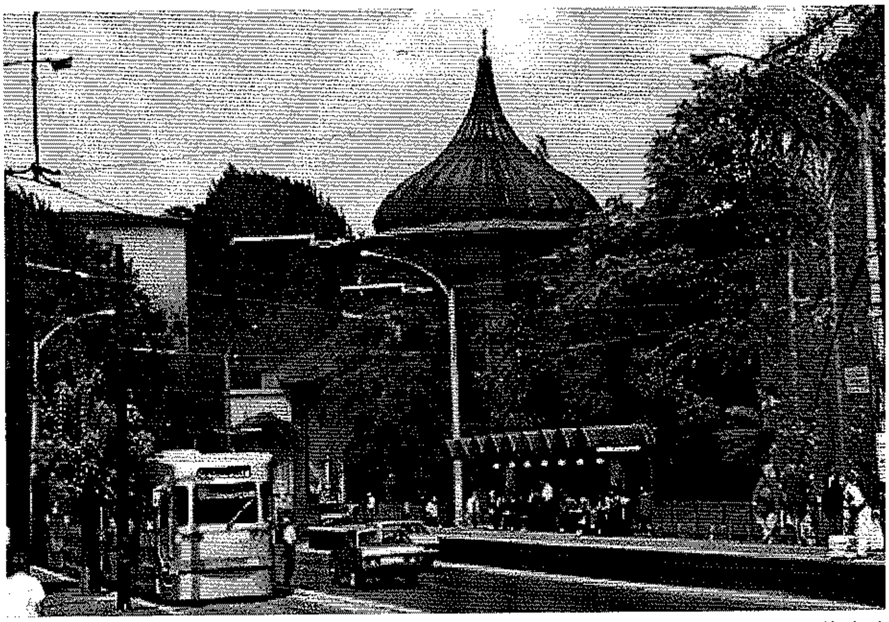
The regulatory obligation for the main operator to accept third parties on its track is compatible with service development and new investments in track. By contrast, the experience of Railtrack in the UK confirms the fears that a monopoly track owner has every interest in creating scarcity in order to maximize position. If track-only monopolies were common in Europe, we might wonder who would have a market-led interest in developing new rail links!

Worldwide renaissance of surface light rail

Besides the pioneering events in Manchester and Karlsruhe, new tramways or light-rail systems have started appearing on urban streets in many countries worldwide.

More than 100 cities in North America and Europe (especially France, Germany, Spain and Italy) have developed or are planning completely new light-rail systems, financed via different public sources. In the UK, there is additional input from the private sector. In some countries, like Switzerland and Belgium, the remaining prewar tram systems have been updated and improved.

In many cases, building a new light-rail system has been the occasion for revamping citywide public spaces. Nantes and Grenoble pioneered this approach and Strasbourg combined its new system with a traffic reduction and pedestrianization programme with special emphasis on rolling-stock design and related urban furniture.



Istanbul's new tramway using refurbished metro cars (Author)

Barcelona's new light-rail line uses the main diagonal thoroughfare crossing the city. In Bilbao, the new light-rail line follows an industrial waterway that is presently undergoing a complete renewal, coordinated by a single public enterprise (Rià 2000) entrusted with the landholdings of different public owners. It links new developments like the Guggenheim Museum with Old Bilbao.

Rouen (France) has a specific combination of trams, buses (classic articulated buses guided by optical system) and 'trams on tyres' (aka busways) designed like tramways and benefiting from a segregated right of way to escape traffic congestion. (See pp. 13–14 for a discussion of LRT financing in France.) This system narrows the reserved busway, leaving more space for other street uses.

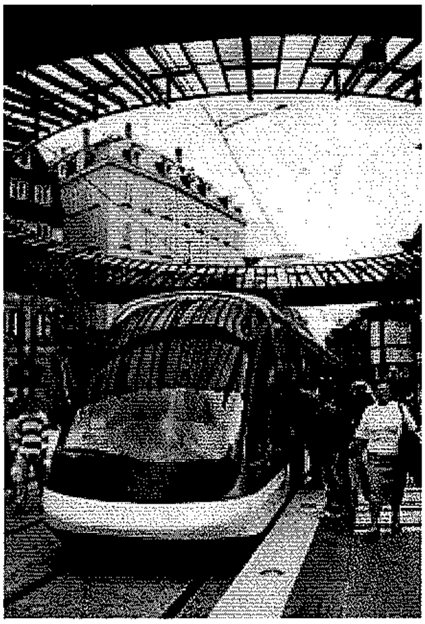
The North American boom in new light-rail systems even in cities like Dallas and Houston is interesting because it recognizes the limits of 'automobility.' Elsewhere, Turkey has an outstanding number of cities with new light rail systems. Sometimes the rolling stock is pre-owned tram cars from Europe—in Istanbul, surplus metro cars have been adapted to run on streets. (See p. 11 for the total number of LRT systems.) In Japan, the government merging separate ministries into the Ministry of Land, Infrastructure and Transport could open the way to new light-rail systems running on roads. (See p. 15 for the case of the Man'yo Line.)

Increasing Public Transport Market

Having described a number of attempts by operators to gain new customers, we have to admit that the number of readily available new customers is small simply because of the unequal competition with cars for the use of public space. Although public-transport operators can regain small market segments themselves, large segments will only be recovered by adopting land-use policies that are public-transport friendly.

The city itself could be developed along lines compatible with effective use of public and non-motorized transport, allowing people to reduce automobile dependence and encouraging linear patterns of urban extensions.

In the UK, in line with its commitment to cut emissions of greenhouse gases and to reduce urban sprawl, the government has decided that 60% of all new urban development until 2010 will be on 'brownfield' sites in existing urban areas



Strasbourg tram as element of urban design (Author)

Portland city planning favours new patronage for tramways (Author)

instead of 'greenfield' locations. In addition, Planning Policy Guideline 13 forbids all development not adjacent to existing urbanized areas. In the future, development of large exurban shopping centres like Bluewater Park will no longer be approved.

The UK government also reviewed its road programme, following the 1995 report of its Standing Advisory Committee on Trunk Roads Assessment (SACTRA). This report concluded that the additional traffic generated by new roads often exceeds the additional capacity they provide. Finally, the government introduced legislation enabling local authorities to levy a yearly charge of £150 (£1 = US$1.80) on workplace parking provided by employers. This levy could be used to improve public transport. Unfortunately, the need to get the agreement of all local authorities in a conurbation to the levy has delayed the implementation of this mobility tool.

Portland's (Oregon) ongoing policy of urban containment is part of the same broad category. Under this policy, all urban development must remain within the borders of the urbanized perimeter set by the 1973 state legislation. This has proved successful in attracting higher-density activities and housing to the city. It also enabled the city to introduce a new tramway system and reduce its automobile dependence.

The examples of the Curitiba (Brazil) busways, Zürich (Switzealand) on-street priority for trams and buses, the Ghent (Belgium) combination of trams and pedestrians, etc., described below illustrate the emphasis on land use.

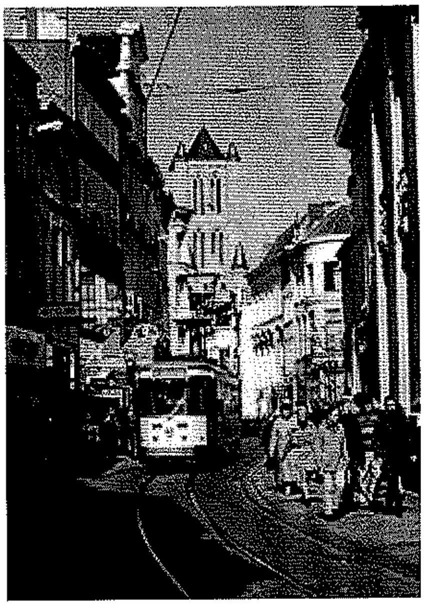
Pre-rail busways in Curitiba

Somewhat paradoxically, the most extreme example of public-transport-friendly land use comes from Curitiba, a very large (pop. 1.7 million) bus-only city. Moreover, Curitiba is the centre of Brazil's national automobile industry and has one of the highest automobile ownership rates. The concept was developed by Jaime Lerner, an architect, three-times mayor and later governor of Parana State. To make buses competitive with cars, all large roads have a double lane reserved for buses (to be used later for light rail). Access and exit is through an elongated shelter where all ticketing and waiting takes place. Multiple doors make the boarding and alighting very fast. The commercial speed of 32 km/h is similar to a metro. Patronage includes all levels of society and links all parts of the city, including the airport. This idea has been replicated in Bogota and Delhi.

Another land-use feature is worth mentioning. To increase development along the corridors served by the transit routes, the city has sold development rights to realtors who are ready to build there. These development rights were acquired from owners of marginal land, such as dilapidated brownfield sites, gravel pits, wetlands, etc. The city acquired this land in order to transform it into city public parks and recreation grounds, while also increasing the density of land occupation along the development corridors.

Zürich blue zone

In 1985, the Zürich city authorities decided to introduce a blue zone (allowing residents unlimited parking) after a survey of the number of public parking spaces occupied by non-Zürich commuting drivers. This blue zone covers the entire Zürich electoral district—everybody else is only allowed 90 minutes of free parking. This measure instantly created a new market for public transport. In addition, it increased the value of the city-owned parking concessions and



Trams sharing street with pedestrians in Ghent (Author)

encouraged suburbanites to return to the central city, pay their taxes, and invest in housing. Drug-riddled areas, such as the notorious 'Needle Park' next to the central station were rehabilitated. Shopkeepers soon realized that 90 minutes parking was ample for shopping if street parking was easy to find. Increased demand for commuter public transport triggered additional commuter rail (S-Bahn) services within the Zürich transport community. Last but not least, the scheme proved a lasting electoral success.

Additional features include an efficient right of way in favour of trams and buses (coupled with a shortening of the traffic light cycle). The entire scheme gives a little more urban space to public transport and a little less to individual transport, but much more mobility to citizens.

Ghent trams & pedestrianization

Over the years, the City of Ghent (pop. 500,000) has gradually reduced car traffic in its historic and commercial centre while keeping trams, making the latter very successful. The number of people over 65 shopping in the centre has been increased by giving them a free pass, and policies to limit traffic have found favour with voters.

Freiburg-im-Breisgau and Vauban extension

Freiburg in Germany (where apartments and car parking spaces are traditionally sold together) has a long-standing record of public transport and bicycle-friendly land use. There is an excellent tramway system and a large Bike & Ride multistorey bicycle park next to the main train and tramway station. In 1985, the city started developing a car-free quarter on the site of the former French army barracks. High-density low-rise energy-efficient apartments for the middle class have proved a successful investment.

Conclusion

Urban rail transport was born with the ascent of the modern city in the 19th century. Market-led entrepreneurs developed rail tracks and services between cities and within cities and their suburbs. Since the early 20th century, the automobile gradually became king of the road and street. Public transport was taken over by public authorities as a service to people with no car. More recently, the increasing dependence on the automobile has shown its limits, opening up new possibilities for public transport, in particular for congestion-free rail corridors.

Although the pioneering examples of Manchester and Karlsruhe are part of a worldwide renaissance of tramways, the best chance for public transport to regain market share may be through adoption of new land-use policies. The authorities and operators have said little about this so far, but successes have been achieved through the cooperation of both parties as well as by appropriate urban rail lobbying. ■

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When will Japan Choose Light Rail Transit?

Kiyohito Utsunomiya

Introduction

Interest in Light Rail Transit (LRT) as a viable urban transportation system has been growing worldwide since the late 20th century. Although there is no definite difference between trams and LRT systems, the latter is an evolved tramway system—tracks are often segregated from other traffic, cars run faster, and everyone has easy access due to level boarding. In Germany, where old tramway systems have been vigorously upgraded as LRT (Stadtbahn) systems since the 1960s, LRT systems have become the core of urban transport in many cities. Also new LRT systems have been constructed in France and the UK some 40 or so years after both countries closed many old tramway systems dating from the Victorian era. LRT systems are also starting to appear in the USA and Canada, two countries known for their love of the automobile.

Under these circumstances, although no new LRT systems have been built in Japan recently, some tramway systems have begun to introduce low-floor cars with improved ease-of-access and efficiency. This article reviews Japanese tramway systems and discusses the possibility of reviving them as LRT systems.

Short History of Tramways in Japan

The world's first commercial electric tramway opened in 1881, and ran 2.8 km from Lichterfelde (near Berlin) to the Anhalt Cadet School. Japan's first tramway was the Kyoto Electric Railway opened on 1 February 1895. In the early days, there were few alternative forms of urban transport and tramways were soon spreading to many other cities. Although the growth of bus services after WWI put some local tramways out of business, there were still 83 tramways with a total route length of 1480 km operating in 67 Japanese cities in 1932.

Aerial bombing during WWII caused tremendous damage to tramways and tram facilities but trams were the first form of public transport to reappear in the war-torn cities. For example, three tramcars—the last serviceable vehicles—were running again in Hiroshima just 3 days after the atomic bombing. Trams were soon carrying huge numbers of people in the early postwar years and contributed greatly to the reconstruction.

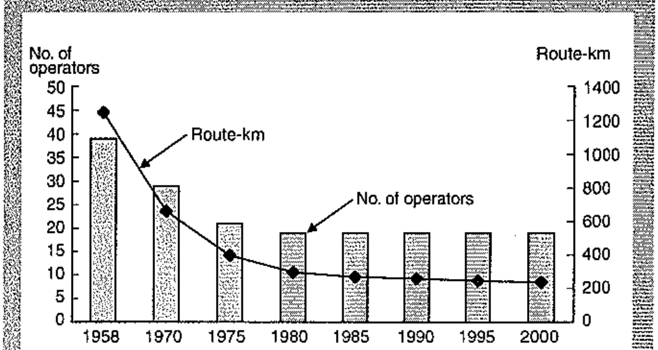
North America turned to the automobile for urban transport immediately after WWII and Europe was quick to follow suite, leading to the rapid decline of trams. However, private vehicle ownership did not begin to grow in Japan at the time, allowing trams to continue holding their own in the urban public transportation networks. In 1954, the Tokyo Metropolitan Government (TMG) introduced Presidents' Conference Committee (PCC) streetcars, which had been developed in the USA since the 1930s.

Japan's rapidly expanding economy in the 1960s led to more private car ownership and the increasing road congestion with resultant delays to tram timetables led many cities to start closing tram systems. As shown in Figure 1, between 1960 and 1990, the number of tramway operators dropped by nearly half, while the total length of track was slashed by about 80%. Lines serving local traffic in smaller centres were generally the first to be closed. Later, subways replaced trams in the three most important cities of Tokyo (except the Arakawa Line), Osaka, and Nagoya. Other smaller regional cities, such as Sendai, Fukuoka and Sapporo, also began planning subways in the 1970s and one tramway track after another was ripped up.

Some exceptional tramway operations managed to remain profitable. Hiroshima and Nagasaki are cities that see trams as a viable urban transit solution. So-called Light Rail Vehicles (LRVs) joined the tram rolling stock in both cities in the 1980s.

Series 5000 *Green Mover* of Hiroshima Electric Railway (Author)

Figure 1 Tramways Trends in Japan



Source: *Tetsudo tokei nempo* (Annual railway statistics), Ministry of Transport

However, very little LRT track has been built since then and Japan seems to have fallen behind other countries where more LRT systems are being built.

Tramways in Japan Today

Overview

There are 19 tramway systems in 18 Japanese cities from Sapporo in the north to Kagoshima in the south (Fig. 2). Tokyo still has the 12.2-km Arakawa Line, a tramway operated by the TMG running on mostly segregated track between Waseda and Minowabashi stations; all other tramways formerly operated by the metropolitan government were closed. The only tramways still operating in Osaka are the Hankai (14.1 km) and the Uemachi (4.6 km) lines operated by Hankai Tramway.

In general, Japanese tramway systems follow the traditional model and most tramway operation are relatively small scale. However, some Japanese operators have recently introduced modern rolling stock, such as low-floor cars offering barrier-free access. Kumamoto City Transportation Bureau in Kyushu introduced 100% low-floor vehicles in 1997 using German-made bogies and equipment. At one time, the Bureau had planned to tear up all its tram tracks, but it changed course in midstream and now operates two lines totalling 12 km. German-built low-floor cars running past Kumamoto Castle have come to symbolize the city.

In 1999, Hiroshima City imported German low-floor tramways by air cargo, creating quite a stir among the news media. Other cities like Gifu, Kagoshima, Matsuyama, Kochi, Okayama and Hakodate have also introduced low-floor trams.

While many tramways face financial difficulties, trams in Okayama, Hiroshima and four other cities are profitable (Table 1). Okayama Electric Tramway and Hiroshima Electric Railway are the leading tram operators and they began attempts in the 1980s to attract more passengers by introducing new cars, installing tramcar approach indicators, and constructing roofed tram stops. Hiroshima Electric Railway's suburban Miyajima Line serving the famous Itsukushima Shrine used to operate independently of the

Figure 2 Japanese Cities with Tramways

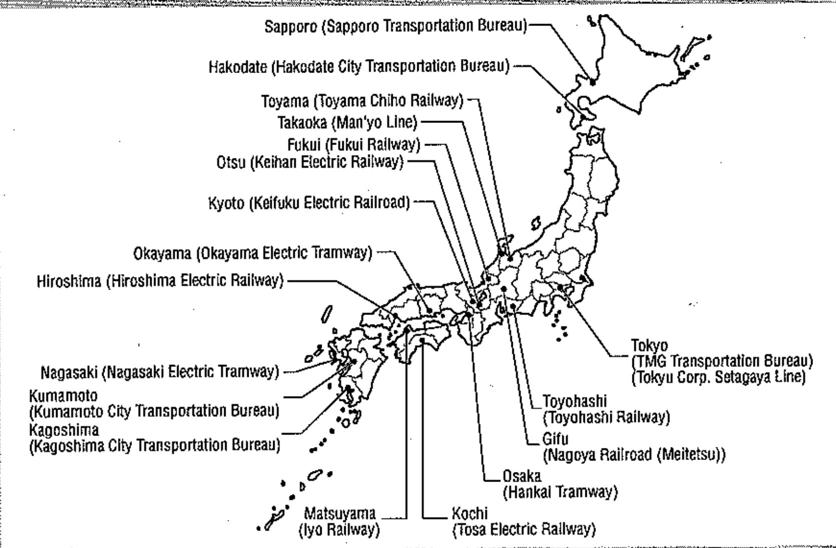


Table 1 Tramways in Japan

City	Operator	City population (1000)	Route-km	No. of lines	Ratio of operating expenditure to revenue (after depreciation)	Start of tram operations
Sapporo	Sapporo Transportation Bureau	1820	8.5	1	107.4	1918
Hakodate	Hakodate City Transportation Bureau	290	10.9	2	110.0	1913
Tokyo	TMG Transportation Bureau	8140	12.2	1	96.8	1911
Tokyo	Tokyu Corp.	8140	5.0	1	112.9	1907
Toyama	Toyama Chiho Railway	330	6.4	1	95.8	1913
Takaoka	Man'yo Line	170	12.8	1	132.3	1948
Fukui	Fukui Railway	250	21.4	2	109.1	1933
Toyohashi	Toyohashi Railway	370	5.4	2	112.1	1925
Gifu	Meitetsu	400	23.9	3	248.9	1911
Otsu	Keihan Electric Railway	290	21.6	2	249.0	1912
Kyoto	Keifuku Electric Railroad	1470	11.0	2	107.6	1910
Osaka	Hankai Tramway	2600	18.7	3	116.4	1911
Okayama	Okayama Electric Tramway	630	4.7	2	84.2	1912
Hiroshima	Hiroshima Electric Railway	1130	34.9	8	86.2	1912
Kochi	Tosa Electric Railway	330	25.3	2	119.6	1904
Matsuyama	Iyo Railway	470	9.6	4	102.5	1911
Nagasaki	Nagasaki Electric Tramway	420	11.5	4	96.6	1915
Kumamoto	Kumamoto City Transportation Bureau	660	12.1	2	123.1	1924
Kagoshima	Kagoshima City Transport Bureau	550	13.1	2	93.1	1912

Source: *Tetsudo tokei nempo* (Annual railway statistics), Ministry of Land, Infrastructure and Transport, 2000.
Notes: Numbers for Man'yo Line are for the predecessor Kaetsuno Railway.
Numbers for Fukui Railway include data from conventional railway operations.
Numbers for Meitetsu include data from operations on the Gifu-shinai and Minomachi lines.
Except for the ratio of operating expenditure to revenue, which refers only to tramway operations, numbers for Hiroshima Electric Railway include data from railway operations.

urban tram network, but now offers inner-city through connections for all trams. Nagasaki Electric Tramway is well known for running a profitable system. It was in the red but recovered by selling its bus business in 1970 and concentrating on trams, and by offering user-friendly services with fares as low as ¥100 (US$0.95).

International comparisons

More than 300 cities around the world have tram or LRT systems. Countries of the former Soviet Union and eastern Europe, where postwar car ownership remained low, still operate a lot of old tramways. The number of trams in Germany is exceptionally high in western countries, although this is partly due to the tramways inherited from the former East Germany (Table 2).

According to statistical data on tramway systems, excluding trams in countries of the former Soviet Union and eastern Europe, the average population of cities with a tram/LRT system is about 600,000 and the average route length is 32 km. Figures 3 and 4 show that cities with populations between 200,000 and 800,000 are typical candidates for trams. In terms of route length, typical tram/LRT systems have networks of about 20 km or 50 to 70 km.

On the other hand, although Japanese cities with tramways have a similar population size to the world norm, most tramway systems in Japan are shorter with fewer lines.

Table 2 Number of LRT Systems and Tramways Worldwide

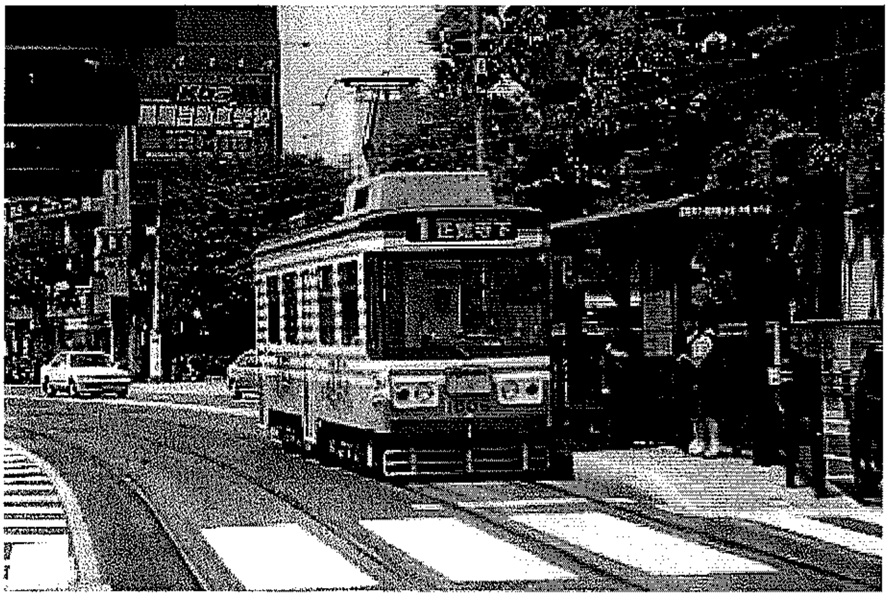
Country		Country		Country	
Japan	19	Germany	59	Argentina	1
Turkey	2	Norway	2	Brazil	2
China	5	Hungary	4	Australia	3
India	1	Finland	1	Azerbaijan	2
North Korea	2	France	11	Armenia	1
UK	6	Bulgaria	1	Ukraine	25
Italy	5	Belgium	5	Uzbekistan	1
Austria	5	Poland	14	Estonia	1
The Netherlands	3	Bosnia-Herzegovina	1	Kazakhstan	5
Croatia	2	Portugal	2	Georgia	1
Switzerland	5	Romania	15	Belarus	4
Sweden	3	Egypt	4	Latvia	3
Spain	3	Tunisia	1	Russia	71
Slovakia	3	Canada	2		
Serbia	1	Mexico	1		
Czech Republic	7	USA	19	Total	334

Note: The table was compiled by the author using information from *A World of Trams and Urban Transit* by M. Taplin (http://www.lrta.org/world/worldind.html).

Analysis of tramway characteristics

Statistical analysis also clarifies the characterstic of tram/LRT systems worldwide into four groupings composed of: Germany and the Benelux; France and North America; the former countries of the Soviet Union and eastern Europe; and Japan. In Figure 5, systems with few lines and/or low passenger levels are plotted

Series 9000 100% low-floor tram of Kumamoto City Transportation Bureau (Author)



Series 1500 tram in Nagasaki City with advertising livery (Author)

Figure 3 Cities with Tram Systems (by population)

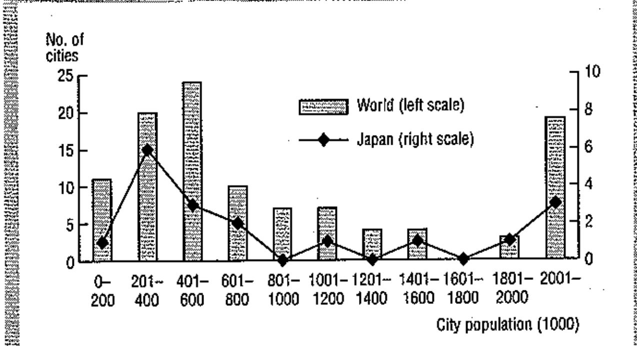
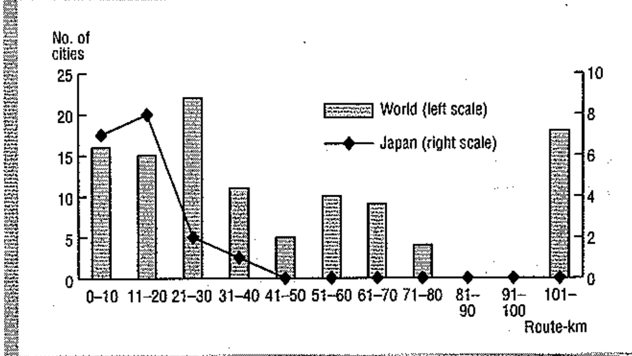


Figure 4 Cities with Trams (by route-km)



towards the right; those with long routes and/or those that began operations fairly recently are plotted towards the top.

For example, in the French and North American group, trams/LRTs do not follow the conventional model of a dense layout in the old city. Rather, they tend to represent newly built systems carrying relatively few passengers linking the centre and suburbs. On the other hand, systems in the countries of the former Soviet Union and eastern Europe are distinguished by large networks with many long lines and high numbers of passengers. The grouping of Japanese tram systems alone near the bottom right of the chart indicates that there is a Japanese type composed of comparatively old small systems, carrying relatively few passengers. This means that Japanese tramways do not serve as the main urban transportation mode.

Needless to say, these results do not imply that all tram systems in a country have the same characteristics. For example, in Japan, the Nagasaki tram network falls within the German grouping. Nagasaki has an extensive but small tram network with high passenger levels run by an operator focused exclusively on tram operations that offers convenient services.

Need for Policies Promoting LRT

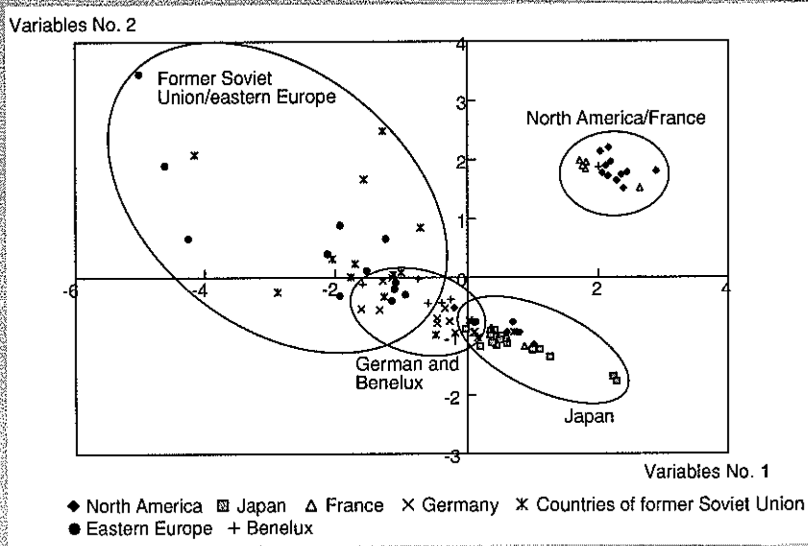
While Japanese tram systems still seem to follow the older model and have not evolved into modern LRT systems, other world cities subsequently constructed LRT systems after abandoning old trams decades ago. Under these circumstances, the widespread opinion today is that present tramways in Japan should be upgraded to LRT systems. Until recently, even medium-size cities in Japan have tended to build monorails or automated guided transit (AGT) systems, which have little effect on road traffic, instead of tramway systems. However, LRT systems have great potential for public transportation in the 21st century.

Advantages of tram/LRT

The governments of some countries—but not Japan—provide subsidies for building and operating trams/LRTs because they offer the following advantages:

- Reduced air pollution
  Cities that depend primarily on automobiles tend to suffer from traffic jams and high levels of air pollution. The degraded environment and far-reaching consequences of global warming are driving the urgent need for public transport systems that can ensure a sustainable environment.
- Medium-capacity public transport
  Many large cities have built subways as a partial solution to traffic congestion, but medium-size cities do

Figure 5 Features of Tramways by Countries and Area



Note: The figure plots each city according to two criterion variables obtained by discriminant function analysis.

not need large-capacity subways. The medium capacity of new LRT systems is an ideal solution for these needs.

- Better accessibility
  Monorails and AGT systems are similar to LRTs in being medium-capacity transport systems and some Japanese cities have built monorails, such as *Yui-rail* in Naha, Okinawa, and AGT systems, such as *Yurikamome* in Tokyo for this reason. However, passengers and operators soon discovered that monorails and AGT systems do not offer the street-level barrier-free accessibility of LRTs, especially for people with limited mobility, such as the elderly and disabled. High accessibility also contributes to faster schedule speeds because it makes boarding and disembarking fairly smooth.
- Low construction cost
  Subways are incredibly expensive (minimum of ¥20 billion per km) to build due to high engineering costs, elevated AGT guideways, etc., require purchase of expensive land and high construction costs for infrastructure (about ¥10 billion per km). LRT construction costs vary with the specific urban conditions, but they generally fall within the range of ¥1 billion to ¥2 billion per km. Moreover, LRT trains can run on existing suburban tracks. For example, in the UK, where construction of LRT systems receives only minimal government subsidy, the Manchester *Metrolink* required only 2.7 km of new track with the other 28.2 km coming from former British Rail commuter lines. The success of the Manchester *Metrolink* was the catalyst for the boom in UK tramway construction (see pp. 22–25).
- Greater flexibility for connections with existing rail lines
  Subways and conventional urban railway lines provide effective transport in large cities everywhere, but branch lines can be used as effective feeders to an LRT network. Since monorails and AGTs are closed transit systems they do not permit through connections with other types of rail. Trams have a very great advantage in this regard as demonstrated by the successful Verkehrsbetriebe Karlsruhe (VBK) tram network in the regional German city of Karlsruhe where trams are running through to the heavy-rail network to link the city centre and suburbs.
- Frequent services
  Removing physical barriers to travel improves accessibility and increases convenience. However, convenience can also be achieved through more frequent operations. Passengers find that one six-car train set running every 15 minutes is not as convenient as one two-car train set running every 5 minutes. All regional centres in Japan have public transport systems, but more and more people are commuting by car. In a 2001 survey in the cities of Maebashi and Takasaki in Gunma Prefecture, about 100 km north-west of central Tokyo, nearly 50% of current car commuters could commute by public transport if they wished, and said they would consider doing so if rail services were more frequent. The survey found that if trains ran each way once every 15 minutes, more than 60% of car commuters said they would use the train. The figure rose to more than 90% when trains ran every 10 minutes.
- Better urban environment
  Urban sprawl has caused hollowing out of city centres in many countries, including Japan. LRTs can help revive urban centres and create conditions that permit people to return there to shop and stroll. There were doubts that LRTs could revitalize cities, because it was assumed that people used to driving to suburban shopping centres would not return even if LRTs were built. Now it is obvious that new trams promote businesses and bring back people into the city centres. Once people return to the city centre, shops take on new life and new businesses appear. LRTs make a virtuous circle in urban development.

Financial incentives for LRTs in Germany and France

Germany has pursued LRT development more vigorously than any other country and it is worth looking at German subsidies for LRT systems.

A 1964 German report on transportation problems in various municipalities recommended putting priority on public transport and indicated that public financing and long-term planning would be necessary. The federal government accepted the recommendations and accordingly raised the tax on gasoline and diesel fuel in 1966 to partly subsidize trams and other forms of public transport based on a 1967 federal law defining federal subsidies to local municipalities improving their transport systems. The philosophy behind this approach of taxing fuel was that car drivers would enjoy better road conditions because of the switch to public transport. In other words, car users benefit indirectly from public transport and should shoulder some of the financial burden of providing public transport infrastructure.

In the early days, the 40% tax on gasoline and diesel fuel financed a limited range of public projects, such as relocating tramways underground. But in the 1970s, federal policies began emphasizing public urban transport. The 1971 Municipal Transportation Finance Law (GVFG) established federal guidelines for subsidies to municipal governments. One result was an increase in the proportion that public transport projects could receive

Series 8100 partial low-floor tram of Hakodate City Transportation Bureau (Author)

from the fuel tax. For example, the federal government paid 85% of the initial cost of the pioneering project in 1992 to modify the infrastructure to allow Karlsruhe city trams run on heavy track used by German Federal Railways. The local municipalities and their transportation bureaus only paid 15% of the cost.

Financial assistance for roads and public transport was apportioned according to a set ratio, but this ratio was abolished in 1992. Thereafter, the regional governments themselves determined how they would finance public transport projects under the GVFG scheme. In 1996, responsibility for planning, administering and financing short-distance public transport systems was handed to the regional governments. Since then, federal money that used to directly finance public transport systems has been given to the regions (Ländes) as grants to be added to regional funds for improving tramways and other public transport systems. The fuel tax has also begun to subsidize operating expenses.

In France, tramway construction is moving forward more energetically than in any other country in recent years. Like Germany, France also funds improvements to urban public transport by levying the Versement Transport tax (calculated according to salary) on corporations and government institutions employing 9 or more people in specific districts. The intent is to have people who benefit indirectly from improvements in public transportation contribute to financing. The tax was first levied in Greater Paris in 1971 and then spread to other regional centres from 1973. Some restrictions on how subsidies raised from the tax could be used were lifted in the 1980s, expanding the variety and scope of urban transport projects.

Subsidies from the Versement Transport tax are not limited to just trams, but tram projects are a significant proportion and the subsidies help with both construction and some operating expenses. For example, about 25% of the capital expenses of Line 1 of the Strasbourg tram network was financed by the Versement Transport tax.

The success of the LRT in raising revenue can reduce its need for public subsidies. Nantes, the first French city to bring back trams, depended on tax subsidies for 60% of capital expenses for the first phase of construction, but an increase in the number of passengers boosted farebox revenues, making it possible to lower the tax rate from 1.50% to 1.25%.

Financial incentives in Japan

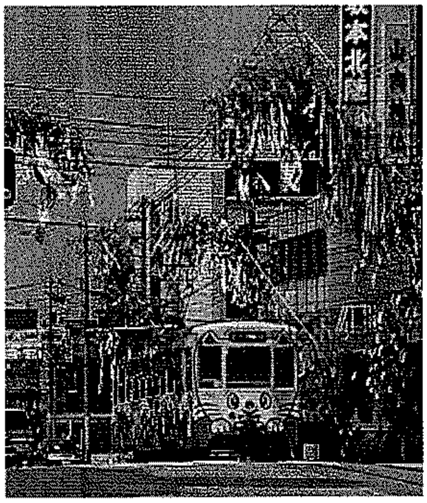
Unlike Europe or North America, public transportation systems in Japan are supposed to be self-supporting, so tramways receive no subsidies for operating expenses. However, the tram revival in Europe and North America since the mid-1990s has prompted local governments in Japan to offer limited subsidies for capital costs involved in building or upgrading tram lines.

In FY1995, the former Ministry of Construction (MOC, now the Ministry of Land, Infrastructure and Transport) strengthened its Urban Transportation Improvement Program by using funds from the General Account to subsidize construction and improvement of tram stops, road beds and other facilities. The subsidies come under the category of 'relocation of traffic impediments.' In FY1997, the MOC launched the Tramway Reconstruction Program, offering subsidies from Road Improvement Special Account. These subsidies encourage tramway modifications that will reduce road congestion on seriously congested roads. In Toyohashi City in central Japan, subsidies paid part of the cost of extending the tram track 150 m from a location near the central station to a concourse just beside it.

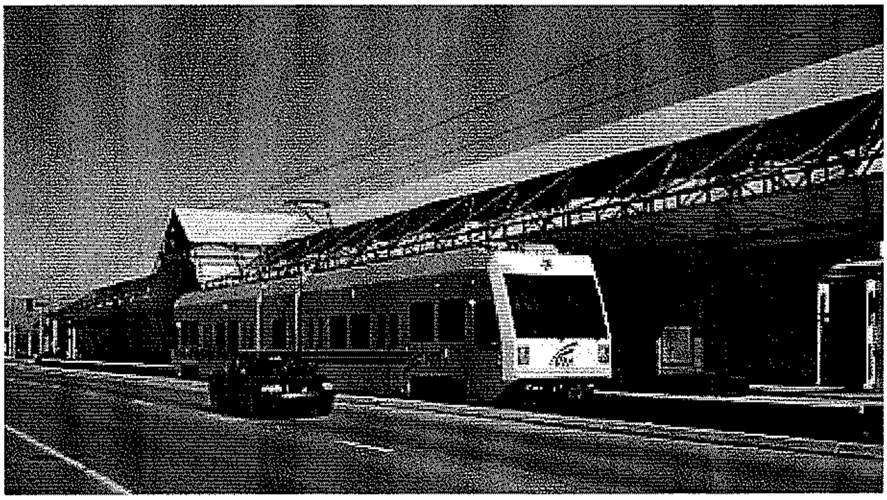
In FY1998, the government expanded the scope of the Tramway Reconstruction Program to permit subsidies for construction, improvement and extension of tram track beds if it can be shown that such work will facilitate road traffic flows. Since that year, the Ministry has expanded the Subsidy Program for Railway and Track Modernization to include subsidies for low-floor vehicles that replace older rolling stock. These incentives promote safer transit for the elderly and have had the indirect effect of promoting development of low-floor cars in Japan.

New movement—Man'yo Line

While financial incentives have been gradually introduced by the national government, local governments and ordinary citizens have begun to change old tramways. The establishment of Man'yo Line Corporation in 2001 symbolized this new movement in Japan.



Tram on Man'yo Line at Takaoka during the *Tanabata* festival (7 August) (Author)



Santa Clara Valley Transportation Authority (VTA) tram in San Jose built by Kinki Sharyo (Author)

The 12.8-km Man'yo Line is a tram line linking the two cities of Takaoka and Shinminato in Toyama Prefecture on the Sea of Japan. When the line was on the verge of closure, a new public–private venture partly capitalized with funds from local citizens rescued the old tramway. The biggest surprise was that although railways in Japan are expected to be self-supporting, the decision to keep the tram open was made with the full knowledge that it would be loss-making and would require financial support from the local community. Projections showed that ordinary expenditures would be more than 10% higher than ordinary revenues 10 years after establishment of the public–private venture. Despite this gloomy outlook, the local community decided to go ahead. This determination was based on the idea that the line offers an effective means of public transport for an aging society, reduces local (and therefore global) pollution, and revitalizes the region as a symbol of urban design.

The required capital of ¥499 million was raised as two grants of ¥150 million each from the Toyama Prefectural Government and the municipal governments of Takaoka and Shinminato, plus an investment of ¥49 million from local businesses and citizens. A further ¥100 million was collected as donations by citizens to buy new low-floor cars and other equipment. The first new car entered service in January 2004 and attracted a lot of attention.

Conclusion

LRT or tram systems could improve transit in the 21st century. So far, unfortunately, no new LRT system has been constructed recently in Japan. Financial problems of regional urban centres are growing due to the increase in public spending for the aging society and a 10-year recessionary economy. Even so, there are nearly 20 tram systems in Japan and recent trends suggest a gradual revival of LRT systems. Following Man'yo Line, JR West is moving ahead with plans to introduce LRT cars on the 8-km Toyama-ko branch line in Toyama Prefecture, where the Man'yo Line is located. The plan is to have LRT cars running through Toyama City centre from the suburbs by the end of FY2006. Other than these projects, more than 20 projects are on the drawing board in various Japanese cities.

Cities such as Kyoto, Yokohama, etc., abandoned tramways in the past but are now exploring the possibility of reviving tramways as LRT systems. Some of Japan's rolling stock manufacturers, such as Kinki Sharyo Co. Ltd. and Kawasaki Heavy Industries, Ltd, have also built and sold light rail vehicles to a number of US cities, including San Jose in California. Hopefully, it will not be too long before they can play a major role in helping LRT systems to spread throughout Japan as well. ■

Further Reading

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Kiyohito Utsunomiya

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Strategic Justification of Three Existing Modes of Transportation in Rouen

Raymond Hue

General Outline of *Métrobus* Light Rail–Bus Network

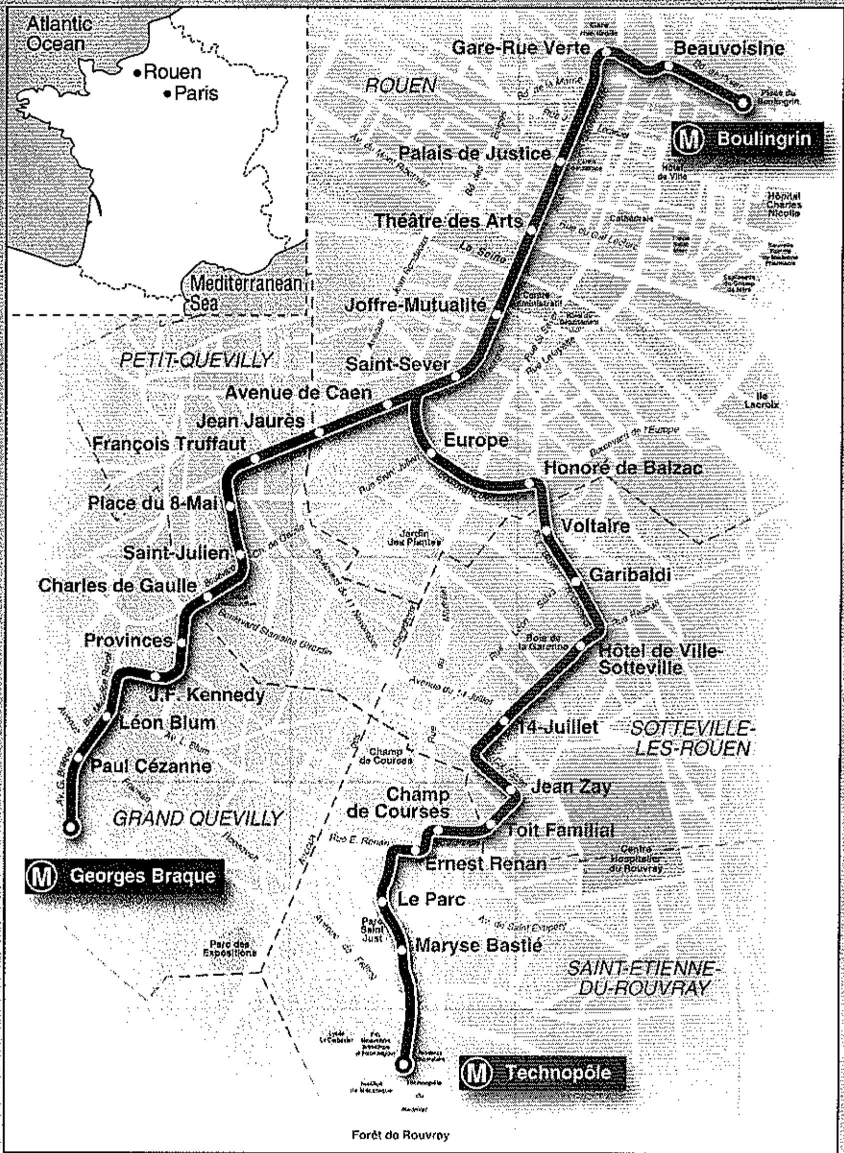
The Rouen Conurbation (pop. 390,000) in northern France is a large metropolitan community composed of 34 districts (*communes*) with transport administered by the Rouen Conurbation authority. In the last 10 years, this body has followed a policy of developing an urban transport network called *Métrobus* based around bus services and a light rail which was complemented by the Rouen East–West Transport (TEOR) project. During the 10-year development period, *Métrobus* network passenger kilometers have increased by 22%, while journeys have grown by 56% and revenue by 64% (Table 1).

Table 1 *Métrobus* Results

	1993	2003	
Passenger-km (A)	10,677,201	13,106,353	22.75%
Passenger journeys (B)	25,316,618	39,718,479	56.89%
Journeys* (C)	21,582,796	30,779,288	42.61%
Fare revenues (D)	9,893,787	16,235,990	64.10%
B/A	2.371	3.030	27.81%
D/C	0.458	0.527	15.07%

Note: Non-connection trips

Figure 1 Rouen Light Rail Network



(TCAR)

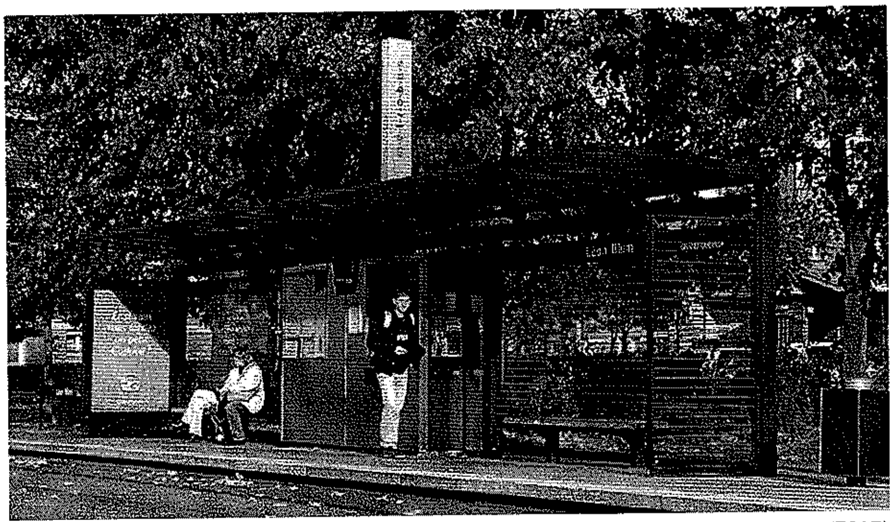
Historical Review of Light Rail

The final decision to build the Rouen light rail was made in 1990 following 10 years of feasibility series. The geography and location of Rouen imposed several major constraints on transportation; the conurbation is bisected by the River Seine and the city of Rouen is surrounded by several elevated plateaus at 150 m. In addition, the city has an ancient and historic centre. These three elements create severe difficulties for urban transport operations and have hindered development of efficient mass-transit systems. Furthermore, other unfavourable factors adversely impact development of mass-transit systems, including: urban sprawl, runaway growth in private automobile ownership; oversupply of city-centre parking; urban road congestion due to absence of bypass; excessive heavy truck traffic in city centre due to high economic activity; and lack of priority attached to mass transit.

The transport capacity and structuring effect of a light rail were major factors in the decision to build the north–south light rail on a segregated right of way.

Table 2 Light Rail Specifications and Figures (2003)

Length	15.1 km
Length underground	2.2 km
Stations	31
Underground stations	5
Train sets	28
Schedule speed	19.1 km/h
Peak frequency (shared trunk section)	3 minutes
Peak frequency (each line)	6 minutes
Passenger-km (A)	1.427 million
Passenger journeys (B)	15.233 million
B/A	10.67



Ground-level Léon Blum Station by architect Jean Michel Willmotte (TCAR)

Description of light rail

The light rail lines follow the routes of the two most heavily used bus lines based on population density and industrial workforce. They cross five rural districts—Rouen, Petit-Quevilly, Grand-Quevilly, Sotteville and Saint-Etienne-du-Rouvray. The two branches south of the Seine join at Saint-Sever Station and cross the river over a road bridge. The common trunk ends at the Boulingrin terminus (Fig. 1). Most of the northern section runs in a 1.7-km tunnel with four underground stations (Beauvoisine, Gare-Rue Verte, Palais de Justice, Théâtre des Arts). The tracks on the south bank are mostly elevated, but there are three underground intersections (Place Joffre, Boulevard de l'Europe and Avenue Jean Rondeaux) and one underground station (Joffre-Mutualité). The Alstom-built rolling stock is a standard French tramway design comprised of two articulated bodies on two driving bogies and a low-floor middle section over a median carrier bogie. The Rouen Conurbation Subway Company (SOMETRAR) was granted the franchise to finance, build and operate the Rouen light rail, while the Rouen Public Transport Company—TCAR, a Connex subsidiary—operates the *Métrobus* network and assumes both the financial and operating risks (Table 2).

Performance assessment

The Rouen light rail is one of the first wave of Light Rail Transit (LRT) systems built in France between 1985 and 1995. Others include Nantes, Grenoble, St Denis Bobigny and Strasbourg. The 10-year history of these networks offers some perspective from which to assess their long-term performance.

As in all urban areas served by a mass-transit system, the Rouen light rail has exerted a considerable impact on Rouen's businesses, metropolitan structure and overall urban development.

Its comfortable carriages provide reliable and frequent services that are easy to access as evidenced by the 60,000 or so daily passenger journeys amounting to some 15 million annual journeys. Moreover, the light rail has played a role in driving the overall results of the *Métrobus* network. Furthermore, its use of high-level architectural features matching the surrounding environment has added to the city's attractiveness. And finally, the light rail has gone beyond its primary transport role to become a development tool through its effect of revitalizing public urban spaces and the city centre.

Historical Review of TEOR Project

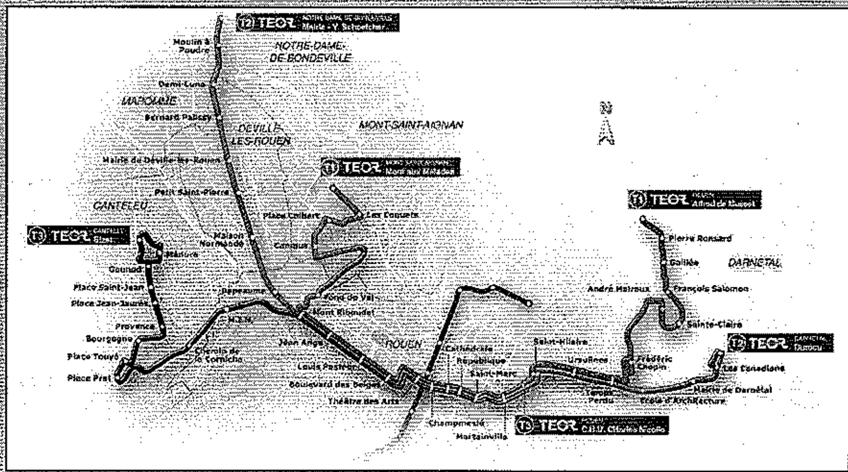
Soon after services started on the first Rouen light rail line in December 1994, the organizing authority ('District' at that time) studied various options for building an exclusive right-of-way line on the east–west axis. However, the solution had to:

- Have the capacity to serve a populous university campus, regional hospital, and the Rouen Heights district
- Be able to handle the grades required to reach the Rouen plateau at an elevation of 150 m
- Match more-patchy demand due to the lower population densities and fewer jobs than on the north–south axis
- Be easily financed in the light of financial constraints imposed by repayment burdens for the Rouen light rail and other new obligations

Various technologies were explored, including a light rail, single-guideway tyred tramway (TVR, Transport sur Voie Reservée), urban cable car, and buses. At the end of 1997, the authority decided to build three new TEOR lines on an exclusive right of way using the TVR concept that would be integrated with the Rouen light rail opened in 1994.

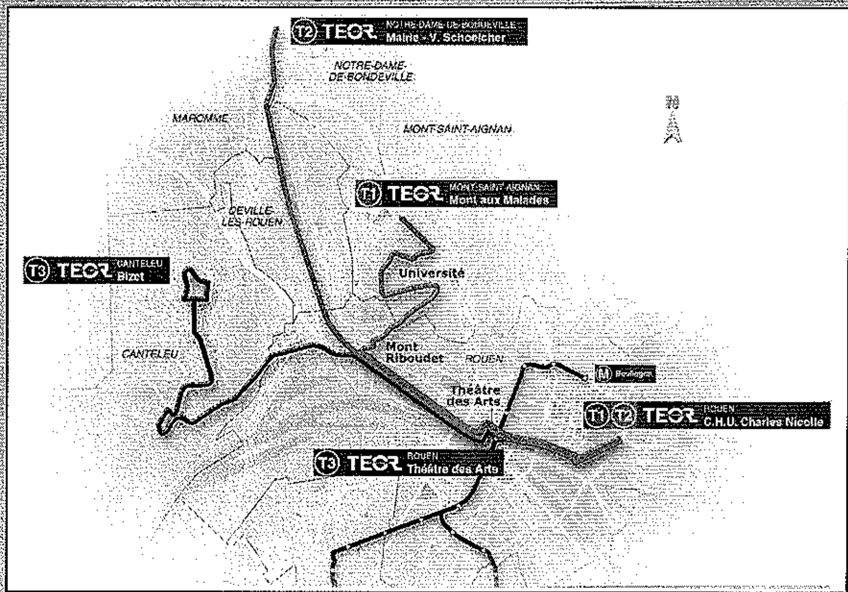
The objective was to operate a mass-transit system on an exclusive right of way through the east–west axis of the Rouen metropolis. The system would offer good operations speeds, frequency and comfort equivalent to a tramway commensurate with available financial means and citizens' transportation needs.

Figure 2 Three Planned TEOR Lines



(TCAR)

Figure 3 Currently Operating TEOR Lines



(TCAR)

Description of TEOR lines

The plans called for building three lines on the right bank of the Seine to serve the heavily populated valleys and plateaus east and west of Rouen, running on a shared segregated right of way to the city centre (Fig. 2). The proposed routes are:

- Line T1 (16 km, 26 stations): Mont aux Malades in Mont-Saint-Aignan to Alfred de Musset in Rouen
- Line T2 (12 km, 25 stations): Mairie-V. Schoelcher in Notre-Dame-de-Bondeville to Durécu in Darnetal
- Line T3 (20 km, 41 stations): Bizet in Canteleu to C.H.U. Charles Nicolle in Rouen

The shared section near the centre of Rouen will be about 4 km with 11 common stations between Mont Riboudet and C.H.U. Charles Nicolle.

The proposed design uses new high-performance technically innovative rolling stock consisting of 66 Irisbus-built *Agora*-type articulated vehicles with optical guidance in order to permit perfect accessibility in the stations. High schedule speed will be assured. Station infrastructure will also be very high quality and able to handle daily movements of up to 50,000 passengers in conditions equivalent to guided transport lines.

Construction plans called for two phases:

- Phase 1 with 50 stations on entire lengths of T1 and T2 and some sections of T3 with completion by 2006
- Phase 2 with completion of T3 after 2006 to serve final total of 70 stations

However, pre-production testing of two Irisbus *CIVIS* vehicles (articulated bus with electric powered wheel axles) resulted in adoption of the proposed optical guidance technology on *Agora* articulated vehicles.

Current situation

So far, only the western ends of the T1 and T2 lines and part of T3 line have been opened (Fig. 3). The current 41 stations (16 fully completed) are served by 38 *Agora* articulated vehicles fitted with optical guidance, as well as by two preproduction *CIVIS* vehicles. The optical guidance system pulls the vehicles to within 50 mm of the platform offering barrier-free access to all passengers and eliminating the need for wheelchair ramps, etc., when the self-service doors open.

The driver can switch from guided to manual operation without stopping or slowing down (Table 3).

Table 3 TEOR Specifications and Figures (2003)

Length	25.6 km
Stations	41
Completed stations	16
Vehicles	
Agora buses	38
Preproduction *CIVIS*	2
Peak frequency (shared section)	3 minutes
Peak frequency (each line)	4 minutes
Passenger-km (A)	1.658 million
Passenger journeys (B)	6.854 million
B/A	4.13

Agora articulated vehicle at stop with ground lines for optical guidance (TCAR)

Performance assessment

Only part of the TEOR project has been completed so far—the sections in the city centre and to the east of Rouen will be built from 2004 on. As a result, it is difficult to assess the performance accurately. The completed segregated right of way exceeds 10 km and people are making close to 30,000 daily journeys in the comfortable vehicles. Some lines are seeing substantial increases in ridership of 10% to 30% compared with passenger numbers on the former bus lines, and undoubtedly, there will be increases as soon as the city centre is fully developed. The TEOR project seems to offer an interesting and a good quality alternative to communities wanting to avoid massive costs by integrating with other transport lines on a previously built segregated right of way.

The Buses

The services offered by the Rouen light rail and TEOR lines outlined above are complemented by bus services organized vertically around the exclusive right-of-way lines as follows:

- Backbone bus network
  Buses in this network operate services radiating from or feeding into the light rail and TEOR lines at frequencies of 12 minutes or less.
- Supporting bus network
  These are typical bus services running at frequencies of between 12 and 25 minutes.
- Expansion bus network
  Regions with very low population densities are mostly served by smaller minibus-type vehicles.
- Interurban coach network
  Long-distance travel between urban perimeters is achieved using interurban coaches.
- School bus network
  When there is no regular bus service, school buses provide links between residential districts and educational areas when schools start and end (Table 4).

Synergy between Three Modes

Although the Rouen *Métrobus* network constitutes a coherent and effective transport network, it is based on a synergy between three transport modes: the Rouen light rail, the TEOR lines and the bus lines.

Network and problems with feeder services

Using the bus lines to feed the light rail and TEOR lines has three major benefits—more economic operating costs; better city-centre environment with only necessary bus services; minimized monopoly of city-centre roads by segregated right-of-way lines. However, since customers form a captive market, they require some form of protection in terms of frequency, reliability and comfort of bus services feeding termini or major stops on the light rail and TEOR lines.

Special attention must be paid to the frequencies of feeder services in relation to the light rail and TEOR lines that they serve, especially because a potential customer may choose to remain on the feeder mode rather than change to the light rail or TEOR line if the connections are bad.

In Rouen, the light rail and the TEOR lines are served by four and three backbone services, respectively, out of a total of 34 bus lines.

In each case, the bus timetable, service frequency, and connecting stops had to be adjusted to match the other services before customers felt satisfied.

Equipment

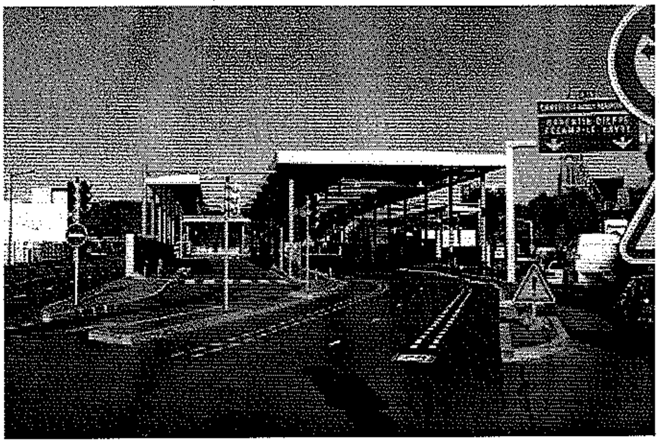
Ideally, customers using a transport network based on different modes each utilizing different technologies should not view the network as multi-speed. The 'appearance' of a single-speed network can be achieved by ensuring that technologies used by each mode are beneficial to all modes.

Various solutions have been adopted on

Table 4 Bus Specifications and Figures (2003)

Regular lines	34
Length	460 km
Stops	1600
Buses	226
Standard buses	162
Articulated buses	48
Minibuses	16
Schedule speed	17.32 km/h
Passenger-km (A)	10.021 billion
Passenger journeys (B)	17.631 billion
B/A	1.76

Connection at Boulingrin terminus of light rail and No. 5 bus line (TCAR)



Segrated right of way at Mont Riboudet on lines T1, T2 and T3 of Rouen TEOR (TCAR)

the Rouen *Métrobus* network as follows:

- Installation of Operation Assistance System (SAE) on all light rail, TEOR and bus lines
- Installation of Passenger Information System (SIV) terminals in all light rail and TEOR stations, as well as in major bus connection stations
  Some information is also provided by in-vehicle electronic displays on all transport modes.
- Network-wide magnetic ticketing
- Through-ticket vending machines throughout light rail and TEOR lines (expected by 2004)
- Same-level barrier-free platforms on light rail, TEOR and Liaison Sud-Ouest Rapide (LISOR) bus lines (in progress)

Consistent information

Passengers making intermodal connections require information about location and connecting services. Station displays must be easily seen, up-to-date, correctly located, and easily followed.

In addition, there must be consistency of design, colour, logomarks, symbols, positioning of displays, etc.

All three transport modes in the Rouen *Métrobus* system use a common set of standards governing these items.

Fare pricing

To assure ease of use and freedom of movement, all three modes in the *Métrobus* system use through ticketing based on the same pricing structure. A ticket can be used on all three transport modes for an hour once it is validated.

Why Three Transport Modes?

Why is Rouen's *Métrobus* system based on three transport modes? There are three reasons: the constraints of urban environment and geography mentioned earlier; politics and history; and service requirements.

The last 20 years have seen major developments in new transport technologies suited to provision of medium-capacity transport in smaller cities. New LRT systems first appeared in Nantes and Grenoble, and were immediately seen as a possible solution to Rouen's problem of how to reunite the two banks of the Seine. A light rail also offered two politically attractive possibilities: revitalizing the hollowed-out city centre, and overcoming the increasingly harmful dominance of the automobile.

Rouen's subsequent choice of the guided TEOR lines showed how a metropolis with limited financial resources could reliably meet higher demand than that provided by buses at reasonable cost.

Although the bus is the only conceivable mode for very remote areas, Rouen has been able to adapt it in terms of both design (low floors, pollution-free standards), and operations (segregated right of way and location of connecting stops) to complement the other two modes as feeder services, thereby ensuring easy and barrier-free access for all passengers to all modes.

As a consequence, Rouen seems to have avoided the main stumbling block of a network based on three different transport technologies and the successes achieved so far are a model for future expansion of the TEOR and buses. ■

Raymond Hue

Mr Hue is Chairman and Managing Director of TCAR. He graduated from the Ecole Centrale des Arts et Manufactures de Paris in 1967, and has held various engineering and managerial positions at the Centre d'Etudes Techniques de l'Equipement Normandie-Centre and TCAR. He is also Vice President of UITP and President of the Light Rail Division of UITP.

Feature

Manchester *Metrolink* Tram System

William Tyson

Introduction to Greater Manchester

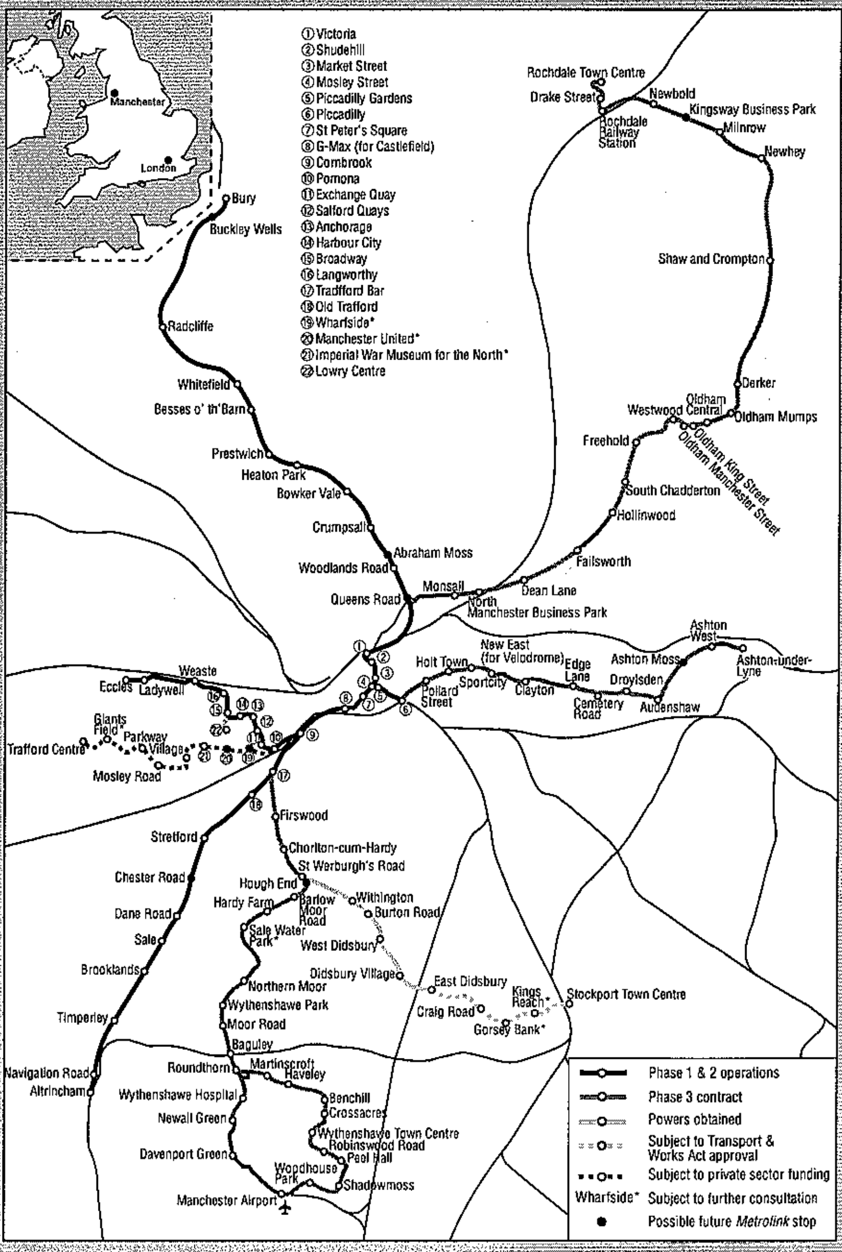
The City of Manchester (pop. 500,000) is at the heart of the Greater Manchester conurbation comprised of 10 municipalities that is home to 2.5 million people. The municipalities appoint a Passenger Transport Authority (PTA) for the whole area to set policies and the Greater Manchester Passenger Transport Executive (GMPTE) to implement them. Buses provide most public transport. They are deregulated and can compete with each other and with other modes. There is a local rail network serving Manchester, and linking it with the surrounding areas and also other regions of the country. Street trams vanished from Greater Manchester in 1951, but returned in a very different form in 1992. This article outlines the development of the new system and explores the reasons for choosing trams. It then goes on to analyze the factors that have made the system successful. Finally, expansion of the system is discussed.

Why Manchester Chose Trams?

In the mid-1980s, the local rail network was in need of major investment in new rolling stock, power supply and signalling. It also suffered because the stations in central Manchester were at least 1 km from most passengers' destinations in the Central Business District and the main shopping and entertainment areas. As a result, the subsidy bill was increasing as the quality of service was getting worse because of the old infrastructure and rolling stock. The PTA was paying more and more and getting less and less so it initiated a comprehensive study of options for the future of the local rail network in 1982. A wide range of options for the future of the network was examined, ranging from building a tunnel under the centre of the city that could be used by local rail services—taking them into the central area—to complete closure and replacement of the services by buses. Two options were to convert some heavy rail lines to light rail (tram) and extend them into the city centre either in tunnel or on the street.

I carried out an appraisal of these options and showed that closure of the lines had a negative benefit-to-cost ratio, and that—at the very least—they should be kept

Figure 1 *Metrolink* Future Network



Source: GMPTE, 2003

open in some form. If they were to be extended into the city centre, light rail conversion with a surface tram line in the city would have the highest benefit-to-cost ratio because it was the lowest-cost way to provide access to the city centre.

These two options were taken forward into further appraisals that showed that the tram option was the better of the two in cost-benefit terms. The PTA adopted the tram option as policy and in 1988, the GMPTE obtained the statutory powers to build and operate it, followed in 1988 by agreement from central government of a grant towards the construction costs.

Delivering the System

Besides being the first modern light-rail street system in the UK, Manchester also developed a new form of business concept by involving the private sector in operation of the system. The government of the day insisted that the private sector should play a role in operating the new system. This was consistent with government deregulation and privatization of most bus services outside London and later privatization of the rail network between 1993 and 1997.

A new form of contract was devised for the tram—Design, Build, Operate, and Maintain (DBOM). As the name suggests it combines a conventional design and build contract with a concession to operate and maintain the system for a period of 15 years. Financial estimates by GMPTE showed that passenger revenue on the tram system would exceed operating costs but would not cover the initial construction costs.

Bids from consortia for the DBOM contract comprised two elements: the cost of building the system, and the amount that they were prepared to pay for the right to operate the system accepting both the cost and revenue risks for the 15-year period. In the event, the construction cost was £160 million (£1 = US$ 1.80) and £5 million was offered for the operating concession.

The main terms of the operating concession are that GMPTE sets the minimum frequency of the services and periods of operation and specifies the levels of reliability that have to be achieved. The operator can set fares but is in competition with commercial bus services and pays all the system operating costs.

Construction took place between 1990 and 1992. Two local heavy rail lines were selected for conversion to the tram network—one to the north of the city and one to the south. They were connected by 2.5 km of on-street track in the city centre, most of which is segregated from other traffic. Both local rail lines terminated at purpose-built bus–rail interchanges (Fig. 1) in the centres of the towns they served (Altrincham in the south and Bury in the north). Passengers from the north were given direct access to the main national and inter-regional rail station at Piccadilly for the first time and passengers on both lines get direct access to the city centre.

Services

Services on the local rail lines before they were converted to trams ran every 10 minutes during the Monday–Friday peak hours, every 15 minutes between the peaks and all day on Saturdays, and every 30 minutes in evenings on the Altrincham line on Sundays. (The Bury line had no trains on Sundays.) By contrast, the trams provide a 6-minute service from 07:00 to 18:00 on Mondays to Saturdays and a 12-minute service at most other times (a 15-minute service runs on Sunday evenings). The trams also run for longer each day than the rail services did.

When the system was built, Europe had no low-floor trams in mass production and all the stations on the former railway lines had high platforms, so the system uses high-floor trams. In the city centre, most stops have high platforms although two have low platforms with a high section at one end. This makes the system fully accessible to the mobility impaired, including passengers in wheelchairs and those with heavy luggage, shopping or children in pushchairs.

This first phase of the system is 31-km long with 25 stops, five of which are in the city centre; a sixth stop in the city centre was opened in 2003. Of the 20 former railway stations, 16 are now entirely tram stops, two are shared between tram and local trains on separate platforms, and two are parts of larger city-centre rail stations. The average distance between stops is 1.3 km. Twenty-six trams that can each carry up to 206 passengers provide the services. Up to 23 trams are in service during the Monday–Friday peaks and 25 are sometimes in service.

Impacts

The tram system opened in sections between April and November 1992 and was an instant success. The local railway lines had been carrying about 7.6 million passenger journeys each year when they were closed for conversion to trams. In the year to 31 March 1994, the trams carried 11 million passenger journeys—20% of whom would otherwise have used the car. I estimated that patronage would settle at 12 million passenger journeys per year after 2 years of operation of the full service. This level was achieved by the end of 1994, just over 2 years from the start of the full service in November 1992. These initial patronage levels have continued to grow. By 1997–98, patronage had risen to 13.8 million passenger journeys, reaching 15 million passenger journeys in 2002–03, or more than double the patronage on the old local railway services.

The tram increased its market share for

Metrolink at St Peter's Square in the business district. The system is fully accessible to the mobility impaired. (GMPTE)

A busy *Metrolink* in central Manchester (GMPTE)

journeys to central Manchester from the immediate catchment areas of the stops to 58% from the former 17% achieved by the trains. The car's share for these trips has fallen from 55% to 33% while the bus' share has fallen from 28% to 9%. As a result, traffic levels on roads running parallel to the tram services have fallen by up to 10%, reducing both congestion and pollution. The tram uses less primary energy per passenger-km than any other mode and the environmental impact is created at power stations where it can be controlled.

Accident rates per passenger-km have also been reduced as a result of the transfer of trips from cars to trams because trams have much fewer accidents than cars. Although the trams run through very busy pedestrian areas, there have been few accidents involving pedestrians. After the initial period of new operations in mixed traffic passed, in over 10 years of operations in a busy city centre, there have been few collisions between trams and other vehicles with only one serious accident (that was not the fault of the tram).

Since the tram system took over two railways that served established suburban areas, it has not had a major impact on regeneration. However, it does link a regeneration area west of central Manchester with the city centre.

Reasons for Success

The system has been a success by every measure and is widely recognized as such. There are several reasons. First, it offers high-quality services that are frequent, fast, clean, safe and reliable. At peak times, it offers faster overall journey times than either cars or buses. And journey times are equal to those of the car even outside peak times. Second, it has opened up new markets for evening- and late-night travel (services now run until 01:30 on Friday and Saturday nights), journeys across the city centre (now 5% of total travel but negligible before), and journeys generated by the system's full accessibility. Third, the system has three major traffic generators and attractors—Manchester at the centre of the network, and the towns of Bury and Altrincham at the ends of the lines. This has resulted in a highly successful commercial operation, because there is a good balance of travel in both directions even at peak times. Outside the peak times, there is a fairly even balance of traffic with passengers boarding and alighting at most stops. This contrasts with the classic model of a city centre to suburb railway line, which is usually dominated by single-direction peak traffic. Finally, the system has generated a high level of public support; it is fully supervised by closed circuit television (CCTV) with automatic recording and is viewed as safe. Despite a few incidents, it still has a good record relative to other modes of public transport. This support has even extended to the mass media; the local *Manchester Evening News* has been a staunch supporter of *Metrolink* and supported the PTA's bid to extend the system.

The only problem is that the trams are now full to capacity during peak hours so part of the extension programme described below includes provision of more trams.

Extending System

The PTA and GMPTE were actively working to extend *Metrolink* even before the system was completed. In the UK, the process of getting statutory powers to build and operate a tram system is very protracted and can take at least 3 years to plan and get powers for a new line. The PTA policy has always been to obtain powers so that work can proceed as soon as funding is available. Consequently, the necessary powers were obtained well in advance for the system extensions shown in Figure 1.

The first extension is the 6.4-km line to Eccles branching from the Altrincham line about 2 km from the city centre. Unlike the first lines described above, this is an entirely new line on a route that has never had a rail service. It serves a major regeneration area in Manchester's old docklands now known as Salford Quays. (Manchester was an inland port served by the Manchester Ship Canal.) This section of the line was planned alongside the development and although much of development area was already occupied before the line opened, the route had been left clear. The line then runs west to Eccles in the municipality of Salford. The section through Salford Quays has its own right of way while the last 3 km to Eccles runs entirely on the street.

Funding for this line came from a combination of sources, including the PTA, central government, the European Union, contributions from private developers in cash or as land gifts, and the proceeds of re-letting the concession for the Bury and Altrincham lines. The total cost of the line was £150 million with some 65% coming from the private sector. The concession for the Bury and Altrincham lines could be re-let because the first agreement contained a clause dealing with system expansion. In summary, this stated that if GMPTE got powers and funding for an extension, the consortium holding the concession would be invited to bid for construction and operation of the extension. If this bid did not represent good value for money in the view of GMPTE, the concession could then be terminated with the concession holder receiving compensation based on the amount originally paid for the concession.

This did happen and a new concessionaire took over on 1 May 1997 with a contract to design and build the Eccles extension and to operate and maintain the whole system. This concession is for 17 years, comprised of a 2-year construction period and 15 years of operation. The private sector, including the concessionaire, paid £95 million toward the £160 million cost of the extension.

Prime Minister Tony Blair opened the first section in December 1999 and the line to Eccles was completed in July 2000. Patronage grew slowly as expected for an entirely new line but growth has been steady and now runs at about 3.25 million passenger journeys per year. The long-term estimate is for an annual patronage of 5.5 million people. Six new trams of a similar design to the original trams were purchased to provide 12-minute services throughout the day. The line also includes a large Park & Ride car park just outside Eccles that is less than 1 km from an exit on the M602 motorway to Manchester. The line completion has already seen more new developments both in Salford Quays and Eccles.

The next priorities for extensions comprised three other lines shown on Figure 1. The first is a 24-km line to Oldham and Rochdale that will take over another local railway line. However, the old route will be partly diverted to run on-street through the centre of Oldham and serve a new bus interchange east of Oldham. It will also be extended from Rochdale railway station into the centre of Rochdale and terminate at the bus station. The second extension is a 10-km line to Ashton-under-Lyne east of Manchester. Two-thirds of this entirely new line will be on segregated tracks over a new route with the remaining one-third running on an existing road. It will serve a major new regeneration area close to the site of the 2002 Commonwealth Games, and a major Park & Ride car park, as well as the town of Ashton.

The third 21-km line will serve Manchester Airport linking it with major residential areas to recruit staff for the expanding workforce. The line will also contribute to regeneration of a suburban area of Wythenshawe that includes some of the most socially deprived areas in the UK. Most of this line will be on segregated tracks at the side or middle of roads but some 3 km runs on an abandoned railway line. At writing (January 2004), funding for these three new extensions is still being finalized.

Conclusions

When these extension lines have been completed the Manchester *Metrolink* will be over 93-km long with more than 80 trams carrying about 45 million passengers each year. At that time, it is likely to account for about 20% of all public transport trips in Greater Manchester. The *Metrolink* is one public transport mode that has enjoyed almost continuous passenger growth since it opened and the factors contributing to the success of the first three lines have been taken into account in planning the new lines. The three new lines will not be the end of the tram story—more lines are in planning and some are shown in Figure 1. Our experience in Manchester shows that the modern light-rail incarnation of the tram has enormous potential to help reduce the adverse impact of the car on large cities and to help achieve wider economic regeneration and social inclusion objectives. ■

William Tyson

Mr Tyson, OBE, is Managing Director of the GMPTE Transport Management Group. He obtained a Master's degree in economics from Manchester University in 1970 while on the the staff of the university and then left to form his own consultancy business in 1980, becoming involved in the economic appraisal of *Metrolink*. Until recently, he was a member of the UITP Transport Economics Commission and was part of a team that advised the British government on new transport policy.

Izmir Metro: Story of a Successful Engineering Project

Emre Aykar

Introduction

The Izmir Metro is a major milestone in Turkey's urban transportation both as a significant infrastructure project in terms of engineering and construction and because the design and implementation of this hugely successful project gave rise to many other urban rail systems in important cities such as Adana, Bursa, Antalya and Eskişehir in Turkey.

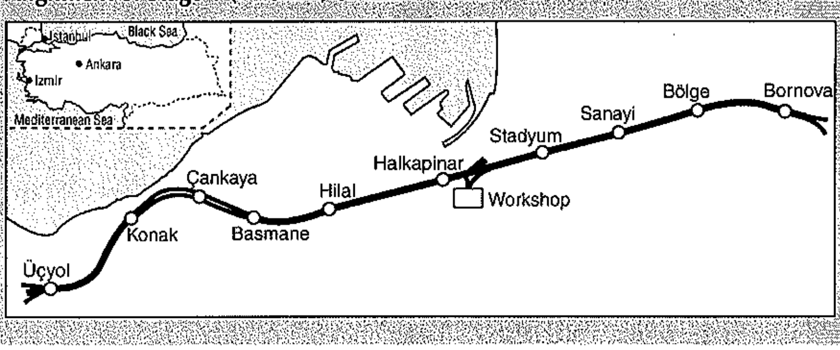
In the 1960s, the city of Izmir had a population of about 1 million. This figure tripled over the next 30 years due to enormous migration. As a result, municipal authorities initiated a transportation study in 1988 to handle the spiralling population. The resultant Transportation Master Plan consists of a 43-km rail network around Izmir Bay to be implemented in four stages with the first 11.5-km stage put out to tender in mid-1992. A contract was signed in early 1993 with site hand-over in early 1994. Construction started in 1995 and was completed successfully in less than 4 years. Testing began in September 1999 and the system came into service in May 2000 as Izmir's population reached 3.4 million.

The total cost of the turnkey, design and built project was US$600 million handled as a joint project of the Yapi Merkezi–AdTranz Consortium. Yapi Merkezi was the main contractor for all design and civil works (tunnels, bridges, viaducts, stations, tracks, infrastructure, depots and workshops) as well as the third-rail power system. ABB-AdTranz of Sweden supplied the rolling stock and installed the power-supply, signalling, telecommunication and remote-control systems.

About Izmir

The city of Izmir has an area of 12,000 km² located on the mid-Aegean coast of western Turkey (38°24′ N and 27°10′ E). It has a large bay about 40-km long and between 2- and 7.5-km wide that has been a major trade hub for millenia. The city is at the head of a long narrow gulf cut through by ships and yachts. The climate is mild in winter and the heat of summer is relieved by constant and refreshing sea breezes. The city behind the palm-lined shore front promenades climbs gently in horizontal terraces up the slopes of the surrounding mountains.

Izmir's history goes back to 3000 B.C. with the discovery of the Zeus Altar in Pergamon (Bergama), the Artemis Temple, and parts of the ancient city of Ephesus. The earliest remains are contemporary with the second civilization of Troy when the city was known as Smyrna in ancient Greek. Alexander the Great (350–323 B.C.) sacked the city in 333 B.C. followed by a Roman period from around 100 B.C. By the 9th century, Izmir was an important naval base and dockyard in the Byzantine Empire (312–1453) and it remained an important international port under the Nicaean Empire (1204–61), finally becoming part of the Ottoman Empire (1299–1923) in 1426. The shore fort was rebuilt by Mehmed the Conqueror after an attack by the Venetians in 1472. Izmir's location on a huge natural harbour has kept it at the forefront of trade and culture for millenia and since the founding of the Turkish Republic in 1923, it has become the third biggest city in the country with fast-developing foreign trade and industry based on agriculture, tourism, culture and educational activities.



Alignment of Stage 1 (11.5 km) of Izmir Metro

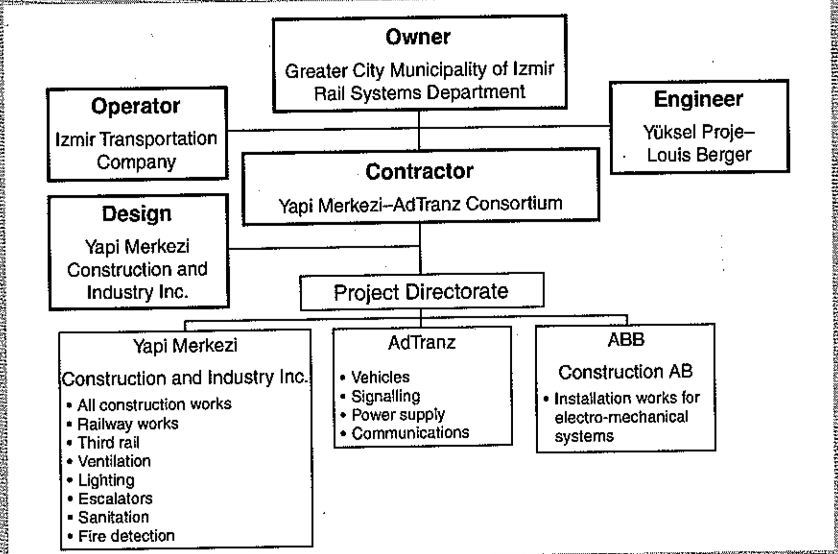
Transportation Study

By 1990, Izmir's existing transportation network could no longer meet the needs of the growing population, especially because the centre corridor was squeezed on both sides by the restricting topography. By 1990, 400,000–600,000 passengers were passing each day through the city centre with a projected figure of 1.6 million passengers in 2010. The old transportation network was inefficient, dangerous, uneconomic and uncomfortable; the ridership potential coefficient (coefficient of ridership x city population = daily transport number) was 1.23 in 1990 and projected to rise to 1.50 in 2010.

The city authorities realized that the system had to be changed as soon as possible by developing an effective public transportation system and it was soon decided that a better structure could only be achieved by building an inner-city rail system with a high capacity based on modern technology that could adapt flexibly and easily to the existing structure of the city. It also had to be built and opened quickly.

The lines suggested in the Transportation Master Plan were discussed and it was proposed to build a 43-km rail network

Project Organization



Project Specifications

Construction period	1995–2000
Project value	US$600 million
Total length	11.6 km
Number of Stations	10
Underground	4
Viaduct	2
Levelline	4
Peak capacity	45,000 passenger/h in each direction
Minimum headway	2 minutes
Number of cars per train	3 to 5
Fleet size	45 cars
Power supply	Third rail (750 Vdc)
Maximum speed	80 km/h
Schedule speed	40 km/h
Station platform height	88 cm
Platform length	125 m
Workshop building	10,500 m^2
Depot area	55,300 m^2

based around the Üçyol–Konak–Basmane–Halkapınar line where the public transportation density in 2010 was forecast to be maximum. Studies on passenger density and construction feasibility indicated the need to build the network in four stages.

Civil Engineering Works

The Yapi Merkezi–AdTranz Consortium won the bidding for all phases of the Izmir Light Rail Transit System (LRTS) from design to training operating staff. The complex geology and changing city topography necessitated use of different construction methods (four tunnelling methods) along the 11.5-km alignment. Moreover, Izmir is in an active earthquake zone, presenting Yapi Merkezi with major challenges in the design and construction phases. Special measures had to be taken to bear potential earthquake loads.

The 1.7-km long tunnels—including the Üçyol deep station platform—were bored through andesite using the New Austrian Tunnelling Method (NATM). Since the Üçyol platform is 36 m below ground level (–36 m GL), the escalator tunnels leading to the cut-and-cover ticket halls were also bored from below by NATM.

At the other end of the alignment, the approximately 1-km long tunnel leading to the Bornova underground station as well as the station itself were excavated by the cover-and-cut method selected because the complex roads and highways in the area prevented leaving open pits for long periods of time.

The Earth Pressure Balance Method (EPBM) was used for the two twin tunnel tubes connecting the Konak, Çankaya and Basmane stations. The four tubes total 2.75 km in length with a finished diameter of 5.7 m. The excavated diameter was 6.55 m with an overburden thickness of 6 to 14 m. The geology consists of various formations, including gravelly sands to sandy silts to silty clays with no boulders or basement rock formations. Sea level (SL) in the area is about –3 m GL and the ground water level is very close to SL. Lenses of sandy gravels had very high artesian potential and the clay water content was nearly at the liquid limit. This difficult geology necessitated cutting the the twin tunnel tubes with a full face, shielded and watertight EPBM tunnel boring machine designed specifically for Izmir's geology and the Metro's requirements. The fourth drive saw a record daily advance of 28.8 m.

The three underground stations at Konak, Çanaya and Basmane were excavated by the cut-and-cover method. In this section, the track level is between –10 and –13 m SL with a mixed geology including a wide variety of materials like gravelly sands to sandy silts to silty clays. The Konak and Çankaya stations are close to land reclaimed over many centuries from the sea with a deep artificial fill of up to 6 m. As a result, 0.8- to 1.2-m thick diaphragm walls ranging in depth from 25 to 33 m were built as groundwater barriers.

Five of the 10 stations are underground, two are elevated, and three are at grade. Viaducts constitute about 2.5 km of the total length with about 3.2 km of lines at grade. Various prefabrication techniques were used when possible to shorten overall construction time. The structural system is composed of bored piles, cast-in-situ foundations and columns, and prestressed prefabricated concrete beams. Besides the aesthetic values, the construction was completed ahead of schedule and a fairly economical solution was obtained by developing and using

Construction Specifications

Types of structures	
Between Üçyol and Konak	
Deep tunnel (Nene Hatun Tunnel) constructed by NATM	1,700 m
Between Konak and Basmane	
Twin tunnels (Ümmühan Ana Tunnel) constructed by EPBM method	1,400 m x 2
Cut & Cover tunnels (with diaphragm walls)	1,100 m
Between Basmane and Bornova	
Viaducts	2,800 m
At grade/box structures	3,600 m
Cut & Cover and cut structures	1,000 m
Total length	11,600 m
Main construction works	
Excavation (including tunnels)	860,000 m^3
Fill (including cement stabilization)	130,000 m^3
Concrete (including prestressed precast concrete)	310,000 m^3
Steel structures (high and normal strength)	12,000 tonnes
Railway line (single track)	37,000 m
Third rail (aluminium alloy rail)	26,000 m
Alignment criteria	
Main line Rmin	250 m
Depot Rmin	30 m
Stations Rmin	600 m
Max. lateral acceleration	0.65 m/s^2
Required lateral acceleration	0.35 m/s^2
Max. superelevation	140 mm
Min. transition curve length	0.4 h
Superelevation ramp	1/400
Max. grade	5% (on the main line), 0% (at workshop), 0.20% (at stations)
Vertical curve	R=(V2/2)>2000 m
Track gauge	1,435 mm
Rail type	S 49 (BV 49) vignole - RI 56 grooved
Rail connection	Aluminothermic welding
Sleeper connection	Vossloh elastic connection
Sleepers	Prestressed concrete; wooden at special areas
Track bed	Ballast
Switches	1:9 R = 300, 1:9 R = 190 on main line, 1:6 R = 100 at workshop
Architectural design criteria	
Safe and comfortable passenger circulation and system operation	
Modular	
Conformance to local environment	
Integration with urban formation and historical background	
Integration with other transport modes	
Constructability	
Durable, low-maintenance materials	
Consideration of future development	
Structural design criteria	
Earthquake resistant	
Elasticity and strength	
Light structures	
Design loads in conformance with international standards	
Primary (dead and live loads, centrifugal, settlement of supports, shrinkage and creep, earth pressure)	
Temporary (acceleration, deceleration, hunting force, thermal forces, wind, snow)	
Special loads (seismic loads, collision, erection)	
Extensive geotechnical investigations and evaluations	
Continuity in structural systems	
Aesthetic viaducts	
Efficient construction methods	
Technically sound and economically feasible structures	

prestressed precast girders with a high efficiency factor.

Üçyol, the first station on the Izmir LRTS is a deep tunnel station at –35 m GL. The design allows a smooth flow of pedestrian traffic and includes adequate space to accommodate both normal and emergency passenger loads. The viaduct stations with side platforms and ticket halls at grade have the same technical standards as the other stations. Despite the necessity to meet all the challenges of a viaduct, human dimensions are well respected. The shape of the columns supporting the beams, the height and even the design of the guard rails are all designed to prevent a bulky appearance that might disturb the surroundings.

The 57,000-m^2 depot is designed to handle all maintenance and operational needs; it has a capacity of 80 vehicles and an enclosed maintenance workshop area of 10,500 m^2. The main concern was to enable vehicles to enter and exit the depot through a grade-separated line without interfering with main-line traffic. There is also an emergency entrance line for use in case of a system failure.

Vehicle Specifications

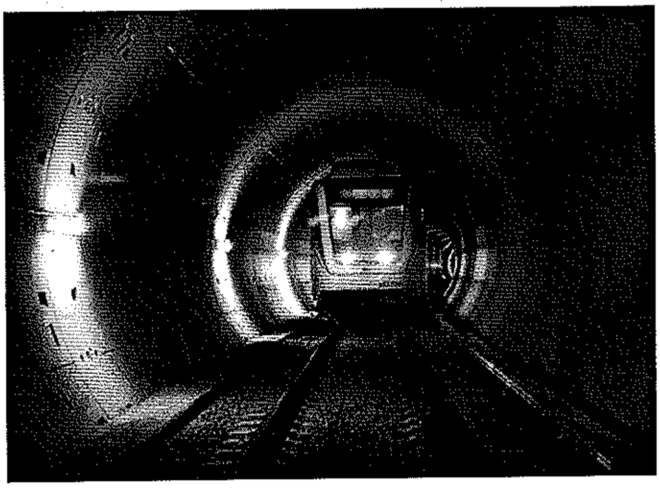
AdTranz was responsible for the rolling stock and the signalling, power-supply and communication systems. (ABB Traction was subsequently purchased by Daimler and became AdTranz only to be purchased later by Bombardier.)

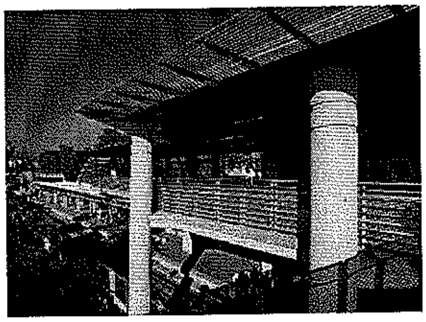
The Izmir Light Rail Vehicle (LRV) is tailor-made for the LRTS. It is 3760-mm high (from head of rail), 2650-mm wide, and 23,500-mm long (over couplers) with a maximum speed of 80 km/h. The maximum acceleration is 1.0 m/s with a seating capacity of 44 and a standing capacity of 140.

All LRVs are self-powered and the drive and braking systems (with wheel-slip protection) are controlled by on-board computer. A train consists of two to five vehicles with driver's cabin at each end. The LRV is a six-axle articulated unit with three bogies. The first and last bogies are powered while the articulated bogie is trailing.

The auxiliary power system is based on a static converter-inverter, supplied from a 750-Vdc third rail and supplying 3-phase x 400 Vac at 50 Hz for compressor, fans, lights, battery charging, etc. The 24-Vdc battery system supplies the on-board computer as well as other safety systems such as automatic train control (ATC), train radio, passenger displays, emergency lights, etc. The tunnel safety aspects have top priority.


Çankaya Station (Yapi Merkezi Construction and Industry)


EPBM Tunnel between Konak and Basmane stations (Yapi Merkezi Construction and Industry)


Sanayi Station (Yapi Merkezi Construction and Industry)


Halkapinar Station (Yapi Merkezi Construction and Industry)


Workshop area between Halkapinar and Stadyum stations (Yapi Merkezi Construction and Industry)

Financing

The Izmir Metro is a good example of the successful application of structured financing in Turkey. The project—Izmir's biggest to date—was fully financed by international banks and financial institutions (Standard & Chartered Bank for Export Credits Guarantee Department (ECGD) guaranteed portion and commercial loan; Bankers Trust Company for commercial loan; Skandinavska Enskilda Banken for the Swedish Export Credits Guarantee Board (EKN) guaranteed portion; Nordic Investment Bank and BHF Bank for AKA) with guarantees from the Turkish government.

Conclusion

The Izmir Transportation Company, an affiliate of the Greater City Municipality of Izmir took over the Izmir Metro in May 2000 after a 1-year commissioning period. Since then, the Izmir Metro has carried more than 150 million people in safety and comfort with no technical problems. The construction site was visited by many international experts who commented favourably on the work. Dr Pierre Laconte, UITP Secretary General said, 'Members of the UITP Rail Systems Committee (see pp. 4–9) have been very impressed today by the various structures being built here. The modern workshop building and fully protected line are especially worth mentioning.' Mr Takashi Takeyama, Head of the Engineering Department of the Japanese Mass Transportation Center said, 'We have seen a perfect metro system construction with very detailed studies and much valuable information collection.'

The final source of pride for Yapi Merkezi is that the company was ranked third by the *Engineering News Record* in the list of Top International Light Rail/Mass Transit Contractors for 1999. ■

Emre Aykar

Mr Aykar is Partner and Chairman of Yapi Merkezi Construction and Industry Inc. He has a Master's degree in civil engineering from Bogazici University in Istanbul. He has a long career in the construction industry and is a specialist in concrete technology, prefabrication, fire engineering and rail systems. His major rail-related projects include the Istanbul Light Metro, Izmir Metro and the Antalya and Eskişehir tramway systems.

Feature

Trams Making Way for Light Rail Transit

Shigenori Hattori

Introduction

In 1978, the city of Edmonton in Canada opened the world's first urban transport system based on the Light Rail Transit (LRT) concept discussed in this article. Over the next 25 years, LRT systems have been built in more than 70 cities worldwide. Of the approximately 350 tram systems now in operation, about 30% can be described as LRT systems, because they have been refurbished and modified to LRT standards.

Due to historical differences and different approaches taken when introducing light rail systems, the term 'LRT' means one thing in Japan and another in Europe and North America. This article examines tramways and LRT systems bearing in mind the different definitions and the differences in rolling stock, lines and operations.

Japanese Definitions of LRT

In Japan, there is renewed interest in the possibilities of tramways and the mass media use the term 'LRT' frequently. Moreover, different writers in different countries use the term LRT differently, making it hard for Japanese to understand exactly what kind of urban transit system LRT is.

The term LRT was first coined in the USA in the early 1970s as an attempt to revitalize the image of tramways, which were seen negatively as an out-of-date system not fulfilling the needs of modern urban transit. When tramcars share the right of way with motor vehicles, their transit potential is limited by traffic jams and competition for space. This fact indicated that LRT systems should basically have their own right of way to support faster operations.

The European and North American definition of LRT has tended to focus on medium-capacity, electric cars running on rails. The cars are about 2.65-m wide and operate on their own right of way over elevated track, underground, etc., permitting higher operating speeds. This type of definition could also include many suburban railways.

In Japan, LRT systems are typically viewed as sharing the road with motor vehicles, like the trams in Grenoble and Strasbourg. Although such systems are known as trams or streetcars in Europe and North America, it is often assumed that even low-floor trams are not LRT systems.

Many Japanese cities had tramways in the early 20th century but most abandoned them in the postwar period of rapid growth in private-vehicle ownership when trams were seen as out-of-date. However, the last 20 years have seen renewed interest as it becomes clear that many LRT systems in European and North American cities are helping to reduce automobile emissions and revitalize city centres. Moreover Japan's greying population is creating further demand for barrier-free urban transit using low-floor light rail vehicles. The Japanese are beginning to see trams as a way to reduce urban pollution and improve city life.

Even so, the old trams that managed to remain in operation in Japan when most cities were tearing up tram tracks are generally seen as vestiges of the past. Consequently, when LRT proponents talk about the advantages of LRT systems, they emphasize the differences from tram systems, stressing the modern rolling stock, track and operating systems. Despite this, LRT systems and trams look similar, making it difficult for most people to appreciate the differences.

New LRT systems in Europe and North America are following government guidelines to promote a modal shift from motor vehicles to a mix of pedestrian and public transit, creating environment-friendly and sustainable development. In these regions, LRT systems are seen as a key part of medium-capacity urban transit systems supplemented by links to cars, buses and other transportation modes through Transportation Demand Management (TDM) strategies.

LRT systems fulfil their role as medium-capacity urban transit systems by operating articulated cars that can be up to 40-m long and sometimes the entire train set can total 100 m.

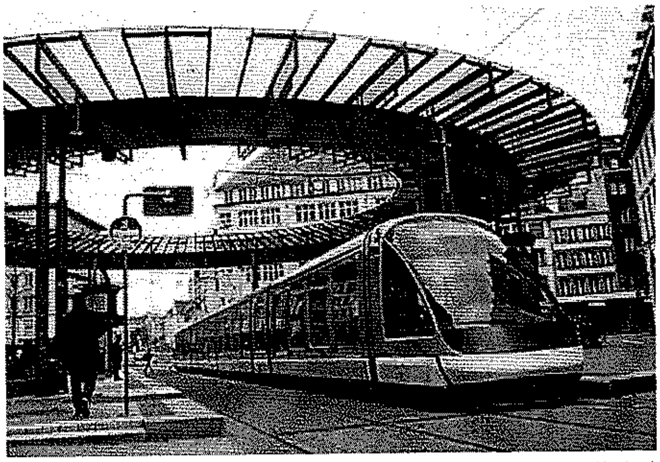
Although some tram operators in Japan are modernizing by introducing low-floor light rail vehicles (LF-LRVs), trams are still not highly regarded as an urban transit mode because most rolling stock consists of 13-m or so bogie cars that are similar to buses. Consequently, we must explain the effective role LRT systems play in urban transit in many European and North American cities to create a consensus favouring upgrading of Japanese trams to LRT systems. Unfortunately, the conditions in Japan are still not right to reach this consensus.

Modernization of Light Rolling Stock

Trams in Japan came to be seen in a more favourable light in 1997 when Kumamoto City introduced models with lower floors about 350 mm over the rail head. Since tram platforms are generally between 200 and 300 mm higher than the road level, low-floor carriages almost eliminate the step when boarding and exiting, which provides nearly barrier-free access for everybody and permits faster schedule speeds. Passengers have always complained about high steps right from the first days of trams but the early 660-mm diameter wheels made low floors difficult to achieve until today.

New York began operating partial low-floor trams as early as 1912. They were called stepless or hobble skirt cars (because women in hobble skirts, which were very narrow below the knees, could board and disembark with ease). The mid-

Stuttgart LRT on own right of way (Author)


Strasbourg LRT sharing road with motor vehicles (Author)

section of the car had a door leading to a low floor with the bogies at the two ends. Similar tramcars ran in the Los Angeles suburbs and elsewhere in the USA, with 176 manufactured for New York. A non-motorized version was built in Europe in the 1920s and was pulled by the motorized cars in a number of German cities.

Today's LF-LRVs use modern motor technologies to cut floor heights to between 300 and 350 m. Switzerland was the first country with genuine low-floor cars in the mid-1980s. During the same time frame, LRT systems were beginning to contribute to urban renewal in the USA; Germany and elsewhere started segregating trams from road traffic and even moved some tracks underground. While these improvements helped boost the role of trams in urban transit it was the appearance of low-floor cars that greatly increased the appeal as people realized that the almost street-level access was very pedestrian friendly. Many cities that had torn up their tram tracks decades earlier began building LRT tracks as part of their urban renewal plans, and cities that still had old tramways began upgrading based on LRT concepts.

New technologies

Development of new LF-LRV technologies has focused on changing the location and configuration of bogies and under-floor equipment to achieve a low, flat floor.

Early developments moved under-floor equipment to the roof or inside the car. The next step was to develop stub axles for the trailing bogies and small-diameter wheels, allowing the low floor to cover about 70% of the carriage floor area (70% LF-LRV). Completely flat floors throughout the cars (100% LF-LRV) were finally achieved by developing independently powered bogie wheels located under the seats (Fig. 1).

Advances in semiconductor technology reduced the size of conventional under-floor control devices as well the need for regular maintenance, contributing to repositioning. Variable voltage variable frequency (VVVF) inverter control transformed the old heavy traction motor into a small, light, three-phase induction motor, eliminating the need for bogie mounting. Insulated gate bipolar mode transistors (IGBTs) also made inverters smaller and more efficient, permitting smaller control and other devices.

Resistors, batteries and other equipment used by regenerative braking as well as auxiliary power units have been unitized and mounted on the car roof. In addition, air brake equipment such as compressors was eliminated by use of electric command braking with a spring-activated hydraulic release mechanism.

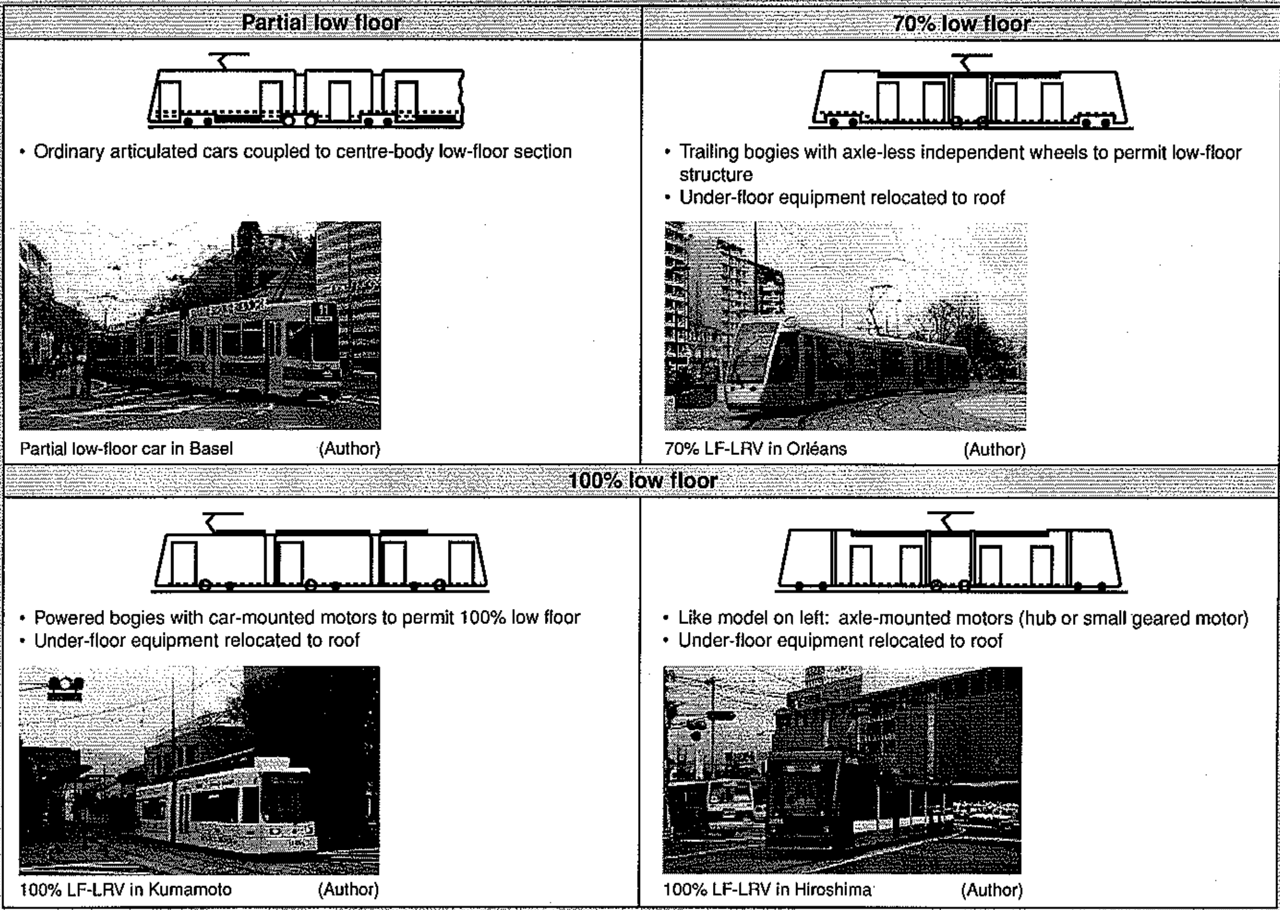
Introduction of axle-less bogies opened up the space usually occupied by the long wheel axles to increase the low-floor area. In the early cars, only the non-motorized trailing bogies were axle-less but later 100% LF-LRV designs moved the traction motor to the bogie side. Modifying the drive made it possible to extend the low-floor space over the powered bogie with the wheels extending inside the car under the seats. Single-axle bogies were also developed to reduce the number of wheels, thereby opening up more low-floor space. To obtain a wide aisle over the bogie sections, the bogies are anchored to the articulated bodies so that they barely rotate on curved track.

The 70% LF-LRV began operating about 15 years ago followed by the 100% LF-LRV a few years later. In 2003, there were more than 4000 low-floor tram sets in operation worldwide. Although this figure includes units with a low-floor area of no more than 10%, about one-third are 100% LF-LRVs (Table 1).

Due to structural limits, 70% LF-LRVs with conventional bogies must have interior steps, but small traction motors make it possible to lower the floor near the bogies to less than 600 mm. Thus, some 70% LF-LRVs have only one step that passengers can easily negotiate. Unlike in Japan, fare collection in Europe does not involve movement through the car between separate entrance and exit doors, so European tram operators do not necessarily require 100% LF-LRVs. Some operators prefer cars with conventional, highly reliable powered bogies and drive mechanisms, or cheaper vehicles, so these are still being manufactured.

Different models of 100% LF-LRVs have been developed as prototypes and some are being used in transit systems. Each

Figure 1 Low-floor LRV Vehicle Types



(●: powered wheels; ○: trailing wheels)

model has technical advantages and disadvantages. Two obvious problems are difficult maintenance of the complex mechanical systems as well as the high cost per unit because there are no economies of mass production yet.

Mergers have forced some manufacturers to produce a variety of different designs but they are attempting to unify the various technologies and develop standard models and equipment, aiming for the day when they can begin low-cost mass production.

Standard 100% LF-LRV

Standard low-floor LRVs appeared between 2001 and 2003 and are promoted by their manufacturers, with various names like: *Combino* (built by Siemens and chosen by Hiroshima Electric Railway); *Citadis* (by Alstom); *Flexity Outlook* (by Bombardier and including technology from the former Adtranz); and *Sirio* (by Ansaldobreda). These so-called System Cars are based on many common design concepts and give an idea of the future of 100% LF-LRV designs.

Table 1 World Manufacturers of LF-LRVs in Early 2003

	Bombardier			Alstom			Former			
	Bombardier	Adtranz	Siemens	Alstom	Fiat	Ansaldobreda	Eastern bloc	China	Japan	Total
Partial (under 70%) LF-LRVs	105	102	210	61		32	43		5	558
70% LF-LRVs	446	42	742	301	58	140	157	30	78	1994
100% LF-LRVs	54	732	581	178	117	28			3	1693
Trailers	60			30						90
Total	665	876	1533	570	175	200	200	30	86	4335

Source: Data mainly from Stadtverkehr 2002/12, Metro Report 2002, and Tramways & Urban Transit
Note: Data for China and former Eastern bloc mainly verified but some estimates

In some configurations, floating bogieless articulated cars are coupled to short cabs running on bogies. The cabs are spring-mounted on the bogies either directly or in a way that permits slight rotation, ensuring little carriage overhang on curves and a smooth ride. The small rotation on curves, permits construction of fairly wide aisles between the left and right bogie wheels. For example, the *Combino* has an aisle width of between 800 and 830 mm. Different track gauges are supported by changing the position of the beam on the bogie frame inside or outside the wheels. The structure of the powered and trailing bogies is very similar. A beam links the left and right axle boxes to provide a cantilever supporting the short axles of the independent wheels and permitting more low-floor space. In most cases, the traction motor is mounted on the side beam of the bogie frame and the drive and brake assemblies are mounted as a unit on the powered bogie. The drive for the independent wheels depends on the manufacturer, but all are based on a conventional design that has proved successful in high-floor vehicles.

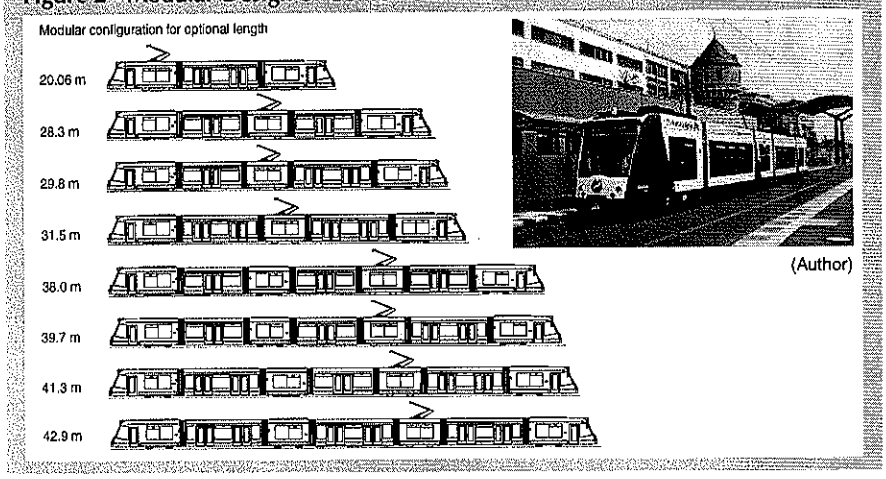
The *Flexity Outlook* sold by Bombardier to Linz (Austria) and Eskişehir (Turkey) has small-diameter 560-mm wheels with conventional axles driven by small electric motors mounted on the bogie frame. The low-floor section is 365 mm above the ground and slopes gradually up to a section that is over the bogies and 450 mm above the ground, making this carriage almost a 100% LF-LRV. The bogies are mounted directly on the car body, which can impact ride comfort depending on the track (especially with regard to vertical wheel/rail interaction). For this reason, Alstom's *Citadis* offers a choice of three bogie types, each suitable for a specific track condition. Some vehicles are designed as modules that can be coupled together to configure the required length, door positions, and other features. The modules include cabs with powered bogies, trailer cars with trailer bogies, and articulations floating between wheeled units. Modular design cuts costs for manufacturers and increases configuration options for operators. For example, the *Combino* offers 9 possible configurations (Fig. 2), ranging from a three-car articulated vehicle measuring 19 m in length (running in Nordhausen, Germany and Melbourne, Australia), to a seven-car articulated vehicle 43 m in length long (running in Basel, Switzerland and Freiburg, Germany). Operator compartments, windows and other modular units are assembled on the body frame fabricated from aluminium structural parts or welded steel. This simplifies manufacturing and results in a lighter body. The plug doors create a smooth, stylish exterior.

Citadis in Lyon (Author)

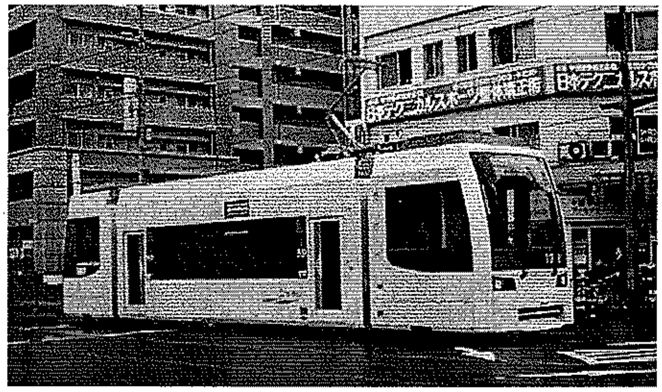
In addition to technical standardization, stiff competition between European manufacturers sometimes results in mergers and takeovers. The above four manufacturers are gradually dominating the market for 100% LF-LRVs, leading to the assumption that standard bodies will become even more prevalent. Bombardier presently makes a number of different drive systems, because of commitments made during mergers, but it intends to standardize on the axle bogies used for the *Flexity Outlook*.

Equipment standardization and modular body designs are driving mass production, which cuts both manufacturing prices and delivery times for 100% LF-LRVs. For example, Amsterdam placed a simultaneous order for 155 cars and took delivery of more than 100 just 1 year later.

Figure 2 Modular Design of *Combino* Trams




ULF tram in Vienna (Author)


Little Dancer A3 in Kagoshima (Author)

Other 100% and 70% LF-LRVs

Some cities are independently developing and running their own 100% LF-LRVs. Vienna has a growing fleet of ultra low floor (ULF) LRVs. Vertically mounted traction motors have lowered the floor to a surprising 205 mm above the ground, and there are plans to put 150 of these units into service soon. Zürich has developed its own low-floor *Cobra* tram with an electric traction motor mounted on the car and a special drive system for the single-axle steering bogie. Six vehicles have been completed.

However, many operators prefer 70% LR-LRVs, because they are cheaper and dependable. Bombardier's recently released 70% low-floor *Flexity Classic* is operating in Dessau and other German cities. Frankfurt and Halle are already operating 100% LF-LRVs and have decided to augment their fleets with the *Flexity Classic*. Alstom's 70% low-floor *Citadis* has been chosen by new transit systems in Montpellier, Orléans and Valenciennes in France, and in Dublin in Ireland. New 70% LF-LRVs are also being developed and manufactured in the Czech Republic, Poland, Spain, and China. Some models have attracted US buyers, partly because of low prices. For example, Portland in Oregon has bought the *Astra* manufactured by Škoda.

LF-LRV manufacturers in Japan

In Japan, many people think that the country's first LF-LRVs were the two articulated vehicles purchased in 1997 by Kumamoto City from the Adtranz/Niigata Engineering joint venture. However, Japan's first low-floor trams date back to 1955 when Class *Deha* 200 cars were manufactured by Tokyu Corp. for Tokyu's Tamagawa Line (today's Den'en Toshi Line) in Tokyo. They had small-diameter (510 mm) wheels on single-axle articulated bogies, permitting part of the floor to be at a surprisingly low (for that time) 590 mm above the ground. The unusual non-standard design led to the model's withdrawal from service in 1969 but if it was still in the public eye today, it would be seen as a pioneer pointing to today's developments.

Most tramway networks in Japan were abandoned after the 1960s, pushed aside by growth in motor vehicle traffic. With no new domestic demand for trams, technical development tapered off until trams were once again viewed positively overseas. In the 1980s, Japanese companies began developing and manufacturing LRVs, but most were exported rather than used to modernize the small domestic fleet. Since the start of these efforts, Japanese manufacturers have built more than 800 LRV sets, but more than 600 were exported to the USA (some being assembled there). These Japanese-built units helped the rebirth of trams in the USA, a fact that is not generally known (Table 2).

But Japanese development of LF-LRVs was delayed by several factors: overseas manufacturers held patents on many of the basic technologies; low domestic demand increased development risks; and Japanese passengers enter by one door and exit by another, paying the fare before exiting—a system that would be inconvenient in a 70% LF-LRV with internal steps. Because of this delay in development, manufacturers imported most major parts for the low-floor vehicles built in Japan. Since 1997, Niigata Engineering has manufactured 100% LF-LRVs for the Japanese domestic market using Adtranz drive units—five went to Kumamoto City, and one each to the cities of Okayama and Takaoka.

This poor development environment changed in November 2000 when the Barrier-Free Transportation Law was passed. This law requires that operators respect accessibility standards when introducing new rolling stock and provides subsidies as tax relief and tax exemptions to compensate for the price difference between conventional cars and the more expensive barrier-free designs. These changes suggest that more low-floor vehicles should be manufactured in Japan. (Domestically built LF-LRVs would make maintenance easier too.) The new regulations and incentives have created expectations that 30% of all rolling stock in Japan will be barrier-free by 2010.

Nippon Sharyo. was the first company to take advantage of the new standards by manufacturing the Class *Mo* 800 LRV for the Minomachi Line belonging to Nagoya Railroad (Meitetsu). The central low-floor between the bogies slopes up to the two ends and wheels of different diameters are used, making the design quite unusual.

Table 2 Japanese LRVs Sold or Exported

Country	Purchaser	Class	Delivered (year)	No. of carriages	Manufacturer
USA	Philadelphia	9000	1980–82	112	Kawasaki Heavy Industries
		100	1980–82	29	
	Buffalo	100	1983	27	Tokyu Corp.
	Boston	3600	1986	50	Kinki Sharyo
		3600	1988	50	
	Los Angeles	100	1988	54	Nippon Sharyo
		100	1994	15	Nippon Sharyo
	Dallas	100	1995	40	Kinki Sharyo
			1999	55	
	Boston	3600	1996	20	Kinki Sharyo
	New Jersey	100, 2000	1999	45	Kinki Sharyo
	San Jose	900	2001	30	Kinki Sharyo
			2003	70	
China	Hong Kong	1000, 1200	1992	30	Kawasaki Heavy Industries
Total				627	

Country	Operator	Class	Delivered (year)	No. of carriages	Manufacturer
Japan	Sapporo City Traffic Bureau	8500	1985	2	Kawasaki Heavy Industries
		8510	1987	2	
		8520	1988	2	
	Hakodate City Transportation Bureau	2000	1993–94	2	Alna Sharyo
		3000	1993–96	4	
	Tokyo Metropolitan Government	8500	1990–93	5	Alna Sharyo
	Tokyu Corp.	300	1999–2001	10	Tokyu Corp.
	Meitetsu	*Mo* 770	1987–88	4	Nippon Sharyo
		Mo 780	1997–98	7	
		Mo 800	2000	3	
		Mo 880	1980	5	
	Toyama Chiho Railroad	*De* 8000	1993	5	Nippon Sharyo
	Man'yo Line	1000	2003	1	Niigata Engineering
	Keihan Electric Railway	800	1997	32	Kawasaki Heavy Industries
	Keifuku Electric Railroad	*Mobo* 2001	2000–01	2	Mukogawa Sharyo
	Hankai Tramway	700	1987–95	11	Tokyu Corp.
	Okayama Electric Tramway	9200	2002	1	Niigata Engineering
	Hiroshima Electric Railway	700	1985	4	Alna Sharyo
		800	1983–97	14	Alna Sharyo
		3500	1980	1	Kawasaki Heavy Industries Alna Sharyo
		3700	1984–87	5	Alna Sharyo
		3800	1987–89	9	Alna Sharyo
		3900	1990–96	8	Alna Sharyo
		3950	1997–98	6	Alna Sharyo
	Iyo Railway	*Moha* 2100	2002–04	6	Alna Sharyo
	Tosa Electric Railway	100	2002	1	Alna Sharyo
	Nagasaki Electric Tramway	2000	1980	2	Kawasaki Heavy Industries Alna Sharyo
		3000	2003	1	Alna Sharyo
	Kumamoto City Traffic Bureau	8200	1982	2	Nippon Sharyo
		8800	1988–93	3	Alna Sharyo
		9200	1992–94	5	Alna Sharyo
		9700	1997–2001	5	Niigata Engineering
	Kagoshima City Transport Bureau	2100	1989	2	JR Kyushu
		2110	1991	3	JR Kyushu
		2120	1991	2	JR Kyushu
		2130	1992	2	JR Kyushu
		2140	1994	2	JR Kyushu
		9700	1998	2	Alna Sharyo
		1000	2002, 2004	6	Alna Sharyo
Total				189	

Note: An articulated tram set is counted as one car.

This design was followed by three low-floor types—known as the *Little Dancer* series—manufactured by Alna Koki (now Alna Sharyo Co., Ltd.). All have conventional axle bogies. The three types are:

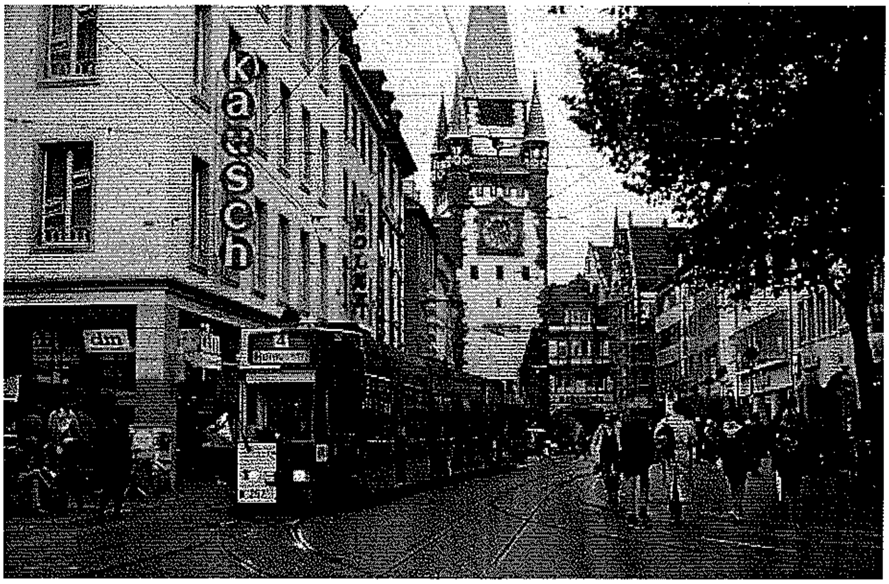
- Single-unit *Little Dancer S* with bogies at extreme ends to permit central low-floor area
- Three-car *Little Dancer A3* with low-floor floating articulation and total of four axles for two cab units (registered as bogie car)
- Three-car *Little Dancer L* with short articulation with axle bogies and small-diameter wheels

Kagoshima City started operating three *A3* vehicles in January; Matsuyama City started operating two *S* cars in March 2002; and Kochi City started operating one *L* vehicle in April. Also in April, Hakodate City took delivery of a refurbished model with a low-floor area between the bogies and internal steps. Nagasaki City started running the three-unit articulated *Ultimate* model in March 2004; the design is an innovative version based on the *A3* and *L* types.

However, all these vehicle designs use existing technologies with a low-floor body placed on conventional axle bogies. Some vehicles do not offer enough low-floor space because of the limitations inherent in the body structure and the overall length. Even so, they have succeeded in the sense that the low-floor sections offer easy access and the vehicles themselves have about the same capacity as a bus, which is considered adequate for a tram in Japan. But these vehicles have not evolved toward the low-floor standards in other parts of the world, where articulated vehicles are common. Structural limitations and the fare collection system do not permit a major reduction in stop times, although boarding/exiting times have been reduced, and these problems remain to be tackled.

However, the future looks bright. Japan's public and private sectors have decided to join forces in developing a narrow-gauge bogie for extra-low-floor LRVs to permit construction of aisles at least 800-mm wide (required for wheelchair users who must move along the aisle to pay the fare when exiting) even when running on 1067-mm narrow-gauge track. The development programme will include work on LF-LRV elements such as ultra-small motors, control and braking devices, and bogie frames. Plans call for the prototyping of bogies that incorporate these elements with a view to launching domestic manufacture of 100% LF-LRVs.

With support from the government, in April 2001, major rolling stock manufacturers joined an association to promote research into bogie technology. The research is focused on development of one type of single-axle steering bogie, and two types of double-axle bogies (one with a hub motor, the other with a beam motor mounted on the side of the bogie frame). There are plans to use the new developments in low-floor articulated vehicles for Hiroshima Electric Railway with a prototype to be built during FY2004. If manufacturing costs are cut, development of 100% LF-LRVs in Japan will encourage more domestic operators to purchase them. Okayama has already taken delivery of Niigata Engineering's 100% low-floor Class 9200, nicknamed *Momo* (peach). So much attention was given to the design of this vehicle that it has a fun-to-ride reputation and shows how cities can use LF-LRVs to improve urban living.



Freiburg Transit Mall (Author)

Rubber-tyre trams

A rubber-tyre tram is a type of hybrid between an LRV and a trolley bus with a guide wheel that guides the tram along a central rail embedded in the right of way. It is being developed in France and takes advantage of the LRT concept while providing a more flexible transit system at lower cost. Power is collected using a pantograph and the controls are automatic. Along some parts of the route, the tram leaves the central guide rail and operates under its own power using a diesel engine to generate electricity. With its modular design and low floor, the tram looks very much like a 100% LF-LRV and has about the same capacity, but the rubber-tyre tram is bimodal and can either follow a central rail or run freely on roads. The extra adhesion provided by the rubber tyres enables it to negotiate urban streets with gradients of more than 10% (100 per mill). France has had considerable experience with rubber-tyre transit systems, notable examples being the subways in Paris and Lyon and the new driverless VAL system. As a consequence, it is well placed to carry on the tradition with rubber-tyre trams. There are three systems using different current collection and guidance methods. The TVR (Transport sur Voie Reservée) system developed by Bombardier has begun operations in Nancy, Caen and Rouen (see pp. 17–20).

LRT Track Modernization

Compared to heavy rail, LRT offers more options when considering where to lay track in urban areas. Indeed, LRT track can be built along almost any city street, and if the streets are too narrow or crowded, etc., the track can be elevated or put underground. Due to this flexibility, LRT track can serve pedestrian districts as a so-called 'transit mall' and many cities worldwide are reporting that transit malls are revitalizing their downtown cores.

LRT has another advantage not enjoyed by similar-capacity automatic guided transport (AGT) systems or monorails—it can be connected to existing railway track to offer through services. This advantage is now being exploited by connecting light rail networks to existing heavy rail lines in order to share the track system by running LRVs on track used previously by suburban and freight trains and by using abandoned rail rights of way.

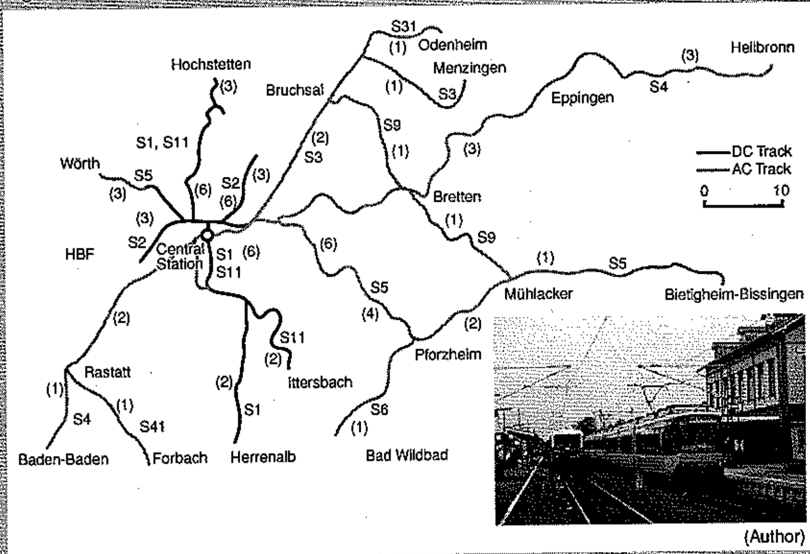
Transit malls to revitalize city centres

Many European and North American cities are revitalizing their centres by constructing pedestrian malls that use nearby city streets as transit routes. Car traffic is prohibited in the pedestrian malls but pedestrians, trams, buses, bicycles, etc., can use them. Americans generally describe these areas as transit malls while Europeans call them pedestrian zones. The problem with the latter term is that it does not distinguish between malls that are served by a public transit system and those that are not.

Transit malls are people-friendly areas for strolling and other urban activities. They are often constructed in city centres that fell on hard times when over-dependence on cars caused road congestion and forced urban functions and businesses into the suburbs. The provision of urban transit into the centre raises the profile and revitalizes it. The transit mall movement began in the 1960s with two successes—Munich Mall (opened in 1970) in Germany and Nicollet Mall (1967) opened in Minneapolis.

Unlike an ordinary shopping mall, a transit

Figure 3 Karlsruhe Transit Network



Note: Numbers in parentheses ( ) show service frequency per hour

mall is developed in tandem with the transit system that will serve it. Development revitalizes not only the city centre but the overall transit system too. Elevators bring customers to the various levels of tall department stores, while the transit system shuttles people horizontally from one end of the mall to the other, creating the atmosphere of a large, unified zone. The transit system provides convenient access to the city centre, reducing the need for parking lots and helping people enjoy city life without worrying about parking fees. The downtown mall distinguishes itself in a way a suburban shopping centre cannot. Transit vehicles are useful not only for transportation but also add atmosphere to the urban landscape.

In Europe and the US, LRT systems are often chosen as the most suitable transportation for pedestrian transit malls; the consensus is that LF-LRVs are easily accessible to everyone, they promote development of pedestrian-oriented urban infrastructure, and they have shown that they can improve urban living. The worldwide LRT trend has caught the Japanese imagination because it suggests how they can regenerate their own city centres; Fukui City is holding public trials with a view to building its own transit mall.

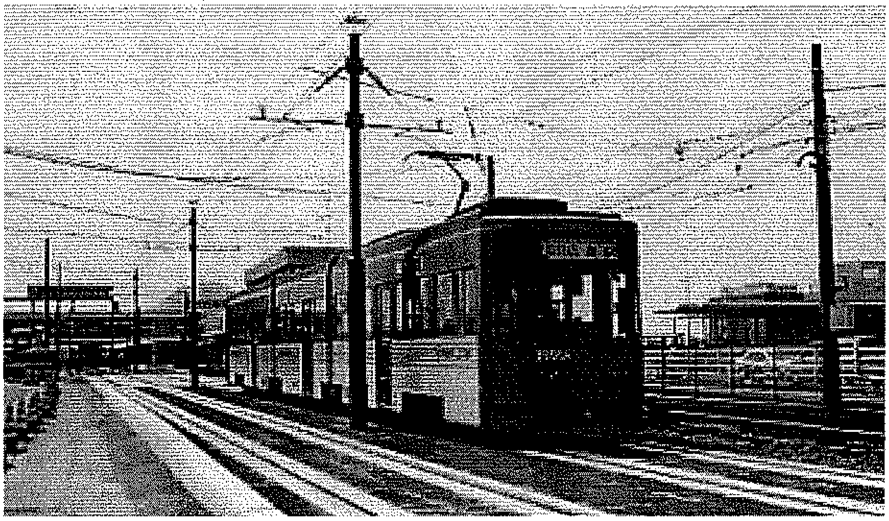
LRT sharing track with heavy rail

The transit system in Karlsruhe, Germany, has become a test case, proving that a tram network can be linked successfully to an existing railway network to provide through services. Development (since 1992) of rolling stock that can run on both AC and DC power made it possible to run through services between the tram network and the Deutsche Bahn AG (DB AG) heavy rail network. One result was a dramatic increase in ridership. The longest line stretches 124 km from Heilbronn through Karlsruhe to Forbach. Japan has also had success running through services between heavy rail and tram networks and the cities of Gifu, Fukui, Kyoto and Hiroshima currently operate such systems. However, Karlsruhe is the world benchmark, because the tram network expanded its service area and offered through services to the city centre at more frequent intervals with fewer changes from one line to another by taking over the DB AG suburban operations. This flexible approach provided vastly improved services at a relatively low cost and became a model for all cities on how to revitalize rail services. Some 7000 trackside Park & Ride encourage residents to use public transport and enjoy the advantages of both road and rail modes. Another result is that the city centres have remained economically healthy, with less pollution and motor vehicles.

Some problems needed to be resolved before launching the through services. First, the DB AG catenary uses 15 kVac at 16.66 Hz, while the urban tram system uses 750 Vdc. Second, the government regulates the two networks differently, enforcing EBO standards for construction and operation of railways, and BOStrab standards for tramways, resulting in different car structures, signalling equipment, and performance criteria. Third, it was technically difficult to reduce the size of transformers for low-frequency AC power transmission. Operations became possible after development of dual-voltage vehicles with small, light AC/DC transformers satisfying space and weight restrictions on trams (Fig. 3).

The January 1996 German railway reforms transferred jurisdiction from the federal to the state level for granting licences to operate short-distance urban passenger services, and for provision of subsidies. This made it easier to apply the Karlsruhe model elsewhere in Germany, starting with Saarbrücken in 1997 and Chemnitz in 2002. Kassel and a number of other cities are planning similar projects.

In France, Strasbourg and Mulhouse plan to introduce a so-called *Tram Train* based on the Karlsruhe model. Other shared-track projects will offer through services linking electrified LRT networks with non-electrified railway tracks, using light diesel railcars travelling into city centres, or hybrid rolling stock with a diesel generator. As a first step, the Siemens' *Combino Duo* with a 180-kW diesel engine is scheduled to start through services at Nordhausen in Germany using the tracks of Harz Railways (HSB), which is famed for its steam operations.



Grassy right of way in Hiroshima (Author)

Blending in with urban landscape

Strasbourg in France decided to run uniquely designed LRVs that would become a symbol for the city and the strategy has successfully improved the city's image. Today's transit systems are expected to blend in with the surrounding cityscape and add to its aesthetic appeal. Cities planning LRT systems sometimes face opposition from residents who fear that the catenary will be an eyesore.

There are various ways to configure the catenary and supporting poles so that they blend in with the urban landscape. Use of centre poles reduces the number of poles, which can also be erected among trees. On narrow streets, the catenary can be strung from buildings and insulated wire eliminates ceramic insulators.

Going one step further, the catenary can be eliminated by using a ground-based collection system like the LRT launched by Bordeaux in December 2003. Such systems were used by trams years ago in Washington, London and other cities. The various available technologies are promoting LRT acceptance in historic city centres where appearance is important.

Noise pollution is another growing issue; LRT noise emissions are much lower than older tram systems due to new resilient wheel designs and improved tracks. Noise can also be reduced by grassing over the right of way as more cities are doing. For example, Zürich in Switzerland reports that a grassy right of way reduces noise levels by 10 dBA, improving the environment of residential neighbourhoods. In Germany, Infund has developed a system of placing rails over excavated depressions and fastening with poured resin. This system has been adopted in a number of places and further reduces noise and vibrations.

Grassy rights of way are also attractive. In places where they extend laterally into parkland, they form a natural carpet that accentuates the park. Since 2002, the Japanese cities of Hiroshima, Kochi and Kumamoto have grassed some sections of their rights of way for trams.

Modernization of Operations

To maximize its role, LRT must be integrated within the overall transit system. This can be achieved by developing a joint network with existing railways and bus lines, by using Transportation Demand Management (TDM) strategies that encourage Park & Ride and other links with motor vehicle traffic, and by establishing convenient fare-payment systems. In Europe, such methods have greatly contributed to improving the urban fabric and increasing LRT ridership.

City residents favour LRT systems only if they offer relatively high schedule speeds and reliability. Schedule speeds in the West are close to 20 km/h even for LRT systems sharing the road with other traffic (17.4 km/h in Grenoble; 19.2 km/h in Karlsruhe; and 21.1 km/h in Strasbourg). Japanese trams generally average only 10 to 15 km/h, making them unable to satisfy today's urban transit needs.

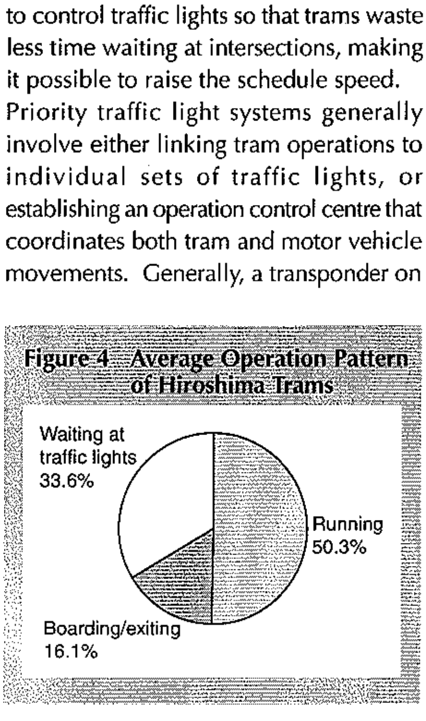
Japanese tram operators aim to raise average schedule speeds to the 20 km/h achieved in other countries but they cannot do so unless the length of times for stops at traffic lights and when boarding/exiting are shortened. Trams in Japan are actually stopped for almost half the travel time (Fig. 4). It is generally agreed that raising schedule speeds requires trams to run on their own right of way with priority at traffic lights and a fare system with no payment when boarding or exiting.

Priority at traffic lights

One way to reduce travel time is to give trams priority at traffic lights. A number of different systems have been introduced to control traffic lights so that trams waste less time waiting at intersections, making it possible to raise the schedule speed.

Priority traffic light systems generally involve either linking tram operations to individual sets of traffic lights, or establishing an operation control centre that coordinates both tram and motor vehicle movements. Generally, a transponder on

Figure 4 Average Operation Pattern of Hiroshima Trams



the tram activates the traffic light, extending the green time or shortening the red time. Some buses have such a system too.

If an operation control centre performs coordination, each tram is located using either a global positioning system (GPS) or ground coils, etc. Wireless signals from the GPS, etc., are transmitted to the control centre, which then controls the traffic signals to give the tram priority. In Zürich, data transmission devices are installed along routes and location code receivers are installed on trams. When a tram passes by, the ground-based device sends a signal via the onboard receiver to a tram control device at the operation control centre. The control centre uses software to calculate the optimum flow pattern at specific intersections and for the general traffic, taking into account the current road traffic information. Trams approaching a traffic light are given priority within these parameters. Tram schedules are input into the control equipment memory and this data is used to compare actual tram locations with scheduled locations. The difference is displayed at the control centre and on onboard monitors, making it possible to bring operations closer to the schedule.

A number of German cities are attempting to optimize traffic flow through information from operation control centres. One example is the Stuttgart Transport Operation by Regional Management (STORM) project in Stuttgart. The aim of this and other such projects is to develop comprehensive operation control systems that give priority to public transport and reduce car traffic.

But LRT vehicles cannot be given priority at all intersections. For example, tramways almost always have to cross major roads and national highways somewhere; in some cases they cross through tunnels, underpasses, etc.

Wireless transmissions

Operation control centres can also use tram location data to control other tram operations and provide information to passengers. In Amsterdam, tram locators are installed along all routes. They transmit wireless signals to the operation control centre where the location data is displayed for all trams. The data is used to give schedule-related instructions to tram drivers and to provide information on departure times at major stops.

Location systems give European LRT operators the opportunity to provide information at stops. The information is displayed on LED panels, and includes the arrival times and destinations of approaching trams. Wireless transmissions from the operation control centre send the data to LED panels along the routes. Arrival data is also transmitted to tram cabs so that drivers can coordinate departure times at transfer terminals shared by buses and LRT vehicles.

Coordination with other transport modes

The biggest difference between tram/LRT systems and other forms of urban transport is that the former are a key urban transit mode in the backbone of the overall network. Buses are feeders for the tram system and the locations where the two systems intersect are passenger transfer points. Suburban Park & Ride facilities provide a link between the car and LRT because free parking encourages people to leave their cars in the suburbs and ride the rails to the city centre.

Coordinated fare systems also promote transit use. In Germany and other countries, transit operations are integrated and joint fare and zone systems are established to offer convenience and easy recognition. To encourage people to choose rail over road, some Japanese operators have recently introduced a reduced-fare pass system, billed as protecting the environment. These and other measures are boosting public transport ridership and reducing car use.

Fare collection systems

In Japan, low schedule speeds prevent trams from becoming the cornerstone of any urban transit system. The fare collection system is one major reason for sluggish speeds. In most cases, the driver verifies that each passenger has paid the fare. The reason is to ensure company profitability and fairness to all passengers, but the time-consuming process keeps trams stopped for considerable periods, increasing travel time.

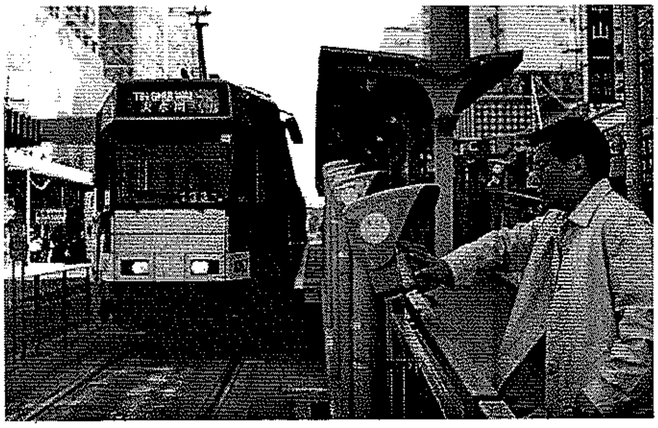
In the West, the driver is generally not involved in fare collection at all. Passengers are responsible for paying their fare, buying the ticket at the stop or on board and presenting it at the designated place. If the ticket has no date and time stamp, they are responsible for getting it stamped. To inhibit fare dodging, ticket inspectors make spot checks and violators must pay a fine that is many times more than the cost of a regular ticket.

This system began in Europe in the 1960s. It lets passengers board and exit from any door, which also increases schedule speed. Even a long articulated LRT vehicle requires only one employee, reducing wage and equipment costs, and increasing profitability.

Tramways still operating in North America used to have a fare box and an employee verifying payment, but since the introduction of LRT systems in 1978, they have switched to the European system. The motive was putting passenger convenience ahead of operator profitability, since convenience attracts more passengers and contributes to urban renewal. In the early stages, there were fears that fare dodgers would increase and revenues would fall, but stringent random inspections has kept the rate low. This encouraged other tram companies to introduce the new system as a way to cut wage costs. San Francisco's Proof of Payment system is a case in point.

In the West, it is felt that offering greater passenger convenience is more important

Bus & Ride in Portland (Author)



Octopus non-contact card fare payment in Hong Kong (Author)

than preventing a slight drop in revenues. In any case, the revenue drop may be compensated for by the fines. The priority is on lower equipment costs, shorter stops, fewer delays and a smaller wages burden. Meanwhile, governments have tended to promote low-fare policies rather than profitability, to encourage the use of public transport and reduce car traffic.

Japan stands out in contrast; transportation companies are expected to make a profit and the principles of fairness for all passengers and respect for the fare system have created a perceived need to verify each passenger's fare payment. Another factor is that fare dodgers pay a fine that is no more than twice the regular fare. The low fines are regulated by law, making it difficult to adopt an honour system even with spot checks. Fines would have to be raised to Western levels, but this would require legal changes. This environment makes it difficult to change.

One solution is greater use of non-contact IC cards. However, information technology (IT) cannot solve the inherent problems of the honour system, because possession of a card or proof of fare payment would still have to be verified. Hong Kong launched its *Octopus* non-contact IC card system in 1997, but continues with rigorous on-board spot checks to promote use of cards and inhibit fare dodging.

The non-contact IC card might not be a final solution to Japan's fare collection problem, but it is one way to raise schedule speed. The non-contact *Setamaru* IC card introduced in July 2002 on Tokyu's Setagaya Line in Tokyo encourages use by awarding points that can be used to travel for free on a subsequent journey as well as discounted travel on Saturdays and Sundays. If other companies introduce such incentives, cards would become more popular, and if the cards could be used on other operators' networks, the city transit system would become even more convenient. Japan's fare collection system may evolve to take advantage of this potential, but will probably not adopt the honour system used in the West.

The Future

It is important to realize that worldwide interest in trams and LRT systems springs not from a desire simply for modern tram systems but from a general consensus that LRT systems open the door to urban renewal. Although such systems can become an essential part of the urban fabric, like roads, parks, water, and telephone and electric lines, there is a limit to what companies can do on their own to use LRT systems to promote sustainable urban renewal. Responsibility for constructing and improving LRT systems is being assumed by both the public and the private sectors, with financial assistance from national and local governments to support both construction and operations.

In Japan, tram systems (especially vehicles) are being modernized. Increased interest has prompted more than 70 regions to study the feasibility of constructing their own LRT systems. However, only a few cities have any chance of reaching the construction stage, mainly because cars are still considered to have priority on city streets. It is difficult to form a consensus regarding securing land for tram rights of way; urban transit is expected to make a profit and the capacity of LRT systems is limited, making it difficult for the public to differentiate between LRT systems and buses.

These obstacles must be removed before Japanese cities start building advanced LRT systems and that day is probably still far off. ■

Shigenori Hattori

Mr Hattori is General Manager of Public Relations at the Nagoya/Boston Museum of Fine Arts. He graduated in 1976 in Economics from Toyama University before joining Nagoya Railroad where he worked for 25 years in the public relations and personnel departments. He was a member of the Nagoya City Transport 21 Working Group and the LRT Systems Technical Specialist Working Group.

Sakai City LRT Plan

City Department of Construction and Urban Planning

Introduction

Sakai City is in the Kansai district south of Osaka. In Japan's medieval period, it was called the city of freedom and was a thriving base for overseas trade. It merged with Mihara Town in February 2005 to become Japan's 15th city designated by government ordinance in April 2006 with a population of about 830,000.

The recent urban structure has formed mainly in the north–south axis along the flow of people and goods towards central Osaka, lessening Sakai's sense of individuality as an independent city. Against this background, the city is aiming for urban development as a nucleus for southern Osaka Prefecture by building communities of distinctive character that make use of historical cultural assets, such as the Mozu tumulus cluster and Nintoku-ryo tumulus, and traditional industries.

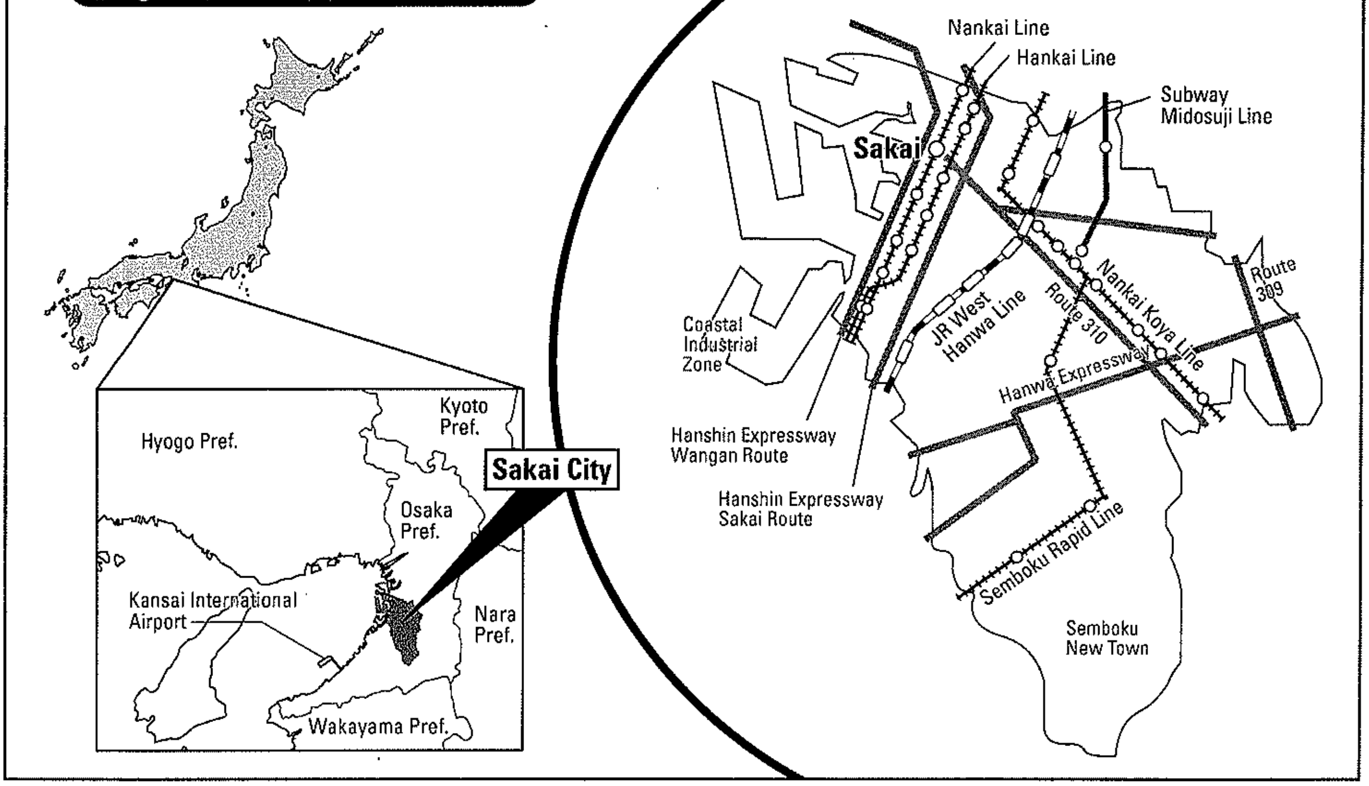
LRT Plan

Current railway network

Six routes currently operate within Sakai City—Nankai Electric Railway's Nankai Line, Hankai Line, and Koya Line, and JR West's Hanwa Line, Midosuji subway and Semboku Rapid Railway (Fig. 1). All run north–south to connect Sakai City and Osaka City. Therefore, construction of an east–west railway transport axis supporting an independent urban sphere for Sakai City has long been a subject of popular conversation.

In addition, the only tramcars remaining in Osaka Prefecture run on the Hankai Line and Uemachi Line operated by Hankai Tramway. Citizens have enjoyed the familiar Hankai Line for nearly 100 years following the start of service between Ebisucho (Osaka City) and Oshoji

Figure 1 Location of Sakai City



(Sakai City) in 1911. However, due to the rapid spread of motor transport in the late 1960s and changes in the transport environment, the current number of rail passengers in Sakai City has fallen to around about 15% of the peak in 1961, and promoting rail usage is an important factor in assuring continued service.

Feasibility studies

There have been plans for an east–west railway in Sakai City for quite some time. In 1920, Kinki Nippon Railway obtained a licence for a section between Sakai and Furuichi. Then, in 1961, Nankai Electric Railway applied for a licence between Sakai and Yao. However, neither of these plans came to fruition.

However, development of the Osaka Bay area increased from 1990, leading to requests for transport access to the coastal area. Taking advantage of this momentum, the Council for Sakai Public Transport comprised of leading academic and business figures was established with the aim of building an east–west railway (Fig. 2). In 1994, this Council issued the report entitled 'The Proper Form of Railway Construction,' which supported the need for an east–west railway. Subsequently, Sakai City worked to enhance its project promotion system, established a railway construction fund, and promoted studies toward building an east–west line using a mini-subway or new transport system, etc.

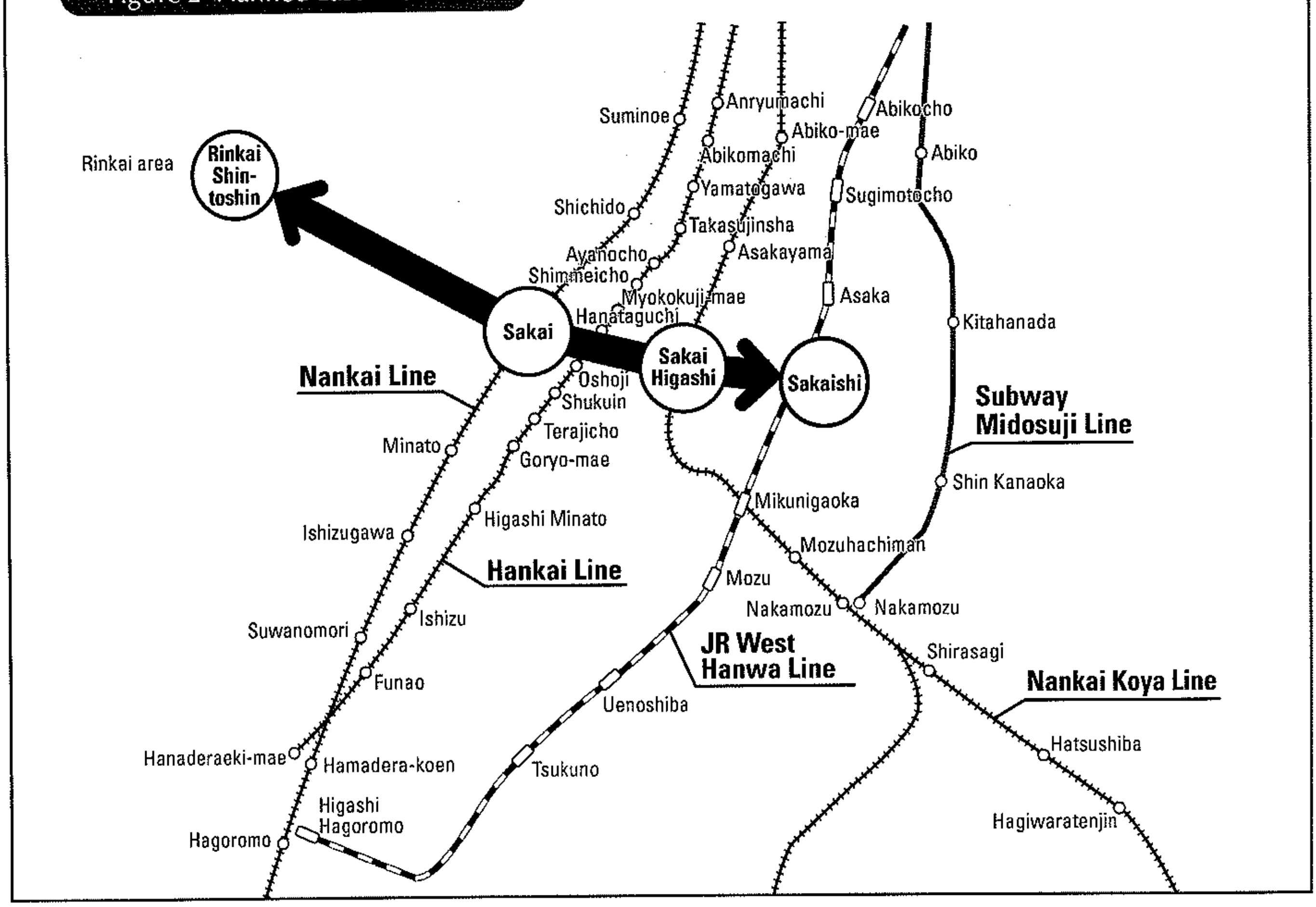
In 2003, the Council was reorganized and suggested the feasibility of introducing a light rail transit (LRT) system for the east–west line. Compared to subways and other new transport systems, LRTs are more barrier-free and people-friendly, have superior scenic and environmental functions, and lower construction costs. Therefore, further studies were conducted from various perspectives based on these and other features.

In addition, the Council for Kinki Regional Transport (an advisory body to the Kinki District Transport Bureau of the Ministry of Land, Infrastructure and Transport) issued a report in October 2004 on the 'Desired Form of Transport in the Kinki Region.' It included the item 'Sakai City east–west railway: Sakai No. 2 section–Sakai–Sakai Higashi–Sakaishi, 8.3 km' in the LRT section.'

Construction goals

By connecting with major stations on the north–south railway lines, the east–west LRT aims to reinforce the east–west transport axis; correct the north–south transport bias; promote community building along the line; and create Sakai City's own independent urban sphere.

Figure 2 Planned East–West LRT



Route

Table 1 summarizes the planned route. Although various possible route alignments were examined, the section between the Rinkai area and Sakai Station is now focused on the Sambo route (Fig. 3), which is expected to have the highest demand based on current wayside land usage and future community building efforts. The section between Sakai Station and Sakai Higashi Station is centred on the Oshoji route, because it is the central axis of the urban district and considering the effects of operations on automobile traffic. The section between Sakai Higashi Station and Sakaishi Station requires further study of the interchange with the Nankai Koya Line crossing in the north–south direction, and also community building trends east of Sakai Higashi Station (Fig. 4).

Early Service Start and Construction of Urban Transit System

Need for early service start

The best situation would be a simultaneous service start on all sections from the Rinkai area to Sakaishi Station. However, to revitalize and create an attractive urban scene, Sakai municipal government wants to start services between Sakai Station and Sakai Higashi Station (1.7 km) as soon as possible.

In addition, ensuring smooth connections with existing railways and using feeder buses will create a convenient urban transit system centred on the LRT, increasing the number of trips to the urban district and activating business prosperity (Fig. 5).

Table 1 Planned East–West LRT Route

Interchanges	Sakai Station on Nankai Line Sakai Higashi Station on Nankai Koya Line Sakaishi Station on JR West Hanwa Line
Statistics Length: Demand density: Candidate route:	 8.3 km 23,156 passenger-km Sambo route and Oshoji route (Fig. 3)

Figure 3 Route Studies

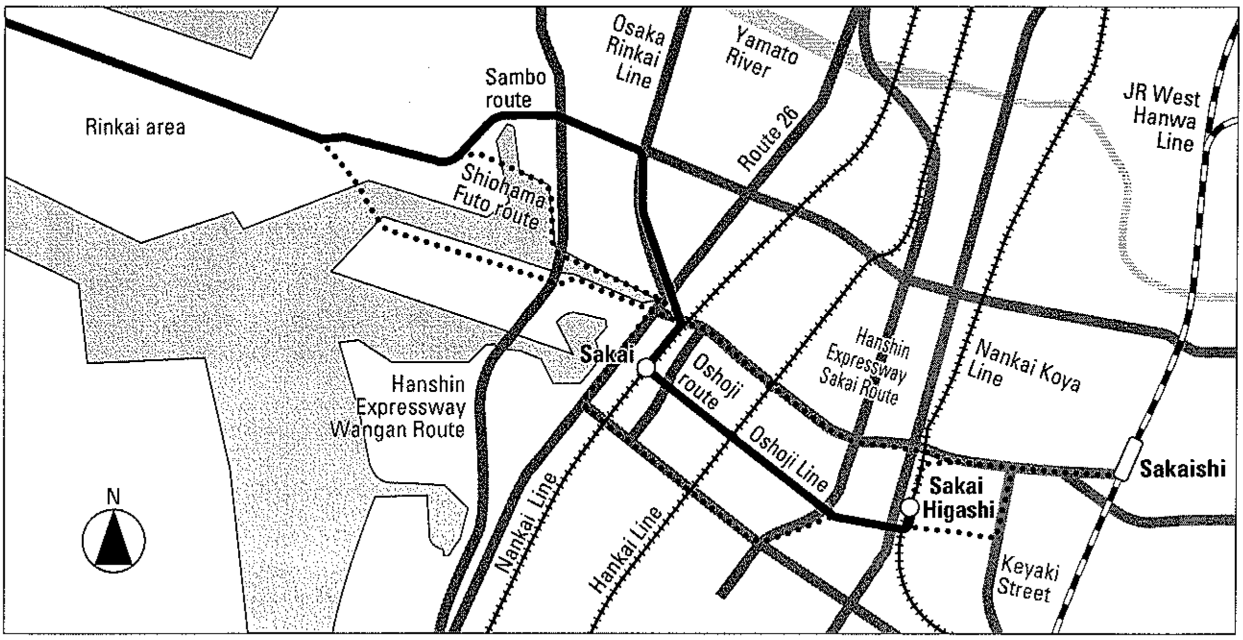
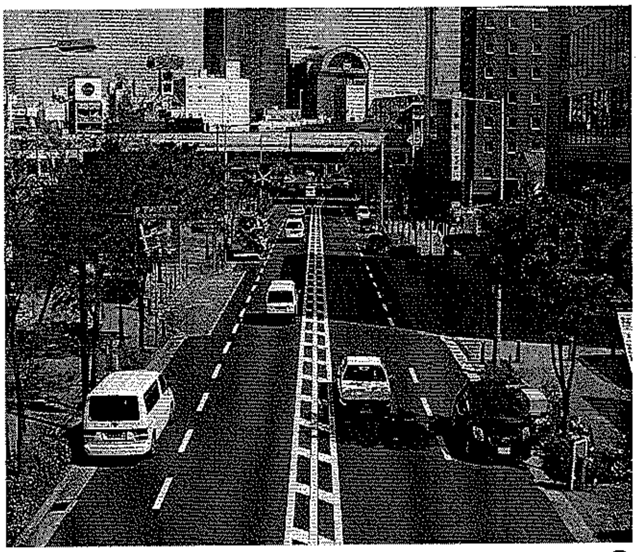
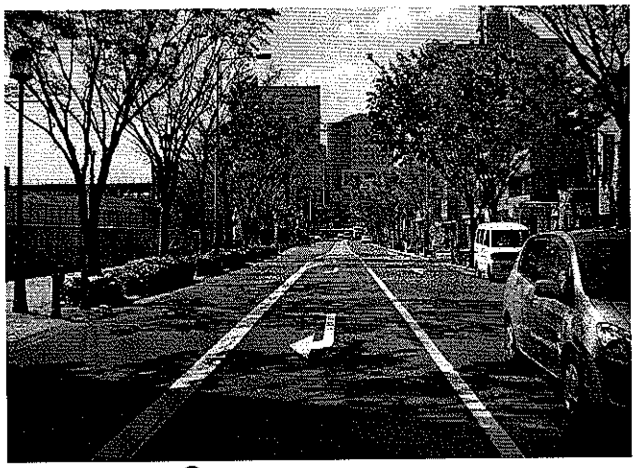


Figure 4 Map of Photograph Locations

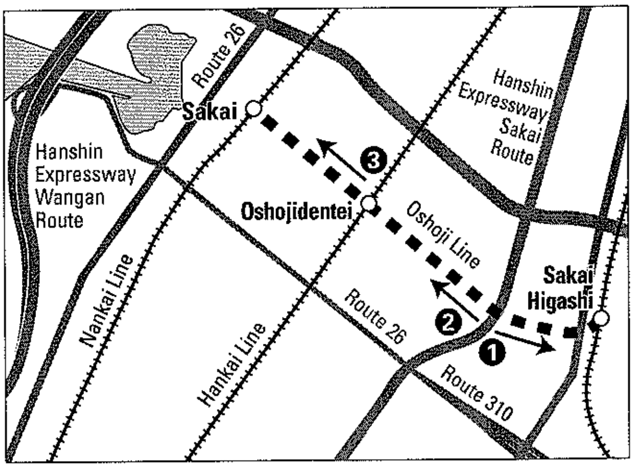
Oshoji Route at ❶



Oshoji Route at ❷



Oshoji Route at ❸



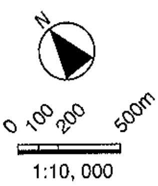
(Photos: Sakai City Department of Construction and Urban Planning)

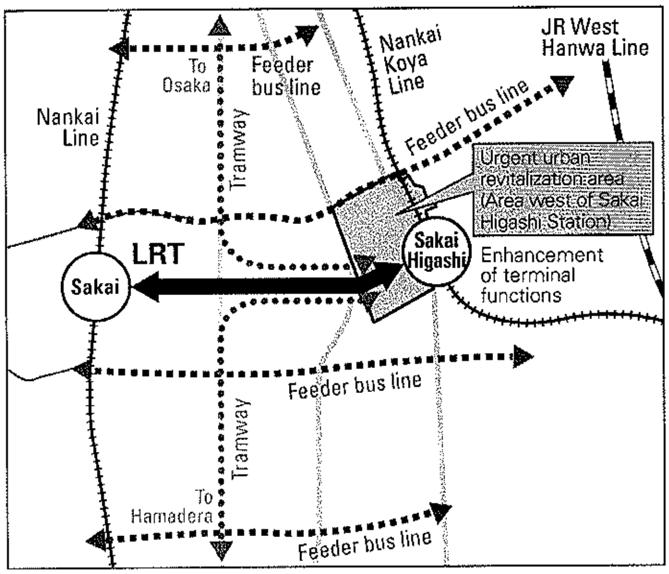
Figure 5 Convenient Urban Transit System

◎ **Need for early service start**

* Need for vitalization of urban district

LRT will:
- Improve urban trips
- Promote community vitalization

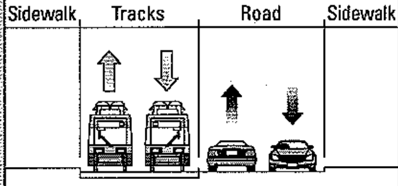
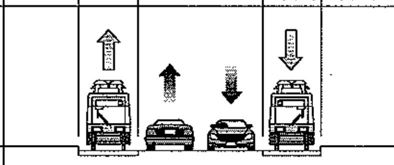
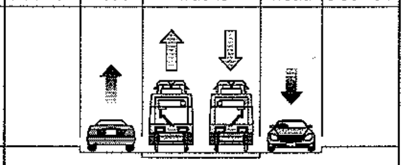




In addition to LRT introduction:
- Smooth connections at railway stations
- Through operations with Hankai Line
- Introduction of feeder bus lines, etc.

Construction of convenient urban transit system

Table 2 Position of LRT on Road

LRT Position	Verge	Outside	Centre
Outline drawing	Sidewalk, Tracks, Road, Sidewalk 	Sidewalk, Tracks, Road, Tracks, Sidewalk 	Sidewalk, Road, Tracks, Road, Sidewalk 
Characteristics	• Train runs next to sidewalk, so passengers can get on and off directly • Care required when parking on LRT side • Care required when loading and unloading goods along road on LRT side	• Passengers get on and off directly from sidewalk • Care required when parking on LRT side • Care required when loading and unloading goods along road	• Easy loading and unloading of goods along road • Easy parking • Passengers must cross road to get on and off LRT

Position of LRT on road

The impact of the LRT on other road users, especially cars, is being studied with focus on the road centre and verge (Table 2).

Project scheme

Overseas, LRTs are often constructed with public funds. However, the basic policy in Japan is to construct railways by repayment of construction costs. Moreover, the Railway Business Law forbids vertical separation of construction and operation, so building an LRT using public funds to support profitable operation by the private sector is an issue.

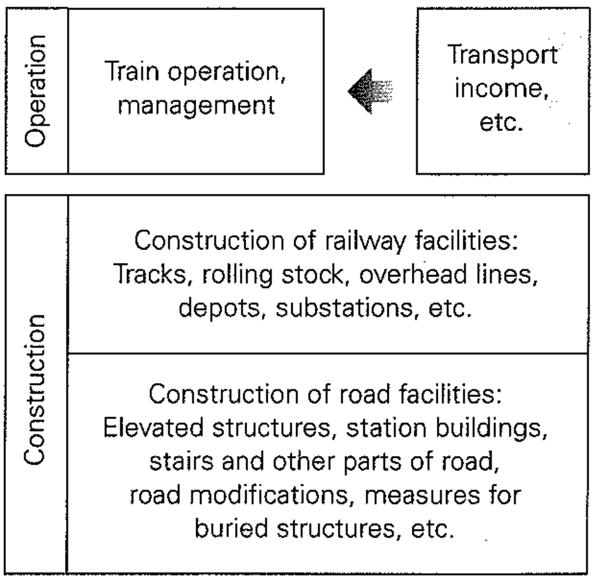
Therefore, funding studies of this scheme have centred on a vertically separated public private partnership (PPP). Under this method, construction costs for road facilities, such as road modification works and tram stops, and for railway facilities, such as rails, rolling stock and depots, are borne by the public sector (city or other public body), and the railway is then managed and operated by a private sector. In addition, public proposal is being considered as a method for deciding the operator (Fig. 6).

Links with Hankai Line

About 7.9 km of the Hankai Line tramway (14.1 km) between Sakai City and Osaka City is within Sakai City and the Hankai Line also crosses the Uemachi Line (4.6 km), another tramway in Osaka City.

Building the first 1.7 km of the east–west LRT as planned would create a tramway network with the Hankai and Uemachi lines, permitting through operation on each line and enhancing the overall transport effect.

Figure 6 Project Scheme



Future Approaches Supporting East–West LRT

Education and consensus building

One issue for trams in Japan is their strong negative image as an outdated and inconvenient transport mode, because the difference between LRTs and tramcars is not clearly understood. In addition, it is necessary to build a popular consensus among wayside residents and other citizens in favour of building the LRT.

Sakai City is working to provide easy-to-understand explanations about the LRT's convenience and environmental friendliness and the role it will play in community building. These activities include holding local lectures and sending speakers in response to requests from various groups. In addition, the Sakai LRT Research and Exchange Center was established as a joint project with Osaka Sangyo University in September 2005. It is conducting various educational activities and promoting research and exchanges on building attractive and prosperous communities.

Study of public transport policies integrated with LRT

Public transport policies integrated with the LRT are being studied to create a pedestrian-centric transit system in the urban district. Subjects include a simple tariff and fare collection system, easy transfers with other transport modes, barrier-free through operation with the Hankai Line, smooth movement in the urban district, and on-time operation.

Integration with community building

Integration with surrounding communities must be studied to aid revitalization. In addition to building the LRT, integration includes strengthening commercial and business functions, establishing a government and municipal office zone, making use of existing historical and tourism assets, constructing tourism and cultural centres, promoting redevelopment projects, and promoting facilities that attract customers.

Securing finances

The guiding principle for building new railways in Japan uses the build, own and operate (BOO) method. However, declining population and passenger levels make it difficult to secure private funding for constructing new lines. In these circumstances, the importance of public transport is being emphasized based on environmental friendliness, convenience for an aging society, and reversing inner city decline. Following successful introduction of LRTs in Europe and the USA, in FY1997, the Japanese Ministry of Land, Infrastructure and Transport established a programme to make space on roads for tramways, and the LRT Infrastructure Project in 2005. However, adoption of novel funding measures, such as issuing of bonds by local municipalities to alleviate the capital burden on operators, has not been approved yet, explaining the lack of progress in public funding of LRT construction.

Future measures, such as vertical separation of infrastructure and operations, PPP funding, novel financial assistance, etc., still need discussion.

Conclusion

Increasingly serious issues such as environmental degradation, global warming, aging societies, etc., are forcing us to refocus our cities and lifestyles based on a modal shift from the automobile to convenient and efficient public transport. Experience in other countries such as in Europe and the USA shows that LRTs are people- and environment-friendly and contribute to revitalization of communities. Sakai City aims to enhance the overall attractiveness and vibrancy of its community. This includes using public transport facilities to access its many historical and cultural assets, such as temples and shrines, ancient burial tumulus including the Nintoku-ryo tumulus (circa 400AD), tourism centres, and other facilities.

In the future, the city intends to facilitate better east–west traffic flows by building an LRT that will connect with other transport networks in the region. Reaching this goal requires consensus building with citizens, discussions between transport operators and related parties, and novel funding methods, such as vertically separated PPP methods.

Sakai LRT Research and Exchange Center

Organizer:	Osaka Sangyo University
Established:	September 2005
Hours:	11:00 to 17:00 (closed Saturdays, Sundays, Public Holidays)
Address:	1-10, Kainochohigashi 2-cho, Sakai City (in Yamanoguchi shopping district)
Director:	Professor Masahiko Tsuchihashi (Faculty of Human Environment, Department of Urban Environment)
Activities:	1. Introducing LRT 2. Performing LRT-related research 3. Recording promotion of east–west LRT 4. Holding exchange activities about LRT and community building 5. Promoting continuance and vitalization of Hankai Line

New Urban Railway Projects

Man'yo Line—Revitalized Tramway

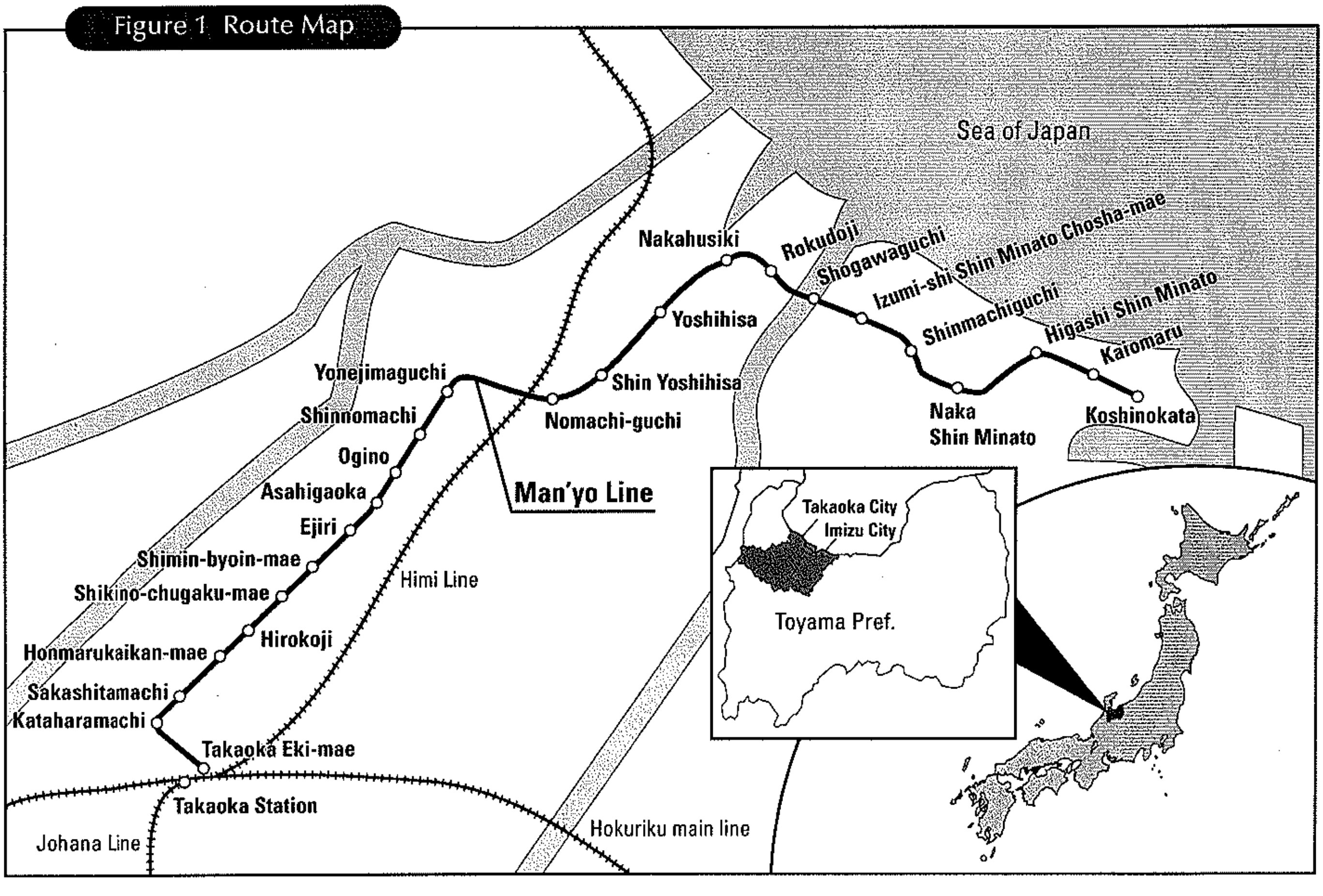
Introduction

The Man'yo Line (12.9 km) is in Toyoma Prefecture in central Japan and connects Takaoka City with the Shin Minato district of Imizu City (Fig. 1). Although part of the suburban section is classified as a railway line, the operations and rolling stock are typical of a tramway. The single tramcars carry about 1.13 million passengers annually along the extremely attractive route with constantly changing scenery for about 40 minutes through the urban district, industrial zone and old townscape, along the harbour, and across a bridge at the mouth of the Sho River.

The Man'yo Line is one of the smallest tramways in Japan and, like other local railways, it was negatively affected by the rapid growth in private automobile ownership during the latter 1960s, as well as by more recent urban depopulation along its route. This caused a decline in the number of passengers to less than 25% of the peak in the late 1960s (4.75 million). The national government's decision to remove deficit subsidies from FY1997 forced the line to consider closure.

However, although railway lines were being closed elsewhere, the local inhabitants expressed their opinion that the 'The Man'yo Line is indispensable' so a citizen-

Figure 1 Route Map



wide agreement uniting trackside residents, government, and financial and political circles was reached in April 2002 with the aim of reviving the line as Japan's first third-sector line.

People Power and Government and Operator Approaches

This unified demand by citizens, government and operator to continue operation of a small tramway was a completely new approach for Japan and the greatest factor in deciding to continue was people power. As the debate over continuation or closure was building, The Rail & Road Transit System, Amenity and Community Design Association of Takaoka (RACDA Takaoka) was established in 1997 to promote the need for the Man'yo Line from the citizens' viewpoint. This association did not run a traditional 'ride-to-keep' campaign, but instead formed a campaign caravan, which visited various locations to broadly appeal the need for public transport, including the Man'yo Line; fundraising collected ¥100 million in seed capital to start the new company. Instead of leaving things to the government, the people strongly promoted the need for railways by thinking, providing funds, and acting on their own initiative.

Series 7000 running through city street decorated for *Tanabata* (Weaver Star) festival (Man'yosen)

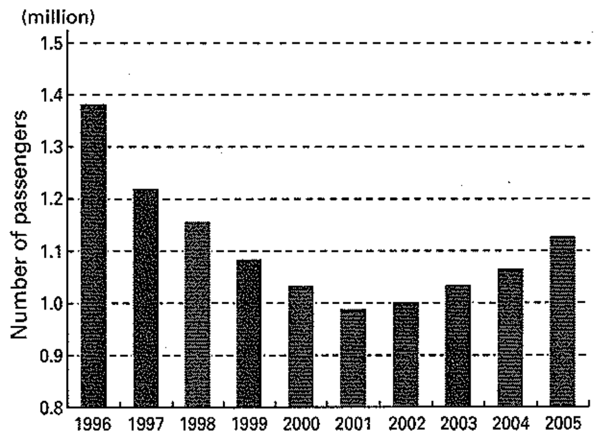
Series MLRV1000 *AI-TRAM* (Man'yosen)

Motivated by the active efforts of the citizens, the government also adopted a number of new measures. One was to clearly position the anticipated ¥580 million yen deficit expected in the 10-year period after the new company started as 'maintenance costs for necessary social capital.' As a consequence, the two trackside cities agreed to an annual line subsidy of up to ¥60 million. This novel idea overturned the conventional thinking that operating deficits are the operator's responsibility.

In addition, the Subsidy Program for Railway and Track Modernization was used to improve the aging tracks and rolling stock to avoid undue burden on the operator. Under this programme, Toyoma Prefecture provided a local government cooperative subsidy equal to the subsidy received from the national government (between 33% and 20% of the project cost). The two trackside cities then subsidized the remainder that would normally be borne by the operator. This helped promote service improvements, such as introduction of new low-floor cars, which in turn helped increase the number of less-mobile and elderly passengers.

Having been the recipient of this people power and government support, the third-sector Man'yosen Company operating the line also took novel measures unhampered by conventional railway business wisdom to improve its revenues. For example, it holds joint trackside events with the Man'yo Line Countermeasures Council, RACDA Takaoka and other support groups to create irregular extra passenger demand. It has created an annual student season ticket that generates student traffic out of term time, as well as a ride-and-cycle system that loans recycled bicycles to commuters at no charge. It has also created a discount system through tie-ups with trackside tourist and other facilities, and has resolutely reduced fares by an average of 18% in the second year of service, etc. In addition, thorough efforts have been made to reduce expenses by eliminating waste and cutting personnel costs.

Figure 2 Trends in Passenger Numbers



Passenger Numbers Recovering and Revenues Increasing

The number of Man'yo Line passengers has been recovering gradually as a result of these unified efforts by the citizens, government and operator (Fig. 2). It recovered from 988,000 passenger journeys in FY2001 to 1 million in FY2002 when the line was restarted as a new company, and has increased steadily since then to more than 1.13 million journeys in FY2005. In addition, the operating deficit of more than ¥70 million has improved to ¥53 million in FY2005.

Especially noteworthy is how a small local private operator faced with a severe business environment has managed to increase its number of passengers for 4 years in succession. There are now great hopes that the revitalized Man'yo Line will help support revitalization of trackside communities and the operator is continuing to make even greater efforts to meet these expectations.