Examples of Benefits of Underground Urban Public Transportation Systems

ITA Working Group on Costs-Benefits of Underground Urban Public Transportation

Abstract—*As the world's population has increased, particularly in urban centers, cities have turned increasingly frequently to underground transportation systems to help solve problems of traffic congestion, noise and air pollution, and densely built-up urban areas. This report briefly considers the issues involved in planning an urban underground transportation system, and then presents examples of such systems now in operation in ten different countries. These countries have used a wide variety of approaches and methods in making decisions regarding the planning and construction of underground transportation systems. Also included is an appendix describing cost-benefit studies concerning proposed transportation tunnels in the United Kingdom.*

Résumé—*Au fur et à mesure que la population mondiale a augmenté, en particulier dans les agglomérations urbaines, les villes se sont de plus en plus souvent tournées vers des systèmes de transport souterrains, ceci afin d'aider à résoudre les problèmes de circulation, de bruit, et de pollution atmosphérique, et des zones urbaines à forte occupation des sols. Ce rapport traite brièvement des thèmes impliqués dans la conception d'un système de transport souterrain, puis présente des exemples de tels systèmes maintenant en service, dans dix différents pays. Ces derniers ont utilisé des approches et des méthodes très variées pour prendre les décisions concernant leur conception et leur construction. On a décrit en annexe des études de coût sur différents tunnels de transport au Royaume-Uni.*

Introduction

Worldwide use of the subsurface has increased substantially over the last two to three decades, particularly with regard to urban public transportation systems (see Table 1). More and more often, the lines of these systems have been placed underground, and the construction volume is still growing: subways are in operation or under construction in nearly 80 cities and metropolitan areas around the world. Prior to the 1950s only in cities with far more than one million inhabitants was there the necessity of using the subsurface for railway transportation systems. Since then, however, a number of transportation systems for cities with less than a million inhabitants have been forced to go underground.

In many cities the subway systems carry millions of passengers per day; it is totally inconceivable that public life could go on without them. The necessity of building new rapid transit systems and extending existing systems will continue to grow in the future as the world's population increases. The number of cities with more than one million inhabitants will increase from about 270 today to more than 400 by the end of this century.

There are two main aspects to the arguments for using the subsurface for transit systems with high capacities, high speeds and a high level of safety:

(1) Urban public transportation needs improvement and promotion, especially in larger cities, because of its advantages in comparison with car traffic—e.g. effective use of energy, environmental protection.

(2) In densely populated and built-up areas the subsurface is, in many cases, the only available space in which to build a new public transport system with high capacity, high speed and a high degree of safety.

Despite these generally accepted advantages and restraints, the high cost of constructing and operating underground systems gives rise to doubts regarding the effectiveness of investing the necessary public funds—a considerable amount. The provision of those funds mainly depends on the decisions of non-technicians who, quite simply, need a "one-value" basis on which to choose between various solutions—including the "do nothing" option.

The following reports provide technical descriptions of systems or lines of underground urban railways in several countries, and attempt to show what effects have been obtained *after* a system or line has begun operation. These summaries do not claim to represent actual cost-benefit analyses, because the use of a traditional cost-benefit analysis as a tool for understanding a planning issue is limited.

In general, an economic analysis must consider four issues involved in creating a public transportation system:

(1) Who pays the capital costs?

(2) Who pays the cost of construction disruption?

(3) Who pays the operating costs?

(4) Who benefits from the system?

Depending on the situation in any given nation with regard to these questions, a cost-benefit analysis can have different results. Other major problems are that of compiling the list of benefits which should be included in planning considerations, and determining how such benefits can be measured or even expressed in money.

The reports that follow provide various approaches to describing the benefits of urban underground railway systems specifically and public transport in general. This can be seen as a first step in justifying the use of the subsurface for urban railway systems. The further tasks of this Working Group will be to compare methods of cost-benefit analyses and to make recommendations regarding their application.

The report from the United Kingdom, which gives an overview of the experience of cost-benefit studies involving tunnels, has been included as an appendix because it summarizes relevant studies that were (in most cases) performed *before* the decision on project realization was made.

Belgium*

Introduction

Mobility is essential to human activity:

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Table 1. Subways throughout the world.

Nation	City	Year of inaugura-tion	Operating (km)	Under-ground operating (km)	Number of routes	Stations	Annual passen-gers (million)	Cars
ARGENTINA	Buenos Aires	1913	34.0	34.0	5	57	207	414
AUSTRIA	Vienna	1976	21.7	19.1	3	27	—	240
BELGIUM	Brussels	1976	13.7	10.6	1	21	35.3	90
BRAZIL	Sao Paulo	1974	20.0	15.0	2	23	209	306
	Rio de Janeiro	1979	12.3	11.0	2	13	20.4	96
CANADA	Toronto	1954	59.9	44.5	2	59	—	632
	Montreal	1966	41.3	41.3	3	46	170	759
CHINA	Peking	1971	23.6	23.6	1	17	45	64
	Tientsin	1980	23.8	1.3	1	18	34	29
CZECHOSLOVAKIA	Prague	1974	19.3	18.8	2	23	207.4	187
FEDERAL REPUBLIC OF GERMANY*	West Berlin	1902	100.9	83.4	8	111	346	340
	Hamburg	1912	89.5	32.0	3	80	180.2	849
	München	1971	32.0	28.5	3	38	101.4	250
	Nuremberg	1972	12.3	8.9	1	19	35	74
FRANCE	Paris (M)	1900	190.2	175.4	15	358	1093.9	3496
	(R)	1938	100.2	26.9	2	63	205.1	561
	Marseilles	1977	9.0	6.0	1	12	27.8	63
	Lyon	1978	11.8	11.8	3	17	47.7	66
GERMAN DEMOCRATIC REPUBLIC	East Berlin	1902	15.8	13.6	2	23	75	340
GREECE	Athens	1925	25.7	2.9	1	21	85	135
HONG KONG	Hong Kong	1979	15.6	12.8	1	15	166	210
HUNGARY	Budapest	1970	24.2	21.2	3	33	330	256
ITALY	Rome	1955	25.1	18.5	2	33	114	208
	Milano	1964	47.1	29.4	2	57	205.8	361
JAPAN	Tokyo (T.R.T.A.)	1927	131.8	107.6	7	124	1603.4	1738
		1960	54.9	49.3	3	60	371.9	440
		1977	9.4	8.6	1	7	123.9	216
		1968	1.2	0.8	9	—	—	—
	Osaka	1933	89.1	77.8	6	87	796.8	792
	Nagoya	1957	54.4	51.8	4	60	323.9	429
	Kobe	1968	7.6	6.8	2	10	104.4	
		1977	5.7	5.2	1	4	16.5	32
	Sapporo	1971	31.6	19.6	2	32	180.4	320
	Yokohama	1972	11.5	11.2	2	12	46.2	70
	Kyoto	1981	6.6	6.6	1	8	—	36
	Fukuoka	1981	5.8	5.8	1	7	—	48
KOREA	Seoul	1974	23.8	13.6	2	20	248	140
MEXICO	Mexico	1969	51.6	38.8	3	57	909.6	882
NETHERLAND	Rotterdam	1968	17.1	3.3	1	12	38	83
	Amsterdam	1977	16.2	3.7	1	18	33	88
NORWAY	Oslo	1966	35.5	10.7	1	44	39.4	162
PORTUGAL	Lisbon	1959	12.0	12.0	1	20	120.5	80
SPAIN	Madrid	1919	86.0	80.5	10	124	391	768
	Barcelona	1924	48.2	47.2	5	72	239	412
SWEDEN	Stockholm	1950	103.6	56.6	3	94	195	885
UNITED KINGDOM	London	1863	387.9	163.6	9	248	559	4087
	Glasgow	1896	10.5	10.5	1	15	6.8	33
	New Castle	1980	23.8	1.3	1	18	34	29
UNITED STATES OF AMERICA	New York	1868	371.1	220.5	23	456	1040	6328
		1908	22.4	12.7	1	13	35.9	291
	Chicago	1892	143.2	16.1	5	140	150.7	1100
	Boston	1897	55.1	21.1	3	51	95	354
	Philadelphia	1907	39.2	25.3	2	54	65	419
		1969	23.3	4.6	1	14	11.3	121
	Cleveland	1955	30.5	0.5	1	18	11	108
	San Francisco	1972	114.0	30.5	1	34	45.3	440
	San Diego	1975	25.3	18.7	2	35	95	195
	Washington	1976	59.8	35.8	3	41	75.6	300
	Atlanta	1979	19.0		1	13	20	120
U.S.S.R.	Moscow	1935	184.0	166	8	115	2318.2	2807
	Leningrad	1955	61.8	61.2	3	38	717.4	937
	Baku	1967	18.7	16.8	2	12	140.8	108
	Kiev	1960	26.2	20.4	2	17	255.2	299
	Tashikent	1977	15.4	15.4	1	12	74.3	105
	Tbilisi	1966	18.8	16.4	2	16	142.5	125
	Kharkov	1975	17.3	17.3	1	13	174.8	187
	Yerevan	1981	7.5	7.5	1	5	—	—

*Additionally, 16 cities in the F.R.G. have light-rail systems that include significant portions of underground operations.

the history of man amply illustrates the intensity of this vital need, which no amount of technological progress can satisfy.

When the first townships were built at the crossroads of the major routes—whether roads or waterways—or at particularly advantageous coastal sites, which became the natural meeting places for populations wishing to exchange their ideas and their products, the local authorities always did what they could to encourage mobility because they recognised how important it was for the social, cultural and economic development of their cities.

As technical advances were made, the road networks were gradually equipped with sewerage and lighting systems, and police services in various forms ensured the safety of citizens. Whenever it became necessary, what is now known as urban renewal work was carried out to ease traffic flows and to create public squares, meeting places for the population and settings for the town's chief cultural and social activities.

For a very long time, walking was by far the main means of urban travel and only the privileged had vehicles (such as sedan chairs or carriages), the capacity and performance of which were limited in any case.

The size of the town, therefore, remained dependent on the capability of the pedestrian. The town remained within fortified walls, themselves a token reminder of the dangers of the medieval period.

These ancient structures changed radically during the industrial revolution of the nineteenth century. The introduction of the railway, which far exceeded the speed and capacity of earlier modes of transport, meant that supplies of food and raw materials could be obtained on a much larger scale, and labor became much more mobile.

Industrial, commercial and administrative complexes were created, manpower crowded into the towns for the new jobs, and new travel requirements developed as large workshops—reached by the employees only after long journeys—took the place of the scattered crafts and trades which had been part of the life of the town.

Since demand generates supply, the first public transport services run by private enterprises were introduced at this time. The vehicles obviously quickly adopted the technique which had made the railways a success: the steel wheel and metal rail, while horse traction was replaced by DC voltage electric power.

The speed and capacity of the new modes of public transport were decisive factors in the development of the towns, which spread beyond their old boundaries to new residential areas that remained linked to the urban center, the latter losing some of its population while increasing its cultural and commercial activities. The population's housing and living conditions improved, and in this respect the development of urban public transport at the end of the nineteenth and the early twentieth centuries was vital to the social progress of urban communities.

The enterprises that operated the urban public transport systems, usually by means of a concession granted by the public authorities, had a kind of monopoly. The services were tailored to requirements and, in many cases, helped to shape such requirements. All the conditions were fulfilled in order to ensure that these enterprises showed an economic return.

In the particular case of Brussels, which is examined in detail in this report, the population of the built-up area increased steadily, from 625,000 in 1900 to 950,000 in 1940. If the period 1914-1918 is not taken into account, the number of passengers carried per year rose from 55 million in 1900 to about 275 million in 1940, with a slight decline during the crisis years of the 1930s. Accordingly, the number of trips per year per inhabitant—a significant indicator of the role played by urban public transport—increased from 90 to 290 over the same period.

This situation was disrupted in the period of economic recovery following World War II by the rapid increase in car use, which had a dual effect.

First, car users became independent of timetables and distance restrictions. This factor, combined with a worldwide policy of cheap, oil-based energy, prompted them to find housing further from their workplaces and to do quite a lot of traveling. While the expansion of towns had been initiated by public transport along certain privileged routes, it was stepped up with the increased use of the car, and occurred on a more general basis. In addition, the cultural and commercial activities, which had hitherto been concentrated, became less readily accessible as they shifted from the town center to the outskirts.

Second, increasing car use changed traffic conditions such that urban road networks could no longer accommodate the volume of private vehicles, in terms of both movement and parking requirements. As town centers became more and more congested, the movement of urban activities to the suburbs continued at an even faster pace.

These two effects, experienced worldwide and amply documented, first gave rise to the promotion and construction of a number of urban roads, which were constructed, in principle, in response to the demand. Experience showed, however, that a few years after coming into service the new roads had generated new flows of private vehicles. This very costly policy ultimately led to the gradual destruction of the urban tissue without resolving the problems posed by congestion.

Urban public transport systems, which were directly affected by the congestion in the towns, gradually deteriorated as a result of a classic sequence of events: reduction of commercial speed, drop in productivity, increased costs, higher fares and fewer services, curbs on investment, deterioration in service quality, and loss of passengers.

The basic impact, which was felt somewhere between 1960 and 1970 depending on the nation, had two aspects: first, in terms of the quality of urban life, where the damage done to the heritage of towns was often very serious; and, second, in social terms, in the sense that the deterioration of urban public transport was unfair to those members of the public who did not have access to private vehicles for reasons of age, physical aptitude or financial situation.

The need to ensure the harmonious development of private and public transport in urban areas was generally recognised and appropriate budgetary resources were made available to implement specific polices with this in mind.

Various forms of intervention by the community have been adopted, and very substantial appropriations have been made available in all countries for the particular purpose of improving public transport in urban areas.

It is no doubt advisable today to take stock of the efforts made along these lines. Not only can the results be assessed objectively after a period of some fifteen to twenty years, but also, the present economic crisis obliges all countries to give considerable thought to every aspect of public investment, and to make stringent cost/benefit analyses of their various community projects. This report, therefore, seeks to provide an objective response along these lines in the light of past experience and with a view to future prospects.

In this connection, it must be noted that the splitting up of the large urban units that existed previously, the greater importance attached to leisure time, and the renewed interest in local autonomy or forms of association will no doubt call for ever increasing mobility, although the needs will be different henceforth, insofar as they will be less concentrated in time and space; and the demands, too, will be more exacting.

Investment in Urban Transport in Brussels, 1930–1983

Institutional Framework

In view of the deterioration in the quality of service and the reduced productivity, which meant that the operating companies were no longer able to meet their public service responsibilities, the Minister of Communications decided in 1962 to set up commissions in Belgium's large built-up areas. These commissions comprised representatives of the transport authority, public works, public transport operating companies and local authorities. The commissions were required to find means of adapting public transport services to meet present and future requirements and to propose specific solutions to the difficulties encountered.

Moreover, since 1963, the Minister has authorised substantial appropriations in the Ministry's investment budget to finance the construction of facilities to ease the flow of public transport traffic in urban areas. In an agreement between the State—represented by the Minister of Communications—and the operating companies, it was agreed that these facilities should be made freely available to the companies on the understanding that they were to be put to use in the best interests of the community.

It was also understood that the operating companies would continue to bear the cost of replacing rolling stock and, more particularly, would use their own funds to finance purchases of modern equipment, which corresponded to the investments made by the State.

The amounts made available in the budget of the Ministry of Communication increased each year. The cumulative total of commitments for Belgium's five main built-up areas reached BF 103 billion at the end of 1983, of which BF 61 billion was for Brussels; total expenditure was BF 91 billion, including nearly BF 56 billion for Brussels.

Investment Projects Carried Out in Brussels, 1963–1983

It is very widely recognised that the promotion of public transport calls for, among other things, for the improvement of commercial speed and regularity. This can be achieved only by separating public transport services from other traffic in congested areas.

Since the narrowness of most streets in old towns means that private and public transport cannot be separated at ground level, it is very tempting to separate them by creating another level and run the public transport services underground. This solution has been adopted in Brussels.

Brussels has been selected for this case study because the large volume of work done in this city and the progress made with these projects permits us to draw significant conclusions on the basis of the very substantial financial investment made over the past twenty years.

The completed infrastructural facilities, more than 30 km of which are now in operation, were designed to be put into use gradually by tramways as they were completed, with the metro section coming into use when warranted by the length of the underground section and the volume of traffic.

This novel method of construction—i.e. by means of an intermediate state known as the "pre-metro"—has meant that, for the cost of a few provisional access ramps, considerable reductions have been achieved in the high cost of interim interest normally paid when constructing new metro lines.

The present underground system (Fig. 1) comprises:

- The East-West diametrical axis with a Y-metro line at each end: 21.9 km and 33 stations;
- The "Petite Ceinture", the small ring tramway line around the center of the city: 3.2 km and 6 stations;
- The North-South diametrical axis, a tramway of 2.9 km with 5 stations;
- The "Grande Ceinture" axis, part of a by-pass used as a tramway; 2.9 km and 4 stations.

The work at hand involves more than 10 km of infrastructure with 13 stations, and will be completed within the next few years. [*N.B.* The interchange stations, which are more important than the

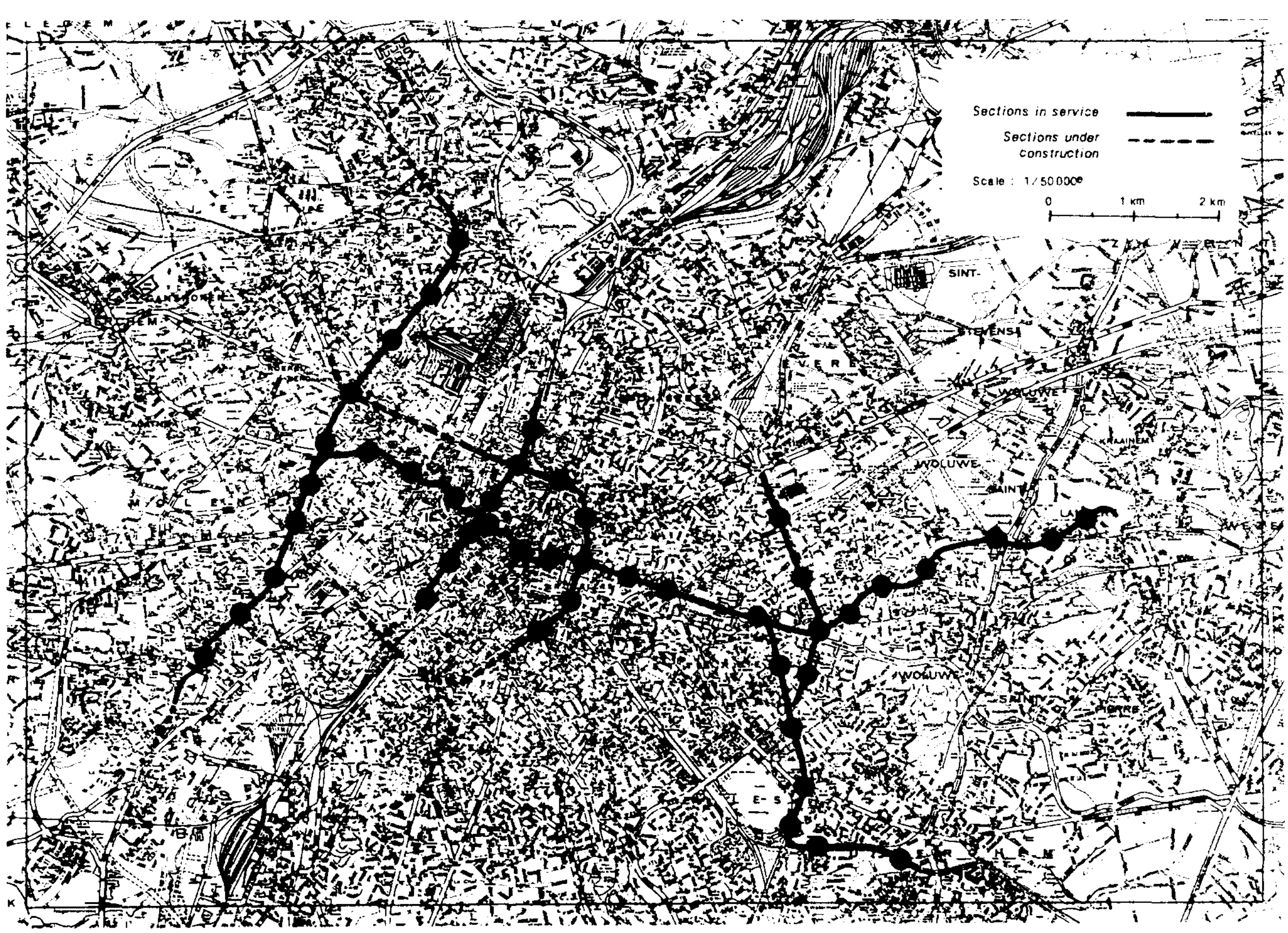

Figure 1. Map of the Brussels metro system.

others, are simultaneously assigned to two axes which intersect and are, therefore, counted twice.]

Figure 2 shows the rise in cumulative investment as the new facilities come into operation. The average cost of the facilities in current francs—including stations, finishing work and equipment—is about BF 1,600 million per kilometer.

Impact of Investment on Operation of Public Transport

The impact of investment may be measured in terms of (1) the user; (2) the operating company; and (3) the community. Each of these three aspects is examined below.

Impact on the user

The following observations must be viewed in the general context of trends in population and employment in the Brussels built-up area (Fig. 3).

The uptrend recorded until about 1970, which had at one time led us to believe in continuous growth, has been reversed; now the population is diminishing, along with the volume of employment and the average per capita income. A policy specifically designed to encourage the population to return to the town is being pursued, but it must be admitted that there is as yet no evidence of its success.

Figure 4 shows the trend in passenger traffic by public transport from 1946 to 1983. Aside from the brief period during the International Exhibition in 1958, the decline was uninterrupted until 1971, when the influence of the measures to promote public transportation began to be felt; thereafter, traffic increased steadily as the trend was reversed. The drop recorded in 1982 is attributable partly to the trends in population and employment and partly to the economic crisis and attendant unemployment.

It is recognised that, all other things being equal, there is a direct correlation between the appeal of public transport and the rate of car ownership. An analysis of the two curves in Fig. 4 does, in fact, show a good correlation between these two variables. A projection of this correlation for the period 1971-1982 shows what the volume of public transport traffic would have been if nothing had been done. The downtrend no doubt would have continued and traffic now probably would be about 150 million passengers per year, i.e. 50 million fewer than at present.

The reversal of the trend must certainly be attributed, at least in part, to the better quality of service and, more particularly, higher commercial speed offered to users. The improvement differs according to the route; the most marked improvement has occurred on the East-West metro route. The time savings for users as a whole amounted to some 10 million h per year.

Impact on the operating company

(1) Length of the network. From the time the built-up area began to expand and residential areas became more spread out, the operating company responded by gradually increasing the length of the network (Fig. 5). The total length has increased from 260 km in 1946 to 433 km in 1982. The increase has been attributable to the development of the bus network, beginning in 1955, to reach the present 260 km, whereas the tramway network has fallen from 260 to

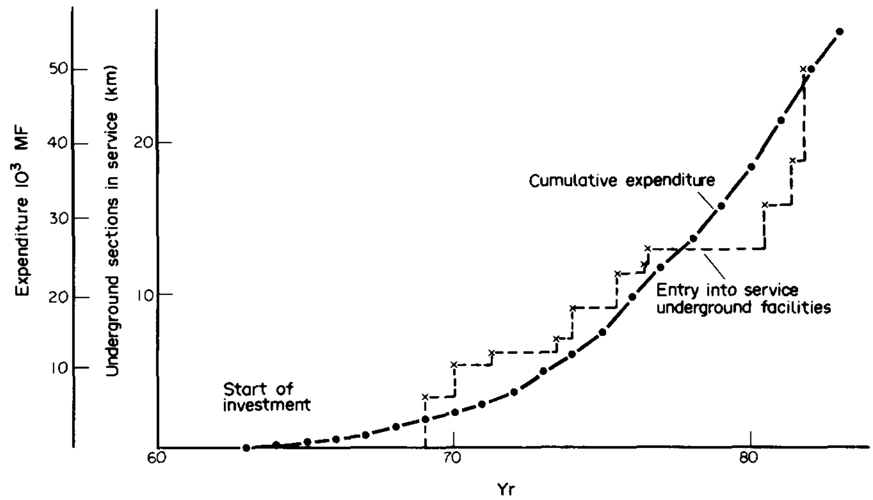

Figure 2. Pattern of investment and entry into service of underground facilities.

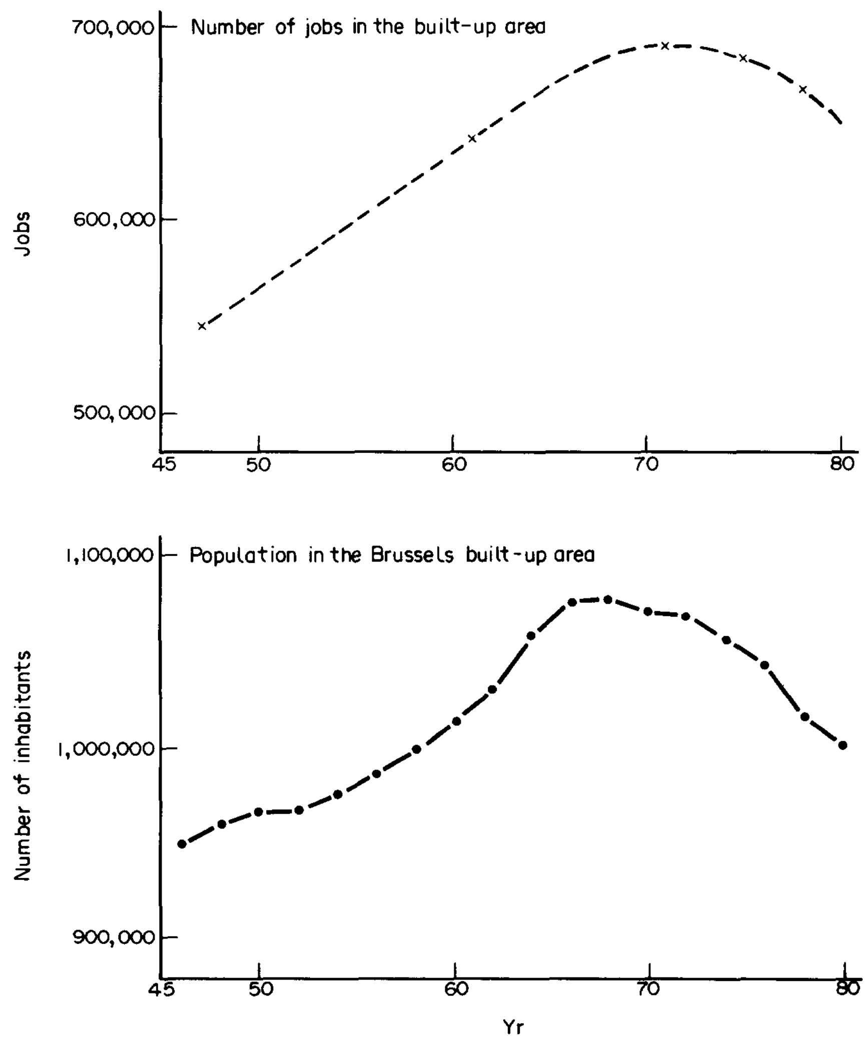

Figure 3. Employment and population trends in the Brussels built-up area.

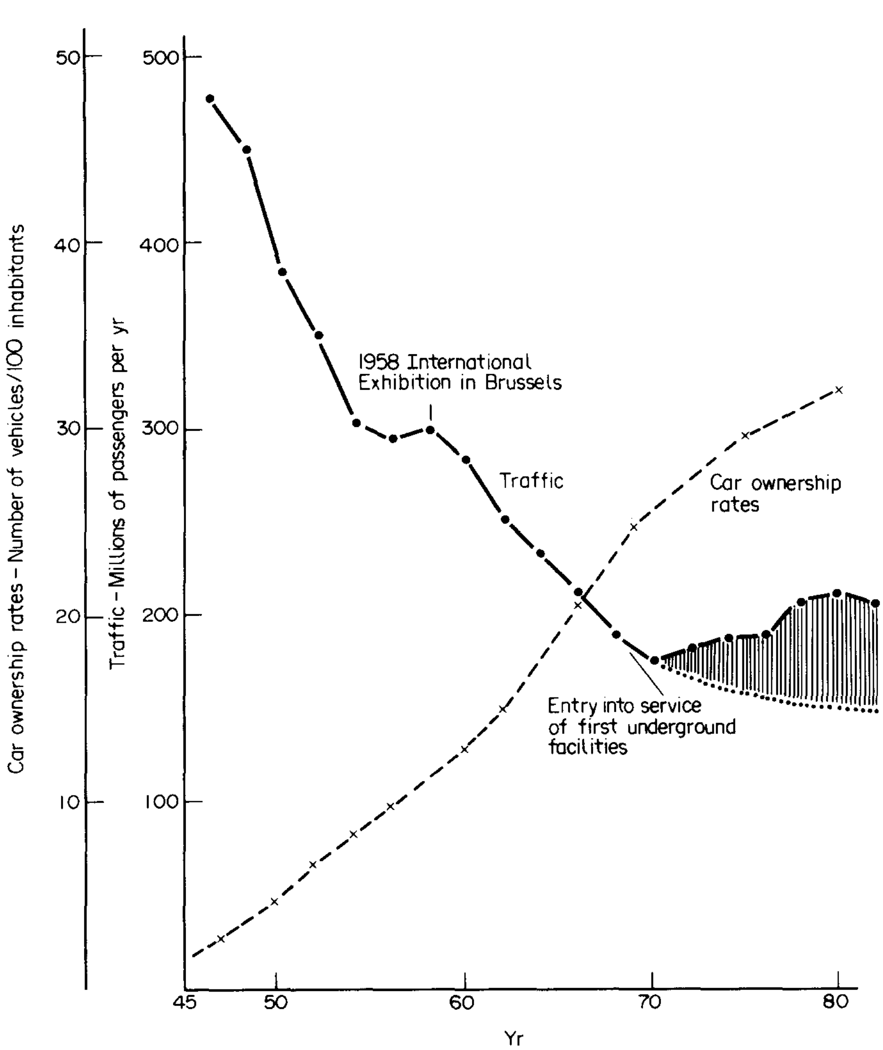

Figure 4. Trends in public transport passenger traffic and car ownership rates in Brussels.

150 km. The metro today covers a distance of 27 km.

(2) Rolling stock (Fig. 6). The main features of trends in rolling stock are:

- A fleet of buses has been built up since 1955 and today totals 600 units.
- The tram fleet has been modernised. Older motor vehicles have been replaced by trams with higher performance and greater capacity, while towed vehicles have been taken out of service gradually. The number of motor vehicles dropped from 925 in 1946 to 420 in 1982;
- Higher capacity metro trains were introduced in 1974 and now total 80.

It should also be noted that the capacity of the stock in terms of seats available remained almost the same (105,000 to 115,000) between 1946 and 1974, and then increased appreciably to almost 140,000 in 1982 as a result of both the introduction of the metro trains and the latest type of articulated four-bogie trams.

(3) Output. Output can be measured in terms of the number of seat-km provided per year (Fig. 7).

For obvious economic reasons the operating company tried for some time to tailor supply to the volume of traffic, while realising that the reduction of supply combined with the extension of the network resulted in the deterioration of the quality of service and a further loss of ridership.

Since 1970, the trend in ridership has been deliberately and spectacularly reversed. It is clear that the upturn in traffic has been partly attributable to the increase in service offered, together with the entry into service of the underground facilities.

(4) Financial situation of the operating company. The financial situation of the operating company has continued to deteriorate for the following reasons: the trend in traffic and the fares policy adopted; the trend in labor costs; the increased supply of services since 1970; the additional cost of maintenance and operation of underground facilities; and the cost of the accelerated modernisation of stock, particularly the purchase of metro rolling stock out of the company's own funds. The revenue/cost ratio has been less than unity since 1962 and fell to 0.23 in 1982; the entry into service of the underground facilities and metro have had hardly any impact on the trend of this indicator (Fig. 8).

Only the very stringent measures taken in the past few years—among others, those relevant to supply in seat/km provided—have made it possible to stabilize the situation to some extent, though at an abnormally low level.

Impact on the community

This impact can be examined in social, urban living and economic terms.

(1) Social. The development of a more efficient transport system is usually thought to increase the mobility of the population and provide access to some of the more isolated sectors of the built-up area.

There is a very specific social impact as regards the districts directly affected by the East-West metro line. The impact is less evident for those served by other routes because the underground sections are not yet long enough for any significant improvement in commercial speeds to have occurred.

(2) Urban life. The creation of dedicated infrastructures underground in city centers relieves congestion and eases the flow of private traffic.

In Brussels, the disappearance of surface public transport on some routes has meant that the whole road system can be used by private traffic. The degree of saturation at peak hours clearly shows that, if the traffic had not been separated, the congestion would have been such that the construction of very costly road infrastructures would have been deemed essential.

It must, therefore, be considered that the work would have had to be carried out in any event and that the question of which budget heading it came under is, in the last analysis, of little interest to the community. From this standpoint, given the comparative capacities of the various types of underground infrastructure, it would probably be better to reserve them for public rather than private transport.

The surface replanning that accompanies the construction of underground facilities often means that the circulation of traffic in general can be improved, while surface areas can be kept for the use of pedestrians, thus helping to improve the urban environment and revitalise city centers. In fact, this has been done and some large pedestrian precincts have been created, while some business areas in Brussels have obviously been revitalised. It should be noted, however, that some very lengthy construction projects have had harmful—in some cases, irreversible—effects on the activity of certain districts, and that expropriated buildings demolished for building sites have not been reconstructed because property developers

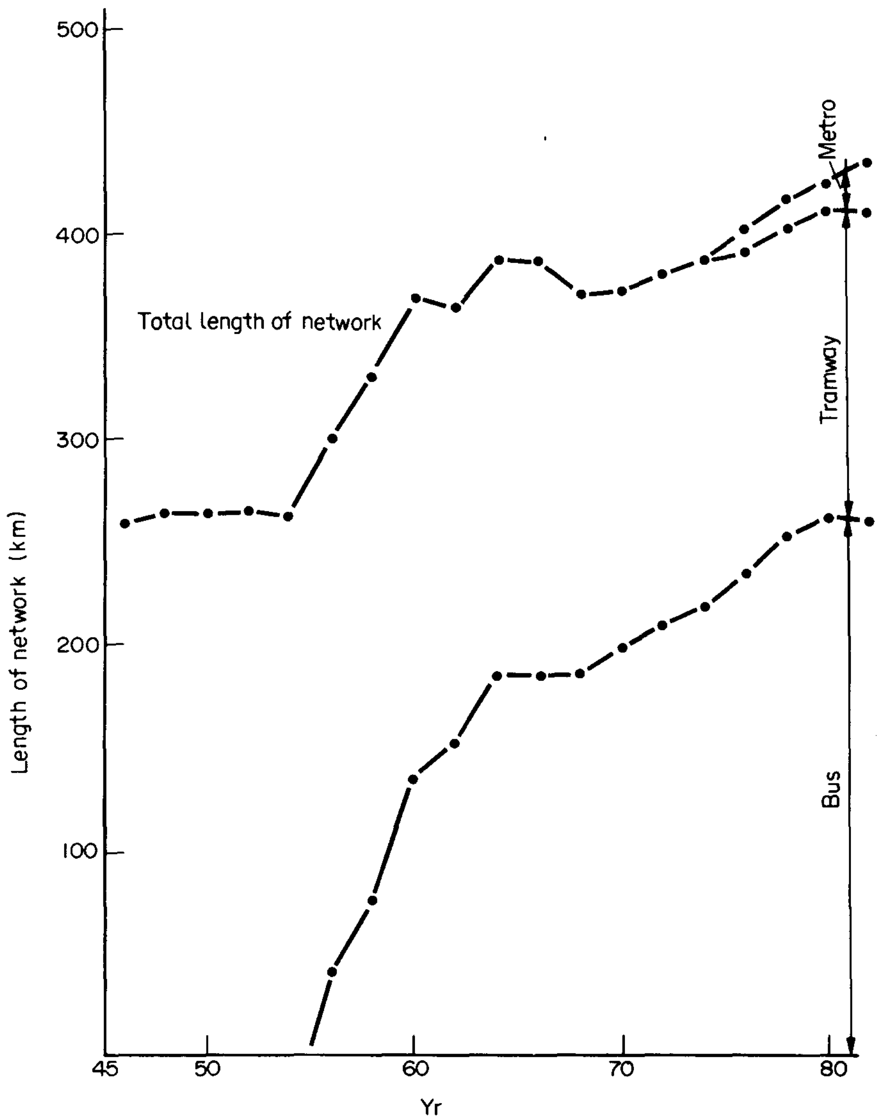

Figure 5. Length of network in Brussels.

have not been available during the recession.

It is often pointed out that one of the indirect effects of building underground infrastructures for urban and public transport is the reduction of pollution—first, because there are fewer buses; and, second, because the combustion engine is more efficient in smooth-flowing traffic.

In Brussels, since the vehicles removed from the surface were essentially trams, the effect on pollution has been negligible. As regards the expected improvement in the flow of private traffic, the volume of traffic has, unfortunately, increased.

The dedicated infrastructure, especially underground, is an essential safety factor, and the reduction in the number of accidents to passengers and others is a positive feature that is by no means negligible. By way of illustration, accidents to passengers and others in Brussels in 1981 were 16 times higher for the surface tramway than for the metro; the financial cost to the operating company—not to mention the cost to the community—was 40 times higher.

(3) Economic. On the debit side, the State has made a substantial contribution towards investment in granting increasing amounts each year since 1963—amounts which, in recent years, have totalled some BF 5,000 million/year. Moreover, the State has covered the operating company's operating deficit each year since 1962.

In weighing this effort, account should be taken of the revenue returning to the State Treasury in the form of taxes and other charges, insofar as the bulk of the work has been carried out by Belgian firms.

On the credit side, attention should be drawn in particular to the work opportunities offered to Belgian industry in this context. The technical management and administrative work called for a number of people in the service of the operating company and government departments as well as consulting firms. The relevant expenditure accounts for about 11.5 percent of the total cost of the work.

With regard to the civil engineering work alone, moreover, an average of 1000 workers were regularly employed on the sites from 1966 to 1982.

Lastly, quite apart from the volume of work it has obtained from this programme, Belgian industry has had the opportunity to develop and perfect advanced technologies that have enabled it to maintain or increase its competitiveness in foreign markets in the fields of civil engineering (excavation and tunnelling techniques, etc.), finishing and installations (signalling, telecommunications in the broad sense of the term, escalators, etc.) and rolling stock (metro and light metro, etc.).

(4) Conclusion. An objective analysis of all the projects carried out in Brussels on the initiative of the Ministry of Communications with a view to promoting urban public transport should provide a reply to the basic question: "Have the results of the decision made in 1963 come up to expectations?"

A second question springs immediately to mind, although its wording will differ according to whether it relates to Brussels or to the general context: "If not, how is the work in hand to be modified in order to get better results?" or, "If not, what action should have been taken?"

Assessment of the Results Obtained

For the public transport user, especially the user benefiting directly or indirectly from the metro, i.e. 25% of all users, there have been particularly substantial improvements, which had been forecast in the pre-project traffic studies and have now been confirmed by the fact that metro traffic is at present continuing to increase whereas total traffic is diminishing.

From a more general standpoint, the work done has helped to smooth traffic flows, revitalised areas in the center of the city and led to the creation of pedestrian precincts. Unfortunately, here and there in the urban tissue remain some scars which, owing to the present economic crisis, have not yet been eliminated.

Finally, from the economic standpoint, the financial procedures adopted did not improve the situation of the operating company and, therefore, the State had to assume the total cost of the investment projects carried out as well as the company's operating deficit.

The results expected were obtained but had to be—and continue to be—paid for at a higher price than expected. In this respect, the key to the problem is probably the financial machinery adopted.

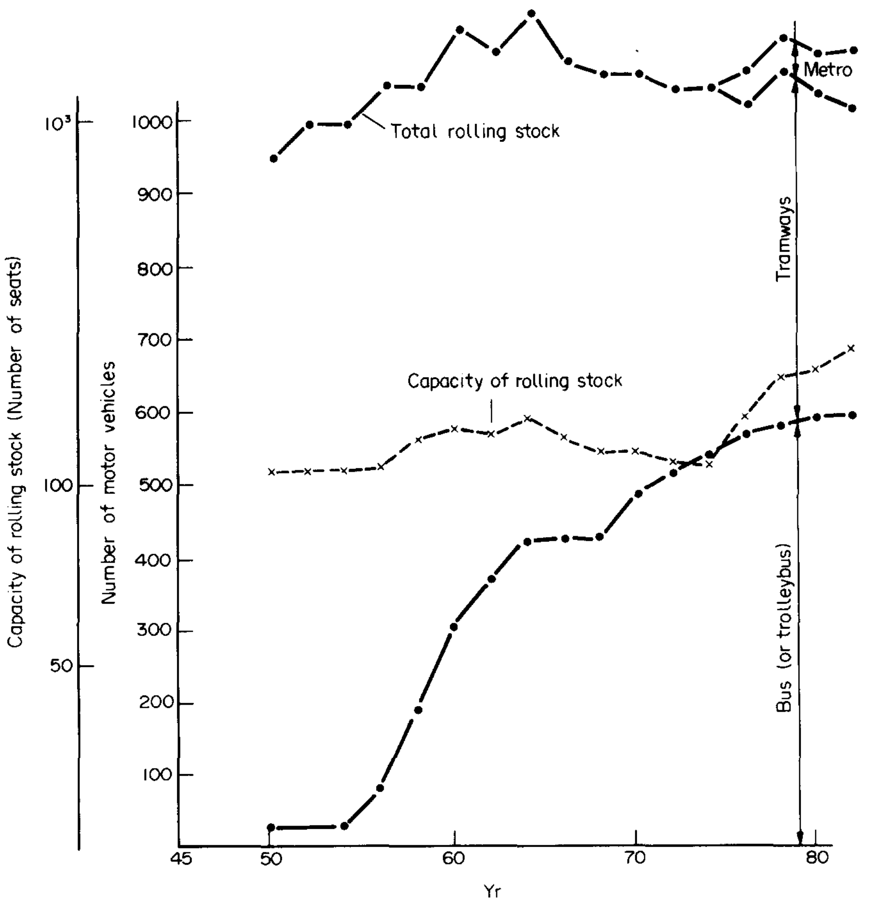

Figure 6. Trends in total rolling stock and capacity of rolling stock.

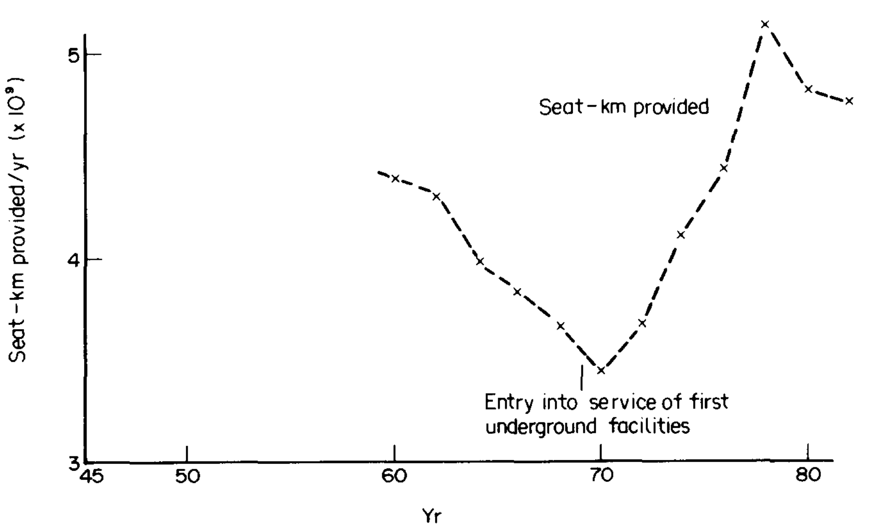

Figure 7. Trends in transport supply (number of seats-km provided per yr) in Brussels.

Alternative Approaches

Brussels

For Brussels, as matters now stand, only a part of the initial programme—in terms of both infrastructures to be built and methods of operation—has been completed.

On the basis of various surveys of user behavior and an updated projection of urban development and transport requirements, the Ministry of Communications examined a number of scenarios, ranging from the stabilisation of the network after completion of work in hand to a more ambitious programme for the gradual development of the metro system.

These studies—which use the conventional analytical models relating to power of attraction and traffic distribution, as well as simulation models—have shown that further development of the metro system would gradually increase its efficiency and make the public transport system slightly more attractive, while also improving the financial situation of the operating company.

However, no final decision had been made at the time of this report.

General Context

While the reasons for the deterioration in the quality of public transport are usually diagnosed correctly and there is a political will to ensure an adequate public transport service on the basis of a "right to transport" and a reallocation of resources whereby public finance can be spent in the transport sector, the approach is sometimes too fragmented and ignores the overall concept of the "urban transport system".

This concept is examined in greater detail in the following section, which tries to ascertain a different approach to the problem and outline the whole range of measures taken by public authorities in the field of urban public transport.

Measures Taken by Public Authorities

Structure of Urban Public Transport Systems

The structure of a town's public transport services essentially depends on the size and population of the town.

When this structure is analysed for those built-up areas that have attained a certain degree of economic development, a distinction can generally be made between three levels according to the size of the town:

(1) **Medium-sized towns**, i.e. a few tens of thousands of inhabitants, usually have only the first level, which consists of a system of bus routes satisfactorily meeting requirements in terms of direct journeys, although there are relatively few interconnections.

(2) **Larger towns** have two levels. The first, comprising bus routes, services the peripheral districts, where there is less dense housing and employment. This system feeds a second network of main traffic routes.

If it is to be efficient, the second level system must offer: (1) a large capacity; (2) high commercial speed; and (3) sufficiently regular services.

These important characteristics are to be found only in the case of tracked vehicles, using dedicated infrastructures. Rail systems allow for the use of large-capacity vehicles and electric power, with all the associated benefits (less air and noise pollution, diversification of primary energy sources, etc.).

(3) **Very large towns** have a three-level structure, comprising the two above-mentioned levels together with a very

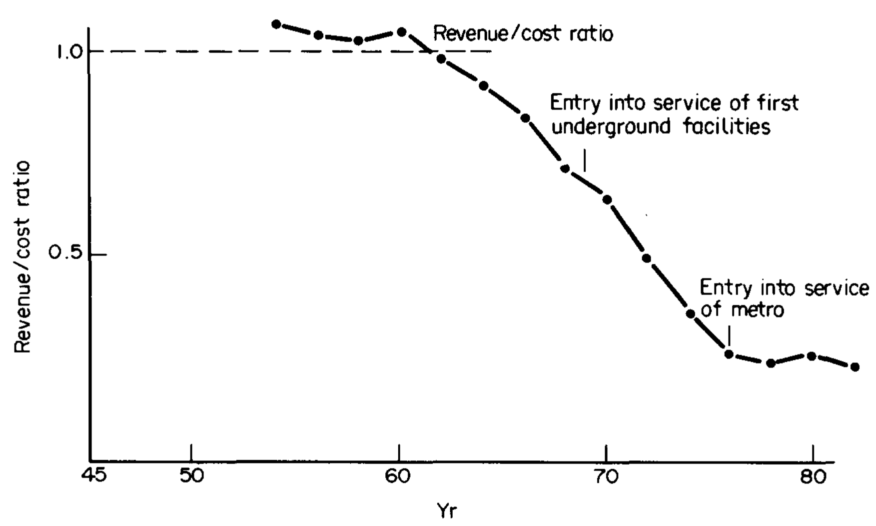

Figure 8. Trend of the revenue/cost ratio for public transportation in Brussels.

high capacity system. The latter system is similar to a regional rail network, having much the same characteristics as the railway, but it is organised in such a way as to ensure very good connections with the systems on the other two levels.

Improving the Efficiency of Public Transport

The measures that may be taken to improve the efficiency of urban public transport systems fall into two categories:

(1) Raising the productivity of the existing systems by taking action with respect to both the operation of each level and the coordination of the different levels.

(2) Introduction of new technologies.

Each of these two categories of measures is examined below.

Raising the productivity of the existing systems

(1) Operation of each level. The dedicated infrastructure separates public transport from other traffic and means that higher commercial speeds and sufficient regularity can be achieved.

The establishment of dedicated infrastructures for buses (Level 1) and tramways (Level 2) should be approached on a systematic basis, a policy that requires both the active collaboration and political will of local authorities to ensure that the road system is, in fact, shared. There are two obstacles to be overcome in this connection: (1) intersections; and (2) the narrowness of roads in town centers or congestion at certain junctions.

The first obstacle can be partly overcome by remote control of traffic lights to give priority to public transport, control that might subsequently be made more sophisticated by allowing for vehicles running late in relation to their timetables.

In any event, if a number of intersections are equipped with such a system along a route, the rate of flow cannot be reduced beyond a certain point without becoming unacceptable to private traffic.

The second obstacle can be overcome by constructing special facilities at certain points which the community can allocate more cheaply to public transport than for private traffic, provided that a minimum amount of equipment is called for; and, more particularly, that the facilities do not include underground stations, which are always costly to run.

The third level referred to above (i.e. railway facilities) necessarily calls for an integrated dedicated infrastructure, with all that it implies in terms of investment and operating costs.

(2) Coordination of the various levels. If a public transport system has a number of levels, they must be coordinated perfectly. Because a passenger may often need to use two or three modes of transport in sequence, it is absolutely essential to ensure that the benefits gained by adapting these modes to traffic flows (speed, frequency, comfort) are not negated by drawbacks related to interchanges.

The average interchange rate is a measure of the complexity of a transport system. However, it must not be automatically assumed that a high average rate is to be rejected, for if the coordination is good, passengers become perfectly adjusted to what the transport system has to offer and they move quickly, making more frequent changes if necessary.

The real efficiency of a transport system is not, therefore, to be assessed solely by ascertaining the average interchange rate, the degree of mobility offered to the population and the accessibility of the main areas of the town, because efficiency largely depends on the degree of coordination achieved among the different parts of the system in terms of: (1) planning the networks; (2) organisation of interchange points; (3) timetables; and (4) fare structures.

Coordination in planning the networks. The various networks are complementary, each having characteristics that make it efficient for a certain type of transport over a certain distance. They must be combined with a view to achieving the optimum in social and economic terms. This involves, on the one hand, the direct investment and operating costs; and, on the other, the direct and indirect benefits accuring to the community.

The quest for optimum solutions calls for studies which, in turn, require broadly based surveys aimed at ascertaining real requirements and behaviour patterns and employing operations research methods.

Moreover, these solutions must be evolutive, that is, they must anticipate how the potential patronage will develop and take account of the interaction that exists between urban development and public transport.

Coordinated planning of interchange points. The points for interchanges between the different systems must be planned carefully so as to ensure that the transfer is as quick and easy as possible. It is clearly an advantage to ensure that passengers have appropriate shelter in bad weather, and that they be provided with accurate information about directions, timetables, etc. From the standpoint of urban life, these interchange points are often places where people arrange to meet; thus, an agreeable setting should be planned for this purpose, offering passengers various services, e.g. telephones, shops, etc.

Coordination of timetables. The less time required for an interchange, the more readily will a passenger accept it; therefore, timetables must be organized so as to reduce waiting time to the minimum. It is then necessary to adhere to these timetables, since lateness on one network will often disrupt the timetable for the second network. It is, therefore, essential to keep to the timetables of the main networks and to make provision for specific controls of vehicle timekeeping for this purpose.

Coordination of fare structures. In social terms, a complex transport system serving a large built-up area must be seen by the passenger as a homogeneous whole, the fare being determined not by the type of vehicle used but, rather, by the service provided.

Therefore, it is desirable to establish uniform fare structures for the whole area served by the transport system, since this is more readily accepted by the passenger and also makes it easier to organise fare collection and to standardize any equipment used for this purpose.

Introduction of new technologies

It is sometimes thought that the introduction of new technologies—such as large-capacity articulated trolleybuses, light metro, or a narrow-gauge metro with automatic drive in a first-level town and the construction of a metro line in a second-level town—will revitalise the public transport in a town.

It should be borne in mind that such a procedure amounts to creating a new level within the existing transport system—a level that is defined and classified in relation to the other levels by its specific characteristics.

Each level in a coherent transport system must ensure optimum development; in many cases, however, a new level cannot achieve this without detriment to the pre-existing levels. Therefore, it is unusual for the newly introduced type of transport to remain restricted to a single route (other than in the special case of a link-up between two specific points—airport, university campus, etc.), since, in the long run, economic necessity will call for its development to a point where equilibrium is established among the various public transport modes.

Investment Selection Criteria

An investment project is not assessed in absolute terms, but in comparison with the status quo or with alternative solutions.

In an entirely free economy, the operating company's choice is essentially economic in that it sets out, on the one hand, the costs—i.e. investment in installations and rolling stock; and operating costs (operation, maintenance, consumption), including the financial costs entailed by the investment—and, on the other hand, the benefits (revenue from the expected traffic and the attractiveness of the solution under consideration), whereby the choice can be justified and, where necessary, an order of priority established when a number of investments are to be phased over time.

It is clear that establishment of this cost/benefit balance first calls for a detailed study of the solutions envisaged together with the most precise evaluation possible of operating methods and costs and an estimate of the transfers—either between different public transport modes or between private and public vehicles—for which provision has to be made.

The establishment of a list of items of expenditure and revenue in constant or current francs, discounted as appropriate, provides a measure of the economic viability of a project in the form of a single indicator.

The public transport system that can develop in a free economy to the point where equilibrium is established—in accordance with market laws—between the cost of the service offered and what the community is prepared to pay is not consistent with the now generally accepted concepts of "public service" and "right to transport". Therefore, the community must make up the difference that will necessarily result when the system deviates from the above-mentioned point of equilibrium.

In view of the pejorative and psychologically undesirable "deficit" that the community must assume, it would be better in this respect to consider that the community compensates the operating company for the unprofitable obligations which are imposed in the case of "public service".

Because the community assumes, as it were, responsibility for managing the transport system, and the operating company is no more than the management body acting on behalf of the community, the selection criteria must be defined at this level.

In addition to the financial and economic criteria mentioned earlier, the other criteria concerned relate to: (1) the individual, i.e. social criteria; (2) the urban community (criteria relevant to urban life); and the nation (criteria relevant to economic policy). Each of these criteria is discussed below.

(1) Social criteria. The investment projects will usually result in higher commercial speeds for vehicles and, accordingly, shorter overall journey times. In most cases, this is a major asset for keeping existing users and attracting new ones, though account obviously must be taken of the reasons for the journey (work, school, leisure, etc.) when placing a value on such time-saving. Because the extent to which the built-up area is covered by the transport system's services determines the degree of mobility offered to the population and the accessibility of key points in the town, it is also an important social criterion.

Finally, the investment project may have implications in terms of the safety of the population. Accidents can be expensive in terms of money and in terms of non-monetary values (physical and mental suffering, etc.), which are certainly experienced even if they cannot be quantified.

(2) Criteria related to urban life. Investment projects have an impact on:

- Traffic in general: reducing private car traffic and road congestions, easing traffic flow, delaying the need for road investment, etc.;
- Pollution: air and noise;
- Quality of urban life: opportunities to develop pedestrian precincts, renewed commercial and cultural activity, etc.

To complete the picture, account should also be taken of the temporary disamenities to which major construction work in urban areas may give rise (essentially as regards the disruption of business activity).

(3) Criteria related to economic policy. The investment projects must be assessed in the light of the nation's energy policy, since greater use of electricity leads to diversification of primary energy sources and reduces dependence on oil products.

The projects may also be assessed in terms of their general impact on employment and on the development of a national industry which may export its products.

Quantification of some of these criteria is clearly very difficult and sometimes calls for lengthy analyses. Rather than ignore them altogether, however, it would seem to be more accurate from the economic and social standpoints to include them in the selection process, if only on an approximate basis.

Over and above the rational selection criteria that a community may apply to investment projects, particular political objectives may be decisive in shaping choices as, for example, in the case of a specific urban development policy using the structure provided by an urban transport axis, or an energy policy seeking to provide against a sudden shortage of oil products.

On the other hand, when the capital market is tight or the level of public indebtedness is considered too high, smaller investment projects may be selected even if the overall rate of return is smaller. Similarly, some investment projects may be postponed until a more appropriate time.

The socio-economic studies must, in the last analysis, be extremely thorough and take account of all objective selection criteria. However, the final decision always rests with the political authorities, who often wish to bring other kinds of criteria to bear.

Financing Investment

As soon as the community recognises the need for the public transport system to have a "public service" character and, accordingly, implicitly agrees to make up any deficit incurred by the operating authority, the community also assumes responsibility for investment, whether in fixed installations or rolling stock.

It would also seem essential, moreover, that the same body be responsible for both financing investment and monitoring management of the transport system's operation.

Which community is responsible: urban, regional or national?

A number of criteria directly concern the urban community such as, for example, the above-mentioned social and urban life criteria. However, other criteria—such as those relating to economic policy—concern the region or even the nation as a whole. The social, commercial and cultural well-being of a large town, which depend on the sound organisation of transport, among other things, are not without interest to the region or nation because they contribute to their own well-being.

Therefore, it would seem warranted to set up a financing system on several levels with the equal participation of local, regional and national authorities. The breakdown might be differentiated, moreover, according to whether the financing related to operating costs in the strict sense or costs bound up with investment projects which increase the value of the community's assets.

Since responsibility for management and financing are inseparable, it is up to the urban community to establish a policy for the use of the road system which is compatible with the financial contribution it makes; and it is up to the central or regional government to provide the local authority with the institutional, legal and financial instruments to implement its policy.

One last observation concerns the budgetary procedure for investment in urban public transport, to wit: the finance is usually provided under the budget of the government department responsible to the management of public transport.

It has been pointed out that investment projects often have implications for traffic in general in helping to ease the flows, and for urban life in making it more agreeable. Such projects also make it possible to reduce or delay investment in public road systems. Therefore, the amounts—sometimes very substantial—allocated to public transport investment projects often relate to work on public roads, and the specific budget headings should not conceal the complementarity of expenditure, which benefits both private and public transport.

Conclusion

Public transport in a built-up area must be regarded as an overall system integrated with the pattern of urban development in that area. The criteria for optimising the transport system are not solely those of the operating agency but also of the community it serves, in the same way as other services.

Therefore, it is essential that the community help finance the establishment and operation of this "public service". This participation entails responsibilities with respect to managing the system, as well as technologies. The institutional framework should provide efficient means of carrying out these responsibilities; otherwise, the investment projects may well prove ineffective and the objectives will not be achieved.

Czechoslovakia*

Public Transport in Prague

The main transport routes in Prague intersect the central, historical part of the city, due to the geographical configuration of the region and the fact that the industrial buildings and administrative centers are located far from the dwelling districts, which are situated on the outskirts of the city. Exceptionally high public transportation loads, as compared with the capitals of other states, are documented by the following figures on the numbers of transported passengers per year.

East Berlin	360 million
Brussels	280 million
Hamburg	460 million
Vienna	435 million
Prague	1145 million (1981)

To deal with the situation of urban public transportation in Prague, Czechoslovakia's capital, the government of the Czechoslovak Socialist Republic decided in 1965 to build a system of subsurface transportation.

In 1967, after comparing several different concepts, the government decided to construct an underground urban railway system with separate right-of-way instead of an underground tramway system only.

In 1980 the lengths of lines for public transportation in Prague were as follows:

Underground lines	20 km (23 stations)
Tramway lines	123 km
Network of bus lines	483 km

A map of the underground system with sections in operation (1983) and sections under construction or planned is given in Fig. 9. Table 2 gives more detailed information regarding the development of the underground up to the year 2000. Some impressions from the interior design of the stations are given in Fig. 10.

The start-up of track I C in 1974 and track I A in 1978, followed by opening of tracks II C and II A in 1980, has proven that the share of underground railway in total number of transported persons is much greater than expected. This is due to the fact that a number of citizens prefer a longer route by the quickest and most reliable transport means—the underground railway.

The total number of passengers transported by urban transportation means and the percentage of different modes of transportation is presented in Table 3. Table 4 provides a perspective on the development in terms of the percentage of passengers using the underground railway system.

Effects and Benefits of an Underground Railway System

The provision of funds for the construction of an underground railway is a question which must be considered and understood as a basic prerequisite of a socially oriented concept of both stimulation of economic growth and permanent and harmonious development of the entire society.

The questions of effectiveness of integrated public transportation systems in an urban agglomeration must be approached from this point of view, recognizing that the construction thereof has become a social necessity. However, this principle, i.e. the priority of interests of the whole society, should not debase the importance of economic calculation. It is merely a reminder that purely economic, i.e. monetary, benefits, expressed by monetary calculation, are not sufficient for making decisions about construction projects in such a crucial area as urban public transportation.

Concrete indices of economic effectiveness—i.e. profitability and cost balance—cannot be applied in the CSSR, since returns on underground railway installation and operating costs cannot be asserted in the same way as in the case of other production investment policies.

The fares, as a source of income, are

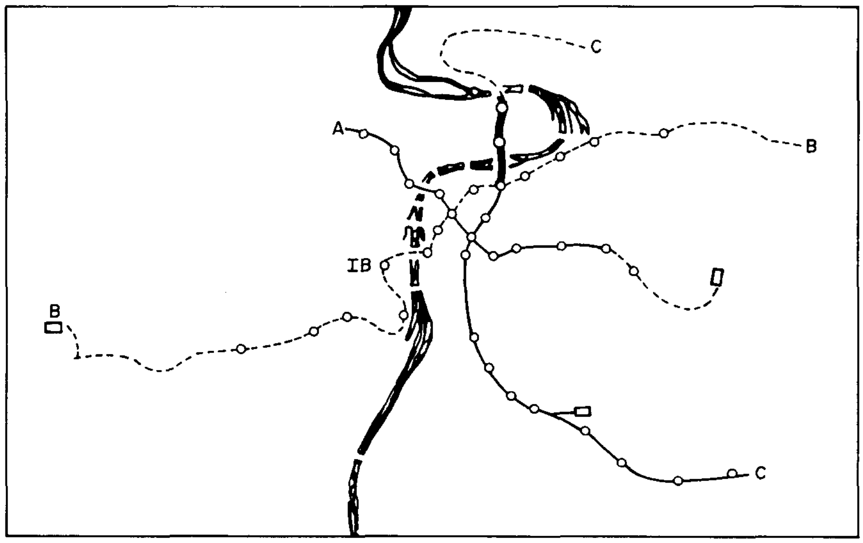

Figure 9. Map of the Prague underground railway.

*This report is based on a compilation of the working group of the Czechoslovak Government Committee ITA, headed by Ing. Jindrich Hess.

Table 2. Development of the underground railway system in Prague up to the year 2000.

Section	Length (km)	Number of stations	∅ distance between stations	Cost in million crowns	Start-up year
IC-Sokolovska-Kacerov	7.1	9	733	3,719	1974
IA-Leniova-N.Miru	4.9	7	799	5,194	1978
IIC-Kacerov-Kosmonautu	5.3	4	1325	2,449	1980
IIA-N.Miru-Zelivskeho	2.7	3	897	1,920	1980
IIIC-Sokolovska-Fucikova	2.3	2	1150	1,926	1984
IB-Sokolovska-n. Smichov	4.9	7	834	7,269	1985
IIIA-Zelivskeho-Starostr.	1.1	1	1050	1,050	1987
IIIB-Unorov. vitezstvi-Smichovs.nadrazi	4.9	3	1637	2,112	1990
IIB-Sokolovska-A.Zapotockeho	4.4	4	1102	3,505	1990
IVC-Fucikova-R. Armady	6.5	4	1625	3,026	1993
VB-Zlicin-Unor. vitezstvi	5.1	5	1020	1,949	1995
IVB-A. Zapotockeho-Hloubetin	3.8	3	1260	1,708	1998
CI-Lhotka-Mladeznicka	7.7	5	1540	2,520	2000
Total	60.7	57			

determined by the overall social and political climate of our state. They are based not on the revenue-to-cost ratio of the underground railway operation, but rather on the entire social philosophy of our society.

This is to say that the revenue-to-cost ratio of the underground railway operation is negative, thus requiring considerable financial contributions. Earnings from fares on the underground railway account for about one-half of operating costs. Viewed from the aspect of society-wide interests, however, the effects and benefits of underground railway operation lie in the non-economical sphere; and therein lies the difficulty of clearly defining them.

Public Transport Improvements

Time savings, i.e. reduction of travel times, is of prime importance for passengers using public transport. Public transport by the underground railway covers an average of 250 million travels per annum. The comparison of travel times by underground railway vs travel times by tramway or bus lines shows a travel time reduction of 18 min per travel, representing a total of 75 million h saved in transportation time.

Expressing this time saving in monetary figures is very difficult, of course, but it is presumed that one saved hour represents a gain of 12 Kcs/Crowns on an average. Annual saving then reaches the amount of 900 million Kcs, which is enough to balance the operating costs of the whole underground railway system.

The increased participation of the underground railway in the urban public transportation was documented above. This implies that more and more passengers make use of this transport means, enjoying such indisputable advantages as increased comfort, accuracy and regularity of traffic and, thereby, reduction of situations evoking stress. Such benefits are, of course, not readily quantifiable. The architectural design of the underground railway in Prague, which was emphasized during construction, is another feature having great psychological positive impact on the traveling public. Neither can this effect be expressed in economic figures.

Improved Transport Safety

Pedestrian underpasses are usually built in conjunction with the construction of underground stations, to ensure safe transit at busy crossings and junctions for all the public, not just the underground passengers. Adding in the substantial relief in traffic on surface transport lines, we can infer the positive implications of the subway, resulting in reduction of accident rates in Prague after commissioning of the underground

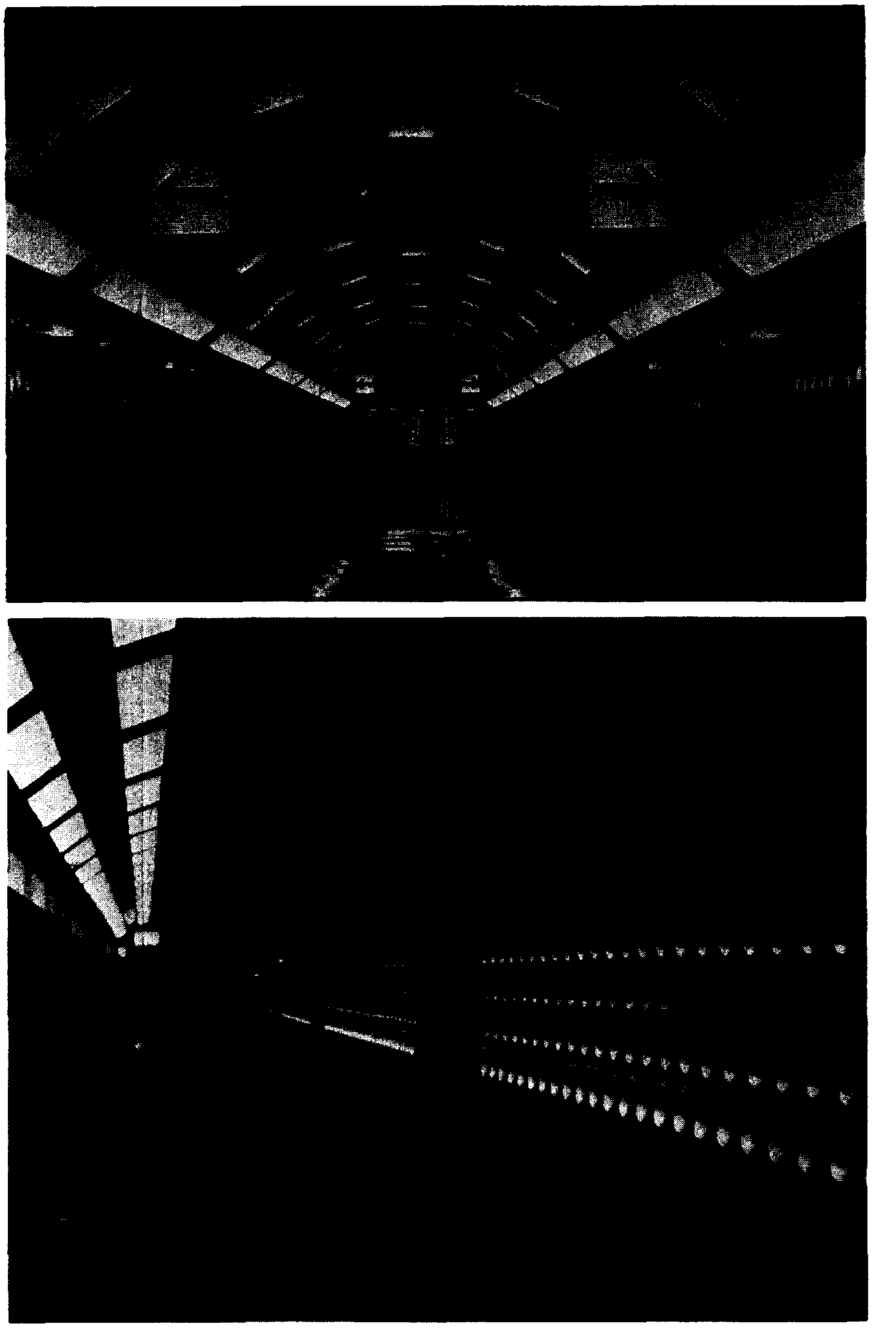

Figure 10. Typical Prague metro stations.

railway tracks in the years 1974, 1978 and 1980. Table 5 shows the results of these calculations.

Reckoning with the assessment of 20,000 Kcs/Crowns per one light injury, 200,000 Kcs per one heavy injury, and 1 million Kcs per death casualty, we may conclude that the reduction of accident rates offers considerable benefits for national economy.

Another benefit, appreciated by underground railway operators, is the easier operation of trains. Because the tracks are separate, the drivers can control the trains without sudden braking and interruption of the ride; and, last but not least, without mental stress.

Other types of positive effects have resulted from the new working environment, which is extremely different for some professions, from the effects of working in aboveground environments.

One such factor is the microclimate. It has been proven that, under climatically favorable conditions, work performance increases as much as 20%, sickness rates drop by 19%, and the number of out-of-work hours can be reduced up to 32%.

Another positive effect is lower noise levels in comparison with aboveground traffic noise. The ILO (International Labour Office) has noted that excessive noise can decrease the efficacy of work by 40-60%.

Not even such aspects as suitable illumination, color scheme of stations, and the like, can be considered negligible. Some authors have mentioned, in studies of environmental effects, an increase of up to 15% in production rate, a 20-40% reduction in accident rates, and a 40% reduction in reject rates.

Naturally, negative effects also must be considered, especially in conjunction with underground work under conditions of artificial illumination and poor ventilation.

Impact on Urban Development

In the course of underground railway construction, an extensive reconstruction of linked access roads, engineering installations, tramway lines and feeder bus stations, including installations for automatic traffic control, took place. This reconstruction was included in overall costs of underground railway construction, which represented 5-8% of the total investment.

Construction of an underground transportation network under the historical part of the town appears to be the basic prerequisite for further development and existence of the city. This factor cannot be expressed in monetary terms.

Routing of individual tracks under the center of the town made it possible to exclude tramway lines from the central square and substantially limit bus transportation in this area. New pedestrian zones have been created, resulting in improved environmental conditions for the citizens and, at the same time, reducing the costs for renewal of adjacent buildings.

Table 3. Number of public transport passengers in Prague, and percentage of different transportation modes used.

Type of transport	Number of passengers in millions (1975)	Percent	Number of passengers in millions (1980)	Percent
Underground railway	64.0	8.9	258.5	22.7
Tramway lines	411.0	56.7	505.4	44.4
Bus lines	249.0	34.4	374.5	32.9

Table 4. Expected development in the percentage of passengers who will use the underground railway.

Year	Km of tracks in operation	Number of stations	Share in urban public transportation (percent)
1980	20.0	23	22.7
1985	27.2	32	33.5
1990	37.6	40	40.1
1995	49.7	49	49.3
2000	60.7	57	49.8

Table 5. Reduction in accident rates in Prague after commissioning of the underground railway tracks in 1974, 1978 and 1980.

Year	Death casualties	%	Heavy injuries	%	Light injuries	%
1970	148	100	612	100	4451	100
1975	96	65	556	91	3786	85
1980	66	45	427	70	2476	56

An example of this renovation may be found at the very center of the city, at Venceslaw Square, which is 740 m long and 63 m wide. Before the environmental adaptation, an average of 92 tramway trains passed through the square every hour, and an average of 90,000 motor vehicles per day on working days. At present, following the construction of the underground lines I A and II A, the tramway lines are entirely excluded in the longitudinal traffic direction and the motor vehicle load has been reduced to 4200 vehicles per day (see Fig. 11).

Federal Republic of Germany*

Investment in Public Passenger Transport

From 1967 to the end of 1984, federal, state and local governments, German Railways, public and private transport undertakings spent a total of DM 32.7 billion on extending the facilities of public passenger transport systems. Between 1967 and 1979, in particular, there was a marked uptrend in the level of annual investment (Fig. 12). Since 1980, the annual sum available has been running at about DM 2.4-2.7 billion.

As far as the sources of the funds are concerned, federal and state government accounted for the major share over the years, providing an average of approximately 52% and 20%, respectively. The amount provided by local government, viz. 24%, is much higher than generally assumed, especially because the transport undertakings and the local government units behind them as owners also bear the costs of the vehicles. The total amount for this is another DM 600 million per year.

The major portion of the funds was invested in improving and extending railway traffic: by far the largest amount, about 60%, went toward underground (U-Bahn), metropolitan (light railway systems—Stadtbahn) and tramway systems. This was followed by about 33% spent selectively on the German Railway's rapid transit schemes (commuter railways—S-Bahn). Most of the remaining funds were used to extend or construct service stations and workshops, central bus stations, interchange stations, park and ride facilities and grade-separating structures.

Construction Work

The funds invested so far over a period of 17 yr have generated a huge volume of construction work on facilities for municipal railway system (underground, metropolitan—Stadtbahn, and tramway).

The development programme covers the following projects:

(1) All-out underground systems (U-Bahn) are being operated or extended in four West German cities at present (viz. in Berlin, Hamburg, Munich and Nuremburg), most of which have more than one million inhabitants.

(2) Metropolitan systems (light railway = Stadtbahn) are being built in 17 cities: Bielefeld, Bochum, Bonn, Bremen, Cologne, Dortmund, Dusseldorf, Duisburg, Essen, Frankfurt/Main, Gelsenkirchen, Hanover, Herne, Ludwigshafen, Mulheim/Ruhr and Stuttgart. The number of inhabitants varies widely, between 200,000 and 900,000.

(3) To finance extensions to their tram networks, nine cities have received investment assistance: Augsburg, Brunswick, Darmstadt, Freiburg, Karlsruhe, Kassel, Krefeld, Mainz and Wurzburg. The number of inhabitants varies between 100,000 and 200,000.

Following the 1967-84 construction period, some 315 km of new non-intersecting routes (tunnel, cutting, elevated) as well as 380 km of on-grade routes (special right-of-way) with a total of 1170 stops will have been put into operation in the municipal railway transport sector.

Installations for the Federal Railway's Transit Services (Commuter railways = S-Bahn)

To open up the region via rapid transit systems, 270 km of new track with 135 stops have been laid and 1020 km of existing track with 410 stations have been converted to meet the needs of rapid transit (S-Bahn) service and have been opened to traffic.

The Costs

The question of costs—and especially of costs for subsurface constructions—is always very difficult to discuss because there are too many factors of influence. The costs for underground railway tunnels with all installations for operation, including stations, vary between 30 and 80 million DM/km. Therefore, it has proven quite absurd to talk about underground railway construction in a generally valid sense regarding cost per km. In the same city, these costs vary considerably from line to line and even from contract to contract. Thus, comparisons between cities have turned out to be impossible. The cost factors described below should be viewed in terms of these limitations.

The main factor influencing the cost of urban railway construction is the relationship between the length of a line in tunnel and at grade. This is remarkably different for the "U-Bahn" and the "Stadtbahn". The results of the first 11 yr of construction period are:

U-Bahn: 78% of track length in tunnel, overall costs 35-40 million DM/km (tunnel and at grade).

Stadtbahn: 23% track lengh in tunnel, overall costs 20-25 million DM/km (tunnel and at grade).

This shows that the "U-Bahn" is nearly twice as expensive as a light railway system on separated track (Stadtbahn).

Another important factor influencing the cost of a metro is the tunnelling construction method, which depends on ground conditions, environmental aspects, conditions of the built-up area, etc. Thus, the tunnelling carcass cost may vary in water-bearing soft ground

*This report is based principally on a paper by Prof. Dr-Ing. Günter Girnau, published in *Advances in Tunnelling Technology and Subsurface Use* 2:2 (1982). The data and figures have been updated.

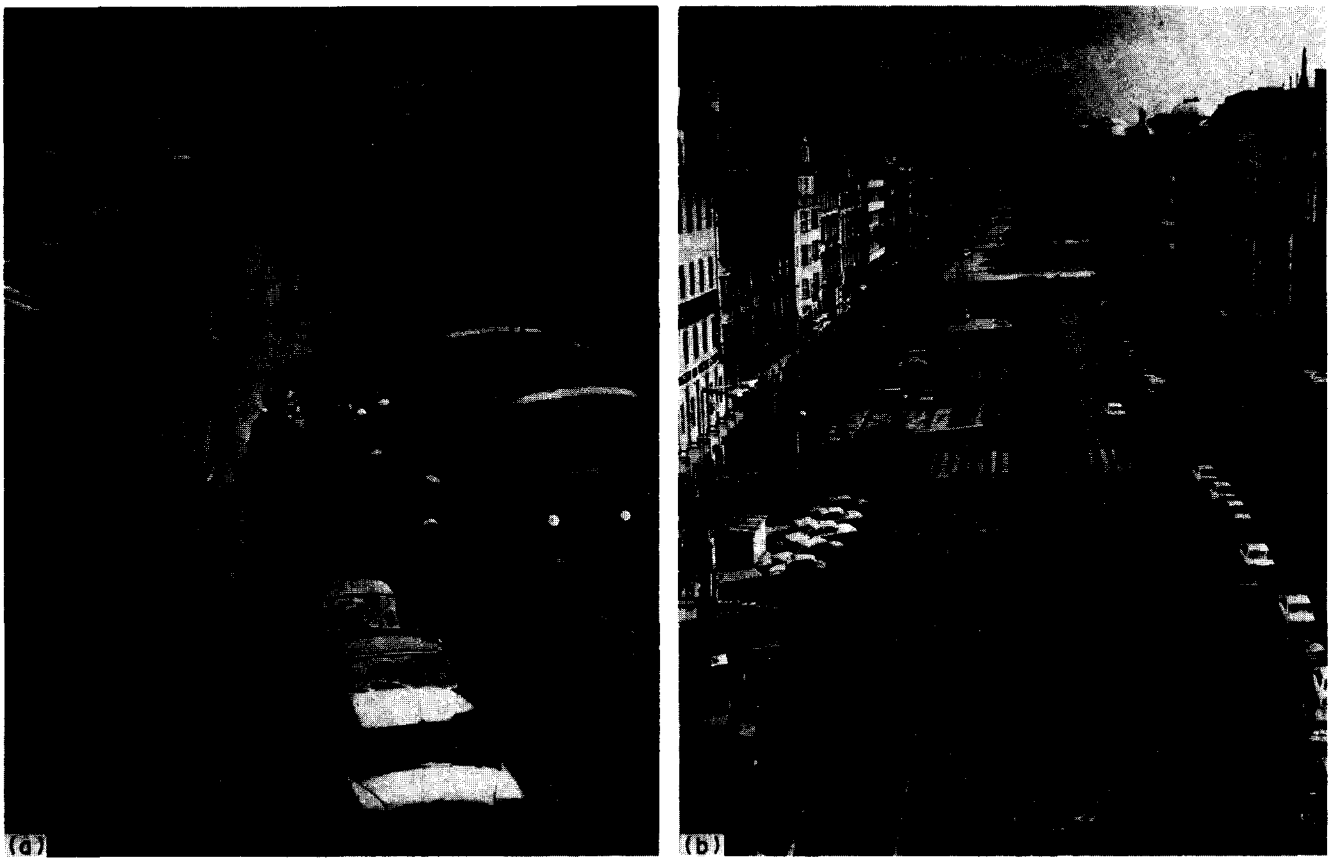

Figure 11. An example of improved environmental conditions in Veneslaw Square, located in the very center of Prague. Before construction of underground lines IA and II (photo at left), an average of 92 tramway trains passed through the square each hour, and 90,000 motor vehicles crossed the square each day. After metro construction (photo at right), the tramway lines were removed in the longitudinal traffic direction, and motor vehicle loads were reduced to 4200 vehicles per day.

in the ratio between 1 (cut-and-cover method) and 2-3 (compressed-air shield driven).

In Germany, however, the technical development between 1966 and 1985, combined with the very strong competition between the contractors, has had remarkable influence on the ratio of costs between the cut-and-cover method and the "underground" tunnelling methods. Figure 13 shows that in Munich today, the costs for the New Austrian Tunneling method (NATM), the shield method, and the open cut are very similar. In 1985, these prices had reached a level that was valid as early as 1975 [9]!

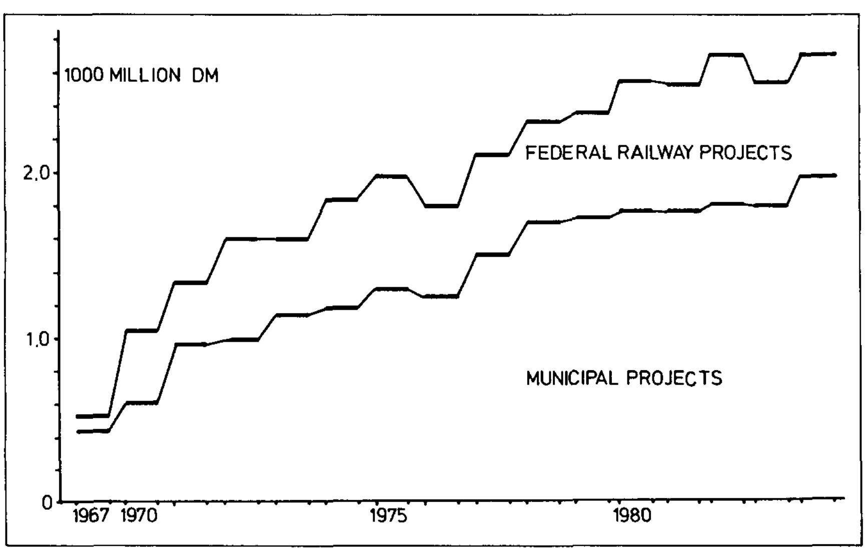

Figure 12. Investments for public transportation in West Germany under the terms of the Municipal Transport Finance Act.

Although there are many other influencing factors—e.g. cross-section, tunnel length, type of lining—they will not be dealt with in detail in this report.

Since 1980, inflation rates in construction engineering have caused problems for the continuation of the entire public transportation development program. While the construction prices could be kept on the same level during the 1970s (for the reasons stated above) these prices rose in 1980-81 by 20%

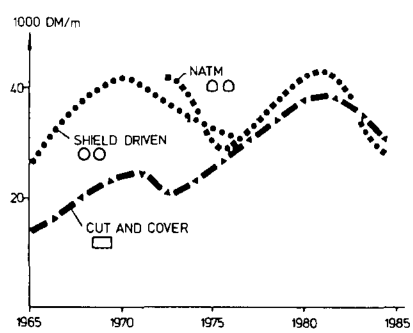

Figure 13. Development of costs for different means of tunnel construction in Munich.

to 40%. However, a decline in prices has again occurred in the last few years.

The Benefits

Although the benefits of this investment activity are undeniable and quantifiable, a statement of the results of investment in local public passenger transport would be one-sided if it were confined to the effects on traffic conditions. It would be erroneous to assess the value of rapid transit systems merely in terms of passenger loads.

The full impact of the construction programmes must be considered in any objective assessment. It is important to distinguish between results reflected in improved transport amenities, from which the passenger benefits, and other results, which are in the public interest both economically and socially.

Transport Improvements

Regularity, punctuality and speed are the basic criteria in determining the attractiveness of public transport. Success is very apparent where route separation has permitted a de-mixing of public and private traffic. This has cut travel times compared with bus and tram services, reduced delays to zero in most cases, and increased passenger loads (Table 6).

From this point of view especially, the examples of Munich (U-Bahn) and Hanover (Stadtbahn) demonstrate in detail the success of the investment policy (Tables 7 and 8).

What is particularly important is that upgrading public transport makes it a genuine alternative for those who still travel by car. Again, the examples of Hanover and Munich represent many systems:

- Counts in Hanover have shown that since the opening of the light railway Line A, 78% of all trips into the city are made by means of public transport within the area of influence of the new line; and that 50% of the passengers have a car at their disposal at any time.
- The urban area of Munich experienced a drop in car movements of 70,000 a day following the start-up of underground and rapid transit services (reference period: 1970-1973).

These statistics suggest that the merits of an attractive public transport system are appreciated and exploited even by car drivers.

Stepping Up Safety

Compared with other vehicles used to move people, bus, tram and underground railway are the safest of all. Pushing ahead with the construction of separate lanes and routes, and the resulting de-mixing of the traffic, could do even more to improve safety.

The pedestrian, in particular, is the

Table 6. Transport improvement due to construction of urban railways in West Germany.

Transport form	Measure	Result
Travel time		
Underground/ light railway	Bus line replaced by rail system	Average travel time cut by one-half
Delays		
Underground/ light railway	Tunnel or separate right-of-way	Delays of up to 10 min cut to virtually none
Passenger loads		
Underground/ light railway	Tunnel or separate right-of-way	Rise in passenger loads: normal: + 15–60 % Extreme: + 109 % (Frankfurt) + 190 % (Munich)
Commuter railway system (S-Bahn)	Separate right-of-way	Rise in passenger loads: + 100–250 %

Table 7. Increase in passenger loads as a result of subway construction work in Munich.

Line	Year	Passenger load	Increase
U-Bahn U3/U6	1972 ("before")	124,000 pass./day	+ 190 %
	1980 ("after")	360,000 pass./day	
S-Bahn	1971 ("before")	160,000 pass./day	+ 244 %
	1980 ("after")	550,000 pass./day	
U-Bahn U 8 (new)	1980	220,000 pass./day without any reduction of passenger loads or other lines	

Table 8. Increase in passenger loads as a result of "Stadtbahn" construction work in Hanover.

Line	Year	Passenger load	Increase
A	1975 ("before")	70,000 Pass./day	
	1980 ("after")	105,000 Pass./day	+ 50 %
	1981	120,000 Pass./day	+ 70 %
B (Only half in operation)	1978 ("before")	32,000 Pass./day	+ 34 %
	1980–1982 ("after")	43,000 Pass./day	

beneficiary of the technical improvements made in public passenger transport. Two examples will demonstrate this:

(1) The sub-grade relocation of railway traffic has permitted extensive pedestrian precincts to be created in many city centers where the pedestrian can move without being impeded by traffic.

(2) Sub-grade stops provide greater safety not only for passengers, but for pedestrian traffic in general, whenever such facilities have subways permitting pedestrians to cross streets.

This separation of traffic types, achieved by constructing separate—mainly underground—routes and lanes for public transport could not fail to be reflected in road accident statistics. In Munich, for example, between 1970 and 1977, the road accident rate fell by 37.6%; the injury rate, by 22.1%; and the number of fatalities, by as much as 40.7% (see Fig. 14).

Environmental Impact

Because underground transport places less strain on the environment, investment designed to create subsurface transport and to increase passenger loads will have both a direct and an indirect effect on the environment. This factor is demonstrated by the following examples.

Measurement of air pollution from the exhaust fumes in the urban area of Munich at 50 points produced the following results: After the opening of the first rapid transit (Schnellbahn) routes (comparison between 1970 and 1973), the carbon monoxide concentration dropped by 25%, hydrocarbon concentration by 35%, nitric oxide by as much as 44%. This reduction in pollution is mainly due to improved car traffic flows, the shift of traffic segments to underground and rapid transit systems, and the use of the park-and-ride systems.

In addition, any investment to improve the routes and lanes for public transport or to improve the vehicles themselves will lower noise levels. Rerouting vehicles via an open cutting or trough, for example, yields a substantial noise reduction in the surrounding built-up area. Routing traffic through tunnels eliminates noise pollution altogether.

In Hanover, opening the metropolitan Line A cut noise by more than 10 dB (A) in the urban area along the route, meaning noise nuisance was halved (Fig. 15). This also means that no specific measures for protection against traffic noise need to be taken in this area. For example, the costs of noise protection windows, which usually run between 2300 and 5400 DM/m of road (Table 9), can be saved.

Economic Implications for Transport Undertakings

It is a fact that improvements in local public passenger transport—especially by use of the subsurface—are synonymous with greater monetary outlays: higher maintenance costs must be taken into

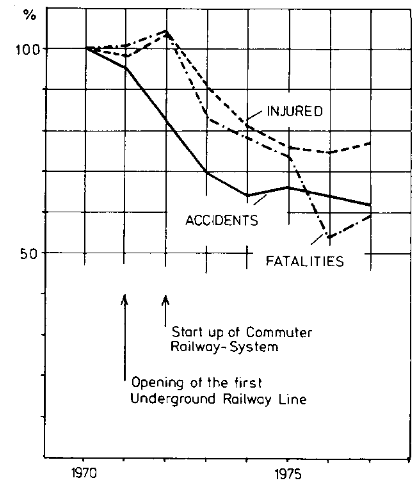

Figure 14. Development of road accident rates in Munich.

account in sub-grade routes and stations in particular. Of crucial importance here are the energy and servicing costs. Moreover, costly safety engineering and the improvements to vehicles to meet the specific needs of rapid transit services also entail higher costs.

For these reasons, it was long feared that these costs would involve a considerable deterioration in the economic situation of transport undertakings. The consequence would have been an unreasonable financial burden on local government, and the whole point of such investment would have been called into question.

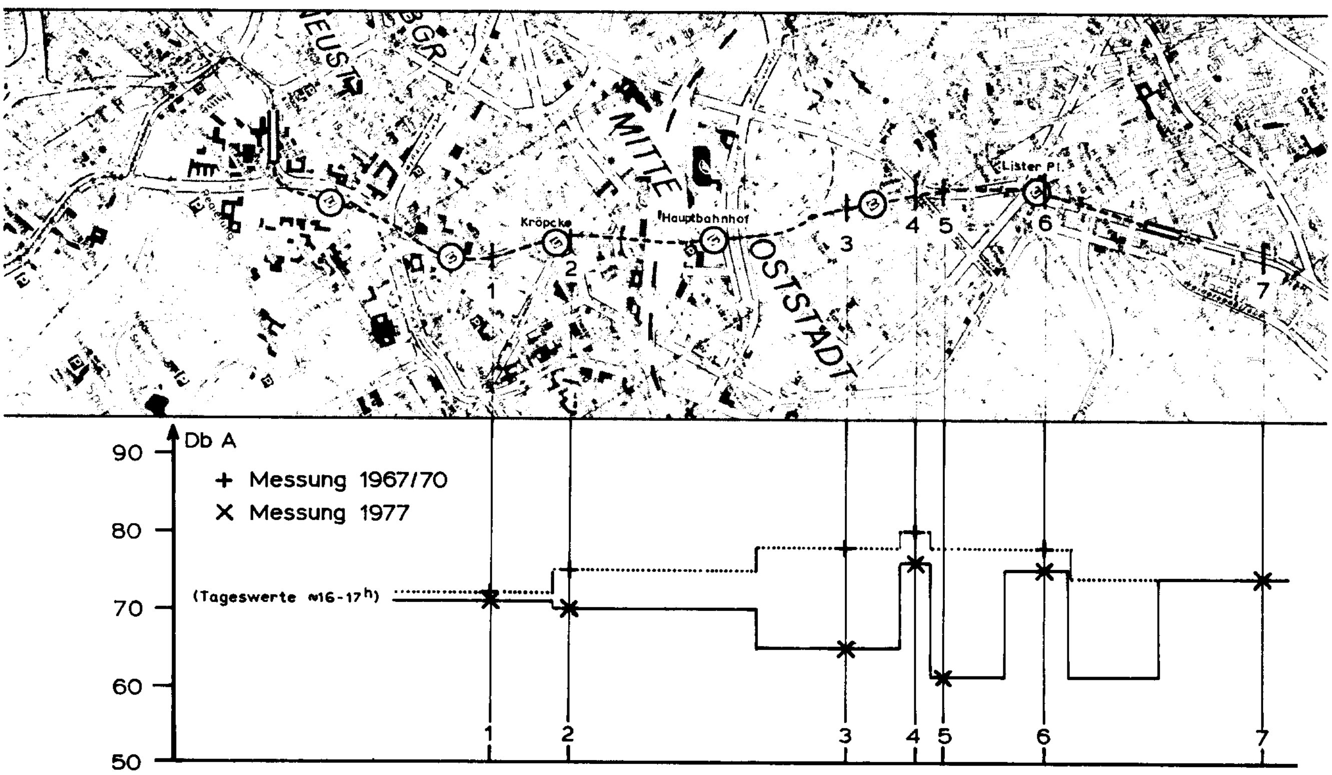

Figure 15. Noise levels in city streets in Hanover, West Germany, before and after construction of an underground light railway.

Table 9. Costs of noise protection window for three- to five-story buildings along both sides of a road.

Exceeding of the immission rate limits by	Approx. costs of noise protection windows (DM per m road length)
5 dB (A)	2300. - - TO 3000. - -
10 dB (A)	2900. - - TO 4200. - -
15 dB (A)	3700. - - TO 5400. - -

Thanks to the federal government's so-called Post-Construction Cost Report (Folgekostenbericht), standards were set right again in this respect. The Report makes it quite clear that:

- The construction of underground, metropolitan railway and rapid transit systems is not the primary cause of the deficits produced in local public passenger transport.
- Post-construction costs of the publicly assisted investment in local public transport up to 1985, even using purely commercial accounting, would have accounted for only about 5% of the total cost cover shortage.

Thus, post-construction costs are far from reaching the levels predicted by the critics of public investment for local passenger transport. In any case, the purely commercial considerations at the back of the calculations in the Post-Construction Cost Report [3] ignore the benefits for the economy as a whole. Yet local passenger transport is promoted precisely because of the public benefit.

An examination of the investment in terms of economic effects for the transport undertakings reveals that urban rapid transit systems can very well be run on reasonable economic lines.

In Hanover, the opening of the metropolitan Line A not only yielded an increase in passenger load on this line by 50% in all, with a majority of the increase being accounted for by genuinely new business; logically, the new business yielded higher fare income which more than made up for the higher operating costs (Table 10). Admittedly, the cost accounting of the Hanover transport undertaking is given a fillip by the fact that the City of Hanover foots the energy bill and meets the costs of maintaining and renewing the tunnel installations. While to that extent, the Hanover example cannot represent all metropolitan and underground railway systems, it remains a fact that investment in local public passenger transport need not produce bigger deficits.

There is yet another aspect which must be noted, namely, that planning for public and individual traffic in metropolitan areas influence each other. This means that big investments in underground railways lead to smaller investments in roads. The city of Munich, for example, opened the first underground railway line in 1971; since that time the underground system has been enlarged continuously by an amount of approximately DM 200 million per yr. In 1970, Munich invested DM 160 million in road construction work; until 1975, this amount dropped to about DM 55 million; and since that time, it has varied between DM 60 and 70 million per yr. In other words, about half of the investments in underground railways were saved by a smaller investment in municipal surface roads.

Overall Economic Impact

From the point of view of the economy as a whole, investment in local public transport is important because it secures jobs in many sectors. An estimated total of 20,000-25,000 building trade employees work in underground, metropolitan railway and rapid transit system construction. Since this work force is concentrated in a few centers, the local importance of these jobs is great. With capital spending totalling DM 2 billion per annum, approximately 40,000 workers in West Germany are directly or indirectly dependent on the construction of rapid transit systems. A secondary effect is that the construction firms working in local passenger transport have been able to apply the experience acquired in handling domestic projects to open foreign markets as well.

Impact on Urban Developments

The catalogue of results should end up with what is perhaps the most important consideration of all. The construction of rapid transit systems must always be viewed specifically as an instrument of urban redevelopment and renewal. Only then will capital spending in local passenger transport—especially where underground, light railway and rapid transit systems are being constructed or extended—have a substantial positive impact on urban infrastructure and yield improvements in the quality of life of our citizens.

This is demonstrated by the following examples, which represent many urban transport systems:

- The function of city centers as market, trading and communication centers is restored (see Fig. 16).
- Residential amenities and recreational values can be improved by providing park facilities.
- Motor vehicle traffic can be bundled on fast arterial roads, so that areas free of traffic at certain times and with pedestrian precincts can be created and kept largely free of motor traffic.
- Sub-grade routing of public transport permits more intensive use to be made of surface land to create higher-density business and residential districts.

Table 10. Comparison of operating cost "Stadtbahn"/tram: example line A in Hanover, 1976.*

Position	"Stadtbahn" (Mill. DM)	Tram (Mill. DM)
Operators†, inspectors, station staff	4,248	5,986
Propulsion energy‡	1,846	1,575
Maintenance (vehicles, buildings, operating equipment)	5,693	4,658
Capital cost§	6,846	5,578
Tunnel lease /¶	0,200	—
Other//	5,299	4,423
Total cost	24,132	22,220
Revenues	18.00-18.5	15.0-15.5
Cost ./. Revenue	./. 6.1-5.6	./. 7.2-6.7

*Service standard 4500 places/h + direction.
†Stadtbahn needs 45 fewer operators.
‡More powerful vehicle engines in Stadtbahn.
§Higher costs for Stadtbahn-vehicles.
/¶The municipal authority bears the costs of maintenance and renewal for tunnels.
//E.g. costs for tickets, ticket machines, taxes; proportional overhead costs for administration, insurance and social payments.

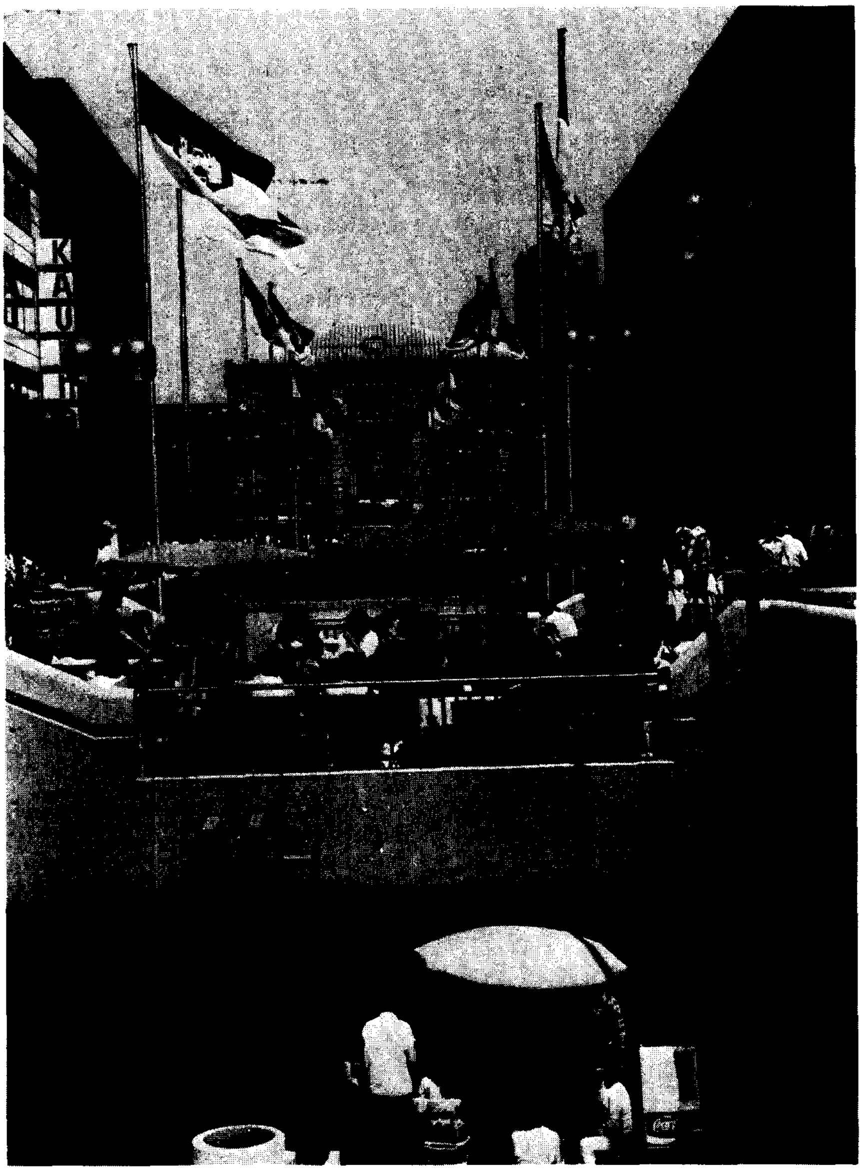

Figure 16. Passerelle and pedestrian precinct above the subway tunnel in Hanover, West Germany.

- Further development of structurally weak areas (e.g. old town districts, renewal areas) can be promoted by construction work for public transport and by supplementary urban replanning.
- Settlement along the right-of-way of rapid transit systems is promoted and urban sprawl checked.
- Public amenities, local recreation and sports facilities can be made more accessible and used by larger segments of the community. It is in dealing with traffic peaks to and from major events that public transport has proved particularly valuable.

Finally, one scarcely noticed factor is the large-scale renewal and modernization of urban utility supply lines and sewerage systems that goes hand in hand with the construction of sub-grade transport installations. When the metropolitan railway in Cologne was built, it involved the construction of 11 km of tunnel (approx. 20 km of new track altogether); but, in addition, 62 km of sewers and piping, as well as 233 km of cable, were laid or relaid.

Much the same is true of other cities. The new lines and networks have been designed to meet future demands, and will obviate the need for regular repairs and extensions to the old system.

Costs vs Benefits

While the assessement of cost vs benefits is very popular today, attention must be paid nonetheless to the fact that many problems in this field are still unsolved. Some of the most important benefits of underground railways are extremely difficult to monetarize. What, for example, is the economic equivalent of growing prosperity of a city, less polluted air, lower traffic noise levels, lower accident rates, etc.?

Despite these difficulties, the German Minister of Transportation began, in the middle of the 1970s, to require a (simplified) standardized cost-benefit analysis [8] for those cities requesting financial support for their projects. The method used a comparison of the "with" and the "without" situation, meaning that the expected effects of the investment are compared with the effects without the investment. The changes are evaluated and monetarized for the following groups and effects:

(1) **For the passengers:**
- Costs for travelling time;
- Fares for public transport;
- Operating costs for private cars.

(2) **For the transit authority (operator):**
- Annualized capital cost;
- Operating cost;
- Fare box revenue.

(3) **For the general public:**
- Noise reduction cost;
- Cost for reduction of exhaust fumes;
- Accident costs.

Because of the great expense of the cost-benefit analysis, the application was limited to projects requiring more than a DM 50 million investment.

However, just a few years of experience with this type of analysis proved that it was insufficient, and it was withdrawn. Now a group of experts works out a new cost-benefit analysis that avoids the deficiencies of the first analysis. In this system many more indicators are considered and, as far as possible, monetarized. But even this improved version can be merely an aid: it cannot replace the political and technical decisions made for or against the investment.

Conclusion

The above discussion demonstrates not only that improvement of local public passenger transport provides the individual passenger with a direct personal benefit, but also that underground construction work in the field of public transport produces other positive effects of various kinds that cannot fail to be in the public interest, both socially and economically. Such measures can contribute significantly toward improving the often-cited and often-evoked quality of life.

Experience in the Federal Republic of Germany indicates, on the one hand, that this requires a huge volume of capital spending and very long construction time in some cases; and, on the other, that this seems to be the only way we have of saving our cities from destruction.

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France*

Introduction

This report gives a brief overview of some of the most significant projects undertaken in France in the area of urban public transportation in the past few years. It seeks to illustrate the fact that as a result of considerable capital spending on the construction of subsurface metro and railway infrastructures, patrons as well as non-patrons, the public authorities, and the community in general have all benefited from the many advantages of these projects, the main feature of which is not directly quantifiable in monetary terms.

Common sense often leads us to believe that the construction of subsurface transit infrastructures is manifestly essential for a particular urban area. It must be admitted, however, that, faced with the often cold hard looks of the financiers, the technicians generally lack any decisive arguments for such construction.

*This report was submitted by Working Group 10 (Subsurface Use) of the French Tunnelling Association (AFTES): J. P. Goddard (R.A.T.P.), Chairman; M. Hugonnard (R.A.T.P.), Recorder.

Recent Public Transportation Policy: Typical Cases

The last decade has witnessed a complete turnaround in the matter of urban public transportation in France. While traffic on the public transit systems had dropped steadily since the 1950s, with a corresponding increase in financial difficulties, a complete swing with regard to avowed policy voiced by public took place in 1973. The essence of this policy was, first, to give preference to public transportation; and, second, to devote the required amounts of resources for the purpose.

Thus, with regard to rapid transit systems (metro and railway), construction started on the first metro lines in the cities of Lyon (1,120,000 inhabitants), Marseille (870,000 inhabitants) and Lille (1,040,000 inhabitants). At the same time, in the Greater Paris Region (10,000,000 inhabitants), existing metro lines were extended into the near suburbs and construction began on a genuine broad-gauge regional rapid transit system (RER), serving the near and outer suburbs while crossing Paris from end to end. Meanwhile, a number of new extension and new services were introduced on the suburban railway system.

This report deals with the following operations:

- The two first sections of the Lyon metro system (Fig. 17);
- The first section of the Marseille metro system (Fig. 18);
- The first section of the automatic metro system (VAL) in Lille (Fig. 19);
- Five metro extensions into the near suburbs of Paris (Fig. 20);
- Construction of the central sections and of the Marne-la-Vallée branch of the Regional Rapid Transit system (RER) in the Paris area (Fig. 21);
- Creation of a new line to Cergy/Pontoise and of the Invalides/Orsay railway link in Paris.

The highlights of each operation are summarised in Table 11.

Benefits

The benefits of underground public transit systems vary greatly in nature. As stated above, most such benefits are either entirely of a qualitative nature or not directly quantifiable in monetary terms.

The advantages have been classified into benefits for the patrons of the new infrastructures, for non-users of public transit systems, for the local authorities, and for the community in general.

Benefits for Patrons of New Infrastructures

Trends in passenger traffic on public transit systems

Indirectly, the benefits of a new infrastructure may be measured from the amount of and trends in registered traffic over time. The traffic may be broken down into previous traffic acquired by public transit but having changed its mode or itinerary; traffic diverted from individual transport modes, e.g. walking, private cars, two-wheelers; and induced traffic, i.e. traffic generated through the sole presence of the new infrastructure.

As regards new infrastructures, the new traffic recorded is in all cases far greater (by at least 50%) than the traffic previously recorded on the transit systems (generally buses) that served the

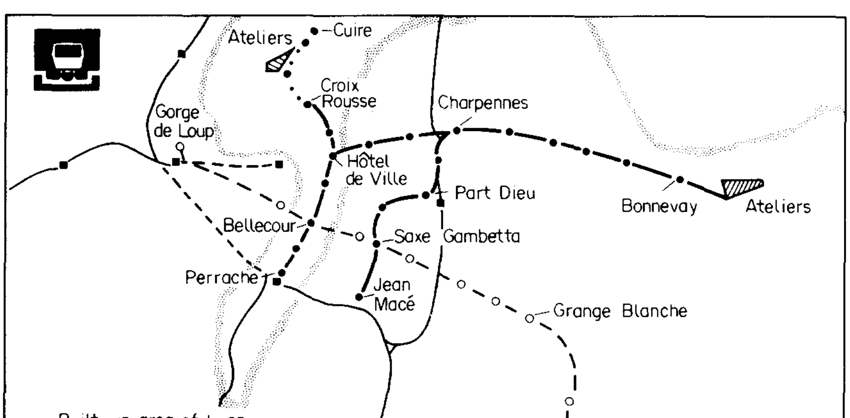

Figure 17. The first two sections of the Lyon, France, metro system.

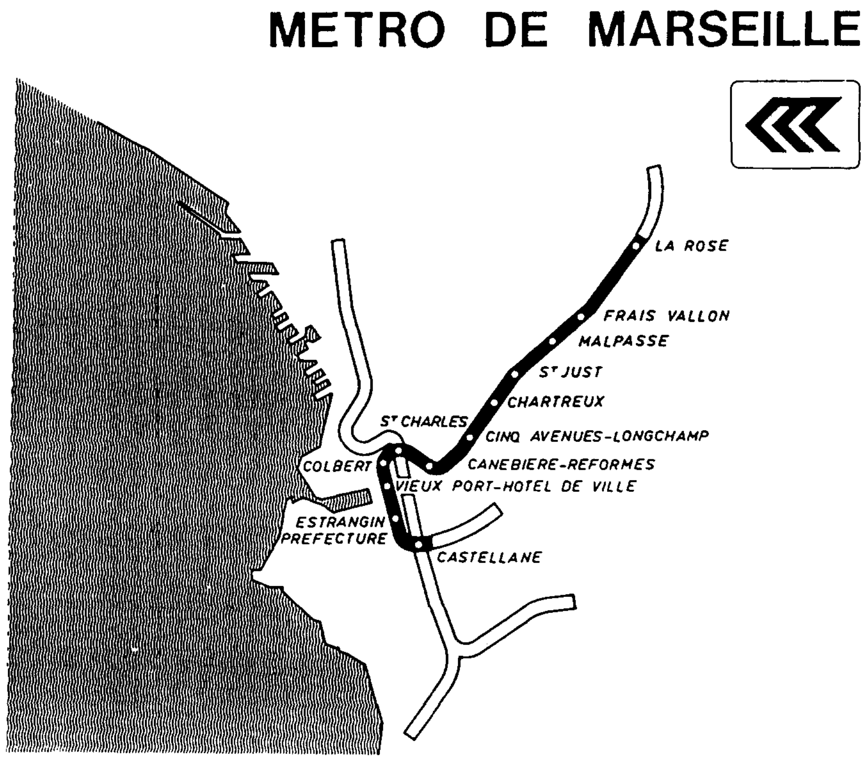

Figure 18. The first section of the Marseille, France, metro system.

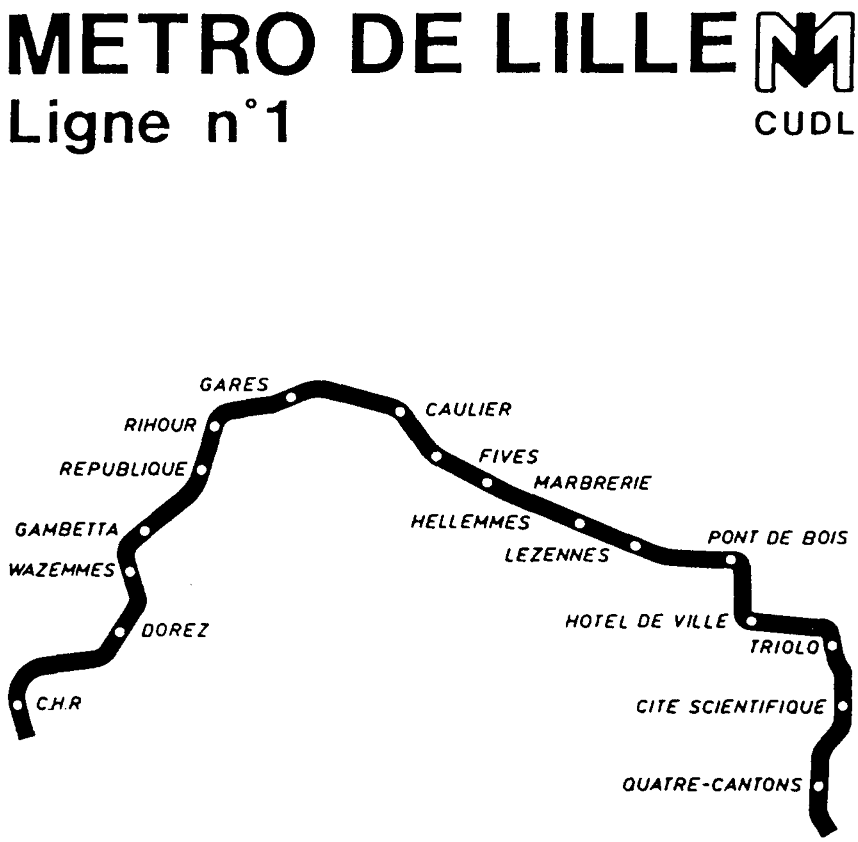

Figure 19. The first section of the automatic metro section in Lille, France.

considered sectors. The most spectacular example is that of the Lyon metro line A, running on the former bus routes 7 and 13, on which the traffic just about tripled.

In Lille, too, the metro recorded 2.6 times the traffic carried by the former bus routes located in its area. This naturally reflects the specific attractiveness of the rapid transit systems, in regard to both patrons who walk to the stations (the average walking distance in the Paris suburbs is 350 m on the bus routes and 660 m on the metro system), and patrons who accede to them by some other mode, whether individual or collective (Table 12).

In this connection, note that developing a metro system often translates into an increased average number of interchanges on the public transit systems, which in Lyon rose from 1.22 to 1.46; in Marseille, from 1.11 to 1.28; and in Lille, from 1.15 to 1.24.

The origin of the traffic on the new infrastructures is shown in Table 13. Note that these data reflect only the short-term effects of the implementation of the new infrastructures, as the surveys from which they have been abstracted were conducted less than one year after operation began.

The observed fluctuations naturally derive from the differences in the nature of the projects. For instance, on the Lyon, Marseille and Lille systems—which were only surface-type systems before the metros were completed—the new traffic carried on public transportation appears considerable (36–56% of the total), whereas it is far less in the Greater Paris Region, though not insignificant in absolute value (only 30,600 trips per day on the RER).

An additional phenomenon worth stressing is the fact that traffic on the new infrastructures continues to increase over time. Moreover, a "boosting" effect with respect to transit on the surface modes is also evident.

Thus, the average annual growth rate of traffic on the metro extensions in the Greater Paris Region is around 6%, while that on the entire metro system is virtually nil, and that on the RER is around 10%.

This phenomenon is worth considering more closely. A survey conducted on the extension of line 13 north of Paris 5 yr after its opening, which supplemented an earlier inquiry performed in 1977 (shortly after the extension started operation), points up the following:

(1) The flow of daily entries in the two stations of the extensions rose from 16,500 persons in October 1976 (the line having been opened to the public in May 1976) to 26,600 persons in February 1981, i.e. a 58% increase, or a little over 10% a year.

(2) Although the population of the town of Saint-Denis, which is directly affected, dropped overall from 96,800 in 1976 to 91,300 in 1981, the pull exerted by Paris—to which it is linked by line 13—has been reinforced by the new accessibility provided by the two newly opened stations.

(3) Fifty percent of the new trips recorded in the two stations of the line 13 extension stem from changes in the population concerned, i.e. arrival of new inhabitants in Saint-Denis, attracted by the new infrastructure; 25% are due to transfers from other transit modes

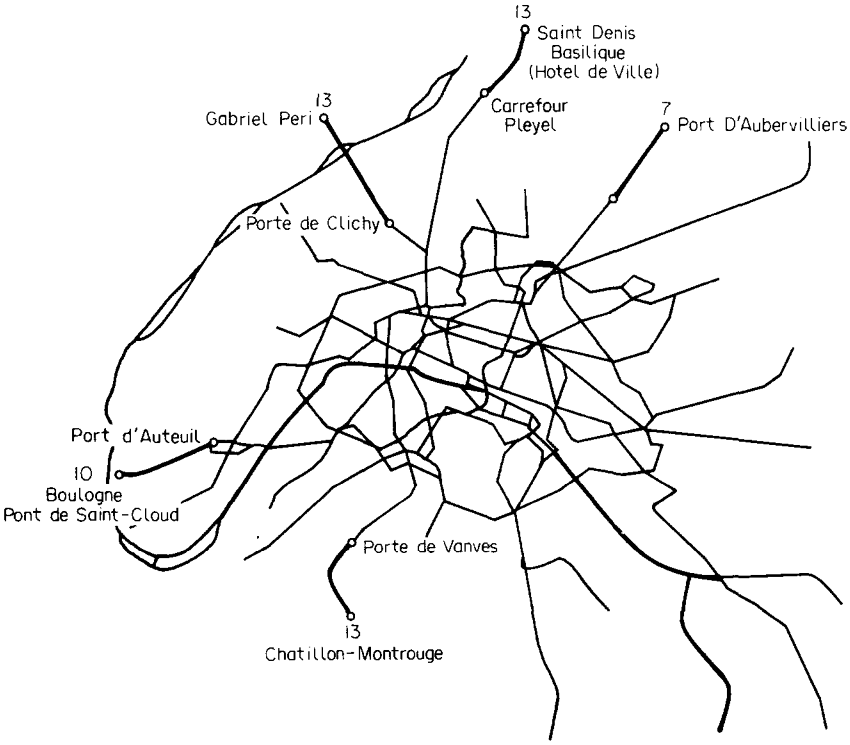

Figure 20. Five metro extensions into the near suburbs of Paris.

delayed in time (at constant mobility); and 25% come from an increase in mobility (induced traffic).

In the same way, in Lyon and Marseille there has been a complete reversal in trends regarding traffic on public transportation in general, as is clear from Table 14.

In regard to Lille, where the metro system most recently began operation (line 1 to "Republique" station, in May 1983), the recorded data are summarised in Tables 15 and 16.

The specific attraction of the rapid transit systems on exclusive rights of way naturally stems from their specific advantages—an average speed of approx. 30-35 km/h, compared with 10-15 km/h for surface systems; regularity; and comfort—as well as from the fact that they pave the way to genuinely hierarchical public transportation systems in the urban areas concerned (as reflected in the growth in the average rate of interchanges).

Moreover, such a specific attraction is directly fostered by the extremely favorable image they benefit from the public, as the following observations point up:

(1) The introduction of metro systems is generally reflected in a ratio of variation of traffic to places x km, which is far greater than 1 and remains good if one considers the trips (Table 17). This is direct evidence of efficiency far higher than is the case for the conventional surface modes.

(2) This increased efficiency is a direct outcome of the expansion of patronage of the public transit system. In fact, only such "heavy" operations can attract to public transportation people who, because they possess a private car, tend to use it in a systematic way or, at least, for most of their personal trips (see Tables 18 and 19).

Advantages to patrons

The most tangible advantage, and that on which the social profitability of projects is generally calculated, is the savings in travel time.

As a rule, time savings are usually important, both on an individual and collective basis, and irrespective of any "psychological" time resulting from the use of a regular transit mode, as opposed to surface transit modes. For the latter, it can often be shown that, failing specific protection against general traffic (such as own right-of-way, bus-only lanes, etc.), the headways between vehicles at any given point follow the exponential distribution law—i.e. they are absolutely random.

Now people living near the La Rose terminal station in Marseille are less than 18 min from the city center—a journey that previously took 45 min by bus. In Lyon, the average time saved by patrons of line A of the metro, in comparison with the previous situation on bus line 7, is approx. 12 min for the same itinerary.

In Lille, the following time savings in trips to the city center have been registered:

- From Hotel de Ville of Villeneuve d'Ascq, by direct metro route (rather than, as previously, by bus), the time saved is about 15 min;
- Starting from the "Cousinerie" district at Villeneuve d'Ascq, by bus followed by metro (instead of bus only, as heretofore), the time saved is around 16 min;
- From Lezennes, by bus followed by metro (instead of bus only, as before) the time saved amounts to 10 min.

As regards the Greater Paris Area, patrons of the new facilities have benefited from substantial time savings in every single case, as shown in Table 20.

However, it is not so much in terms of time saved, i.e. a "flow", but rather in terms of "stock", i.e. accessibility to the city center and its functions, that the full potential of the new facilities may be gauged, for both existing and potential patrons.

Thus, in the case of Lyon, the catchment area of the metro (Table 21) represents one-third of the population and jobs in the urban area, either directly (people living less than 500 m walking distance of the stations) or indirectly (people using feeder modes).

Corresponding figures for the Greater Paris area are shown in Table 22.

At the same time, the fact that such projects help foster a better understanding of the city among the most disinherited sectors of the population translates into a real "opening up" of the town. With regard to the most favored sectors of the population, these projects offer public alternatives that are genuinely competitive with private transportation.

Last, it must be stressed that such operations frequently coincide with lowered transportation costs for patrons

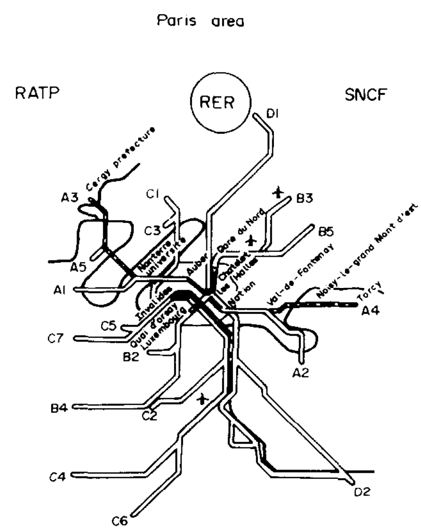

Figure 21. Construction of the central sections and the Marne-la-Vallée branch of the Regional Rapid Transit System (RER) in the Paris area.

Table 11. Highlights of selected operations for the Lyon, Marseille, Lille and Paris area systems.

System		Opening date	Length (km)	No. of stations	Capital costs (millions of FF net of tax on 1/1/1983
Lyon Metro					
Section 1 — Line A — Line B (to "Part dieu") — Line C (to "Croix rousse")		1978	12	17	2,950*
Section 2 — Line B (to "Jean macé")		1981	2.4	3	720*
Marseille metro — Line 1		1977–78	9	12	2,700*
Lille metro — Line 1 (to "République")		1983	8.7	13	
Paris metro extensions	Line 13 northwards	1976	2.4	2	565
	Line 13 southwards	1976	2.3	3	360
	Line 7 northwards	1979	2.3	2	560
	Line 13 bis northwards	1980	3.2	2	780
	Line 10	1980–1981	2.4	2	590
	Subtotal	1976–1981	12.6	11	2,855
Regional Rapid Transit System (RER) — Central sections — Marne-la-Vallée branch		1977 1977	8.8 7.9	2 4	4,310* 1,235*
Suburban railway system — New line to Cergy-Pontoise		1979	23	2 new stations 4 existing renewed stations	1,120
— Invalides/Orsay link		1979	0.85	2 existing renewed stations	1,170

*Costs possibly overestimated due to updating.

or, in the least favorable case, with similar costs for an increased quality of service.

For patrons giving up the use of their private cars, the savings may be considerable. In the same way, for those already using public transit modes, the implementation of integrated fare systems usually leads to an objective drop in costs. [This was the case with the creation of the "hourly" ticket in Lyon in 1978. The ticket allows interchanges with other modes during its period of validity.] All such factors combine to even out social inequalities in the area of urban transportation.

The above elements taken together show that the attractiveness of rapid transit is incomparably greater than that of the surface modes, which are dependent on the other surface traffic. As the discussion below shows, this fact means that the advantages of the subsurface modes extend far beyond those specific to their own patrons.

Advantages to non-users

Strange as it may seem, the implementation of rapid transit systems also results in advantages for a great many persons not directly concerned with them.

Specifically, the modal transfers recorded lead, in the short term, to a reduction of the automobile traffic flows along parallel roads. However, all of the surveys conducted agree that this phenomenon is entirely transient, and that the situation quickly returns to its former state. Indeed, in the European countries, the gap between car ownership and the road network capacity is such that any drop in traffic quickly entails the arrival of new users.

In any case, there remains the fact that the possibility made available to new patrons to use the road network should be considered from the standpoint of additional means of mobility—and, hence, represents a gain in this respect. Moreover, it is clear that improving a mass transit system leads to reduced growth in car ownership trends. In this connection, it may be pointed out that Paris is the least motorized of French cities.

Among the other positive effects of implementing rapid transit facilities in towns, there is also the fact that their very construction is often the occasion of the reconquest of space by the pedestrians, especially in the downtown areas of cities. This was the case in Lyon, when the streets of Victor Hugo and of La Republique were turned into pedestrian malls. Similarly, in Marseille, four vast new squares totalling 7600 m^2 were built in the city center. And in Paris the planned construction of a pedestrian plaza, the largest in Europe, will connect Les Halles with the Georges Pompidou Museum. These are just a few instances among many of how mass transit is synonymous with space savings, the latter being a basic requirement in the heart of cities.

Table 12. Feeder modes on new infrastructures for the Lyon, Marseille, Lille and Paris area systems.

System		Feeder mode: Walking (%)	Bus (%)	Private car (%)	Other (%)
Lyon metro		65	28	4	3
Marseille metro		63	27	7	3
Lille metro		71	21	4	4
Paris metro extensions	Line 13 northwards	46	44	8	2
	Line 13 southwards	59	30	9	2
	Line 7 northwards	49	45	6	—
	Line 13 bis northwards	71	24	5	—
	Line 10	87	10	3	—
	Average	60	32	7	1
Regional rapid transit system (RER) — Marne-la-Vallée branch		34	38	17	11
Paris suburban railway system — New Cergy line		43	27	28	2

Concurrently, the environmental impact appears—broadly speaking—to be positive, due to the underground nature of most of the rights of way; and the new pedestrian zones and the reduced bus traffic in the central areas result in an appreciable decrease in noise and pollution.

It must be noted, however, that in Lyon, although the planting of vegetation along most of the pedestrian malls and the reduced noise and pollution levels have substantially improved the local life environment, some residents and shopkeepers in the section of the Rue de la Republique between the Place Bellecour and the Place de la Republique complain of the heightened noise and sundry "happenings". In fact, this sector is located in the midst of the densest population of bars, cinemas, etc., and is the most frequented spot in the city.

Table 13. Modal origin or patrons of new infrastructures for the Lyon, Marseille, Lille and Paris area systems.

System		Previously used mode: Public transit (%)	Private cars (%)	Other modes (incl. walking & 2-wheelers) (%)	Induced traffic (%)
Lyon metro		64	11.5	9	15.8
Marseille metro		63	15	13	9
Lille metro		41	11.5	2.5	45
Paris metro extensions	Line 13 northwards	90	6	1	3
	Line 13 southwards	83	11	1	5
	Line 7 northwards	89	6	2	3
	Line 13 b is northwards	85	8	2	5
	Line 10	83	11	2	4
	Average	87	8	8	4
Regional rapid transit system (RER) — Central sections		95.5	3	—	1.5
— Marne-la-Vallée branch		80.0	12.5	5.5	2
Paris suburban railway system — New Cergy line		81	9	4	6
— Invalides/Orsay link		81	2	4	13

Table 14. Traffic trends in public transit in Lyon and Marseille.

City	Year	Annual metro traffic (millions)	Annual traffic on surface systems (millions)	Trips on public transit systems (millions per yr)
Lyon	1967	—	177.5	138
	1977	—	132.7	109
	1979	42.1	132.9	121
	1980	47.7	140.6	130
	1981	55.3	147.7	140
	1982	60.4	145.3	141
	1983	62.4	143.3	140
Marseille	1967	—	90.6	82
	1977	—	85.2	76.5
	1978	20.5	91.0	93.1
	1979	26.6	99.2	98.2
	1980	27.7	98.2	98.0
	1981	28.7	96.7	98.0
	1982	29.8	102.2	103

Advantages for local authorities

For the local authorities, the construction of rapid transit facilities offers a great many advantages.

Apart from the problems of financing the capital cost of such facilities (to which we shall refer later), projects of this nature are, above all, efficient in terms of operating costs and revenues. Leaving aside the dry figures, it must be understood that without such facilities, the operating cost of surface systems increases steadily, at the same time that the commercial speed of the vehicles inevitably drops (see Costs, below).

In this connection, attention has already been drawn to the beneficial effects imparted by such projects on the transit system in general, of which they substantially improve the image. This in turn leads to increased utilization and to improved acceptability, in particular for the implementation of specific rights of way for surface systems.

Concurrently, the construction of rapid transit facilities is a powerful factor in orienting urban growth, even though there may be some parasite movements. This has been the case for a long time in the Greater Paris area, as shown by the example of line 13 and, perhaps even more, by the rapid growth of the new town of Marne-la-Vallée, located east of the Paris conurbation and now entirely served by the RER.

As an illustration, Table 23 shows the changes that have occurred in the zones of influence of the east and west branches of the RER system.

In Marseille, the construction of the metro system has influenced the housing market, as shown in Table 24.

Finally, the case of Lyon illustrates even more vividly what urban dynamics may be generated by the construction of a metro system. To consider the general aspects first, construction of the metro has led to the following benefits:

(1) It has stimulated the implementation of a comprehensive traffic and parking management policy in the city center;

(2) It has offered the local political authorities occasions to develop some spectacular projects, such as:

- Pedestrian malls;
- Housing renewal
- Elimination of unsanitary housing and, concurrently, construction of new municipal housing;
- Actions to enhance the image of certain districts;

(3) It has promoted development of arts (sculpture, painting, etc.) and open-air cultural activities.

Apart from such projects, in which the public authorities have managed to keep the initiative, the urban dynamics in the private sector have concentrated on the recuperation and utilization of some of the most favored areas from the standpoint of accessibility, e.g. the Presqu'île area.

Table 15. Annual passenger traffic on public transit systems in Lille.

Year	Annual metro traffic (millions)	Annual trips on surface systems (millions)	Trips on public transit systems (millions per yr)
1982	—	47.3	42.1
1983	8.1*	49.7	47.9

*Covering a 7.5-month operation period, i.e. 13 million trips annually, by extrapolation.

Table 16. Passenger traffic during a typical week on public transit systems in Lille.

	Typical week in November 1982	Typical week in November 1983	+/- trend
Traffic on • Bus • Mongy (Street car) • Metro	1,168,125 1,031,900 136,200 —	1,535,911 1,005,800 183,700 346,400	+ 31.5 % - 2.5 % + 34.9 % —
Interchange ratio	1.147	1.240	+ 8.1 %
Total trips	1,018,340	1,238,265	+ 21.6 %

Table 17. Fluctuations in transportation supply and demand in Lyon.

		Fluctuation in places x km offered (%)	Demand fluctuations (%)		Elasticity of demand vs supply	
			Traffic	Trips	Traffic	Trips
Lyon	1977–1979	+ 20	+ 31.2	+ 11	1.56	0.55
	1980–1982	+ 8.8	+ 9.4	+ 8.5	1.07	0.96
	1977–1982	+ 40.5	+ 54.4	+ 28.4	1.34	0.70
Marseille	1977–1979	+ 25	+ 44	+ 28.4	1.76	1.14
	1977–1982	+ 28.8	+ 46.5	+ 34.6	1.61	1.20
Lille	1982–1983	+ 17	+ 22.2	+ 13.8	1.30	0.82
Average for France except Lyon, Marseille and Lille 1977–1982		+ 31.7	+ 26.8	—	0.96	—

Table 18. Traffic diverted from other modes, depending on the nature of the trip.

	% of trips to work — school	% of other trips
Marseille metro	26.6	31.5
RER — PARIS		
— Central junctions	6.1	11.9
— Marne-la-Vallée Branch	11.7	21.8
Paris metro		
— Line 13 northbound	4.7	10.5
— Line 13 southbound	9.8	11.1
— Line 13 bis	8.9	9.1
— Line 7	5.0	9.1

The opening of the first section of the system was accompanied by turning the roadway along which the metro runs in the Presqu'île area into a pedestrian mall. This 2 km-long stretch of roadway is mainly bordered with shops from Perrache to Cordeliers, and with public transit service from Cordeliers to Hotel de Ville.

Since 1978, the banks have had their eye on the surroundings of some stations, e.g. Cordeliers, and have taken them over. More recently, some of the more frequented stretches of the pedestrian way, e.g. near the Bellecour station, have become the site of a novel kind of commerce in the capital of gastronomy that Lyon always has been: fast foods. All the great names of that industry jostle with one other here: Quick, Burger King, McDonald's etc.

No wonder, then, that the considerable increase in use of the pedestrian area has exerted an appreciable influence on the commercial sector. The latest survey conducted by the Chamber of Commerce and Industry on the shopping habits of households in the greater Lyon area has pointed up the critical importance exerted by the "pedestrianization" of the Rue de la République and the Rue Victor Hugo, as well as the "irrigation" of the Presqu'île by five new metro stations.

Over the past ten years, the CCI has conducted three inquiries, in 1973, 1976 and 1980. The 1976 inquiry coincided with the completion of the metro system in the Presqu'île, and was conducted six months after the opening of the new Part Dieu shopping center. There was

Table 19. The nature of passengers on transit systems in four French cities.

	Lyon		Marseille		Lille		Paris
	before metro	metro	before metro	metro	before metro	metro	All transit systems
Men	37	45	38	48	41	52	46*
Women	63	55	62	52	59	48	54*
Top executives	4	11	3	7			9.5
Employees and medium executives	25	33	21	37			38
Workers and service staffs	17	15	22	11	nd	nd	19.5
Students and schoolchildren	32	27	23	27			13
Non-working people	21	14	31	17			20

*Correspondingly, 55 % and 45 % on metro and RER networks.

Table 20. Time saved by Paris patrons of selected metro lines.

	Line 13 to "Saint-Denis-Basilique"	Line 13 to "Châtillon-Montrouge"	Line 7 to "Fort d'Aubervilliers"	Line 13 to "Gabriel Péri-Asnières-Gennevilliers"	Line 10 to "Boulogne - Pont de Saint-Cloud"	RER — Central sections and Marne-la-Vallée branch
Average time saved per trip (in min)						
— people walking to the stations	10.6	13	9	10	5.5	15
— other modes of access to the stations	3	4	5	6	3	15
Annual time savings (hours)	1,240,000	1,800,000	2,400,000	2,300,000	280,000	19,100,000

Table 21. Catchment area of the Lyon metro.

Area concerned	Population*	Jobs†
Urban area as a whole	1,160,000	500,000
Metro, including:	325,000	190,000
— Directly served	185,000	155,000
— Feeder modes	140,000	35,000

*General population survey 1982.
†Situation in 1979.

no question of the threat: the survey showed that the Presqu'île—the number one financial, non-food center in the Lyon area—had registered a drop of more than 35% in gross revenue in a matter of three years. In contrast, the 1980 survey showed that the construction of the metro and the pedestrian malls had sharply curbed this trend (see Table 25).

It is estimated that roughly 3% of the gross sales of the stores in the Presqu'île are directly related to the metro, on which 20% of the traffic is related to shopping purposes.

All in all, then, it is impossible to underestimate the economic impact of this type of operation. Any economic analysis must consider the creation of jobs directly related to construction of the metro facilities, as well as the indirect effects on growth of the job market (due to increased accessibility of the jobs) and increased productivity due to the shortened transit times.

Finally, it would be appropriate to estimate the capital outlay saved through such projects, especially in regard to traffic and parking facilities that need not be built, thanks to the metro system.

Advantages for the community in general

In addition to the promotion of industry and the development of the exportable technical know-how arising from such operations, a great many other advantages associated with the metro benefit the community in general. Typical advantages include:

(1) Energy savings resulting from both the modal transfers and the use of transportation that tends to consume energy of non-oil origin. A complete energy balance sheet drawn up for the city of Marseille yields the following results:

- Energy expended in the construction of the system amounted to 52,000 oet, i.e. only one-third of the annual oil consumption for the automobile traffic in Marseille;
- The annual energy consumption of the metro amounts to 4500 oet, whereas the savings due to modal transfers from private cars alone amount to 1400 oet;
- The overall consumption of the mass transit systems increased from 10,700 oet in 1976 to 15,600 oet in 1979. Thus, the additional energy consumption generated by the operation (construction plus operation) is very low compared with the energy that would have had to be spent to construct an equivalent road infrastructure with a carrying capacity equivalent to that of the metro, in addition to the energy generated by the additional trips that would have resulted from the metro implementation (some 10,500 oet) if they had been made in private cars.

(2) The enhanced safety resulting from the transfer of trips from private cars to a mass transit system. In the case of the line 7 extension alone, this figure was estimated in 1980 to be FF 1.1 million.

(3) The leverage exerted by such operations on the local urban policy and on the overall land-use policy.

Table 22. Service provided by recent extensions of the RATP network.

	Line 13 to "Saint-Denis-Basilique"	Line 13 to "Châtillon-Montrouge"	Line 7 to "Fort d'Aubervilliers"	Line 13 to "Gabriel Péri-Asnières-Gennevilliers"	Line 10 to "Boulogne - Pont de Saint-Cloud"	RER — Central sections and Marne-la-Vallée branch
Scope of service: Population served within 1000 m walking distance						
• Total	31,600	51,500	51,200	70,200	45,200	414,000
• Per km of line	13,150	22,400	22,250	21,950	19,650	24,790
Jobs reached within 1000 m walking distance						
• Total	21,200	18,700	18,200	39,500	24,500	654,000
• Per km of line	8850	8150	7900	12,350	5350	39,120

Table 23. Urban changes in the zones of influence on the East and West branches of the RER.

Growth from 1962–1975	East Branch	West Branch	Total Paris Region
Population	+ 46.1%	+ 10.4%*	+ 16.3%
Dwellings	+ 55.5%	+ 22.9%	+ 21.5%
*This phenomenon is largely related to the absence of available land, and to the resistance of the local authorities to any further densification.			

Table 24. Changes in the housing market related to the opening of the Marseille metro system.

Year	Total housing units completed in Marseille	Housing units completed in metro-related sector	
		No.	%
1975	4328	256	6
1976	5013	1085	22
1977	4278	902	21
1978	3510	837	24

Table 25. Market share of various locations in Lyon.

District	Buying operations (%)			Trends in gross revenues (%)
	1973	1976	1980	1976–1980
Presqu'île	19.9	12.9	12.2	+ 5%
Left bank (excluding Part Dieu)	11.1	9.4	7	− 25%
Part Dieu	–	5.2	7.9	+ 84%
Remainder of Lyon	12.4	11.9	9.7	− 12%
Villeurbanne	7.4	6	6	− 2%
Remainder of urban area	Increasing			

Costs

Capital Costs

It is evident that the major obstacle to the construction of rapid transit systems is their capital costs, which may reach and even exceed FF 200 million (before tax) per kilometer of line. This means that local authorities cannot handle by themselves an expenditure of this size.

In France, a number of sources may be mobilized for the purpose, namely:

- State grants covering 20–40% of the total capital costs;
- Contributions by local communities (region, department) in the form either of grants or loans at low interest rates;
- "Transit taxes" paid by the companies that may amount to 1.5% of the wages in the case of the impletation of transit systems on their own right-of-way;
- Loans on the financial market.

Nevertheless, it is rather remarkable that in none of the cases of Lyon, Marseille, or Lille, did the annual charges on loans taken out on such projects have any marked effect on the income taxes paid by the residents, thanks mainly to the "transit taxes" paid by the companies.

Note, finally, that the means of financing practiced in France is compatible with the concept that the advantages of the transit systems should be evenly distributed among the many interested parties involved.

Operating Costs

These are the second main targets of people opposing the construction of rapid transit systems. They stress that all policies tending to favor mass transit end up increasing the operating shortfalls and, hence, the costs borne by the taxpayers, whether national or local. However, an analysis of the examples of Lyon and Marseille, which are the most significant in this respect, shows that this contention should be seriously reconsidered.

Of course, it is true that there is a substantial increase in the deficit during the first year's operation, mainly due to a steep rise in the offered space x km (up 13% in Lyon, and up 22% in Marseille), which is not entirely compensated for by the additional traffic recorded, in part because of the fare reforms introduced. Thus, in 1978 the operating deficit in Lyon rose by 28%; and, in Marseille, by 46%.

However, it is unwise to conclude that this is a general rule for the years to come, because of the continuous growth in traffic on the metro, in particular, and on the transit systems in general. Thus, in Marseille, for instance, the deficit has grown by less than 2.5% per annum since 1978; so that, in comparison with the initial trend recorded prior to the opening of the metro (+14% in constant francs between 1972 and 1977), the steep hike in 1977-1978 has already been absorbed. Moreover, had the metro not been installed, the continued tendency of the city's financial contribution to grow would have led to a contribution in 1983 of FF 322 million, whereas in fact it amounted to approximately FF 270 million.

In the end, it should be clear that, to the extent that public transportation is perceived and managed as a collective asset, and that its cost is more or less arbitrarily distributed over all of the beneficiaries of the system, there is no sense in searching for sheer profitability, whether in regard to surface modes or metro.

The construction of exclusive rights-of-way increases the overall productivity of the system (naturally, above a given threshold in demand for transportation) while very substantially raising the supply of transport. In fact, it provides a guarantee over the long term as transit modes on their own rights-of-way become increasingly efficient and because their operation is unaffected by environmental changes, especially with regard to traffic congestion.

Conclusion

Clearly, any strictly financial appraisal of the advantages of a metro system is fraught with uncertainty, despite attempts usually made in this respect, e.g. cost-benefit analyses. Conversely, it is just as immoderate to pretend that such projects cost a lot of money and bring in nothing.

It has been the purpose of this report to point up the fallacies inherent in each of these approaches. The best proof of this contention is the continuous growth to which such systems give rise, as illustrated in the case of Paris no less than in Lyon and Marseille.

Although Paris has rapidly shown itself to be a city for which the absence of a powerful rapid transit system is inconceivable, this was not the case for Lyon or Marseille. In these cities, the still limited growth of their respective metro systems has provided adequate proof of their effectiveness by inducing a deep-seated transformation of their transit systems under entirely satisfactory financial conditions while, moreover, initiating a desirable change in the overall conditions of long-term management of these cities.

Japan

Introduction

In Japan, nine cities—Tokyo, Osaka, Nagoya, Sapporo, Jokohama, Kobe, Kyoto, Sendai and Fukuoka—are operating underground public transportation systems at present. In several other cities, such systems are under construction or in the planning stage.

Because the traffic situation and the concentration of buildings in the big cities make the use of the subsurface for urban railway systems unavoidable, it is not necessary to show the benefits of using the subsurface. Thus, this report focuses on descriptions of existing systems.

Tokyo and Yokohama

The following figures and tables give a brief impression of the transportation systems in Tokyo and Yokohama, which represent, in the former case, a large subway system (track length of nearly 200 km); and, in the latter case, a smaller system (23 km track length).

The map of the Yokohama subway system is shown in Fig. 22. In both cities the networks are still growing and line

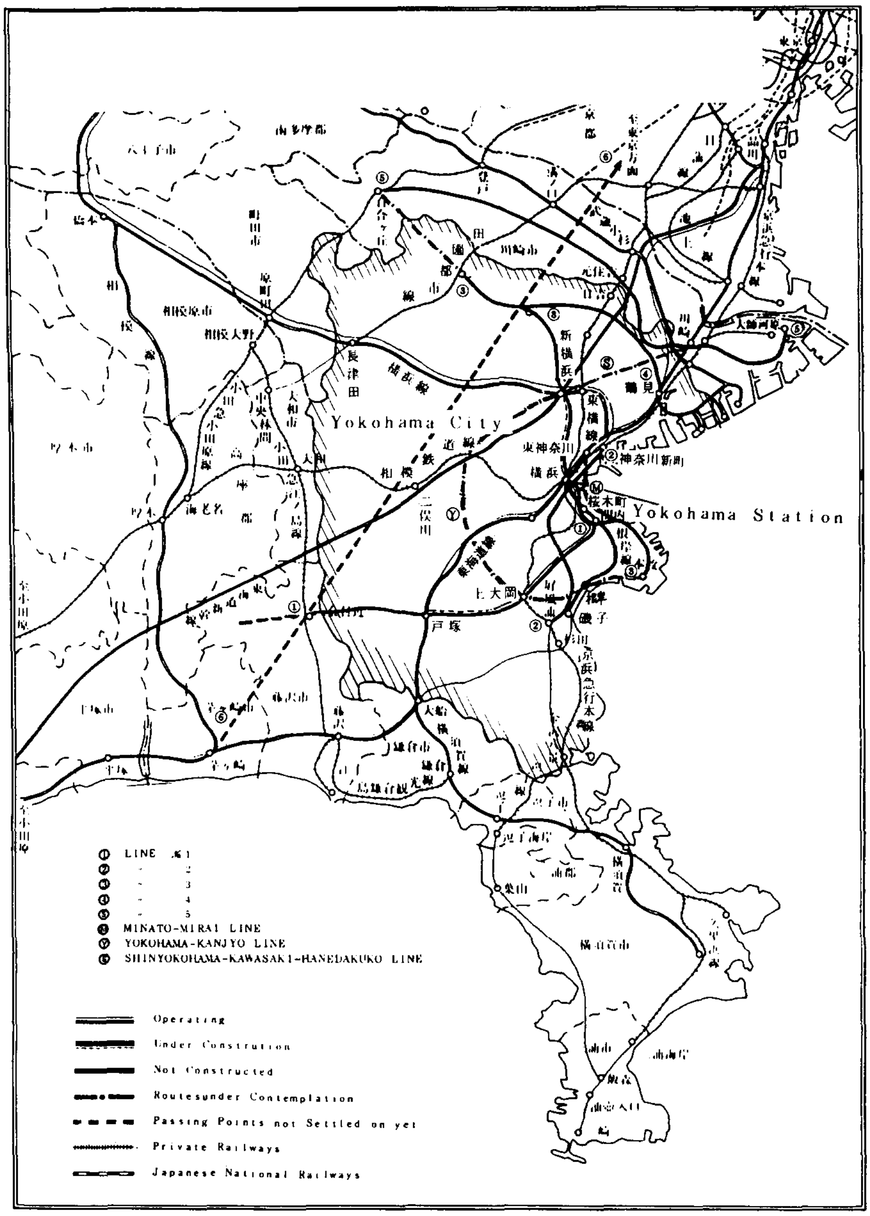

Figure 22. Yokohama municipal transport area's rapid transit railway network.

Table 26. Data on the underground railway systems in Tokyo and Yokohama.

	Tokyo (1981)		Yokohama
	T.R.T.A.	T.B.T.M.G.	
1. Number of Lines	7	3	2
2. Operating kilometerage (km)	131.8	54.9	11.5
3. Number of stations	124	60	12
4. Number of rolling stocks	1738	440	70
5. Car-km per yr (million km)	166	47	6
6. Passengers-carried per yr	$1665 \cdot 10^6$	$388 \cdot 10^6$	$46{,}050 \cdot 10^3$
7. Passengers seasonal passengers ratio	64.8 %	62.2 %	50.3 %
8. Passenger-km per yr [million km]	12,187	2387	236
9. Passenger seasonal passengers ratio	71.7 %	66.5%	58.1 %
10. Fare revenue	127.3 billion Yen	40.0 billion Yen	4836 million Yen
11. Fare seasonal passengers ratio	48.9 %	47.3 %	39.4 %
12. Average passengers carried/day	$4562 \cdot 10^3$	$1064 \cdot 10^3$	$126 \cdot 10^3$
13. Average passenger kilometers (km)	7.3	6.1	5.12
14. Average fare/passenger kilometer [Yen]	10.45	16.76	20.52
15. Load factor	56 %	33 %	31.54 %
16. Improving investment for operating lines	13.8 billion Yen	2.1 billion Yen	0
17. Investment for new lines	48.0 billion Yen	18.8 billion Yen	29,300 million Yen
18. Staff	10,680	4378	559

extensions are in the planning stage. Table 26 gives additional data regarding aspects of operation.

The expansion of the networks over the years is shown in Figure 23, which shows that there was a rapid and steady increase in the network length in Tokyo from the late 1950s until today.

Corresponding to the expansion of the subway in Tokyo, the tramway was closed down step by step (Fig. 24), resulting in a shift in traffic volume to the subway (Fig. 25). It is remarkable that the subway today carries nearly three times as many passengers per day as did the tramway (which operated in the 1950s), which had nearly the same route length.

The total cost for the construction over the years of new subway lines for Tokyo (TRTA) and Yokohama are shown in Figs. 26 and 27. From 1950 to 1981, 797.5 billion Yen were spent in Tokyo; from 1966 until 1981, 178.1 billion Yen were spent in Yokohama.

Figure 28 provides data regarding the revenues and expenditures. It is interesting to note that in Tokyo (TRTA), there is very little difference between the expenditures and the revenues. In some years expenditures were higher than the revenues, but quite often the reverse was true.

The traffic volume of the Tokyo

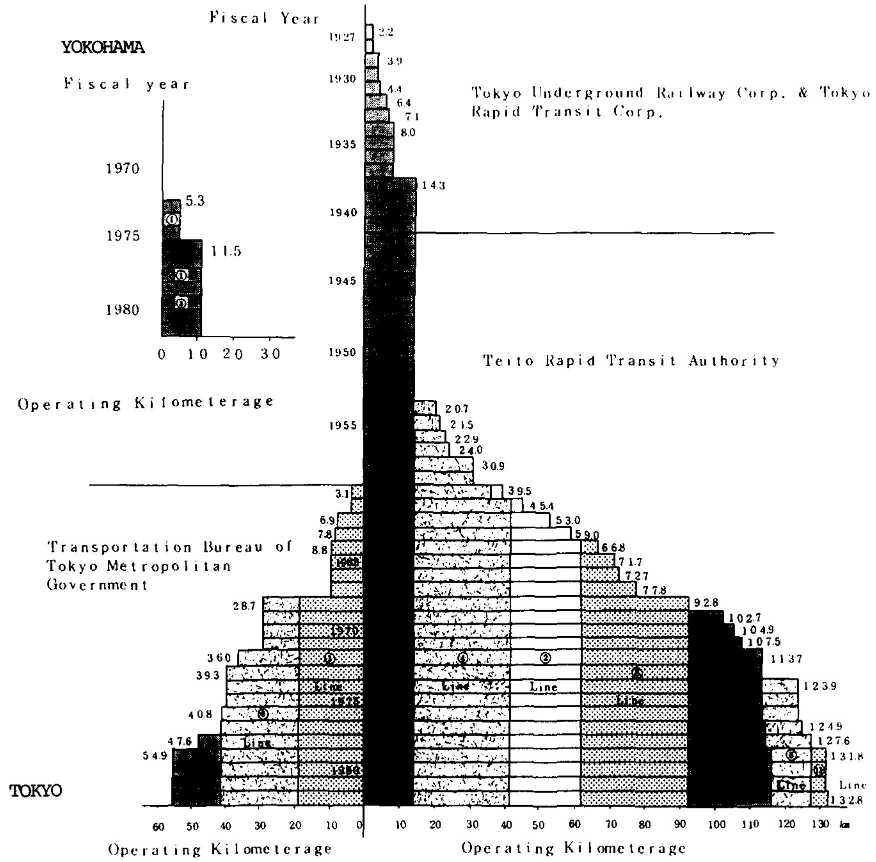

Figure 23. Expansion of subway networks in Tokyo and Yokohama.

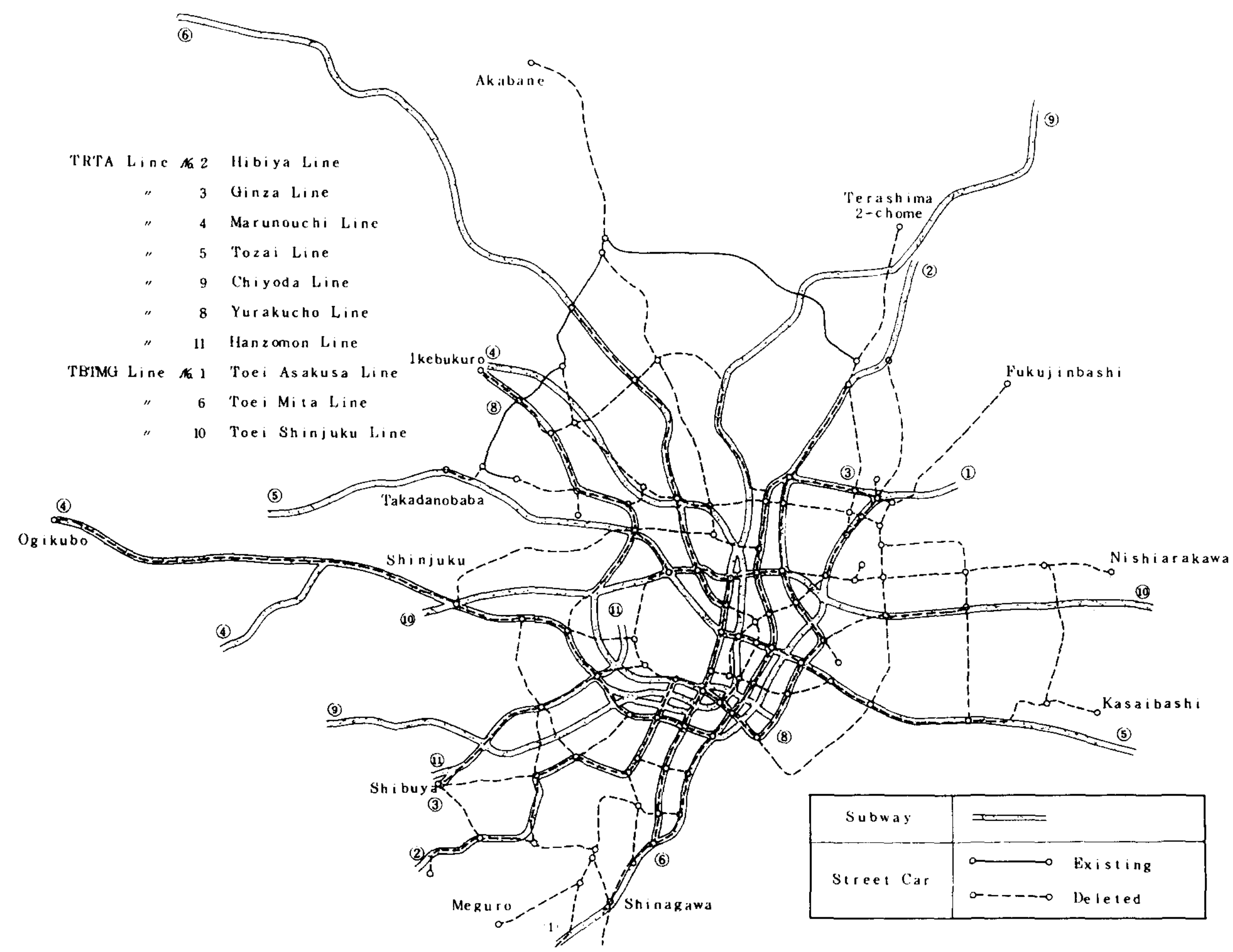

Figure 24. Comparison between street car lines (which have been deleted) and subway (new line) in Tokyo.

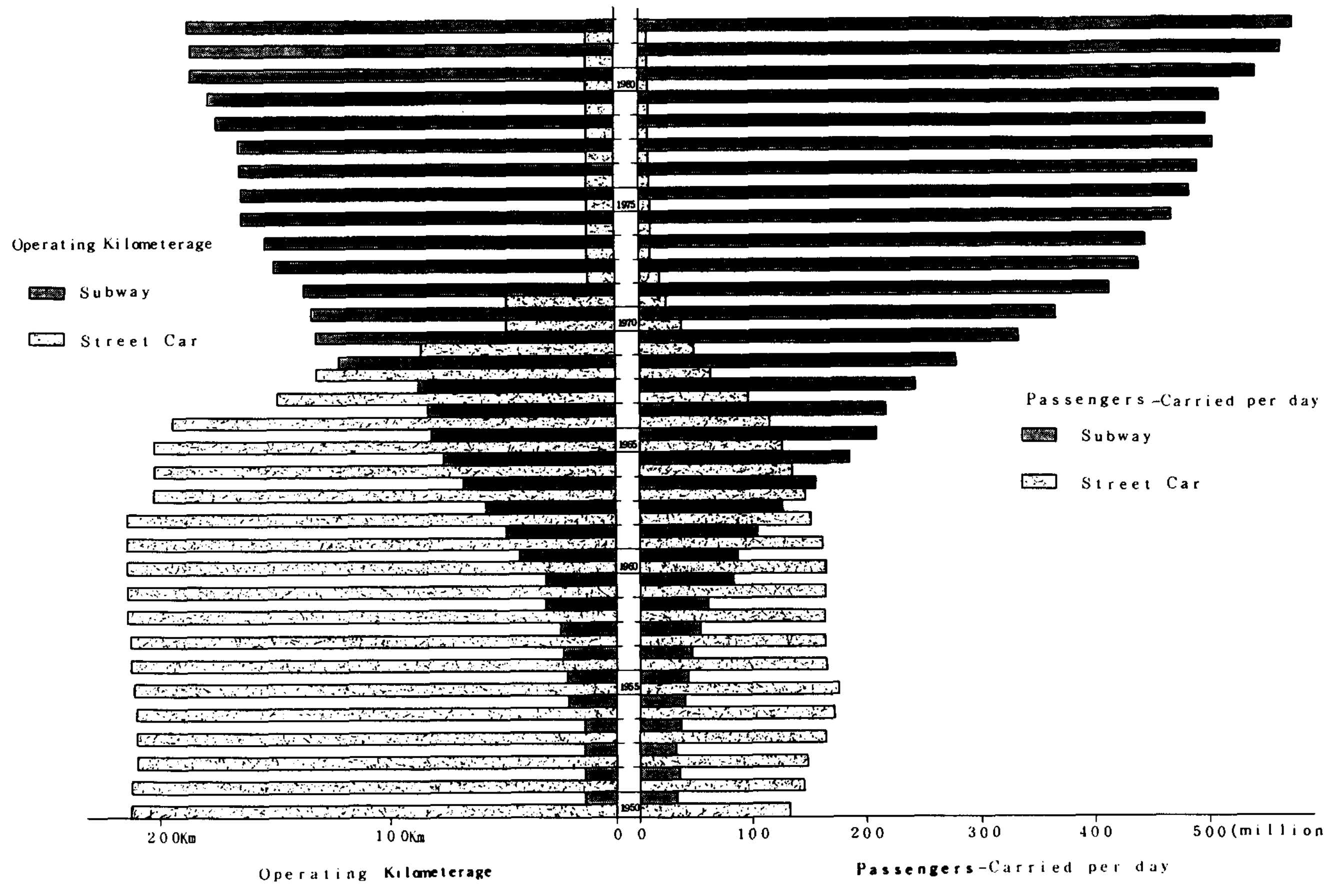

Figure 25. A comparison of subway vs street traffic in Tokyo during the first year of subway operation, when street car routes were being eliminated.

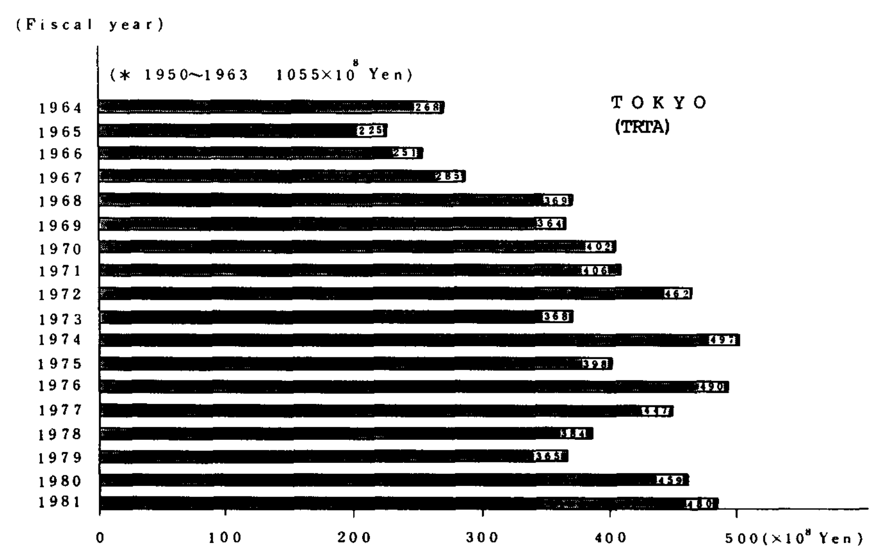

Figure 26. Total construction cost of new subway lines in Tokyo.

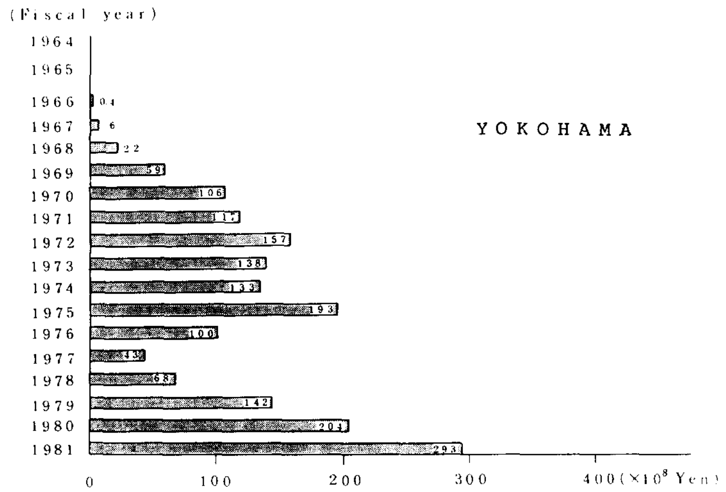

Figure 27. Total construction cost of new subway lines in Yokohama.

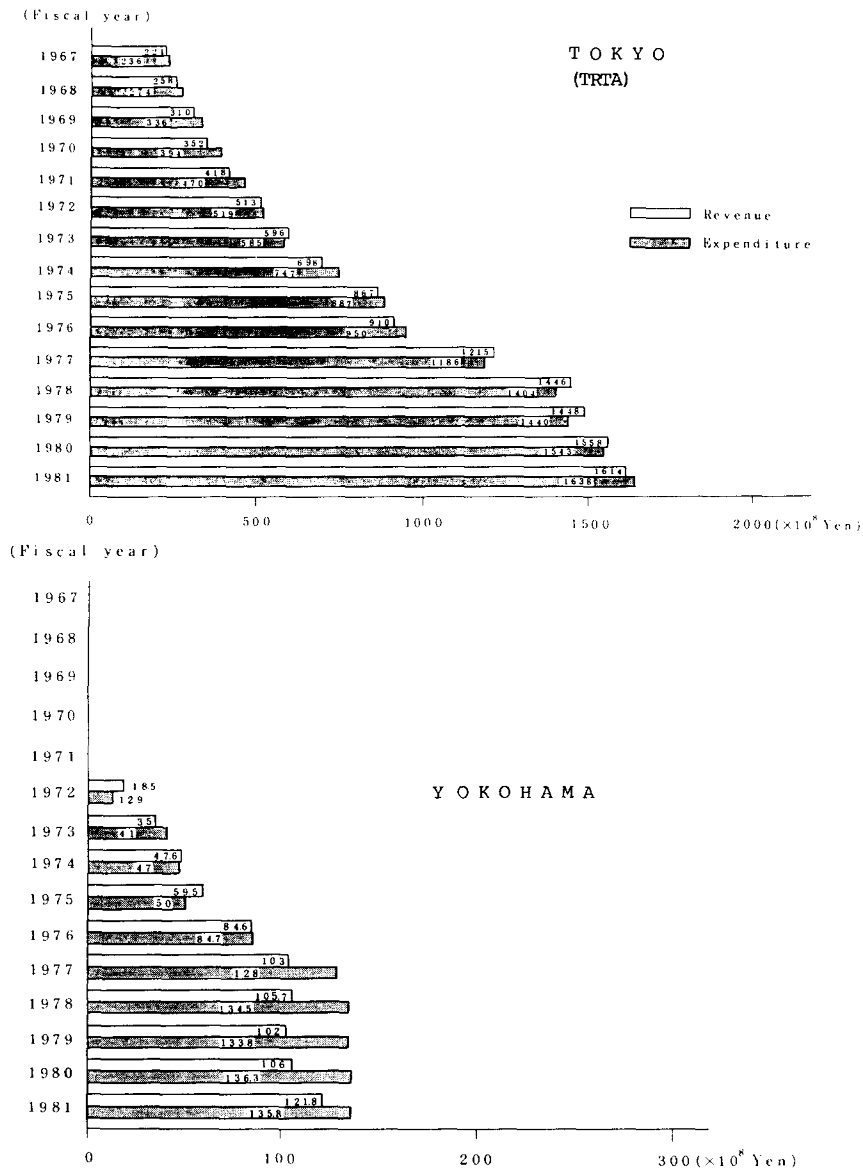

Figure 28. Development of revenue and expenditures for the Tokyo and Yokohama subway lines.

subway shows a tremendous increase since 1960, when the first extensions were opened (see Fig. 29). In 1980 nearly 14 times as many passengers used the subway as in 1950. This figure is even more impressive if it is compared to the traffic volume of the railway which, generally speaking, has remained at the same level since 1970; or to the traffic volume of the bus, which is trending downwards.

A special service of the railway systems in Tokyo is illustrated in Fig. 30. There are six subway lines with connections to the Japanese National Railways or to private railways. Trains of the single systems use the track of the other systems, offering a through service without interchange; this is a highly attractive option for the passengers.

As can be seen from these few figures, underground urban railways are imperative for these Japanese cities.

Fukuoka*

Fukuoka, located at the northern part of Kyushu Island and covering 36,554 km^2, is Japan's eighth largest city, with a population of 1.16 million (Fig. 31). Fukuoka has long since taken on the role of a gateway to trade with China and Korea (the distance to Korea, for example, is only 230 km), and today is the center of politics, economy, culture, and transportation for Kyushu Island.

Accelerated population influx into the city, especially after World War II, has resulted in a substantial population increase: from 0.60 million in 1955 to 1.16 million in 1985.

This increase is mainly due to the centralization of many branch offices and local agencies of the national government, as a result of access faculties from the nearby airport (located only 4 km from the city). This increase has been assisted by the wealth of information emanating from the city's educational institutions that have been established around the national Kyushu University, which was founded in the nineteenth century.

Transportation in the City

Fukuoka was first urbanized along the coast, which faces to the north, and since 1950 habitation has been rapidly developing landwards. Residents commuting to the center city, which has lacked rail transportation, have had to depend on low-speed buses running through the narrow streets.

The most active zones in the city are the area around the Hakata station of the National Railways (JNR), and the Tenjin area, in which the terminal of a private railway is located. Both areas are big business centers. These zones, which were formerly served mainly by tramways and buses, were saturated by congestion caused by the rapidly increasing use of cars.

In 1971 the city's authorities decided to construct the subway network in order to mitigate such traffic congestion. After a certain lead time, construction works began in 1975 for the No. 1 and No. 2 lines, which totaled approx. 15 km (see Fig. 32). The No. 1 line starts from JNR's Hakata station and runs about 10 km west of the city, to the JNR's Meinohama station, which is on the Chikuhi line. This arrangement permits mutual through-operation between the JNR line and the No. 1 subway line. The No. 2 line, branching from near the starting point of the No. 1, runs northeast about 5 km and joins the Miyajidake line of the private railway at Kaizuka station.

The through-operation began operating in 1983. At the same time, the section of the JNR line from Hakata to Meinohama, which was nearly parallel to the No. 1 subway line, was removed. Because of the protracted period of time estimated for the work just beneath JNR's Hakata station to be completed, a temporary station was provided during the work period. In March 1985 the formal structure was completed. A section representing about one-third the length of the No. 2 line has been put into operation; the rest is expected to be opened in 1986.

Benefits of Subway Operation

Shortening of travel time. The mean effective speeds of tramways and of buses in Fukuoka in 1972 were lowered to 11 and 12 km/h, respectively, due to traffic congestion, whereas the mean effective speed of the subway is assured at 30 km/h. The subway is used for approx. 180,000 rides/day; the average ride is 4.5 km. Thus, use of the subway can save 46,636 man-h/day, in comparison with transportation by other means. These savings may be evaluated as approx. 70 million Yen/day, or 25.55 billion Yen/year ($US 98 million/y), based on 1500 Yen/man-h. Even greater benefits are expected when the No. 2 line is fully operational, because its completion will bring the total number of rides per day to 250,000.

Through-operation with the JNR line. Passengers from the city of Karatsu, about 50 km west of Fukuoka, can now

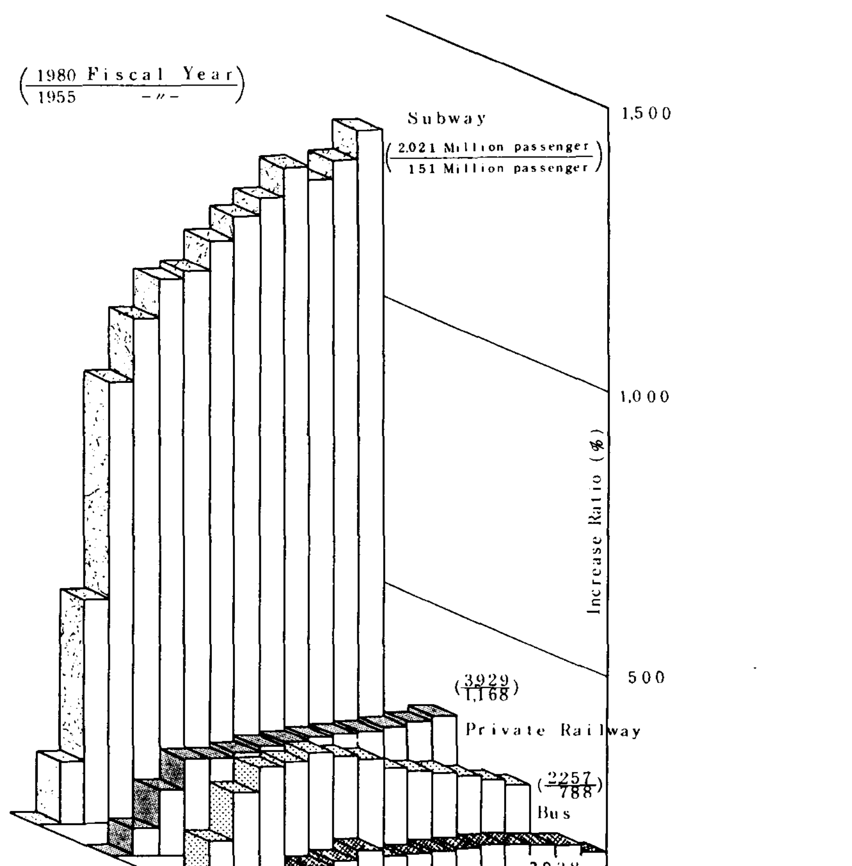

Figure 29. Growth rate of passengers in the Tokyo metropolitan transport area, 1955–1980.

*This section on Fukuoka was written by Hirokazú Matsubara, Director of the Fukuoka Municipal Transportation Bureau.

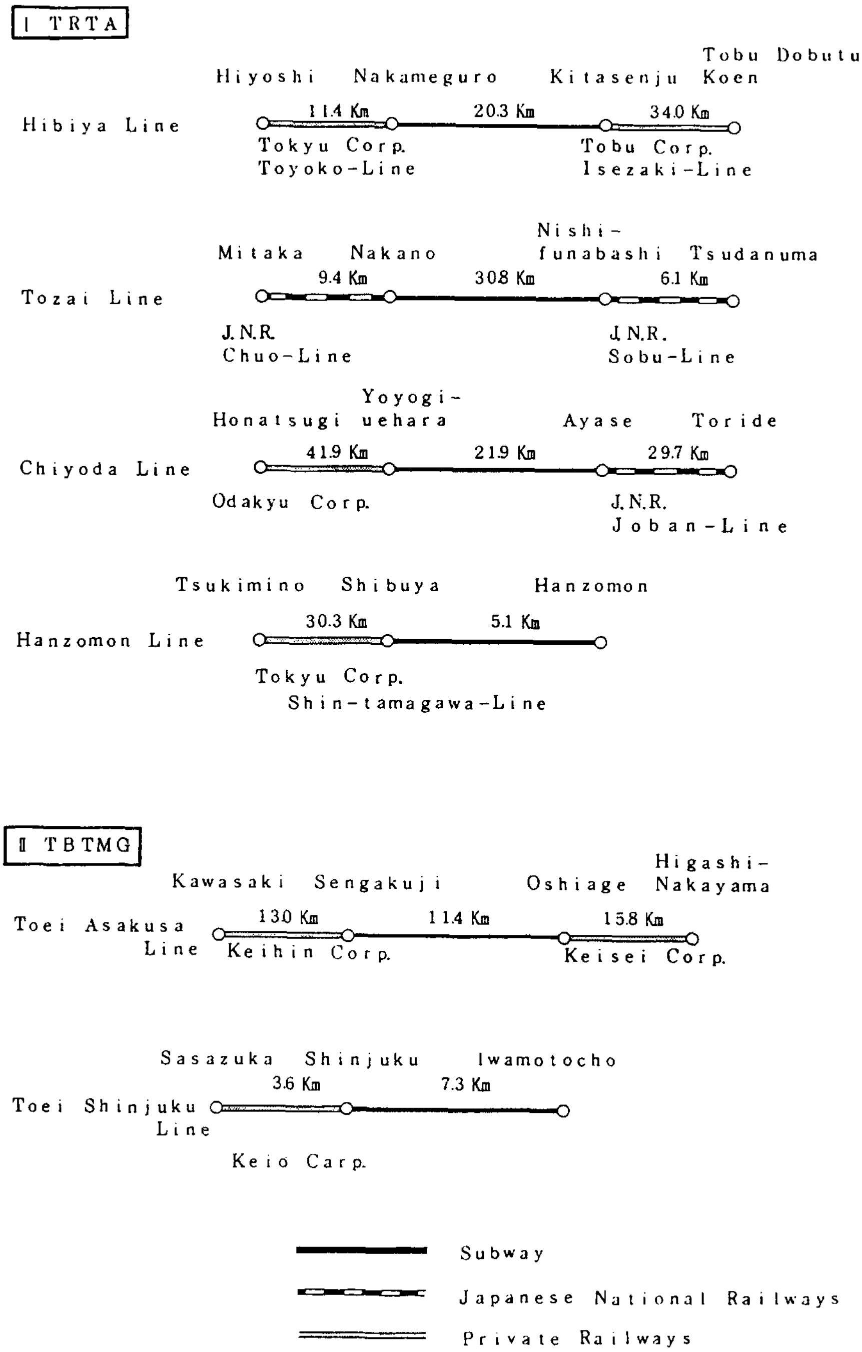

Figure 30. Reciprocal through service of the Tokyo subway.

travel to the city's central zones without changing lines, owing to the subway's through-operation with the JNR's Chikuhi line. Simultaneously, the Chikuhi line itself, which was stagnant before, has been reactivated as an important commuting route. Approximately 22,000 passengers are taking advantage of this through-operation. Assuming the time necessary for one change is seven minutes, 2567 man-h/day—equal to 1.405 billion Yen/yr ($US 5.404 million/yr)—can be saved.

Facilities for changing at Hakata station. Hakata subway station was designed to be located just beneath the JNR's station in order to minimize the transfer path between the two stations (Fig. 33). Whereas previously it took passengers 10 min to walk from the Shinkansen station to a bus stop, for example, only 5-min walk is now required to attain the subway station. An estimated 30,000 passengers per day change from the JNR line to the subway line (and vice versa) at Hakata station, resulting in a savings of 2500 man-h/day. This figure translates into a savings to passengers of 1.369 billion Yen/yr ($US 5.265 million/yr).

Removal of level crossings. The 12 km section where railway tracks were removed has been revived as a useful road for urban traffic. This section had included approximately 40 crossings, which had caused not only frequent

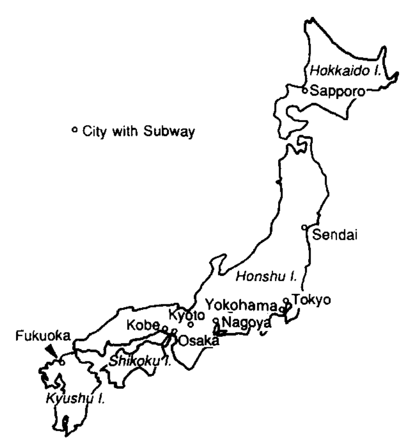

Figure 31. Location of Fukuoka, Japan.

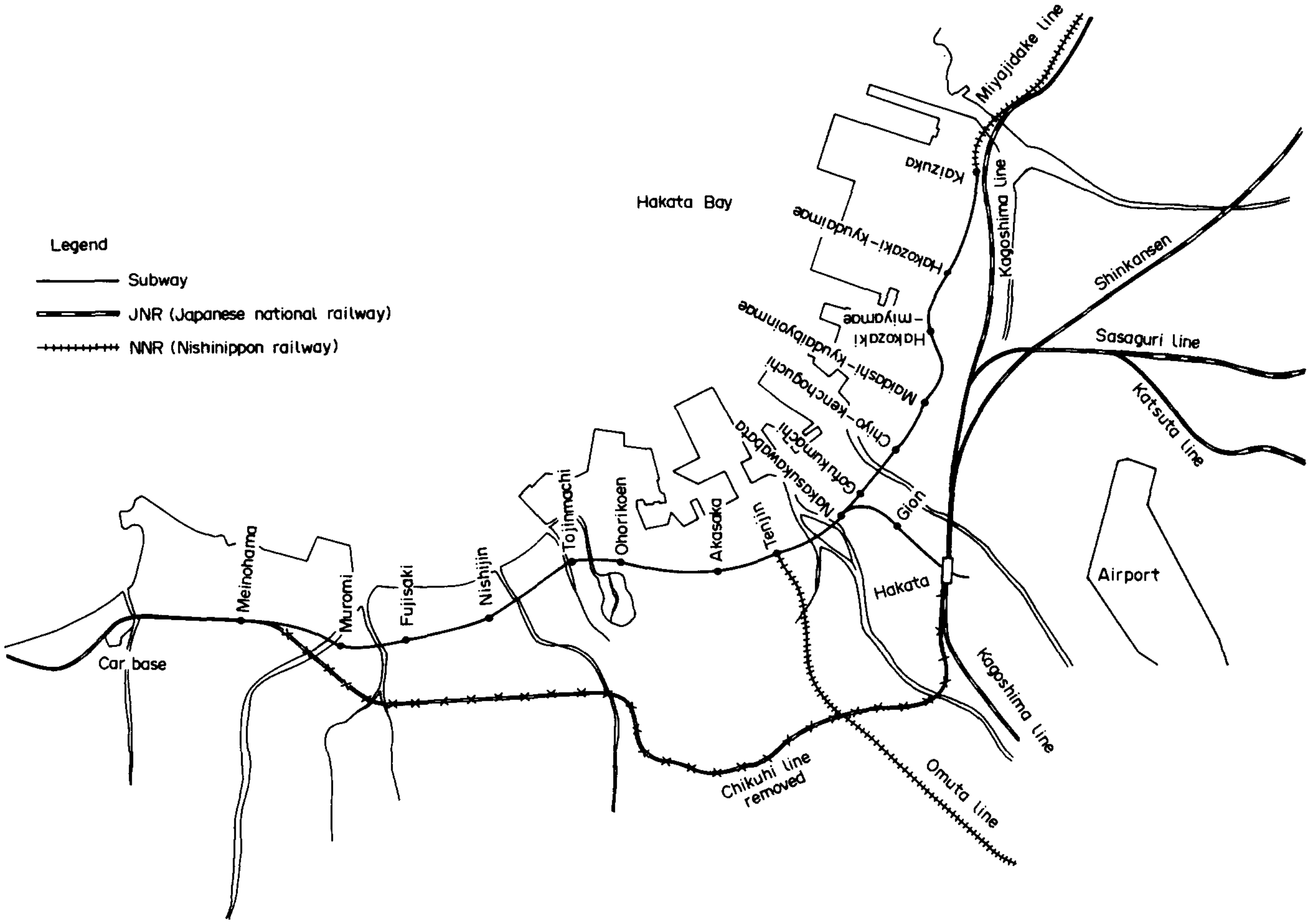

Figure 32. Route map of the Fukuoka municipal subway system.

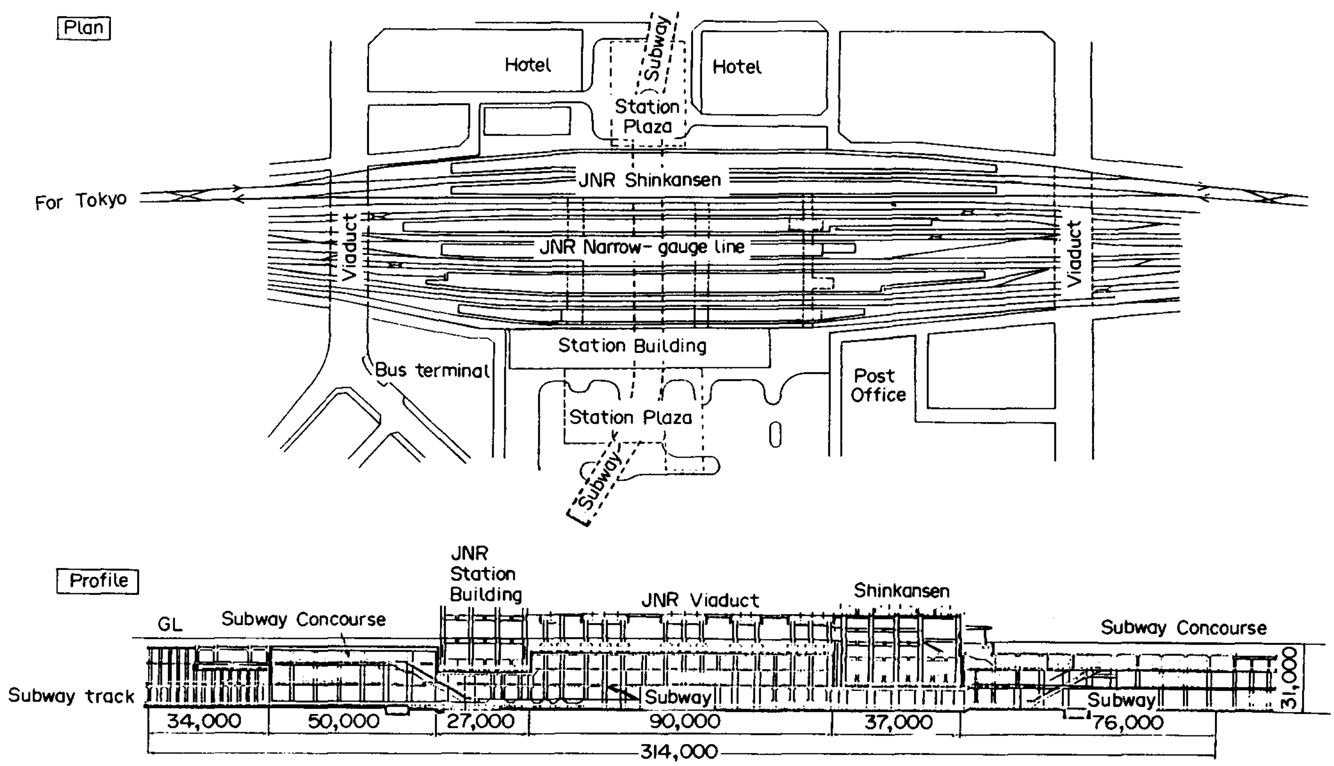

Figure 33. Outline of Hakata Station, Fukuoka.

car/train crashes, but also traffic congestion on the roads traversing the JNR line due to the security stops required for cars. The removal of railway track has totally eliminated these difficulties.

Enlargement of commuting range. Before the subway was built, only low-speed buses were available to transport commuters on the most congested route, from the west-side area to Tenjin zone. On this route, a typical trip, e.g. from Chikuzen-Maebaru to Tenjin, took 50 min. Now, however, the subway links these areas in 31 min and the arrival time is extremely punctual. Defining here the commuting range as that in which the travel time is within 30 min, the commuting range for Fukuoka has been extended from 12.5 km by buses to 20 km by the through-operation of subway. This increase in the commuting range by a factor greater than 1.6 has also resulted in more effective and improved land use.

Development of areas along the subway line. Development of areas around subway stations—e.g., new buildings and repairs of commercial facilities—has been promoted in conjunction with the opening of subway. As a result, these areas have enjoyed an increase in commercial business.

Increased safety of pedestrians. Because most subway stations are located under a large crossroad, exits to the surface from the subway are provided at four corners of the crossroad, so that commuters can approach their destination without crossing to the other side of the street (see Figs 34 and 35). This arrangement noticeably improves the safety of pedestrians.

Postscript

The benefits of the Fukuoka subway enumerated in this report have been limited to those which are perceptible. Among these benefits, some are convertible to monetary values; others are not. While the former benefits are rather easily elucidated, the latter benefits must be expressed in descriptive terms because no definite, effective method for evaluating them yet exists.

From the point of view of maintaining urban facilities, a broader examination of such benefits should be undertaken. This problem will be addressed in a future study that will be performed when the No. 2 line is fully operational.

The Netherlands

Introduction

In the Netherlands, subway systems are in operation and under construction in two cities. The Rotterdam metro, which began service in 1968, has a route length of about 17 km (approx. 3.3 km of which are underground) and a total of 12 stations. Further extensions and new lines are under construction. In Amsterdam, a 18.5 km line was put into operation in 1982. This report discusses some details of the Amsterdam metro.

Description

The Amsterdam metro line is the first part of a planned network with a total route length of 78 km, of which 18 km will be underground (Fig. 36). The Eastern line, which was built first (in 1972–1982), starts at the Central Station in the heart of Amsterdam and runs to the suburb of Bijlmermeer. The underground portion of the line totals 3.5 km; five stations are underground, and another 15 stations are on the elevated part of the line.

The alternative solution for this connection involved the use of buses. However, the city's street pattern is not suitable for that kind of solution.

The investment costs of the Eastern line were (based on historical price levels):

Underground part:	Hfl 575 million
Elevated part:	Hfl 400 million
Rolling stock:	Hfl 109 million

The annual operation and maintenance costs are about Hfl 144 million (1982 prices), including capital costs on that part of the investments that has not been covered by state aid.

The revenue-to-cost ratio is at this time about 1:6.4.

In the service area of about 18,000,000 m^2, there are now approx. 150,000 inhabitants and about 50,000 people employed. In the near future, this figure will rise to approximately 200,000 inhabitants and about 100,000 people employed.

Before the metro line began operation, public transportation consisted of two bus lines between Bijlmermeer and the city center, and a North-South railway station, which is now combined with one of the metro-stations (with a cross-platform relation).

Auxiliary measures related to the Eastern line are: (1) park-and-ride facilities at three stations in the Bijlmermeer suburb; and (2) feeder bus-lines (local and regional).

The underground facilities are provided with a number of supplementary facilities that make them suitable for use as shelters in war time. For this purpose, airtight doors have been fitted in the tunnel section and in the entrances. Emergency provisions were made, such as the insertion of a mechanical ventilation system, drinking water storage, toilets and diesel generating sets.

Effects and Benefits

Public Transport Improvements

The travel time from the suburb to the city center has been cut from 40 to 20 min. Delays have been diminished to virtually zero. These advantages have led to a 20% increase in passenger load. In combination with the time savings mentioned above, this represents a remarkable savings from the point of view of political economics.

Figure 34. View of a street with tramway prior to construction of the Fukuoka subway (1974).

Figure 35. View of the same street as in Fig. 34, after construction of the Fukuoka subway (1985).

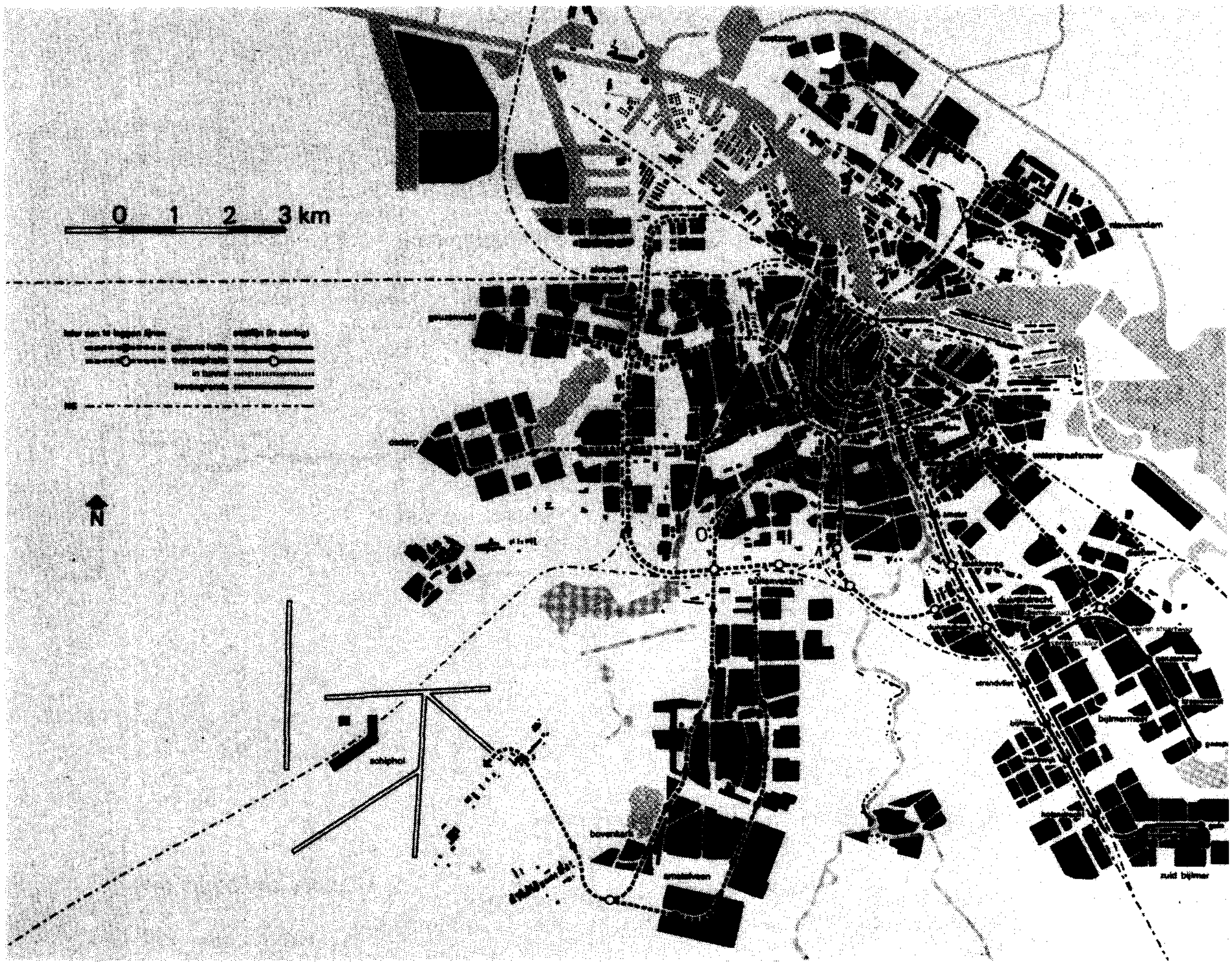

Figure 36. Map of the Amsterdam metro system.

Traffic Improvements

One clear index of the success of the new line is that the modal split in the service area has changed by about 8% (up from 56 to 65%) in favor of public transportation. Other effects—e.g. a decrease in car traffic density in the downtown area, a reduction of the rate of increase in private car traffic—are difficult to show, because the effect of just one line is too small and other influences may be more important. These effects may be measured more easily when more lines are in operation.

Improved Safety

The risk of accidents for public transport is obviously decreased, because the bus service that formerly was part of the normal traffic was substituted by a system that has its own right-of-way on a separate track. Car traffic may benefit from this situation because disturbances of the traffic flow by buses are reduced.

The underground stations in the city center all have pedestrian underpasses with many entrances and exits. Stairs, ramps and lifts are used between the street level and the underpass and between the underpass and the platform level (Fig. 37). The facilities are easily usable for all people—handicapped, the elderly, people with perambulators, and even cyclists. These facilities help improve the safety not only of the subway passengers, but also of pedestrians crossing the street.

Environmental Impacts

As can be imagined, the environmental pollution of an electrically driven subway is much lower than pollution caused by buses, especially with regard to fumes. In the underground part of the line, noise pollution is also reduced.

The new suburb of Bijlmermeer has been designed with complete separation of different kinds of traffic. Because this solution includes the railway system, any visual intrusion is avoided as well.

Economic Implications for Transport Undertaking

A moderate increase has been observed in fare income, due to the increase in the modal split and passenger loads.

The metro type of public transport requires less personnel in comparison with a bus system. On the other hand, higher operating costs for lighting, maintenance, etc., are associated with the metro. The overall effects of these operating costs have not yet been calculated.

Impact on Urban Development

Placing the public transport underground results in greater possibilities for utilization of surface land by road traffic (as far as possible, in the narrow streets of the old part of the city).

Preservation of historic buildings is possible by a very careful execution of the construction works and special precautions to protect the buildings.

Renewal of utility systems in Amsterdam has not taken place. Along the Eastern line, some adjustments were made in combination with the construction of the tunnel.

Private investments have been stimulated along the line, and a number of private office buildings have been built along the line.

Some public investments also can be noticed; one of the most important Amsterdam hospitals, located outside the old city center, was recently rebuilt next to one of the metro stations. The

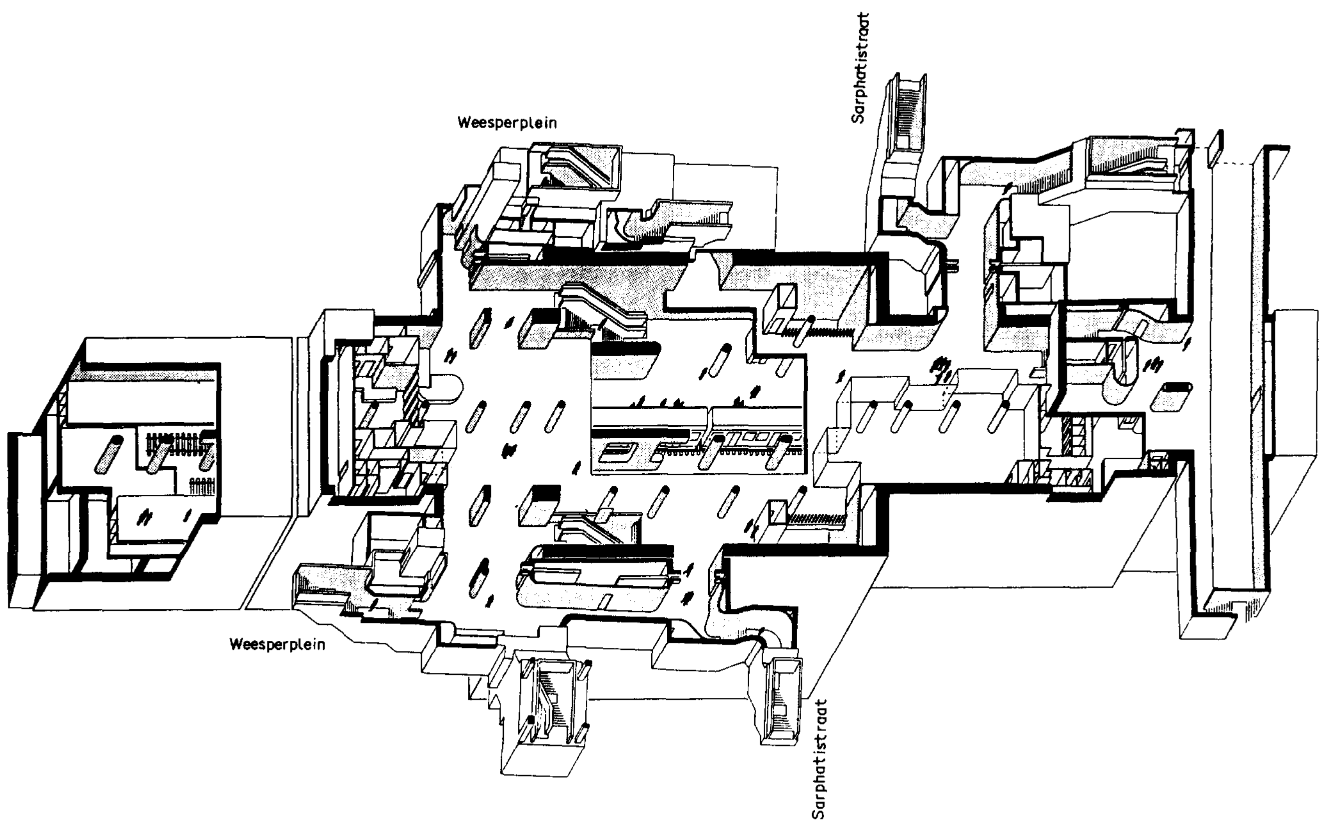

Figure 37. Entrance hall of the Weesperplein Station, Amsterdam metro.

new town hall, combined with a musical theater, is built as an annex to one of the metro stations in the city center. Another aspect of development was a regional public park that was created at the south border of the suburb. The world gardening exhibition (Floriade 1982) was held in this park.

Overall Economic Aspects

During the construction period of the Eastern line (1972-1982), approx. 500 direct working places with a Hfl 100 million yearly investment were available. Furthermore, approximately 500 indirect working places in the supply industry were created. Since the construction was completed, no new working places in this kind of construction activity have been created.

Scandinavia*

Introduction

As the limitations of traditional cost-benefit analysis as a tool for understanding a planning issue have become increasingly apparent, other methods—such as goal-achievement analysis, balance sheet and position analysis—have been suggested. While the realm of consequences that can be considered has been extended thereby, there is still no method for systematically and unequivocally grasping the totality of consequences and values that go into the decision-making process.

In considering the metros of the Nordic countries (and the non-metros, in the case of Copenhagen), we find that cost-benefit analyses have been used to a very limited extent.

Metros have been argued for in rather general terms. Costs and benefits have been articulated in a political discourse, and the weights given to various consequences have been expressed implicitly in political decisions. For the most part, only investment and operational costs have been qualified. Future revenues and travel time savings have also been estimated to some extent.

However, at least in Stockholm, interest in the application of cost-benefit analysis has been growing. In the Public Transportation Plan 1983 for the Stockholm region, such analysis has been recommended explicitly.

This report briefly relates the decision history of the metro systems in the Nordic capitals, showing which costs and which benefits were ascribed to metros when they were decided on. The experience of the application of cost-benefit analysis in the Stockholm region is also reported, and the complexity of consequences and values related to metro systems and the potentials for cost-benefit analysis are discussed.

History of Decisions

As is the case with many major decisions concerning changes in urban constructions, the decisions to construct metros were preceded by decades of surveys, studies and discussions. In Stockholm, metros were discussed for the first time during the period 1905-10, and the decision on the construction of a metro system was made in principle in 1941.

In Oslo, a committee introduced a plan for suburban railways with tunnels through the inner city in 1919, although the main decision on metros was not made until 1954. It appears that in Helsinki the discussion on metros started after World War II; the city's first metro was decided upon in 1969.

Table 27 shows the year when each of the three cities decided to construct a metro, the population at that time, and the GNP per inhabitant (at 1980 price levels). Tables 28-30 provide additional information on population, design and technical data for these metro systems.

Stockholm

The need to provide suburban areas with public transportation emerged as a problem in Stockholm during the first decade of the century. In 1910 a system of suburban railways to pass the center of the city in tunnels was proposed to the City Council. A feasibility study was presented, showing a 2-5% rentability of

*This report was written by Stig. Nordquist, Professor and Director of Nordplan, Stockholm, Sweden.

Table 27. Population in metropolitan area and national economic level the year when the principal decision to construct a metro was made.

City	Year when principal decision was made	Population	GNP per inhabitant of the nation (1980 price level)
Helsinki	1969	800,000	FMK 27,000
Oslo	1954	450,000	NOK 29,000
Stockholm	1941	800,000	SEK 10,000

Currency rates:
1980:$US 1 = FMK 3.84, NOK 5.18, SEK 4.37
1985 (Feb.): $US 1 = FMK 6.69, NOK 9.21, SEK 9.10

the investment. At the time, Stockholm had a population of approx. 450,000.

The argument for the system was very similar to the argument that has been used up to the present. The growing city needed an advanced public transportation system so that travel time between home and work did not exceed 30 min, including walking and waiting time. Only a metro could meet this standard.

International experience was reported from a number of cities—Berlin, Hamburg, Köln, Dusseldorf, Wien, Paris, Rotterdam, London and Liverpool—and was referred to in the discussions. However, no decision was taken at this time, nor during the next two decades, although the question was raised from time to time.

In 1931, the public transportation system again was attended to comprehensively. It was stated that, generally, a metro system would not be justified for a population smaller than one million inhabitants. Although the Stockholm region population was, at that time, only 650,000, it was argued that the special topography—i.e. an inner city mainly surrounded by water—would justify a metro system despite the lower population level.

A decision was made to provide one metro link in tunnel only. The main decision on a metro system was postponed and studies were continued in the 1930s. By 1941 the issue seemed to have matured. At this time the population was 800,000 inhabitants and was expected to rise to 900,000.

In the final debate in the City Council, three main questions were formulated by the commissioner responsible:

(1) Would Stockholm remain too small to have a metro system?

(2) Which would be the best alignment of the first metro to be constructed—the shortest route, through the inner city, or a detour that would cover a larger area?

(3) Should costs for tunnels and tracks be covered by the transportation company or by the City?

It was argued in the debate that metros were required to solve the housing problem. Only a metro system could provide the region with sufficient housing without exceeding a maximum travel time of 30 min between home and work. Furthermore, a decision was urgently needed in order not to delay the modernization of the city center. Metros had now been discussed, it was said, for 35 yr now it was time to decide.

And decisions were made: a metro system would be built; the first line would be a "detour" through the inner city; the City would pay for the tracks and tunnels. In 1941, when this decision was made, the GNP per inhabitant in Sweden was about SEK 10,000 (at 1980 price level).

After the main decision was made, construction work on the first metro line started in 1945; the first link was opened in 1952. Three lines with branches have been completed in stages over the following decades, as illustrated in Tables 28-30 (and see Figs 38-42). The feasibility of extending the system continually has been examined. Some of these studies are referred to and commented on below.

Oslo

A proposal for a network of suburban railways for the Oslo area, partly built in tunnels, was presented in 1919, when Oslo had a population of approx. 300,000. That proposal and similar proposals in 1937 and 1948 were not considered by the City Council, however.

Suburban railways were constructed continuously during the 1920-1950 period. A tunnel that carried the suburban railway from the western sector into the center of the city was opened in 1928. However, the railways were not carried through the center of the city.

In 1949 an office for "planning of suburban railways and metros" was established. The planning of a metro system in the modern sense was started thereby and, in 1954, the City Council made the major decision to build a metro system. The decision was unanimous, although opinions differed with regard to the extent of the first stage and, thus, sparked an animated debate.

In retrospect, the decision was remarkable. Oslo would be the smallest city in the world to have a metro system. The population in 1954 was about 450,000, with a projected future population of 700,000. The gross national product per inhabitant in Norway at the time was about NOK 29,000 (at 1980 price level).

The arguments for suburban railways had changed over the years. In 1919 it was argued that such railways would support a sound housing policy, as they would make it possible for people to live in one-family houses in rural surroundings. In the '30s and '40s, relief of street congestion became the primary motive. In 1954, the rapidly growing need for housing in the suburbs was again a main argument, together with congestion problems.

Construction work started at the beginning of 1955, directly after the decision was made by the City Council. The first line, the Lambertseter line, was opened in 1957. Thereafter, the system has been developed in stages (see Figs 43-47).

Table 28. System data for the metro systems of Helsinki, Oslo and Stockholm as of January 1, 1985.

Population of the metropolitan area as of 1/1/84	Helsinki* 900,000	Oslo 800,000	Stockholm 1,500,000
SYSTEM DATA			
Total length of metro lines (in km)	11	30	100
Total length of metro lines underground (%)	25	25	60
Number of stations	8	35	94
Number of stations underground	4	5	62
Number of depots	1	1	5
Number of traffic control centers	1	1	4
Rolling stock (number of cars)	84	156	888
Signal system	Automatic operation	Cab signals	Cab signals
Number of full-time employees	140	580	2500
*Helsingfors + Esbo + Vanda			

Table 29. Traffic and financial data for the metro systems of Helsinki, Oslo and Stockholm.

		Helsinki	Oslo	Stockholm*
TRAFFIC				
Traffic volume	Average No. of pass. in 24 h	114,000	100,000	420,000
Share of total public transportation volume in the metropolitan area	%	12	25	42
Capacity	seats places	5200 15,600		
	No. of seats in rush hour		50,000	140,000
Production per yr	Million car km	7	9	64
ECONOMY				
Costs per yr†	FIM	89		
	M SEK		not available	680
Costs coverage	%	51	52	27

*Exchange rate (Jan. 2, 1985): 1 SEK = $US 0.11.
†Capital costs (including roadbed), operational and maintenance costs.

It seems that, until recently, the extension of the system has not been controversial and cost-benefit analysis has not been applied. However, extensions that were considered only a few years ago are today being questioned because of the high costs of construction. For the only extension that is being seriously considered, buses are being studied as an alternative. Otherwise, a question of immediate interest in Oslo is the connecting up of the metro systems in the east and west; this is a problem because of differences in cars, current collector systems and signalling systems.

Although the tunnel length of the system is fairly short, the tunneling in the center of the system has been complicated. In autumn 1984 a leak in the central station was discovered. The leak will be very costly to correct: costs on the same order as the costs for the original construction work have been mentioned.

Helsinki

In Helsinki, a metro system was not discussed until the 1950s. In 1956 the Metro Commission was established; in 1963 it presented a proposal for a metro system. The City Council made a major decision on a metro system in 1969, at which time the population of the metropolitan area was about 800,000 inhabitants and the GNP per inhabitant in Finland was FMK 27,000 (at 1980 price level).

Construction work on the first line started in 1970, and 11 km of the line was opened in 1982. This line is now being extended; no decision has been made concerning whether to further develop the metro system (see Figs 48 and 49).

In Helsinki, the metro has been under debate from the very beginning. A bus system was studied as an alternative in the '60s and was recommended by some experts; however, the plan was never considered by the City Council. In 1964 a group of foreign experts invited to express their opinions mainly supported the metro plan of 1963. One reason for growing hesitation about the metro system might be that population growth has been slower than expected. Another reason might relate to the successive improvements of the bus systems—e.g. the use of bus lanes.

Furthermore, the construction of the first line has been delayed by several years and the estimated costs have been exceeded considerably. A corruption affair at the beginning of the '80s connected with construction of the metro may also have had some influence on opinions concerning future metro development.

Copenhagen

In Copenhagen, the State Railways presented a proposal in 1940 for a suburban railway system with underground lines through the inner city. However, funds for implementing the plan were never granted.

Table 30. Technical data for the metro systems of Helsinki, Oslo and Stockholm

Technical standard	Helsinki	Oslo	Stockholm		
			Tb1	Tb2	Tb3*
Maximum length of train (No. of cars)	6	6	8	8	10
Width of car (m)	3.2	3.2	2.8	2.8	2.8
Maximum gradient (H‰)	35	50	40	40	40
Minimum curve radius					
horizontal (m)	150	150	200	250	600
at stations (m)	∞	∞	300	300	∞
vertical (m)	3000	1500	1500	2000	4000
Gauge (mm)	1524	1435	1431	1431	1431
Tunnel area, single track (m^2)	30	23	22	24	24
Maximum running speed (km/h)	90	70	80	80	90
Maximum journey speed (km/h)	50†	32	30	35	40
Maximum acceleration (m/s^2)	1.2	1.1	1.0	1.0	1.3
Average retardation (m/s^2)	1.2	0.75	1.1	1.1	1.1

*Metro system Nos 1, 2 and 3
†From Botbyhojden to Kampen 13.4 min; length, 11.4 km.

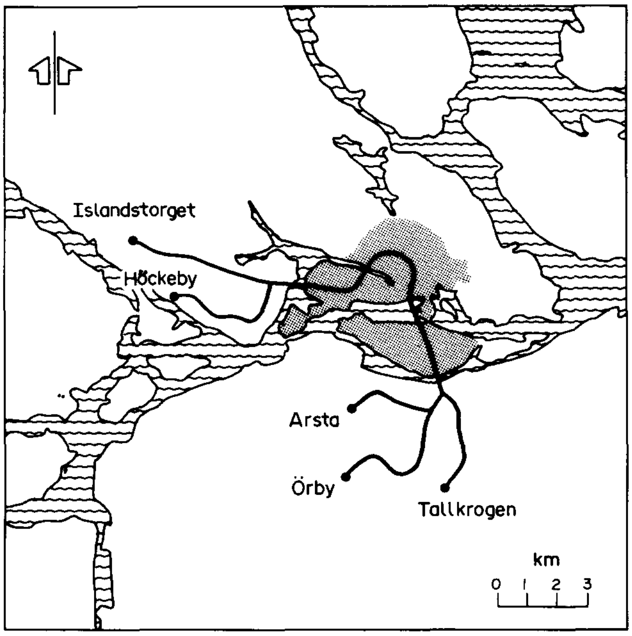

Figure 38. Stockholm metro plan 1941.

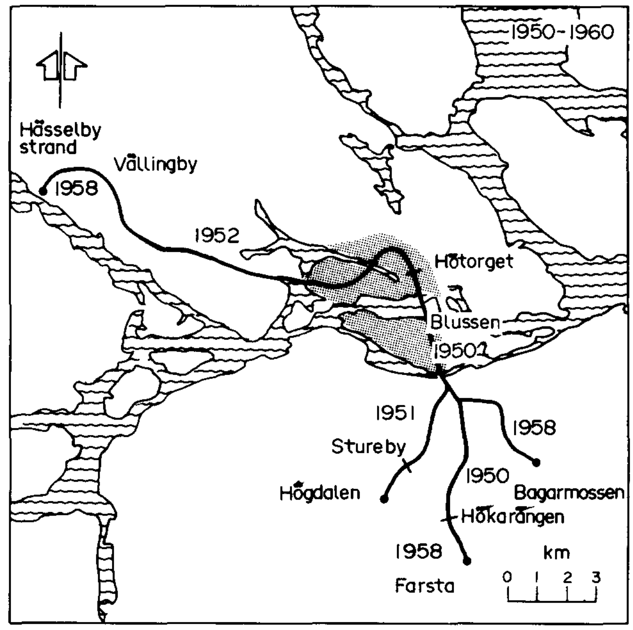

Figure 39. Stockholm metro plan 1950-60.

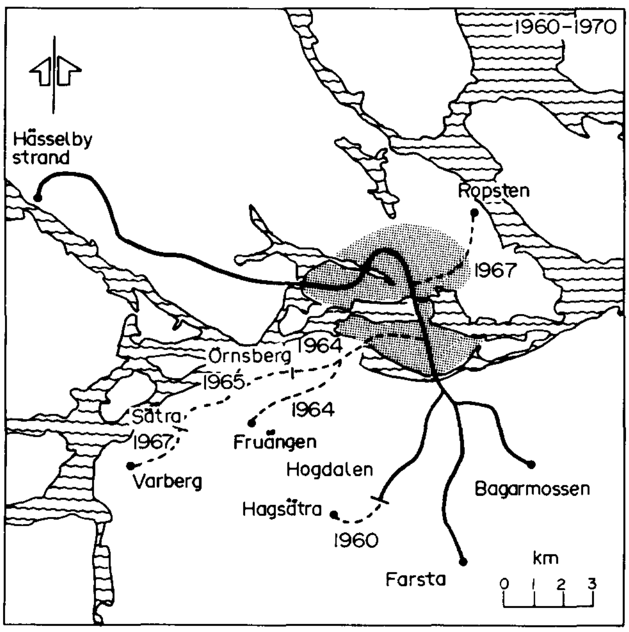

Figure 40. Stockholm metro plan 1960–70.

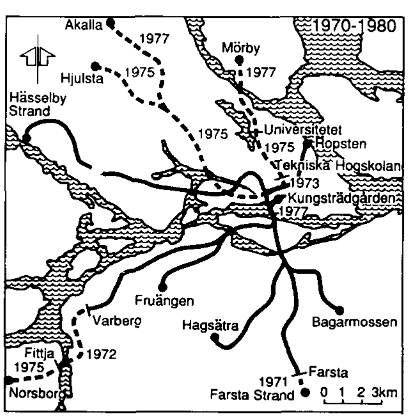

Figure 41. Stockholm metro plan 1970–80.

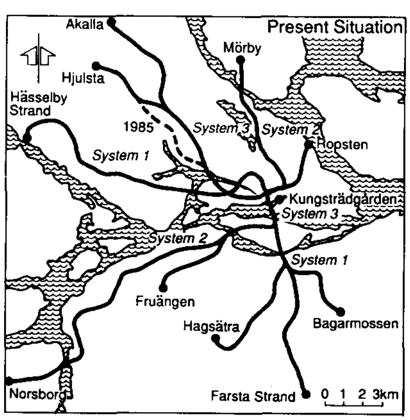

Figure 42. Development of the Stockholm metro as of 1985.

In the 1950s alternative future transportation systems for the metropolitan area were analyzed, and in 1961 a proposal was presented by a metropolitan traffic committee. The population of the area was approx. 1.5 million at the time and was expected to grow to about 2.0 million in the next twenty years.

The committee recommended a higher share of public transportation in the future and the construction of metros in the inner city, one line north-south and one east-west.

The committee also declared that metros would hardly relieve the traffic situation in the next ten years and that, therefore, the traffic system would reach a critical situation. Despite these alarming observations, a metro system has never been approved.

The consequences of this decision not to build a metro—for urban structure, traveling, and quality of life—and a comparison with the other Nordic capitals that do have metros might give fruitful insights into the metro issue.

In summary, the capitals of the Nordic countries are comparatively small to have metros, a situation that has been observed in the debate. In addition, it is remarkable that the largest city, Copenhagen, has no metro system, despite the fact that metro planning for the city began at an early date.

In the cases of Helsinki, Oslo and Stockholm, reference has been made to the special topographical conditions and special urban structure, which make bus systems infeasible. The construction costs have mostly been underestimated and further extensions increasingly questioned, particularly in Helsinki and Oslo.

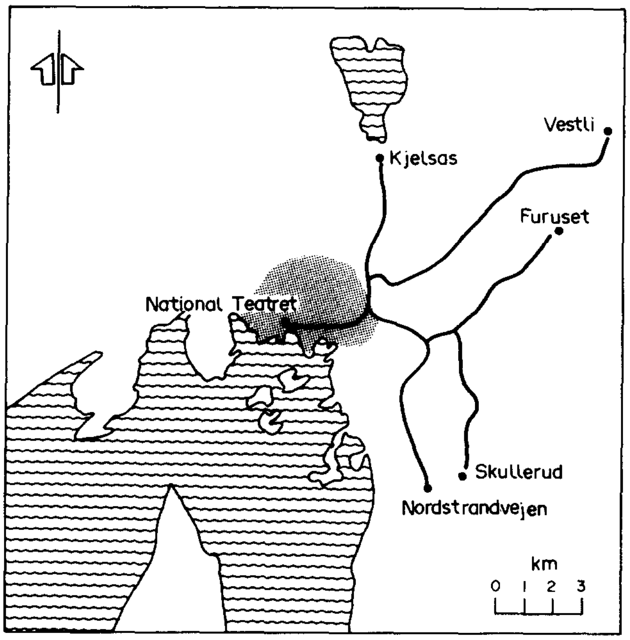

Figure 43. Oslo metro plan 1954.

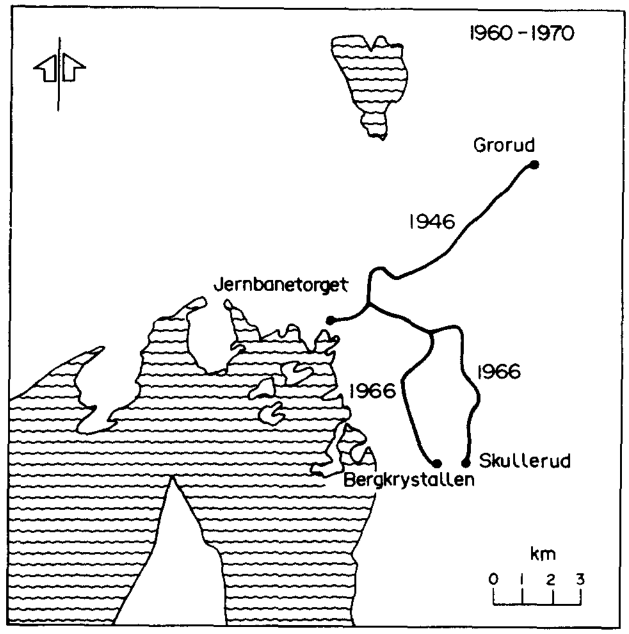

Figure 44. Oslo metro plan 1960–70.

Cost-benefit Analysis

Major decisions on metros in the Nordic capitals have been made without application of cost-benefit analysis. Increasingly, however, cost-benefit analyses have been attempted for various traffic planning and metro project decisions in Stockholm. As noted above, the Public Transport Plan for Stockholm 1983 recommends that cost-benefit analysis be regularly applied.

In the metro plan of 1965 the following rule of thumb was formulated: The minimum population to justify a through line is 100,000 clustered around each end of the line, and the maximum population that can be served by one through line is 200,000 clustered around each end of the line. The minimum population requirements were based on economic considerations—number of travellers, costs and revenues; no social or ecological factors were considered.

Rules of thumb have also been formulated for assessing extensions of lines. Stockholm's Public Transportation Plan 1983 specifies design criteria for such extensions (see Fig. 50). The minimum population of the catchment area of the extension is related to the investment required and achieved reductions in travel time. Again, this recommendation is based on generalized assessments of monetary costs and revenues and consideration of travel times; however, external non-monetary costs and benefits are not considered.

However, the studies of extensions of existing lines have not stopped at an application of such general rules, but rather, have included more detailed analyses. At least three cases can be referred to in this regard; they are discussed below.

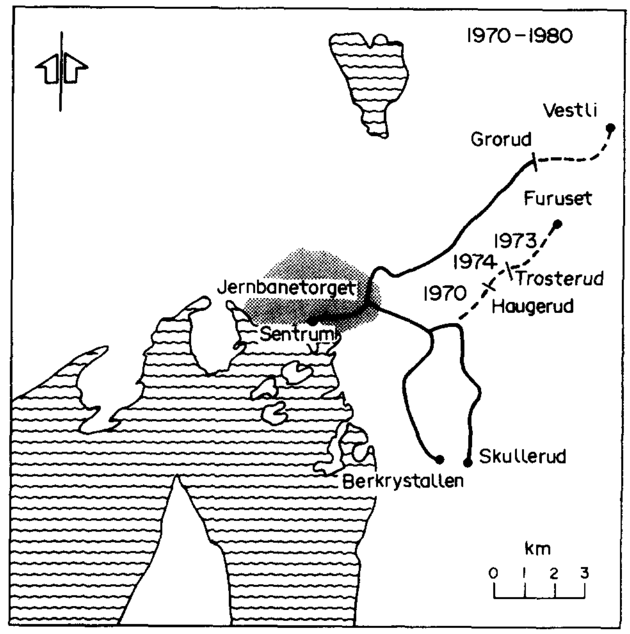

Figure 45. Oslo metro plan 1970–80.

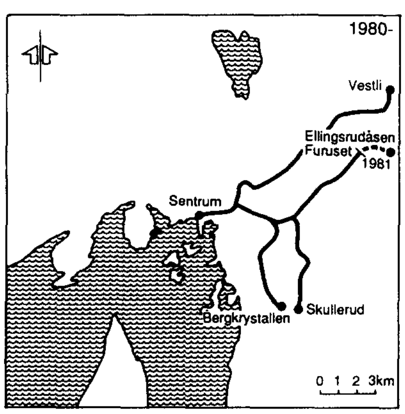

Figure 46. Oslo metro plan 1980–.

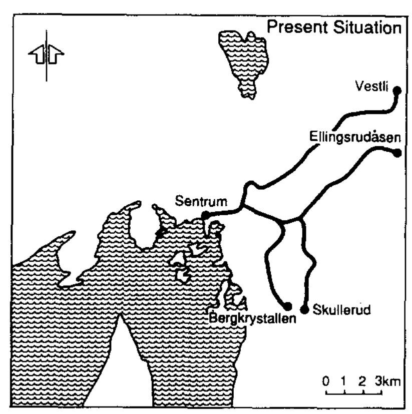

Figure 47. Development of the Oslo metro as of 1985.

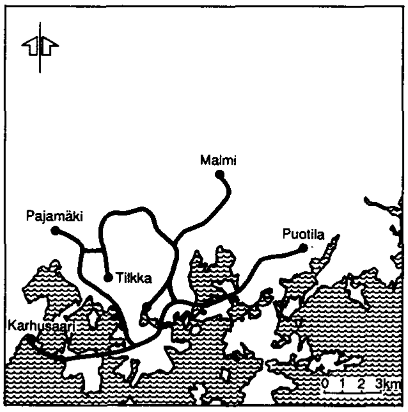

Figure 48. Helsinki Metro Commission 1963 proposals for 1980.

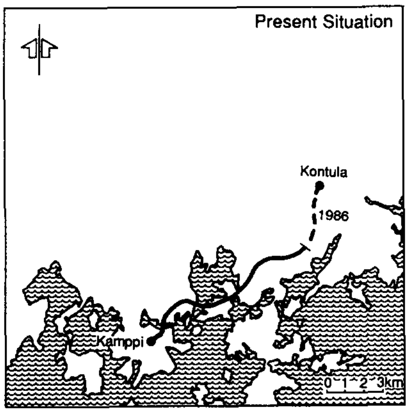

Figure 49. Development of the Helsinki metro as of 1985.

Northeast Extension

The first case concerns an extension in the northeast sector. Since 1978 the metro has run to Mörby Centre. In 1975 and in 1980 a decision was made to extend the metro 6.5 km to Täby Centre. A contract was even signed, in which the municipality pledged itself to build a new housing area for 2400-2500 households and about 2500 work places, and the County Council committed itself to the construction of the metro and a metro station in the area.

However, these decisions have been strongly opposed by the inhabitants of the area, who prefer the existing railway. This opinion has even been expressed in a referendum. For the present, an extension of the metro is not in the programme and the municipality is requesting the County Council to pay SEK 5 M for breach of contract.

A further extension of the metro, from Täby Centre to Akersberga (a distance of about 16 km), has also been discussed. Three alternatives were considered: a new metro, an upgraded railway, and a system of express buses.

Discounted costs for construction, operation and maintenance have been considered, as well as user costs and effects on land use. The assessments have been made for a period of 25 yr, with an interest rate of 4%. When calculating user costs, travelling time, waiting time, walking time to and from the station, and transfer time have been given different weights in the analysis. Land-use effects have been estimated by the use of the so-called TRANSLOK model, which relates land use to availability.

The analysis resulted in considerably higher construction plus operating costs for the metro than for the other alternatives (see Table 31). The bus alternative had the lowest costs. User costs were about the same for the metro and the railway and were lower than for the buses. Total cost was lowest for the buses and highest for the metro. Land use effects were most favorable in the metro alternative but not to the extent that the higher costs would be justified.

Northwest Extension

A second case involves the "Södra grenen" (or Rissnegrenen) extension in the northwest sector. The Järva line was opened in 1975. "Södra grenen" is a 7 km-long branch of that line from the Västra Skogen station. The new line will mainly go through built-up areas presently served by railway and buses. But the promoters of the new line justified the line by proposing development of a new residential area, Rissne, for 10,000 inhabitants.

Again, as for the northeast line, a contract was signed between the municipality and the County Council interrelating the development of Rissne and a new metro through the area. The cost-benefit analysis in this case considered construction and operating costs as well as user benefits because of the shorter travel times.

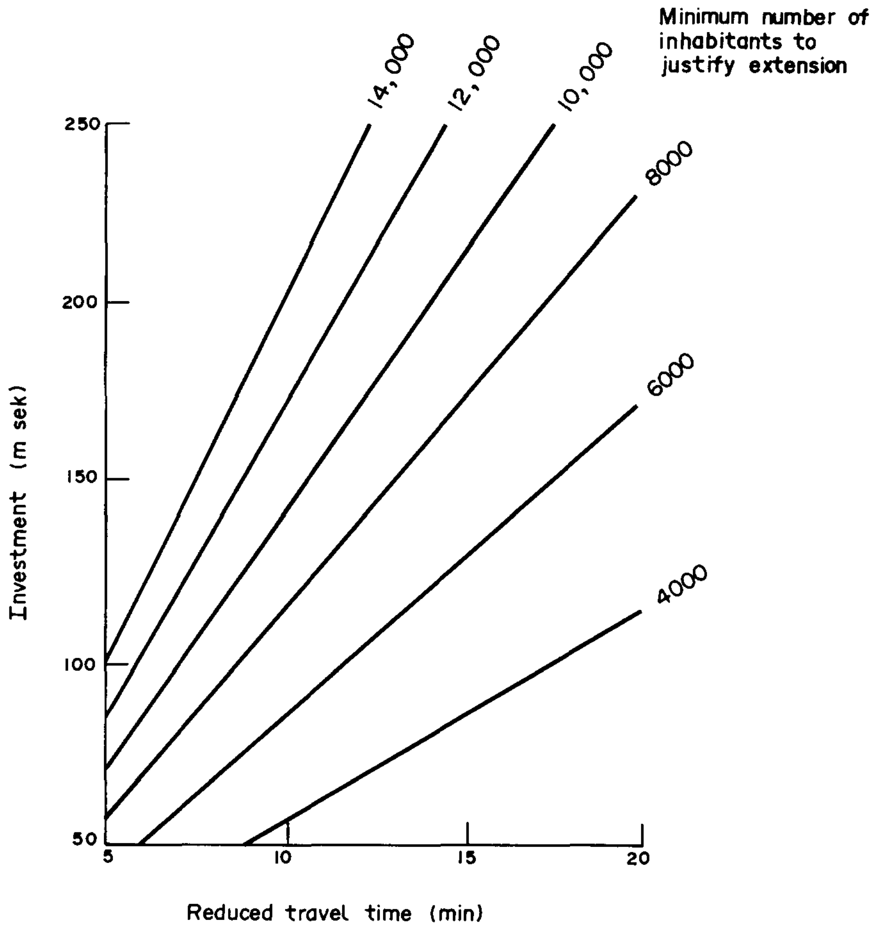

Figure 50. Criteria for extending a metro line, based on the Stockholm Public Transportation Plan, 1983.

Table 31. Cost-benefit analysis for transport alternatives for the northeast sector of Stockholm (Taby Centre - Akersberga); discounted costs.

Alternative	Investment costs (MSEK)	User costs (MSEK)	Total costs (MSEK)
Metro	2,195	193	2,388
Upgraded rail	1,620	193	1,813
Buses	1,313	207	1,520

The annual cost of the new metro was estimated at SEK 36.5 M, while the reduction of bus costs was only SEK 0.5 M. The limited reductions in travel times would by no means balance the additional costs of the metro. It was decided to build the new line regardless. After about half of the construction had been completed, an interruption of work was proposed in the County Council, but this proposal was not accepted. The Rissne area and the new metro were completed in 1985.

Skarpnäck Extension

The third case involves the Skarpnäck extension. This is an extension of the southern metro line by 3 km from the present end-of-line station, Bagarmossen, to a new housing development, Skarpnäck, which has 3250 households. The alternative to a metro extension was a bus service. Construction and operating costs were considered, as well as effects on land use. It was shown that in the Stockholm region, the density of residences is 3.2–3.6 times higher and the density of work places, 1.5–1.8 times higher in sectors served by metros than in areas served by other means of transportation.

This experience was applied in the cost-benefit analysis for the Skarpnäck extension in the following way. It was assumed that a metro would lead to a higher density of land use than a bus service, and that this would mean lower user costs, as some people would otherwise live in areas requiring longer travel times. Furthermore, the lower density of work places associated with use of a bus system would result in establishing work places in other areas, requiring longer travel times. This situation would lead to a smaller number of women in the work force, which would, in turn, mean a reduction in production value.

The result of this analysis—expressed in discounted values for a period of 35 y and at an interest rate of 4%—has a benefit of SEK 132 M and a cost of SEK 263 M, representing an overall loss of SEK 130 M. Nonetheless construction of the metro was approved; it will begin in the next few years.

These three cases indicate that further suburban extensions of metro lines in the Stockholm region may not be profitable. On the other hand, the profitability of central parts of the system or the system as a whole has not been tested.

As we have seen, cost-benefit analysis to date for metros in the Stockholm region has included construction, operating and user costs only. User costs refer to travel time, including time on the metro plus walking time to station, waiting time and transfer time. In one case, effects on land use also have been estimated quantitatively.

Environment and Energy Issues

The Public Transportation Plan 1983 states that effects on environment, safety and energy consumption hardly can be dealt with in each separate project but, rather, must be assessed more generally. The report carries out such an assessment and comes to the conclusion that a higher share of public transportation means improved environment, increased safety and less energy consumption, except for low-frequency routes and hours. However, the analysis compares private cars and buses, and does not directly indicate the effects of the metro.

Approximately 30% of the people living or working in the central area of Stockholm are exposed to higher rates of toxic gases than is acceptable, according to the norms. In the other parts of inner Stockholm, the corresponding figure is 15%. The contribution of different vehicles to this pollution is shown in Table 32. The fact that the contribution of metros to pollution is nil while it handles 6% of the total traffic to and from the inner city indicates that their importance, cannot be disregarded.

Noise is a problem in 80 km of streets in the inner city. A noise level above 70 dBA is considered unacceptable. To reduce the noise level by even 1 dBA, however, requires a 25% reduction in the motor traffic on the street. Again, the fact that the metros cause hardly any noise disturbance in the inner city indicates their importance that, from the noise point of view, their influence cannot be disregarded.

A comparison of the energy consumption of different transportation means is intricate. The loading factor has to be considered, as well as the fact that a trip by car generally goes by a shorter route than the corresponding trip by bus or metro. Furthermore, a systematic analysis should consider the energy consumed in the construction of tunnels, motorways, etc. A well-known observation was made in the analysis of San Francisco's Bay Area Rapid Transit system. The analysis found that the energy savings gains by reduced passenger car traffic would not be enough to balance the energy consumed in the construction of the system, even in the lifetime of the system.

Assuming normal load factors for bus and metro, but not considering the longer routes of public transport and not considering the energy consumed in construction of the systems, the energy consumption with various passenger volumes has been estimated (see Fig. 51).

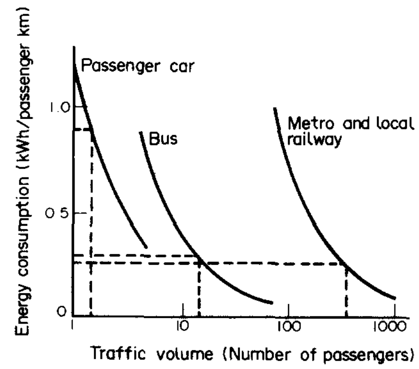

Figure 51. Energy consumption of various modes of transportation for commuter traffic in rush hour. Load factors: 1.3 persons/passenger car, 16 persons/bus, 300 persons/metro train.

Accordingly, energy consumption in rush hour by passenger car is about three times higher than energy consumption by bus or metro. During low traffic periods, however, energy consumption by metro is about 1.5 times higher than by bus or passenger car.

Safety consequences are also different for various means of transportation. The number of persons killed and injured per million passengers/km in the Stockholm region is approximately 0.05 for the metro, 0.20 for buses and 1.25 for passenger cars. Because the total cost of traffic accidents is estimated at SEK 1000 M, these differences have considerable impact on cost-benefit comparisons.

The Metro Culture

An assessment of metros should go beyond consideration of construction and operating costs, travel time and pollution.

When a metro system is decided on, an urban structure and a metro culture will follow. As a high-capacity and high-cost means of transport, a metro system encourages concentration; thus, the density of land use becomes higher in the areas around the metro than in the rest of the city. Metros are associated with multi-storey buildings rather than single-family houses. In the center of

Table 32. Vehicle share of the pollution in inner Stockholm (1982).

	Co (%)	HC (%)	NO$_x$ (%)
Passenger cars	98.6	97.8	49.0
Lorries	1.1	1.8	40.8
Buses	0.3	0.4	10.2

the city, land values generally increase near the stations and, thus, press for higher density of land use.

Metros also mean a higher concentration of travelers. Streams of people flow through stairs, escalators and pedestrian conveyors, filling the platforms and the cars. Tiring and unhealthy as this may be, it has become a more or less accepted price of metropolitan life. As noted above, when people are invited to give their opinion in a referendum, it seems that they prefer railways and buses to metros, if an alternative is workable.

Metros also seem to attract a criminal element. The City Council of Stockholm conducted a survey of "non-appropriate youth environments" in 1978. The metro stations were indicated as the worst environment by all the respondants, as they are becoming centers for violence, drugs, alcoholics, etc.

The metros also have their supporters, however. It seems that, in addition to its regularity and speed, the metro system is appreciated because it is easy to conceptualize and to learn. Furthermore, it is a system to be trusted in the sense that once you have a metro line, it is not as easily relocated as a bus line.

Because metros are becoming so costly for the municipalities and because they have such a strong influence on urban structure and on urban life, the decision on whether or not to build a metro system certainly needs to be well thought out. Making such a decision requires a profound understanding of the social implications of metros and the metro culture. However, the application of cost-benefit analysis in a more limited sense is also necessary to clarify the consequences of a metro system. Therefore, improvement of this methodology is urgently needed.

Acknowledgements

This research was supported by the Swedish Rock Mechanics Research Foundation. I wish to express special thanks to Bo Österlund, VBB AB, who collected and prepared data. I also wish to acknowledge several people for information and views: Manfred Diegelmann and Paavo Suhonen of the Traffic Planning Bureau in Helsinki, Reidar Bollum of A/S Oslo Sporveijer; Kjell Jansson, Gunnar Lind and Bertil Linner of AB Storstockholms Lokaltrafik; and Göran Tegner of the Traffic Planning Bureau of Stockholm County Council.

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Venezuela

The outrageous growth of the population of Caracas, which in 40 yr has doubled to a total of about three million inhabitants in 1985, led to serious consideration in the 1960s of a mass transportation system as an alternative to the existing ground transportation system. It was decided that the most advisable solution was an underground railroad system, most routes of which would run underground, but without eliminating the possibility of ground-level construction when local conditions advised it.

The main line of the subway network follows the bed of the city valley, along which most of the highly populated areas are located.

The system consists of three lines with a total length of 59 km. It is estimated that in the year 2000 the subway will transport approx. 2.5 million passengers per day, or 760 million per yr; this figure represents a rate of 13.5 million passengers per km per yr.

Line 1 runs along the valley; lines 2 and 3 connect highly populated areas in the south of the city to line 1; transfer stations are shown in Fig. 52.

Line 1 has 22 stations, 20 of which are underground; its total length is 21 km,

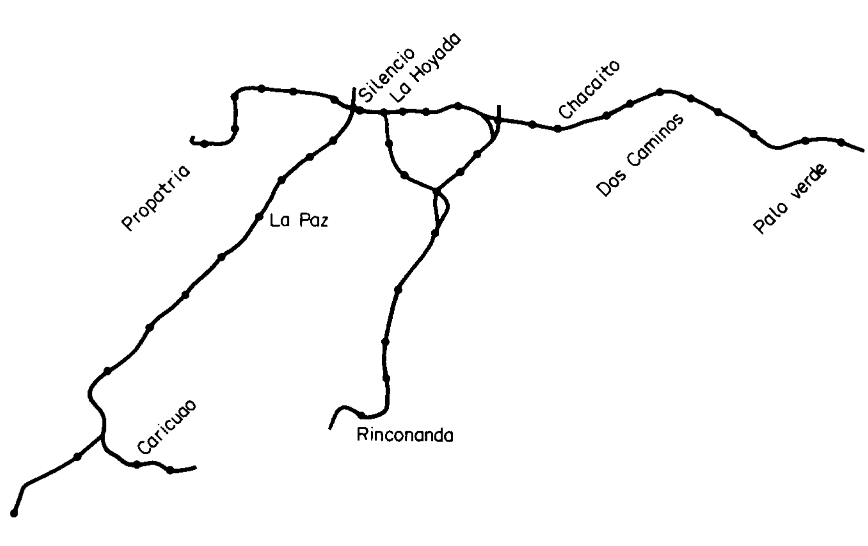

Figure 52. The Caracas metro system.

from which there are 14 stations in operation. A 12 km extension is planned. In 1985, 300,000 people were transported daily through this section of the route. That figure translates into 8 million passengers per km a yr, making it the third subway system in Latin America and the 14th largest in a group of 60 systems in operation throughout the world. This fact in itself justifies the urgency to complete the system.

It is estimated that by the end of 1988 lines 1 and 2 will be completed, as shown in Table 33. The completion date for line 3 has not yet been established.

Underground Railroad vs Ground Transport

The selection of a mass-transportation system, based on reasons of speed, safety, reliability, and comfort, becomes an important contributor to the social benefits that the users take advantage of.

Viewed from this perspective, and without losing sight of the economic importance of the required investment for its construction, the advantage of the metro becomes obvious when compared, as in this case, to the ground transportation system that operates on routes parallel to the existing underground line.

Speed and Time Savings

The average subway speed of 36 km/h compares to a ground transport speed of 18 km/h.

The average travel time per passenger in the subway is 6 min, compared to a 12 min average time using ground transport system for a similar route.

Given the 300,000 passengers transported daily by the subway, the time-saving factor comes to 30,000 h/day (6 × 300,000 = 1,800,000 min). This represents 10,950,000 hr per yr.

Of no less importance are the reliability, comfort and education factors that this first stage of the metro represents to Caracas society.

Safety and Reliability

A positive comparison can be made with regard to the safety of passengers carried by metro versus those transported by the ground transportation system.

The metro's special features and the automatic central controls that are continually monitored from the main operational control center, with access to emergency local controls in the event of a possible collision, in themselves provide a safety advantage.

Equally important is the reliability that the system offers through its routine schedules and high passenger load capacity. A train comprising seven coaches, each with a 200-person capacity, can carry a total of 1400 people.

Comfort

Because the trains and the underground stations are climatized, passengers find the environment in both the stations and the trains comfortable and attractive. This comfort factor may be translated into a higher performance in daily activities. At the same time, people are not really affected in a significant way by the artificial lighting during the six-minute period that is the average time a passenger uses the system.

Impact on Urban Development

An increase in construction activity in the areas close to the subway stations is already foreseen. In part this is due to the fact that an underground transportation system eliminates the need for more space and the very high operational cost of enlarging the ground transportation system. The areas near the stations are destined to provide entertainment and recreation (Boulevards) for the residents.

Contamination

Caracas, which is located in a narrow valley, is starting to feel the effects of the environmental contamination caused by the fumes of the 150,000 vehicles that run through it every day. The underground electrical railroad tracks lessen the contaminating effects by the equivalent of 15,000 automobile trips per day.

Conclusion

Of the 5 million trips a day taken in vehicles, 3 million are made by passengers transported by public transportation services, particularly along the 410 km of expressways and main feeding roads that form the principal city road network.

An idea of the advantages of the subway can be obtained by comparing the 7320 passengers per km per day transported by the ground transportation systems to the 25,000 transported by the subway—i.e. nearly four times as many people are transported by subway.

The use of the electrical railroad underground system of the Caracas metro basic line represents an obvious benefit to the public, which compares it in a positive way to the ground transportation system. In addition, it is an example of efficient organization.

Table 33. Plans for the Caracas metro.

Lines	Length (km)	Stations	Average distance between stations (m)	Cost (Thousand Bs)	Operation date
1					
Propatria–Chacaito	12	14	920	5829	1983
Chacaito–Dos Caminos	4	4	1000	2210	1987
Dos Caminos–Palo Verde	5	4	1250	1729	1988
2					
Caricuao–La Paz	16	9	1770	2499	1987
La Paz–Silencio	4	4	1000	2526	1988
3					
Rinconada–La Hoyada	18	8	2250	1275	?

Summary

Over the past two decades, underground construction for urban railway transportation systems has increased substantially, and the volume of construction continues to grow. On the other hand, the high costs of underground construction promotes the opinions that the costs of such subsurface systems are extravagant.

The examples discussed in this paper permit the following conclusions:

(1) Urban railway transportation with its own right of way is a high quality, safe, quick and attractive mode of transport. It is necessary to serve large volumes of passengers along corridors with concentrated traffic streams.

(2) In many very large cities around the world, the use of the subsurface for transportation purposes is an absolute must because there is no room at all for railway lines on the surface or above ground.

(3) The use of the subsurface compared with the surface solution can result in many advantages and benefits in the following respects:

- **Time savings:** Savings in travel time for passengers and even for car drivers; and improved punctuality.
- **Comfort and safety:** Smoother transport for the passengers; higher safety for passengers, pedestrians and car traffic.
- **Environmental protection:** Reduction of noise, vibration and air pollution; and avoidance of visual intrusions.
- **Town planning improvements:** Renewal of downtown areas; creation of pedestrian zones; positive effects on historic monuments and buildings.
- **Economic aspects:** Higher fare income due to higher passenger loads; lower operation costs; positive effects regarding political economics.

This list is likely to be incomplete. Moreover, it shows that the benefits belong to very different categories with regard to the possibilities of quantifying or measuring them. Resolving these problems will be a future task of this working group.

In conclusion, it can be stated that for many cities, the use of underground space for railway transportation systems is a vital measure to preserve the life of their downtown areas. □

APPENDIX
COST-BENEFIT STUDIES INVOLVING TUNNELS IN THE UNITED KINGDOM*

Below are listed a number of cost-benefit studies undertaken in the United Kingdom, in which an element of tunnelling was involved, or in which grade separation was the major reason for undertaking the project.

The first section deals with schemes proposed by London Regional Transport; the second section involves British Rail and metropolitan area authority proposals; and the third section offers highlights of the history of the methodology used by the Department of Transport and a synopsis of a paper on the cost-benefit analysis of grade separations.

London Regional Transport Proposals

Short title: *VICTORIA LINE STUDY*
Full title: "Estimating the Social Benefit of Constructing an Underground Railway in London"
Authors/Date: C. D. Foster and M. E. Beesley/1962
Publication data: Royal Statistical Society Journal, Series A (General), Volume 126, Part 1, 1963.
Synopsis: A pioneering freelance study undertaken on the proposal on the first new cross-London tube railway to be built in the last 50 yr. The authors attempted to measure the non-financial benefits of the scheme, including passenger time savings, reduction in overcrowding on existing lines, and the relief of road congestion. One of the authors had been involved in a 1960 study of the benefits arising from Britain's first motorway—the M1. The Government gave financial authority for the construction of the Victoria Line prior to completion of the study. This decision by Transport Ministry officials may have been influenced by their awareness of the generally favorable conclusions of the study.

Short title: *BRIXTON EXTENSION STUDY*
Full title: "Victoria Line Extension to Brixton or Streatham—Social Benefit and Loss Study"
Author/Date: M. E. Beesley, for London Transport/1963
Publication data: Not published.
Synopsis: Adopting the same evaluation techniques used in the "Victoria Line Study" (see above), Dr Beesley showed that, while the shorter extension to Brixton was justified, in social benefit terms the longer extension to Streatham was not justified. In 1966 the study was updated and, subsequently, the 5.3 km Brixton extension scheme was authorised by the Transport Ministry. This was almost certainly the first occasion when a major rail investment proposal was authorised on cost benefit rather than financial grounds. This became possible following the passage of laws permitting the Government to make transport infrastructure grants towards the cost of worthwhile schemes.

Short title: *ALDWYCH BRANCH STUDY*
Full title: "Extension of Aldwych Line to Waterloo—Social Benefit and Loss Study"
Author/Date: London Transport/1964
Publication data: Not published.
Synopsis: This study showed that a short extension of the Holborn-Aldwych branch to Waterloo was not justified on any basis because of high cost per kilometer, limited passenger capacity and moderate time savings. Subsequently, the project was abandoned even though land acquisition powers had been obtained.

Short title: *HEATHROW LINK STUDY*
Full title: "Report of a Study of Rail Links with Heathrow Airport"
Author/Date: Heathrow Link Steering Group (see Note), for the Ministry of Transport and the Board of Trade/1970

*This report was prepared by D. G. Jobling, Principal Project Manager, London Underground Ltd, London, England.

Publication data: HMSO 1970.

Synopsis: This study compared alternative rail links from central London to Heathrow Airport with the base option of continuing the coach services (operated by the main airlines), which were increasingly subject to road congestion. A 5 km extension of the existing London Transport Piccadilly Line from Hounslow West to Heathrow produced the best benefit-to-cost ratio. Subsequently, construction of this extension was authorised by the Transport Ministry.

Note: The Heathrow Link Steering Group is an ad hoc body comprising representatives of Ministry of Transport, Board of Trade, British Airports Authority, British Rail, London Transport, state airlines and local authorities.

Short title: *FLEET LINE STUDY* (Note: Before opening, the Fleet Line was renamed the Jubilee Line)

Full title: "The Case for the Fleet Line Re-stated"

Author/Date: London Transport/1971.

Publication data: Not published.

Synopsis: Following completion of the main Victoria Line, a further major cross-London tube railway from Baker Street to Lewisham was proposed by London Transport without success. This study re-examined the case for the new line in three ways, viz:
(1) By stating the general transport benefits;
(2) By cost-benefit analysis
(3) By setting out the broader planning benefits and illustrating their worth in terms of increased property values.

The cost-benefit analysis followed the general lines of the Foster and Beesley Victoria Line study (see above), but incorporated nine years' experience in developing improved evaluation techniques, particularly as regards traffic estimation. Unlike the Victoria Line, time savings for the Fleet Line were modest, the largest benefit being relief of street congestion. The full scheme was never authorised, largely because of the inadequate benefit-cost ratio. Finally, a small (4 km) initial section between Baker Street and Charing Cross was built, primarily to reduce the overcrowding on the parallel Bakerloo Line.

Short title: *HEATHROW TERMINAL 4 STUDY*

Full title: "Public Transport Access to Heathrow Terminal 4"

Author/Date: Working Group under joint leadership of Department of Transportation and Greater London Council/1980.

Publication data: Not published, but available from Department of Transport.

Synopsis: Following a planned inquiry into a proposal to build a fourth terminal at Heathrow Airport remote from the existing central area terminals (which resulted in Government approval of the scheme), a review of the public transport options for service the terminal was undertaken. Quantified costs and benefits showed that an extension of the London Underground in the form of a single track loop line or a shuttle bus from an existing station to the new terminal building were of equal merit. In arriving at this conclusion, the cost benefit framework took into account both capital and operating costs, benefits to users, the effects on other public transport services and road users and any environmental impact on the option.

The Airports Authority made clear its preference for a rail link and made provision for a station in the terminal plans; however, financial arrangements for the 6 km tube line were not resolved until 1982. Although the works are now virtually complete, the railway will not carry passengers until the air terminal becomes operational.

Short title: *DOCKLANDS LIGHT RAILWAY STUDY*

Full title: "Public Transport Provision for Docklands—Summary of the Assessment of Schemes"

Author/Date: Docklands Public Transport and Access Steering Group (see Note)/1982.

Publication Data: Not published, but available from GLC—Transportation Department.

Synopsis: The original Fleet Line proposal to serve Lewisham was modified in 1975 to service London's declining dockland and Thamesmead (a new town). However, it became clear that Government funding for such an expensive scheme (see Note) was not going to be forthcoming in the time span being allowed for the redevelopment of the dockland areas. Therefore, a review of lower cost solutions was undertaken. These solutions included express buses and a self-contained light rail system that would use abandoned or underutilised tracks.

The technical feasibility and the availability of the routes for the light railway were established by 1981. In the following year the Steering Group reported the case for the railway to the Government. This shows that the quantifiable transport benefits represented about 50% of the capital cost. The Group, therefore, argued that the balance of investment could be justified by the railway's contribution to the redevelopment of the area served. Subsequently, the scheme was authorised.

Notes: The Docklands Public Transport and Access Steering Group comprises representatives of the Greater London Council, London Docklands Development Corporation, Departments of Transport, Environment and Industry and London Transport. The scheme involved 19 km of double track railway with 14 stations, mostly in deep-level bored tunnel.

Proposals by British Rail and Metropolitan-Area Authorities

Short title: *WEST MIDLANDS LIGHT RAIL SCHEME*

Full title: "Rapid Transit for the West Midlands—Final Report" (June 1984)

Author: West Midlands County Council and WM Passenger Transport Executive/1984

Synopsis: This report takes account of four principal variables:
(1) The benefits accruing to public transport users.
(2) The marginal cost and revenue savings to passenger transport executives.
(3) The benefits of lower accident costs due to the lower levels of congestion resulting from having a light rail system.
(4) The disadvantages to residual road users caused by the priority given to the light rail (however, these would be offset by the new "park and ride" measures).
The rate of return estimated for this project was between 0.4 and 20%.

Full title: *GLASGOW RAIL IMPACT STUDY*

Author/Date: Martin Vorhees and Associates, Transport Road and Research Laboratory, Scottish Development Department/1982

Synopsis: This report includes a retrospective cost-benefit analysis of a scheme to provide significant improvements to Glasgow's urban rail network. The analysis is similar to that used in the West Midlands study (see above) in its selection of components for the cost-benefit study, to wit:
(1) User benefits (journey time savings and fare savings in comparison to buses).
(2) Non-user benefits (less road congestion).
(3) Resource savings:
(a) Reductions in business travel, implying more time available for work, which is a net benefit to the community as a whole.
(b) Savings in the number of buses required to serve areas without rail connections.
(c) Extra revenue generated by passengers who have been abstracted from cars. These savings are equated to savings in public transport costs.
The report acknowledged a negative return on investment. It also mentioned unquantifiable issues such as severance, e.g. the loss of individual trip opportunities, the effect on a farmer whose land is divided by a new road, and air pollution.

Short title: *BRITISH RAIL CROSS-LONDON TUNNEL SCHEME*

Full title: "Cross-London Rail Link via Victoria and Euston"

Author/Date: Transmark/1980.

Synopsis: A highly detailed cost-benefit study of the feasibility of linking two of London's major British Rail terminals by an underground tunnel through the center of London to permit through-running by Intercity trains to southeast England (primarily Kent, Surrey and East Sussex). The consumer surplus accrued to the scheme is principally journey time; and the producer's surplus consists of the marginal net revenue of carrying the traffic generated by the scheme. The externalities discussed in the report are:
(1) Congestion costs eliminated through savings in travel time (estimated by speed-flow diagrams and formulae) and vehicle operating costs.
(2) Accident costs avoided.
This scheme was dropped due to its very high capital cost. The use of an already existing surface line to the west of London has been proposed as a cheaper solution.

Department of Transportation—Cost-Benefit Methodology

It is worth mentioning two further instances in which cost-benefit analysis has been used on a wide scale. The first of these is COBA, a method first used in the early 1970s by the Department of Transport to assess the worth of possible trunk road investments. The COBA manual could be described as a complete text of how to evaluate a scheme. The user benefits that COBA assesses are time savings, savings in operating costs, and accident savings.

These user benefits are combined with two other elements in the COBA analysis: (a) capital costs and (b) maintenance cost savings (both track and user).

One of the major milestones in cost-benefit analysis methodology was the report of the Leitch committee in 1977, which assessed what was then current CB practice and compared U.K. practice with practices abroad. The principal recommendations suggested the inclusion of the following:
(1) Noise contours around a new scheme.
(2) The extent of severance.
(3) A measure of visual intrusion.
(4) Generated air pollution.

Full title: *COST BENEFIT ANALYSIS AND THE CONSTRUCTION AND FINANCING OF RAIL/HIGHWAY GRADE SEPARATIONS* (from "Transportation Research—A", Oct.-Dec. 1984)

Author/Date: J. S. Dogson/1984

Synopsis: This paper deals in detail with benefits accruing to users, non-users and railway operators by opting for grade separation, as opposed to separation at grade crossings. For the users, the main benefits outlined are:
(1) Reductions in number of accidents,

both for passengers on the train and for road users.

(2) Possible delays to trains, e.g. speed restrictions on level crossings, reduced.

Among the benefits to non-users are:

(1) Reduction in road vehicle delays through the eradication of level crossings.

(2) Reductions in accident numbers for road users.

(3) Time savings for road users due to the elimination of level crossings.

The operators will benefit not only by the reductions in possible delays mentioned above, but also by the reductions in maintenance and staffing costs associated with level crossings.

Comments: After discussions into the benefits (especially of time and accident savings), Dodgson gives examples of five grade separation schemes on Canadian railways, and their results.