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Light Rail Transit Systems: A Definition and Evaluation

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Abstract
Rail transit represents a family of modes ranging from light rail to regional rapid transit systems and it can be utilized in a number of different cities and types of applications.

Many European cities of medium size employ very successfully light rail mode for gradual upgrading of transit service into partially or fully separated high speed, reliable transit systems. Analysis of these cities show that with population densities and auto ownership very similar to those in the United States cities, their transit systems offer a superior service and have much better usage than our cities.

Many modern features of light rail technology are not known in this country. Wider use of different rail systems, greatly increased transit financing, introduction of more qualified personnel into transit industry and improved transit planning and implementation procedures are recommended to close the gap in urban transportation between some more progressive European cities and their counterparts in this country.

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LIGHT RAIL TRANSIT SYSTEMS - A DEFINITION AND EVALUATION

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FINAL REPORT

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16. Abstract

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Many European cities of medium size employ very successfully light rail mode for gradual upgrading of transit service into partially or fully separated high speed, reliable transit systems. Analysis of these cities show that with population densities and auto ownership very similar to those in the United States cities, their transit systems offer a superior service and have much better usage than our cities.

Many modern features of light rail technology are not known in this country. Wider use of different rail systems, greatly increased transit financing, introduction of more qualified personnel into transit industry and improved transit planning and implementation procedures are recommended to close the gap in urban transportation between some more progressive European cities and their counterparts in this country.

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SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The material presented in this report leads to the following major <u>conclusions:</u>

1. Rail transit represents a family of modes ranging from the systems with light vehicles operating at grade, to fully controlled grade-separated high-speed systems. Within this broad range different combinations of vehicles/trains and rights-of-way can be selected for a great variety of applications in urban transportation.

2. After a decade (mid-1950's to mid-1960's) of discussions concerning transit modes in several European countries, including the possibility of replacing light rail with buses, use of monorails and other modes, light rail (Cityrail) is now more accepted than at any time since World War II as the optimum mode for service on lines with intermediate passenger volumes. Their most typical application is for main lines in medium-size cities.

3. Many European cities have been systematically modernizing their light rail systems; some of these systems already have <u>travel speeds</u> as high as 25-31 mph, transporting capacity of up to 18,000 persons/hour, high reliability and other features similar to those of rapid transit. This high type of service has been achieved mainly through provision of rights-of-way partially or fully separated from automobile traffic and construction of modern light rail vehicles.

4. Light rail mode is inferior to buses for operation in mixed traffic on surface streets. On the lines with partial or full separation light rail offers a <u>quality of service</u> superior to that of buses. This feature is a more important advantage than its higher capacity, and it is the major reason for use of light rail in European cities. For such lines bus mode requires lower investment, while light rail has lower operating cost, mostly due to lower labor requirements.

5. Compared with rapid transit, light rail requires considerably lower investment (full grade separation not required), but its capacity and reliability of service are also somewhat lower. The advantage of light rail is that it can be constructed sooner (due to lower investment cost) and then gradually upgraded into rapid transit when demand justifies and additional finances become available. Since the two modes are technically highly compatible, such a transition can be easily done, as has been the case in several cities. A number of solutions for all transition problems (different vehicles, high- and low-level platforms, control, etc.) have been developed and successfully demonstrated.

6. Consequently, bus mode is superior to light rail in low density and other areas where private rights-of-way for public transportation cannot be economically justified; rapid transit is superior where high-capacity high-speed service is required. Light rail is the optimal solution for intermediate services where a high quality service, competitive with automobile, is required, demand is moderate and available finances are limited. In growing urban areas, for example, light rail can attract transit ridership and provide better collection-distribution than rapid transit. If the demand later requires, upgrading of the system can be easily done.

7. With respect to public transportation United States cities are far behind the progressive cities in Western Europe. The two most important factors contributing to this situation are: grossly inadequate financing, and lack of highly qualified personnel in management and technical areas of transit in this country.

8. Rail technology has been the most underutilized transit mode in this country. Its use has been reduced virtually to only two modes: rapid transit and suburban railroad. A variety of modern lighter types of vehicles and services adaptable to many urban situations have not even been tried here.

9. Three important trends characterize current transit needs in U.S. cities:

- High-quality, fast and reliable transit service must be provided to perform the role this mode should have in urban areas: transportation system competitive with automobile, rather than an inferior service limited to captive riders and peak hour commuters;
- Large areas of cities with medium-to-low densities often make the large capital investment in extensive rapid transit networks difficult to justify;
- Rapidly increasing cost of labor makes an increasing reliance on higher-productivity modes imperative.

All these trends make light rail, due to its characteristics mentioned in points 4-6 above, an optimal system for a number of applications.

10. There are at least 25-30 cities in the United States and Canada which could successfully use light rail mode to upgrade their transit very significantly at a moderate cost. Among them are the cities which already have older major surface rail services (Boston, Cleveland, Newark, Philadelphia, Pittsburgh, San Francisco, Toronto), as well as medium-to-large cities which have the need for a high quality transit system, but do not have finances for rapid transit. Columbus, Milwaukee, Rochester, Seattle, and The Twin Cities are examples of such cities. Of course, their bus operations should also be further improved.

11. The greatest barrier to the introduction of light rail in American cities is the irrational prejudice against rail modes among some groups, and the poor image which it may be given through its association with old and obsolete streetcars. The greatest technical problem is finding rights-of-way for light rail lines. This problem is, however, less serious than finding rights-of-way for rapid transit or freeways. For example, light rail could be introduced on many sections of unused railroad rights-of-way; conversion of low-volume commuter railroad lines to light rail could result in reduced costs and increased level of service.

12. Making detailed information about modern developments and experiences of cities which utilize light rail available to public officials, transit planners, operators and general public is the most effective way to achieve inclusion of light rail in transit planning and secure a realistic evaluation of its merits for each individual potential application.

* * *

Based on these conclusions, it is recommended that a concerted effort be undertaken to make light rail systems accessible to U.S. cities. The following actions are suggested for that purpose:

1. Make technical information about light rail systems available to the public officials, transportation planning and transit operating agencies, particularly in the cities which may have potential for use of this mode.

2. Organize a well-planned modern light rail system demonstration in one city to obtain experience with the use of this mode in the United States.

3. Explore ways and means to develop interest of potential producers of light rail equipment (vehicles, electrical equipment, rail manufacturers, etc.) to reactivate and modernize production of various system components in this country and to bring quality and costs of those products to levels competitive with those offered by foreign producers.

4. Improve general information about transit planning, plan implementation procedures, modern technical developments and operational methods in cities with advanced transit to stimulate closing of the present gap in urban transportation between some European and U.S. cities.

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F O R E W O R D

The Urban Mass Transportation Administration of the United States Department of Transportation sponsored this report to provide information and guidance for cities which intend to modernize their transit systems.

The purpose of the report is to define and evaluate light rail systems. In particular, the report presents the latest developments and experiences with this mode. Its characteristics are analyzed in detail and actual data on its performance, demonstrated in practice, are given. These values often do not represent the ultimate capabilities of light rail systems, however.

To collect up-to-date materials, opinions of the best experts in the field, and to inspect the latest developments, the author of this report personally visited the following 11 cities in five countries:

- Belgrade, Yugoslavia
- Bielefeld, W. Germany
- Brussels, Belgium
- Cologne, W. Germany
- Düsseldorf, W. Germany
- Frankfurt, W. Germany
- Gothenburg, Sweden
- Hannover, W. Germany
- Rotterdam, The Netherlands
- Stuttgart, W. Germany
- The Hague, The Netherlands.

Detailed technical material was obtained through correspondence for two additional cities:

- Bern, Switzerland
- Toronto, Canada.

The main reasons for selection of these cities were:

- Some of the most advanced light rail systems presently in operation: Cologne, Düsseldorf, Frankfurt, Gothenburg, Hannover, Rotterdam.

- Interesting approach to transition from surface to grade separated operation: Brussels, Frankfurt, Hannover.

- Parallel construction of rapid transit and light rail: Rotterdam.
- Expansion of light rail recently done or planned for the future: Bern, Bielefeld, Gothenburg, Rotterdam.
- Small cities (below 300,000 population) with modern light rail systems: Bern, Bielefeld.

This report is expected to be particularly useful to the North American cities which presently operate surface and separated rail systems. Most of these cities will be faced with major modernization of rail fleets, fixed facilities and operations in the coming years. These cities are:

Boston, Massachusetts	New Orleans, Louisiana
Cleveland, Ohio	Philadelphia, Pennsylvania
El Paso, Texas	Pittsburgh, Pennsylvania
Fort Worth, Texas	San Francisco, California
Newark, New Jersey	Toronto, Ontario - Canada

The report should also provide information for the cities which presently have only surface transit but consider introduction of more advanced, higher quality transit systems in the future.

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I. INTRODUCTION

The inherent advantages of rail technology for urban public transportation - high speed, capacity, comfort, reliability, potential for automation, etc. - are well known. However, it is usually believed that these characteristics, coming only with rapid transit, can be economically obtained only in high density corridors which justify the high investment cost of this mode, i.e. mostly in large cities. The fact is that there are other rail systems, considerably cheaper, which can provide service characteristics similar to those of rapid transit. Light rail mode combines to a considerable extent low investment (and, therefore, better collection-distribution capability) of buses with high level of service, capacity and potential for automation of rapid transit mode.

Light rail transit consists of modern light weight urban rail vehicles operating predominantly on private rights-of-way, at surface level or fully grade separated. In some cities this mode is being introduced as permanent basic transit carrier; in others, the intention is to gradually, when the demand requires and funding permits, light rail be upgraded into rapid transit. The majority of West European medium-size cities which have modern and successful transit systems utilize the light rail mode.

A comment about the term "light rail" is appropriate here. The terms "Limited tramline", "Express Tramway" and similar ones were used for this mode at different times, but dropped later as unpractical. Two shorter terms, "Light rail" and "Cityrail," are presently in use. This report will use the first term, "Light rail", while the second one, "Cityrail", will refer to those systems which have special "trade" names, such as "Stadtbahn" in Germany or "Pre-Metro" in Brussels.

A. PURPOSE AND SCOPE OF THE REPORT

The purpose of this report is to define the light rail transit: its physical components in general terms (since detailed descriptions are available elsewhere in the literature), its operating characteristics, and its place among urban transportation systems. Light rail is also compared with other modes of public transportation (particularly bus and rapid transit), and its potential use in U.S. cities is examined. The possibility of transition from light rail to rapid transit is also discussed.

Since choice of technology is closely related to the general policy in urban transportation, this report includes an analysis of current trends and problems of urban transportation in general, and public transportation in particular. Consequently, to examine the potential role of the light rail transit in the U.S. cities, an analysis of the existing urban transportation situation is made and the significance of modern transit services is given in Chapter II. The basic problem of the lack of separation between transit and other traffic, is particularly emphasized.

Chapters III, IV and V present the system description, its applications and comparisons with other transit modes, respectively. Chapter VI evaluates the system and discusses its potential use in the United States. Conclusions and recommendations are placed in the beginning of the report.

B. PRESENT NEED FOR MODERN TRANSIT

With the introduction of the private automobile as a popular mode of urban transportation, lack of fast arterials, adequate street capacity and parking facilities became an acute problem. It was clear that a major effort had to be undertaken to adjust urban streets and highways so that they could accommodate a certain level of demand for automobile travel.

As passengers diverted from public transportation in favor of the automobile, public transportation systems became negatively affected in two ways: by reducing its revenues (forcing increase of fares), and by slowing vehicles due to traffic congestion. Both factors contributed to further diversion of passengers to automobiles, creating the well-known vicious circle.

With these trends underway and in the difficult financial situation, the privately-owned transit companies applied in most cases the solutions which involved the lowest cost in the short run: economies were sought by reduction of frequency and general quality (level) of service. Unable to obtain capital for improvements -particularly for separation of transit vehicles from other traffic - the companies usually introduced buses which were cheaper to purchase and could better "mix" with other traffic than could rail vehicles - streetcars. The conversion did result in reductions of transit costs in the short run, but at the same time continued or even accelerated the vicious circle of transit patronage decline and increased automobile congestion. Transit vehicles operating in the same traffic lanes as automobiles suffered increasingly from delays and low reliability of service, thus providing a low-cost/low-level-of-service package for the public.

Having lost the qualities which made it competitive with automobile travel, such as low fares, frequent service, high speed, etc., transit became less and less acceptable for travelers who had the choice of using private automobiles, and the downward spiral continued. Although a number of other factors (alterations in urban structure and travel patterns, lack of comprehensive planning and coordination on a metropolitan basis, lack of diversified transport technology, obsolete operating methods caused by obstruction to change by different groups, etc.) undoubtedly played a significant role in these developments, the basic factor leading to the steady decrease of transit passengers was the widening disparity in levels of service between private and public transportation. This can be clearly illustrated by an analysis of trends in transit passengers. Statistics traditionally show passenger trends by technologies; however, the most important functional classification of transit services is on surface modes, i.e. those operating predominantly in mixed traffic, and modes on separate rights-of-way - rapid transit. Streetcars operating in mixed traffic offer a similar type of service to that of the trolleybus and motorbus running on the same facility. Surface modes require much lower investment, but offer a low level of service, in most cases inferior in speed and reliability to that of the private automobile. Separated (mostly, although not necessarily, rail) transit offers high level of service: often faster than automobile travel and reliable at all times due to fully controlled rights of way.

Transit passenger trends between 1955 and 1970, classified into "Surface" and "Rapid" modes, are shown in Table 1. Surface transit patronage decreased during the 16 years by 43.5 percent, while rapid transit patronage remained generally constant. Similar difference in trends between the two types of services has been recorded in most cities individually (New York, Philadelphia, Cleveland, Paris, etc.). In London, for example, according to London Transport statistics, surface buses lost 30 percent of their passengers between 1953 and 1962; underground railways maintained the same number, while suburban railroads increased their patronage by 14 percent during the same period.

These statistics clearly show that separated transit has a drastically superior passenger-attracting capability compared with surface transit. The basic reason is that separated transit offers a service competitive with that of the private automobile (speed, reliability, etc.) for a significant number of urban trips.

TABLE 1

TREND OF TRANSIT PASSENGERS BY MODES
IN THE UNITED STATES *

1955 - 1970

Millions

Year	Streetcar		Trolleybus		Bus		Total Surface		Rapid Transit		Total	
	Number	Index	Number	Index	Number	Index	Number	Index	Number	Index	Number	Index
1955	1207	100.0	1202	100.0	7250	100.0	9659	100.0	1870	100.0	11529	100.0
1956	876	72.6	1142	95.0	7043	97.0	9061	93.8	1880	100.6	10941	95.0
1957	679	56.3	993	82.5	6874	94.8	8546	88.5	1843	98.5	10389	90.0
1958	572	46.6	843	70.1	6502	89.7	7917	82.0	1815	97.1	9732	84.4
1959	521	43.2	749	62.3	6459	89.0	7729	80.0	1828	97.8	9557	82.8
1960	463	38.4	657	54.6	6425	88.6	7545	78.2	1850	99.0	9395	81.5
1961	434	36.0	601	50.0	5993	82.6	7028	72.7	1855	99.3	8883	77.0
1962	393	32.6	547	45.5	5865	80.8	6805	70.4	1890	101.2	8695	75.4
1963	329	27.3	413	34.3	5822	80.4	6564	68.0	1836	98.2	8400	72.8
1964	289	24.0	349	29.0	5813	80.2	6451	66.7	1877	100.4	8328	72.3
1965	276	22.9	305	25.4	5814	80.2	6395	66.2	1858	99.4	8253	71.5
1966	282	23.4	284	24.6	5764	79.5	6330	65.5	1753	93.8	8083	70.1
1967	263	21.8	248	20.6	5723	79.0	6234	64.4	1938	103.8	8172	70.9
1968	253	21.0	228	19.0	5610	77.4	6091	63.0	1928	103.1	8019	69.5
1969	249	20.6	199	16.5	5375	74.1	5823	60.3	1980	106.0	7803	67.6
1970	235	19.5	182	15.1	5034	69.4	5451	56.5	1881	101.0	7332	63.5

*Source: American Transit Association: '70-'71 Transit Fact Book; Washington, D. C.

It should be noted that, based on several examples of transit riding trends related to automobile ownership, which will be given later in this report, there are definite indications that if modernization of transit services were undertaken, passenger trends on both modes in this country would have been much more favorable for transit.

It is also significant to note in Table 1 that, despite major conversions from streetcars and trolleybuses to motorbuses, resulting in an increasing network of bus services, the number of bus passengers declined every year but one between 1955 and 1970.

The sharpening urban crisis in recent years, a significant portion of which is urban transportation, has forced both governmental bodies and professionals to take a hard look at the long range impact of current trends in transportation rather than only to plan for extrapolation of historical trends. It has now been finally recognized that after some 50 years of efforts to provide adequate facilities for individual transportation, this goal has not been satisfactorily achieved in most medium and large cities. The automobile-highway system, which ideally satisfies the needs for transportation in rural areas and small towns, cannot satisfy <u>all</u> transportation needs in medium and large cities. The basic problems of an all-automobile approach are extremely high (although partly hidden) costs, high space requirements for both movement and parking, inability to serve the whole population and - a problem which has recently become critical - the negative impact on urban structure, character and environment.

Solution to the problem is then to provide a transportation system consisting of several complementary, coordinated modes. Such a system is referred to as a "balanced transportation system"; one could also designate it as an "optimal transportation system" for a given set of conditions.

The phrase "modern transit system", as used in this report, means a transit system which is capable of attracting and retaining choice riders* (i.e. provides level of service comparable with that of private automobile for some categories of urban travel) and is economically feasible.

C. THE EXISTING AND NEW TECHNOLOGIES

Once the fact is accepted that modern urban transportation must consist of both private as well as public transport systems, the problems of determination of the "optimal mixture" of the two and of selection of the optimal modes of public transportation arise in each city.

This realization that transit systems must also be improved and modernized has resulted in recent years in the appearance of a great number of technologies for public transportation, usually described by their promoters as "new", "advanced", etc. While there is no doubt that innovation in transit and introduction of new technologies are necessary and highly desirable, the contention that the existing technologies are obsolete, inadequate, etc., is not factually sound and is often expressed by those who do not distinguish organizational, institutional, and financial problems of public transportation from technological and operational characteristics. This view is also widespread among those who are not familiar with modern versions of basically standard transit technologies since many of these are not known in this country.

Consequently, while research, development and demonstration of entirely new concepts should continue, the greatest <u>immediate</u> benefits in transit can certainly be achieved through modernization of our existing, badly neglected and obsolete transit systems and facilities and through introduction of innovative methods of operation which basically utilize standard technologies.

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*"Choice riders" are persons who have a private automobile or some other mode of travel available, but use transit; persons who have no other mode available are referred to as "captive riders."

Major innovations in standard technologies and operations which are widely utilized in other countries and virtually unknown here can be found, for example, in fare collection methods, scheduling, information for the public, central communication systems, many technical components, different types of services and vehicles. In particular, a successful modern, although basically standard transportation technology which is used in Europe, especially for intermediate services, is the light rail system.

II. MODERN TRANSIT: REQUIREMENTS AND SOLUTIONS

A. REQUIREMENTS FOR MODERN TRANSIT

The preceding chapter has shown that balanced urban transportation can be achieved only if modern public transit is provided, i.e. a system which attracts and retains choice (as well as captive) users and operates at a cost which is acceptable to the community. Based on this definition, the basic requirements which a modern transit system must satisfy can be determined. These requirements are:

1. Area Coverage

The transit network must be such that most of the developed urban area is served, i.e. that every point within populated areas of the city is within an acceptable walking distance from a transit station. The only exception to this may be low density suburbs where park-and-ride facilities are provided for automobile access to stations. Only with adequate area coverage can transit service provide for travel between most points in the city. Without it, public transit is simply unavailable for some trips or for certain segments of the population.

A special feature of the network must also be that it provides reasonably direct connections between most points so that travel does not involve circuitous and excessively long travel.

Both of these requirements, coverage and directness of lines, are often far from adequately satisfied in our cities. Most transit networks are heavily oriented toward the central business district (CBD) and provide little service in other areas. When such service is available, its quality is so low that it is often unacceptable for most non-radial trips. Excellent examples of this deficiency are the Cleveland and Lindenwold rapid transit lines. Although superb in their technology, operation and level of service, both are greatly underutilized because they do not serve a sufficient number of points and do not have complementary systems with acceptable levels of service. They are therefore limited to a relatively small number of users. Expansions of such networks would be beneficial not only through provision of service to additional areas, but also through increased utilization of existing lines.

Common practice in transit planning in American cities in recent years has been to extend transit lines outward, while few, if any, improvements are planned for the central urban areas. The feeling of urban travelers that there is a public transport system serving the whole city, which is being gradually enhanced in European cities through construction of expanded transit networks (particularly rail), integration of services, fares, information, etc., has disappeared in most American cities. This inadequacy of transit service has been one of the significant factors contributing to the blight of their inner areas.

It is clear that if extensive area coverage is to be provided, high capacity systems must be used for the main lines, while low investment systems must be employed in low density areas. A wide variety of service types can be applied between these two extremes.

2. Competitive Level of Service

A sine qua non for transit's ability to attract and retain passengers is that it must provide a level of service which is competitive to that of the automobile, at least in the categories of travel which it serves. Speed, reliability of service and comfort are the most important characteristics which must be provided, and they can be achieved only if transit services are separated from other traffic, at least on the sections where traffic congestion is critical. In other areas, separation can be partial, providing separate lanes or tracks for transit with special treatment at intersections.

The significance of separation of transit from other traffic has been discussed in Chapter I and clearly illustrated by the figures in Table 1.

3. Acceptable Cost

The total cost of transit service must be acceptable to the community. Whether the total cost is paid by the users, or the fares are lower than required for full coverage of costs and part of the cost is met from other sources, is an important issue, but not directly relevant here; the important point is that the total cost is such that the community will accept it.

Since labor costs are the dominant factor in the total cost of transit service and their increase has been faster than the increase in other cost components, labor-intensive modes and operating methods must result in a particularly rapid cost increase. Consequently, the requirement for an acceptable cost of transit service can be satisfied only through increasing productivity of labor. That is achieved by automated operations (e.g. fare collection), by utilizing larger units (vehicles), or - as the last step - by full automation of the systems. This requirement must be considered extremely important in planning new transit systems: the potential for full automation is a very essential feature. All major investment should be directed only toward systems with higher productivity than existing ones.

B. PRESENT SOLUTIONS

Desirable characteristics of transit systems in terms of capacity, cost, level of service, etc., vary greatly between different lines in a given city and among different cities. If existing transit modes are ranked by their capacity and level of service characteristics, assuming the same type of ways for all surface modes, their sequence would, in general, be as follows:

- Minibus: the lowest capacity mode suited for low density demand, short distance travel, and low level of comfort.
- Standard bus (or trolleybus);
- Standard streetcar (PCC* for example);
- Articulated bus (or trolleybus);
- Light rail (articulated 6- or 8-axle, or multiple-unit (MU) trains);
- Rapid transit, varying from 2-track lines with 5-car trains (Paris) to 4-track lines with up to 10-car trains (New York City): the highest capacity mode applicable to high demand density, medium-to-long trips, and high level of comfort.

Various factors influence selection among these modes and some are often found in the capacity domains of others. For example, streetcars have sometimes been abandoned not because of their capacity characteristics, but because of high fixed costs and traffic conditions in narrow city streets. "Stretching" the application of the individual mode above or below its optimum domain, however, always results in some inefficiencies and problems: high cost, irregularity of service, negative side effects, etc. There have been a number of examples of such "stretching." A number of inter-urban rail services were provided where they were not economically justified. Use of standard buses on high capacity lines (e.g. approaches from New Jersey to New York and transbay lines in San Francisco) results in low level of service and attracts only a portion of potential transit users. It is therefore extremely important to select the optimum transit mode for each type of service in an urban area.

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*PCC (Presidents' Conference Committee) car is the best known US-developed streetcar. Technically very advanced for its time (1936) this model is now in some aspects functionally obsolete.

Opposite this requirement of providing optimum modes for each type of service is the requirement for economy of scale: unification of modes and types of vehicles, simplicity of operations, interchangeability, etc. The number of modes and vehicle types which a city utilizes is a compromise between these two requirements: economic and operational efficiency of individual lines vs. the economy of scale of the whole system.

Transit systems in this country have suffered seriously from the excessive relative weight given to economy of scale. Pressed by financial difficulties, transit companies went to the extreme of simplification. Consequently, today despite the wide variety of requirements for transit service, most U.S. cities are served by one or two types of buses only. With few exceptions, most bus services consist of a few variations of the standard GM bus operating in mixed traffic. There are relatively few significant plans for their separation or for major upgrading of their level of service in the foreseeable future through separated ways (busways). The other type of transit presently in use is rail rapid transit which is in operation, under construction and/or planned in a number of cities. Offering a high type of service, this mode is physically capable of providing adequate public transportation for most cities, except that its extremely high investment cost makes it feasible only for a limited number of medium-to-large cities and heavily traveled lines. Thus, the two available systems offer two extreme "packages" of service: low investment/low level of service with buses (generally with 8-12 mph travel speeds) and high investment/ high level of service rapid transit (20-45 mph travel speed).

C. THE "GAP" IN INTERMEDIATE SERVICES

Most medium and large size American cities are presently seriously planning improved transit service. Their existing systems - mostly buses in mixed traffic - offer a low level of service so that they increasingly serve only captive riders. Although transit service must be provided for this group of citizens, a modern transit system should do much more: it should permanently serve a significant portion of all urban trips. Its speed, capacity and reliability of service are essential for the functioning and vitality of urban areas.

1. The Existing Choice of Modes

Many studies for transit modernization and development have considered various forms of improved bus service including some with partial running on private rights-of-way, a number of unconventional proposed modes, and rail rapid transit. Since none of the proposed unconventional systems has yet been proved in practice as superior to existing transit modes on a large scale, no city has so far adopted such a system for its basic network; only several individual lines are planned as demonstration projects. Light rail mode has been considered several times, but usually not adopted for the reason that the vehicles for it could not be obtained: the industry would virtually have to build a prototype, resulting in a very high cost for a small order; numerous modern light rail vehicle types produced in other countries were, until recently, not even considered. Thus, paradoxically, while a number of new concepts have received research and demonstration financing from various industries and governments, light rail has not, until recently, received any funds for development of domestically produced modern vehicles and their demonstration. (So far no significant benefit has been obtained from these new concepts; light rail on the other hand with its proven qualities for a number of different types of applications properly applied could have brought significant improvements.) While there is no doubt that development of new systems must be carried on for future applications, the complete neglect of a proved technology in the present serious crisis in urban transportation can hardly be considered rational.

Consequently, improved bus service and rail rapid transit have been the only practical, readily available choices for modern transit in this country.

a. Bus Potentials and Limitations. Buses, as all other modes of public transportation, have been neglected in this country for several decades. Despite their superior transporting capacity and general importance of their service, they have been treated equally with other vehicles on urban streets. The illogical concept that vehicles rather than persons are units for transportation system performance still dominates planning and operations in most cities. Consequently, bus services are generally unsatisfactory and badly neglected so that major improvements can and should be made to them: provision of bus lanes in individual streets, preferential treatment of buses at signalized intersections, special lanes on freeways, improved station designs, etc. are some of the potential improvements; only a small number of them have been introduced so far (e.g. reserved lanes in Baltimore, Chicago; Shirley Highway bus lanes in Washington, D. C. area; "Blue Streak" service in Seattle, etc.).

On the other hand, if buses are used for heavily traveled high-speed trunk lines, they have several limitations. On special freeway lanes they can carry large numbers of people if they do not have many stations; but their distribution in CBD is a problem: if they are placed in tunnels, their capacity becomes very restricted at stations due to the slow

low-platform loading; also, their noise and exhaust would be highly objectionable. Alternatively, bringing a number of buses from a private right-of-way on a freeway to urban streets would cause uncontrollable delays to buses, defeating the concept of reliable, separated transit service. This type of service has therefore been successfully used for peak hour service (Shirley Highway, Lincoln Tunnel approach in New York-New Jersey), but not as an all day, permanent and reliable transit service. In off peak hours such service is usually not sufficiently competitive with private automobile to attract a significant number of choice riders.

Another serious limitation of buses is their relatively high labor intensiveness without possibility of system automation.

Finally, the physical and operational capability of buses frequently represents a limiting factor in their transporting capacity. The highest recorded frequency of buses on urban streets without special control is 60-95 buses per hour, carrying passengers at rates of 3,000-6,000 persons per hour. With special arrangements such as reserved lanes, preferential treatment at intersections, availability of another lane for passing and staggered stops, the maximum frequencies recorded in line-haul service have been 130-150 buses with hourly rates of 8,500-11,000 persons (San Francisco and New York, respectively). Rates higher than these - up to 29,000 persons per hour - have been recorded only on freeway lanes without stations, i.e. not in line-haul service.* However, with high frequency of bus service reliability and punctuality of service, safety (particularly on high speed bus lanes without physical separation of opposing directions) and economy (high labor costs) of bus mode become serious problems.

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*See reference 7, Tables 8 and 9.

It can be concluded that buses will, in addition to lightly traveled lines where they are the only feasible transit mode, offer an improved service on medium-volume lines; on high-volume lines requiring high-capacity reliable service they will become increasingly inferior to higher-productivity, more automated modes, primarily rail.

b. Rail Rapid Transit Potentials and Limitations. Rail rapid transit offers the highest quality of service of all modes for line-haul transportation. It can provide any speed desired for urban conditions with virtually absolute safety. Hourly passenger volumes as high as 20,000-40,000 can be transported by rail rapid transit without much operational difficulty. Its riding comfort is high. Negative side effects of modern rail systems are extremely small: noise is very low, exhaust fumes non-existent, structures are esthetically pleasing.

Major limitation of rail rapid transit is its very high investment cost ($15-30 million/mile). Since this high cost is required for the whole length of rapid transit lines, it limits application of this mode basically to the high density corridors; bus and automobile are required as its feeders in low density areas.

Since rail rapid transit, due to its high level of service, has the highest passenger-attracting capability, it has considerable potential for an increased role in U.S. cities. High cost of all sections of its lines will, however, remain the major problems of its extensive further development in the cities which already have it, and its introduction into many other cities which need high quality transit.

2. The "Missing Mode" and Light Rail Potential

Thus, while buses and rail rapid transit satisfactorily provide the low and high volume transit services, the present choice of solutions for intermediate services is highly inadequate.

The "missing mode" should have a capability to transport 2,000-15,000 persons per hour per direction; more importantly, it should offer an intermediate level of service/cost combination: a level of service higher than bus at a much lower cost than rail rapid transit. In addition, such a mode should be conducive to gradual upgrading to rapid transit and eventual full automation.

Light rail (Cityrail) is a system which has been successfully applied for such intermediate services in many foreign cities. One of the main reasons that light rail has seldom been considered for new transit services in this country may be a general unawareness about modern developments of this system and its characteristics. This report presents basic technical, operational and economic data of the modern light rail system. Based on a definition of its optimal applications, drawing from the actual experiences of a number of foreign cities, this report will show that light rail system has a great potential in our cities since it is in many situations superior to any other technology for intermediate types of service.

III. L I G H T R A I L S Y S T E M D E S C R I P T I O N

This description of light rail is based on the systems and facilities which are currently in use. All the facts and figures are based on actual operating systems, except where potential changes or modifications are explicitly discussed.

Among the numerous cities utilizing light rail throughout the world, nine cities in four European countries have been selected as typical for different sizes and types of urban development: Brussels (Belgium), Rotterdam (Netherlands), Cologne , Düsseldorf, Frankfurt, Stuttgart, Hannover and Bielefeld (West Germany) and Gothenburg (Sweden). These cities form the basis of a detailed analysis of light rail characteristics and applications, although frequent references are made to important features of rail systems in other European as well as U.S. cities.

The general characteristics of the nine selected cities which are relevant to light rail are summarized in Table 2.

A. PHYSICAL COMPONENTS

1. The Vehicles

Light rail systems have historically evolved from street railway (streetcar) systems. The standard vehicle of streetcar systems was a 4-axle, electrically powered vehicle. Four-axle trailers were also common, and the standard train unit was one motor car and one trailer.

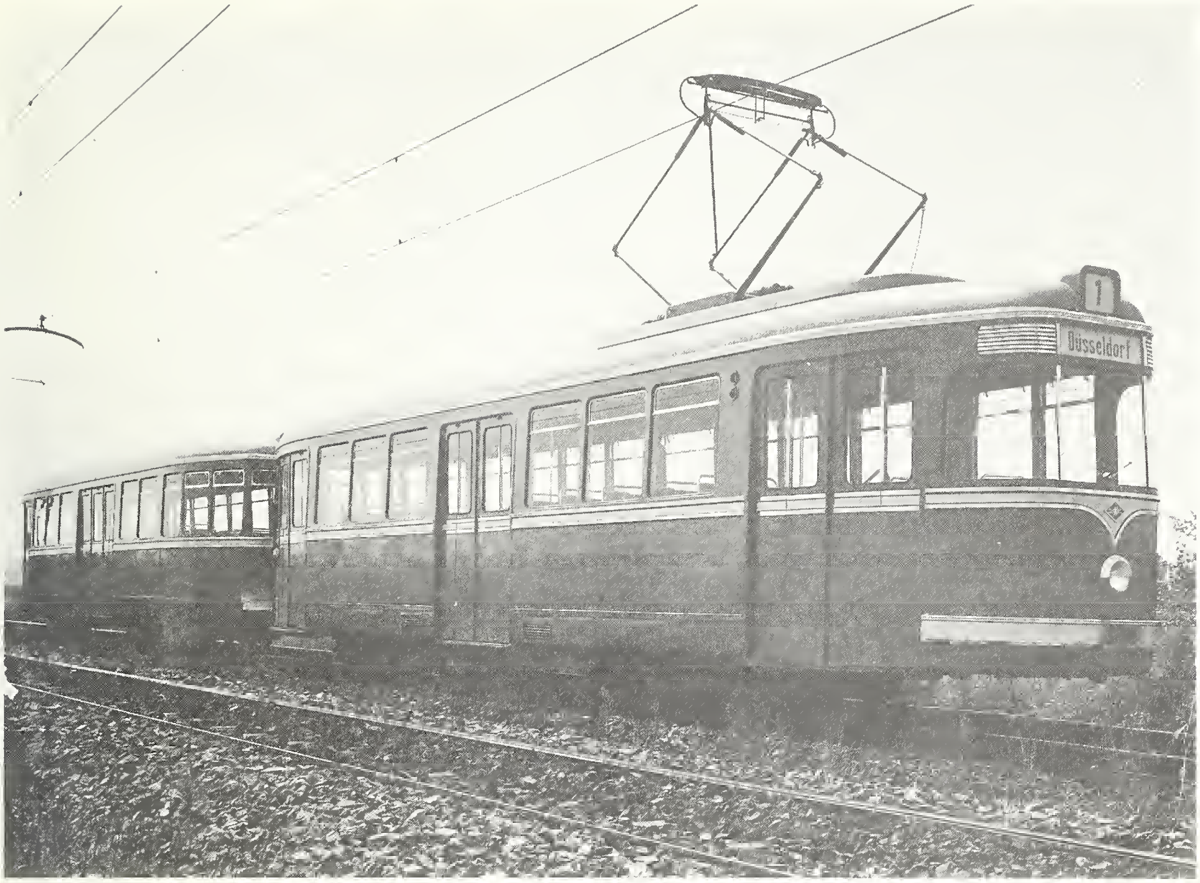
With the changing character of transit systems, i.e. a general upgrading of their services and gradual conversion of streetcars into light rail and provision for further conversion to rapid transit, the trend over the past two decades has been toward larger units. During the mid- and late 1950's a number of different types and constructions of articulated vehicles

TABLE 2

SELECTED CITIES WITH LIGHT RAIL (CITYRAIL) SYSTEMS

City	Population (000)		City Area km^2 (mi^2)	Population Density in City persons/km^2 (persons/mi^2)	City Character	Car Ownership (persons/car)	Riding Habit (annual rides/capita)	Existing Modes[1]
	City	Served Area						
1. Brussels	1,200	1,200	270 (104)	4400 (11540)	Tertiary -adm.,hdqt. Industry	4.5	148	S,CR,B
2. Cologne	860	1,289	251 (97)	3400 (8870)	Tert.-adm. Industry	4.1	127	CR,B
3. Rotterdam	700	866	202 (78)	3460 (8970)	Port-trade, Industry	4.6	177	S,RT,CR,B
4. Düsseldorf	673	1,113	158 (61)	4250 (11030)	Tert.-adm. com. industry	4.0	170	S,CR,B
5. Frankfurt	668	1,200	140 (54)	4770 (12370)	Tert.-fin, hdqt., industry	3.0	148	S,R,CR,B
6. Stuttgart	632	891	207 (80)	3050 (7900)	Tert.-adm. Industry	3.3	154	S,CR,B
7. Hannover	523	840	145 (56)	3610 (9350)	Tert.-adm. trade. Industry	4.6	125	CR,B
8. Gothenburg	452	661	360 (139)	1250 (3250)	Industry, dispersed	3.6	132	CR,B
9. Bielefeld	170	285	48 (19)	3520 (8950)	Centralized Light ind.	3.7	126	CR,B

[1]S - Suburban RR; RT - Rapid Transit; CR - Light rail (Cityrail); B - Bus



P-2. Typical 4-axle car with 4-axle trailer

appeared in Europe. A number of manufacturing firms produced these vehicles including even some 4-axle articulated designs (Bremen, Stuttgart); however DÜWAG (Düsseldorfer Waggonfabrik Uerdingen, AG) became the leading producer of light rail vehicles, particularly with its 6- and 8-axle (respectively, single- and double-articulated) cars.

P-3. Articulated light-rail vehicles (Jan Wellem Platz, Düsseldorf)

P-4. Interior of a 6-axle articulated car (Rotterdam)

P-5. Six-axle single-articulated car

P-6. Interior of the above car

P-7. Eight-axle double-articulated 2.5 m. (8'2") wide car

P-8. Interior of the above car

The main reasons for the development of articulated vehicles initially were higher capacity, minimum street space occupancy by the vehicle (longitudinally as well as narrower profile in the curves) and increased labor productivity, since instead of the driver and two conductors operating a two-car unit, an articulated car could be operated by one driver and one conductor (the latter has been eliminated in most cities in recent years). Because of their narrow profile in curves, light rail vehicles are legally permitted to operate in compositions up to 45 m. (148 feet) long, while the maximum permitted length of buses is 18 m. (59 feet) when articulated. In addition, the attractive appearance of the vehicle, better utilization of all seats, faster boarding and alighting of passengers, etc., were also factors favoring the articulated cars.

Six- and eight-axle cars have proved to be so practical and well received by the population, that they have definitely prevailed in most of the light rail systems. Nearly all West German cities as well as Zurich, Rotterdam, Amsterdam, St. Etienne and other West- and East European cities have adopted articulated cars. Even Brussels, which traditionally relied on the 4-axle European version of the PCC vehicle operated as a single car, has now adopted articulated vehicle as the standard unit for its Cityrail ("Pre-Metro") operations. The 6- and 8-axle cars sometimes operate with a trailer, thus offering even higher capacity where required. Several cities (e.g. Cologne) are even planning for the option to operate up to three 8-axle cars coupled as MU trains on the heavy volume lines when they get private right-of-way on their entire lengths.

There are some exceptions to this trend. Gothenburg, Sweden, utilizes single-unit powered cars which can be coupled to operate as MU trains; the advantage of this type of vehicle fleet is that the second car can be dropped off in off-peak hours, i.e. offered capacity can be tailored to demand in smaller increments; two 4-axle powered vehicles are, however, considerably more costly both to purchase and operate than one 8-axle articulated vehicle of comparable capacity. - The Hague, Netherlands and Antwerp, Belgium also utilize 4-axle single cars (sometimes coupled) which are the European version of the PCC. These two systems still have considerable running in the streets, although private rights-of-way are being increased in both cities. Belgrade, Yugoslavia has adopted as its standard unit a 4-axle motor car with 4-axle trailer; one of the main reasons for not using the articulated vehicle in this case is that it is not produced by a domestic manufacturer.

Several different models of light rail vehicles are shown in photographs on the following pages. The basic dimensions and characteristics of light rail vehicles are given in Table 3.

a. Dimensions and Capacity. The length of 4-axle vehicles is fairly constant in all cities: 14.10 m. (46'3"). The length of typical 6-axle vehicles varies between 19.10 (62'8") and 21.20 m. (69'7") - (Frankfurt and Cologne, respectively). The 8-axle vehicles usually have a length of 25.60 m.(84'0"). However, Cologne utilizes 8-axle vehicles with a length of 30.10 m. (98'9").

Width of most vehicles was formerly 2.20 m. (7'2"). However, some cities operate vehicles with greater widths, such as 2.35 m (7'8") in Frankfurt, 2.50 m. (8'2") in Cologne and 2.65 m. (8'8") in Gothenburg. Most of the cities planning for eventual conversion to rapid transit are now adopting greater widths: 2.35 - 2.65 m. (7'8" - 8'8"). The significance of this greater width is that vehicles 2.50 m. (8'2") wide have four seats abreast while the narrower vehicles have only three.

P-9. 8-axle two-directional car

P-10. Interior of the above car

P-11. The latest design of standard articulated car (Mannheim)

P-12. Interior of the above car: upholstered seats, air conditioning

TABLE 3

LIGHT RAIL VEHICLES: TECHNICAL DATA OF EXISTING MODELS

Item	Dimension	Vehicle Type								
		4-Axle			6-Axle			8-Axle		
		Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.
1. Length	m ft	13.60 44'7"	14.10 46'3"	18.00[1] 59'1"	19.10 62'8"	20.00 65'7"	23.00[2] 75'6"	23.50 77'1"	25.60 84'0"	32.85[3] 107'10"
2. Width	m ft	2.20 7'2"	2.20 7'2"	2.65 8'8"	2.20 7'2"	2.35 7'8"	2.65 8'8"	2.20 7'2"	2.35 7'8"	2.65 8'8"
3. No. of Seats		16	35	53	30	40	64[2]	52	64	89[3]
4. Total Capacity		80	110	165[1]	150	180	231[2]	220	250	335
5. Weight-Empty	tons	15.2	16.0	17.0	19.8	22.0	29.5[2]	25.4	28.0	33.6
6. No. of Powered Axles		2	4	4	4	4	6	4	4	8
7. No. of Motors		2	4	4	2	2	6[4]	2	2	4[5]
8. Power/Motor	KW HP	40 54	50 67	66 88	100 134	110 147	150[6] 201	100 134	150 201	175[6] 235
9. Percent Adhesion Weight	%	50	100	100	80	80	100	60	64	100
10. Max. Speed	km/hr m/hr	60 37	70 44	125 78	60 37	70 44	80 50	60 37	70 44	80 50
11. Max. Accel. Rate	m/sec^2 ft/sec^2	1.0 3.3	1.2 3.9	2.0 6.6	1.0 3.3	1.1 3.6	1.6 5.2	0.9 3.0	1.0 3.3	1.3 4.3

[1] Articulated vehicle (Stuttgart GT-4)
[2] Rapid transit vehicle (Frankfurt)
[3] GT-8 Model for Freiburg
[4] Latest Belgian PCC for Brussels
[5] Four motors power eight axles
[6] 200 KW possible

P-13. Interior of a 2.20 m-wide 8-axle double-articulated car (Rotterdam)

P-14. Interior of 2.65 m-wide 6-axle articulated rapid transit car (Frankfurt)

The number of seats in most European systems is relatively small by American standards. The main reason for this is that the European cities have heavier passenger loads and somewhat shorter trips. Thus, most 4-axle vehicles have about 35 seats while the 6- and 8-axle vehicles vary between 30 and 85 seats. The total capacity of 4-axle single-body vehicles is usually between 80 and 128 passengers, while the articulated vehicles have capacities of 150-335 persons.*

b. Weight and Propulsion. Considerable effort has been applied to produce light-weight vehicles, primarily to achieve savings in power for traction, less wear-and-tear on the track, and lower noise levels. Typical empty weights of 4-axle vehicles are 15.5-16.5 tons, for 6-axle vehicles 21-23 tons and for 8-axle vehicles 27-29 tons. The Cologne car with the length of 30.10 m. (98'9") and width of 2.50 m (8'2") is the lightest vehicle per unit of area with its 29 tons of net weight. Most of these weights do not include air conditioning.

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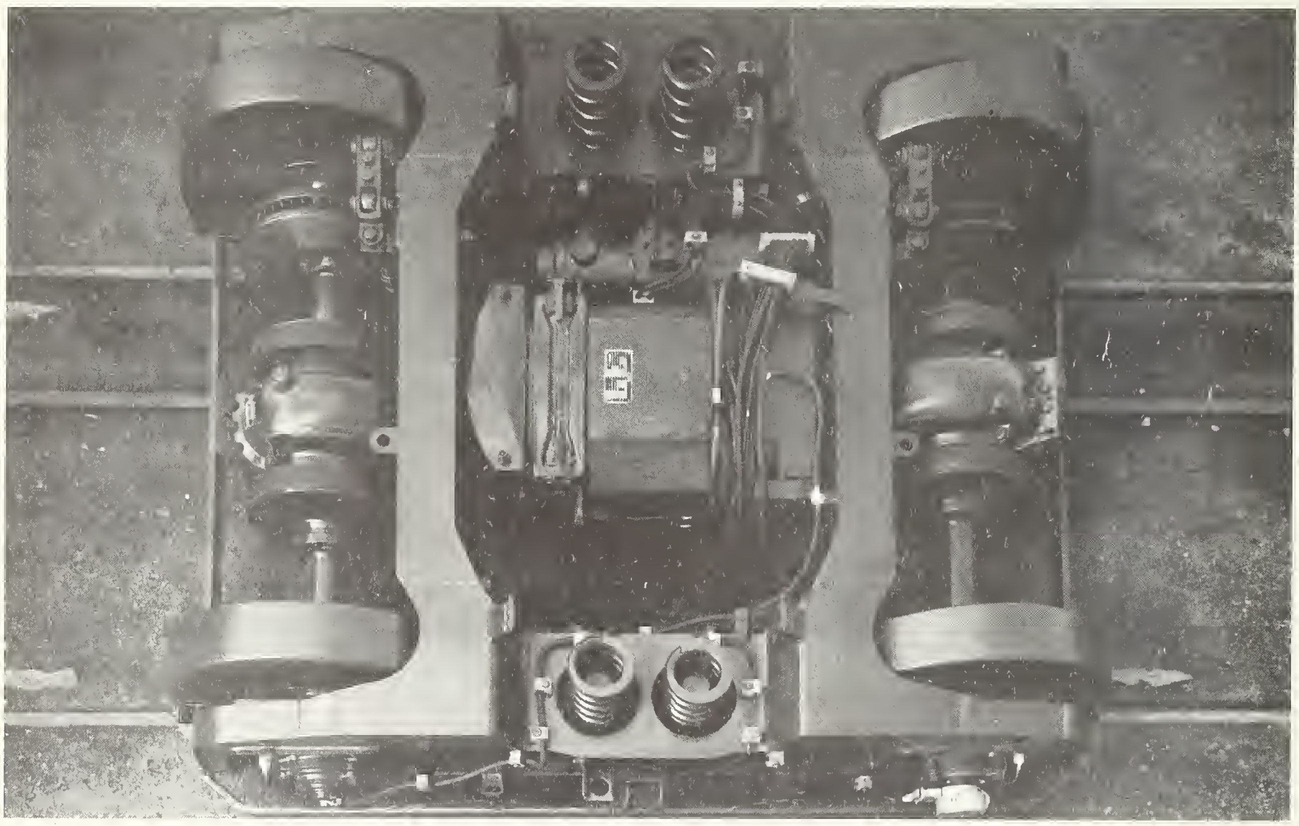
*These capacities are determined on the basis of the maximum weight of the vehicle prescribed by law, and they are some 10-15% higher than the maximum practical capacities.

The vehicles designed for rapid transit operation have somewhat greater weight. For example, the 6-axle, 23.00 m. (75'6") long Frankfurt car with 2.65 m. (8'8") width weighs 30.7 tons.

The standard propulsion for 4-axle vehicles is provided by one motor per axle. The total power per vehicle is usually 200 KW (268 HP). With articulated vehicles in most cases only the front and rear trucks are powered, while those under the articulation are not. The weight distribution is such that the 6-axle vehicle has 80% of weight for tractive adhesion, while the 8-axle vehicle has 60-64% as adhesive weight. The most widely used construction, the DÜWAG monomotor truck, has only one motor which powers both axles. Such a motor formerly had 100 KW (134 HP). In recent vehicles more powerful motors have been used; for example the 8-axle vehicle in Cologne has 2 x 175 KW (235 HP), or a total of 350 KW (470 HP).



P-15. DUWAG truck (single motor)

P-16. Six-axle articulated rapid transit car (Frankfurt)

P-17. Interior of the above car

The monomotor truck design has been proved in many cities to be very successful for light rail as well as for rapid transit systems. Over 5000 such trucks have been built so far. The advantage of a single motor is that it rigidly couples both axles and thereby reduces the probability of wheels spinning. In addition, there is certain weight saving and simplicity of this design compared with those which provide one motor for each axle.

c. Maximum Speed and Acceleration. Maximum technical speeds of light rail vehicles can equal those of rapid transit vehicles. There have been vehicles with maximum speeds of 100-125 km/h (62-78 mph). Also in this country, 30-40 years ago, some rail vehicles, such as those on the Norristown Line in Philadelphia and South Shore Line in Chicago, were capable of developing speeds of 120 km/h (75 mph) and even higher. However, the maximum technical speed depends on the type of service. In European cities light rail services are mostly urban with relatively short interstation distances, so that maximum technical speeds are usually in the range of 60-80 km/h (37-50 mph).

Acceleration rates on electric rail vehicles can be as high as the passengers can tolerate. The original American PCC car had a maximum acceleration rate of 2.1 m/sec^2 (6.9 ft/sec^2 or 4.75 mphps), which proved to be too high for standing passengers. The rate was consequently reduced. The typical acceleration rates of light rail vehicles in Europe are 1-1.2 m/sec^2 (3.3-3.9 ft/sec^2) although some models (European PCC) are capable of achieving 1.9 m/sec^2 (6.3 ft/sec^2). The maximum rate of acceleration can be maintained up to approximately 40 km/h (25 mph). The jerk is usually kept below 1.2 m/sec^3 (3.9 ft/sec^3) with the exception of PCC cars, which exceed it.

Light rail vehicles are thus capable of the maximum acceleration rate possible in transit service with standing passengers.

d. Passenger Comfort and Side Effects. On well-built and maintained track (which is standard for most West European cities) modern light rail vehicles have extremely high riding comfort. Sway is minimal and suspension absorbs any incidental shocks from rails. The vehicles which operate on predominantly urban lines with short travel distances and high peak hour loadings are designed with a relatively low seating/standing ratio, and the seats are usually made out of hard plastic material which is easy to maintain. Stanchions are provided for standing passengers. For the lines which operate on longer distances and have lower peak hour loadings, the seating/standing ratio is considerably higher and soft seats are used.

With respect to the side effects, the light rail system is superior to most other modes. With modern track construction noise levels of light rail vehicles are extremely low. Since their main brake is dynamic, the pneumatic system has been eliminated from most models, further decreasing the noise and dust created by frictional brakes. The only sound produced is a certain humming of the wheels on the rails. There is, naturally, no exhaust.

P-18. High-speed interurban 8-axle car

e. Vehicle Maintenance. Most of the light rail vehicles are designed and built with maximum emphasis on economy and simplicity. In many respects the modern light rail vehicles are simpler than PCC cars. Their technical maintenance does not require extensive highly skilled labor: trucks, electrical and mechanical equipment are easily accessible*. Vehicle interior is rather simple (sometimes hard seats, but well molded and durable) and easy to clean: an example of this are the seats suspended from the ceiling via stanchions, eliminating supporting bars under the seats to facilitate cleaning.

f. The Latest Trends. In recent years with increasing orientation toward semi-rapid transit operation (i.e. tunnels, viaducts and other reserved rights-of-way for light rail) several important trends have become obvious. Some of the major items are worth describing.

Fare collection based on the honor system has become standard practice in most West European cities. Users are encouraged through appreciably increased single fares (up to 40%) to purchase prepaid tickets (10-ride, weekly, monthly, etc.), which either have to be only shown, or the user has to cancel them when he enters the vehicle. He shows the ticket only if requested by an official performing spot check control. Thus, a very small percentage of riders has to purchase tickets on board so that rates of loading and speed of the system are increased. This change in fare collection has allowed even the largest vehicles to operate with only one employee: the driver who also issues tickets. In subway sections of light rail lines there is a prepaid ticket system, so that boarding of vehicles occurs without any delay for fare collection.

The experience of many cities with articulated cars continues to be so successful, that most of them have shifted

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*For discussion of mechanical characteristics and maintenance of light rail vehicles see reference[3].

P-19. Prototype car for surface and subway operation (Hannover)

P-20. Interior of the above car

exclusively to these vehicles and adopted them as standard units for the future. This is the case even with some systems which plan to convert light rail later entirely into rapid transit. The best example is the 6-axle articulated car in Frankfurt which is capable of MU operation of up to four articulated vehicles and a total train capacity of 924 persons. Reasons for popularity of the articulated vehicles remain to be their large capacity, presence of the operator in the vehicle, better distribution of passengers on available seats, better utilization of right-of-way width (smaller overhang) and track length, particularly in stations, and smaller number of car ends with vehicle control equipment needed for two-way vehicles when they operate as rapid transit.

There is a trend toward wider vehicles: those in tunnels are planned typically to have a width of 2.65 m. (8'8") (Frankfurt) or even 2.70 m. (8'10") (Brussels). Capacities of these vehicles are correspondingly increased.

With the progressing orientation toward rapid transit types of operation, two-directional vehicles with doors on both sides are regaining popularity due to their practical aspect of easy direction changes. Frankfurt and Brussels articulated cars for tunnel and partly reserved right-of-way operation have this feature.

With respect to passenger comfort, the seating/standing ratio is becoming higher with every model, soft seats are increasingly popular and vehicle appearance is constantly being improved.

2. Rights-of-Way and Alignment

Operation of old-type streetcars in the streets presents a number of problems. Neither can the streetcar operate well because of numerous obstacles, nor can the other traffic easily overtake the streetcar either during its movement or at steps.

P-21. Old type streetcar operation: slow and unreliable (Brussels)

These problems were a major reason for substituting buses for streetcars. Buses offer higher flexibility of movement within the street. However, on the lines where both transit travel is considerable and street traffic is intensive, mixing of transit and other vehicles leads to the already discussed extremely negative consequences for any mode of transit travel. Cities which always pursued a policy of maintaining high level of transit service realized that the only solution to this problem was a separation of the two: transit and all other vehicles, rather than an attempt to make a "smoother mix" by using "flexible" vehicles.

Separation of transit vehicles from other traffic, the major factor which created the light rail concept, has been persistently pursued as a basic policy in a number of European cities. These cities now have significant portions of light rail lines on private rights-of-way. For example, in Munich 55% is on private rights-of-way, i.e. separated from other traffic; in Belgrade, 90%; in Cologne city center, 95%, the whole network 63%; in Gothenburg, 70%; Hannover, 42%; even smaller cities such as Antwerp, Bielefeld and Freiburg, have appreciable portions of their lines separated. Different methods of separation, including some very imaginative ones, will be systematically reviewed here.

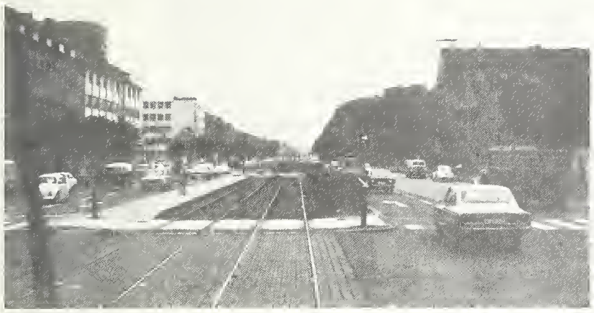
a. Separate Lanes in Streets. Separation of the track without any physical barrier can be done either by a single solid pavement marking line (The Hague) or by diagonally striped lines with the same purpose but visually somewhat more effective in keeping out other traffic (Hannover, Gothenburg). In most cities, buses are also allowed in these lanes, but an active police enforcement is applied to keep other vehicles out. This type of right-of-way is basically satisfactory since it allows higher speeds and independence from traffic congestion, although reliability and safety of operation are not as high as with physical separation between lanes.

P-22. Transit lane separated by pavement marking (The Hague)

P-23. Transit lane on a bridge separated by markings, used by light rail and buses (Gothenburg)

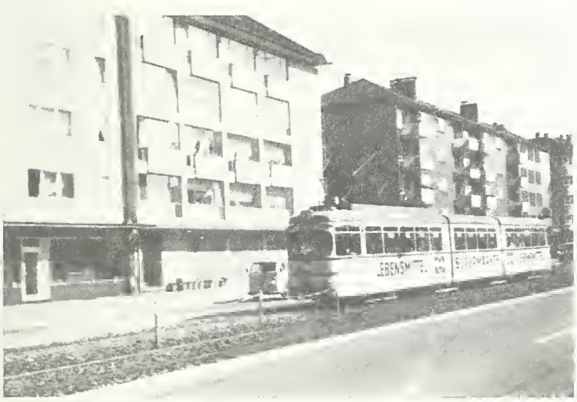
b. Central Median. Right-of-way for light rail in the street median is the most common surface separation of this mode. A width of some 7.0 m. (23 feet) provides fast, reliable and safe operation of transit vehicles. (This arrangement can also be used for buses, although their safety and reliability are not as high because of possibility of lateral instability under slippery conditions.)

The problems related to this type of operation are crossings at intersections, which often have to be controlled by special signals, and the location of light rail stops, which require wider right-of-way. This can be resolved by providing



P-24. Median light rail right-of-way (ROW) (Cologne)

P-25. Median light rail ROW on a bridge (River Rhein, Cologne)



P-26. Light rail in the median (Wuppertal)

P-27. Median ROW with flowers in a central urban area (Rotterdam)

P-28. Track reconstruction from pavement into the median private ROW (Bielefeld)

P-29. Median ROW protected by concrete barriers (Stuttgart) a minimum additional width and staggering the stops for the two directions along the line with a mild S curve in the track between them.

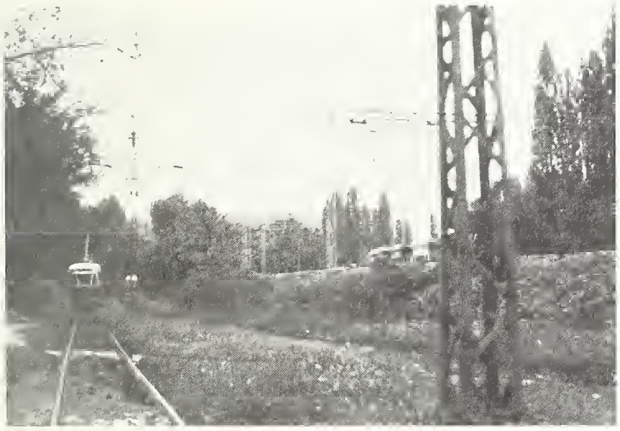
Several cities are presently engaged in providing this private right-of-way within existing streets. Instead of an eight-lane arterial with parking on the sides and tracks in the middle of the pavement, the reconstructed street eliminates parking, introduces special signals for left turning traffic at a reduced number of intersections, and provides a reserved right-of-way for light rail vehicles. Bielefeld and Hannover, for example, are now carrying out such reconstruction.

It should be noted here that provision of separate rights-of-way for light rail in streets and elsewhere is a basic, generally accepted policy in all studied cities. Transit, considered vital for the city, must represent a transportation system offering a fast and reliable service. This can be achieved only through separation of transit from other traffic wherever that is reasonably possible. Benefit/cost analyses are therefore not performed for individual sections of lines; some sections with headways as long as 7.5 - 15 minutes are also placed on private rights-of-way as parts of the basic rail transit network important for the system performance. - Bus lines, carrying generally lighter passenger volumes, have less separation, although an increasing number of bus lanes are being introduced in congested areas.

c. Lateral Private Right-of-Way. In a way similar to the central reservation, it is possible to provide reserved rights-of-way for light rail vehicles on one side of streets, between curb and sidewalk, usually within a green strip. Brussels, Antwerp, Hannover, Belgrade, Stuttgart, and a number of other cities have utilized this design on many of their lines, including some very recent constructions.

P-30. Lateral placement of a new light rail line (Rotterdam)

P-31. Lateral light rail ROW (Belgrade)



P-32. Light rail in a park: an attractive alignment (Belgrade)

P-33. Transportation way through green areas with minimum intrusion (Belgrade)

P-34. High-speed alignment through green area (Cologne)

d. Alignment Through Parks. Rail lines through parks and park-like areas have also been used for many years with very good results. Since the rails do not significantly alter the park area they are passing through, the environmental harm caused by them is negligible. Therefore they are much more readily accepted in such operation than the construction of a highway. Successful operations of rail vehicles through parks and other green areas can be found in Cologne, Stuttgart, Belgrade, The Hague, and many other cities. With the current difficulties of finding grade separated rights-of-way in urban areas, this compatibility of light rail with parks may be one of its significant advantages.

e. Light Rail in Pedestrian Areas. It is interesting that several cities (Düsseldorf, Rotterdam) which have operated light rail lines on short sections through pedestrian areas (shopping streets, major squares, etc.) claim that these two modes, light rail and pedestrian traffic, are quite compatible and create no problems under such conditions. Clearly, one would not even think about planning a high or even medium speed of light rail operation through pedestrian areas, but it is significant that for certain sections crossing or parallel use of ways by light rail and pedestrians is feasible.

f. Control at Intersections. Since uncontrolled intersections of light rail lines with major traffic movements can create serious problems and may defeat the advantages of their separation elsewhere, light rail vehicles are usually given special phases at intersections. In most cases the solution is a special signal which includes the light rail vehicle movement into the signal phase compatible with it. If signals operate on a fixed time basis, there is no advantage for transit vehicles. Under this condition the only measure which can minimize delays to transit vehicles is locating the stops before or after intersections in such a manner that transit vehicles can move utilizing a scheduled program to minimize signal delays. The most elaborate design of such an operation can be found on Eschersheimer Strasse in Frankfurt, where both light rail and rapid transit vehicles operate jointly on the tracks in the street median and cross a number of complex intersections. However, delays caused by the traffic signals cannot be completely eliminated; in some cases they may be significant.

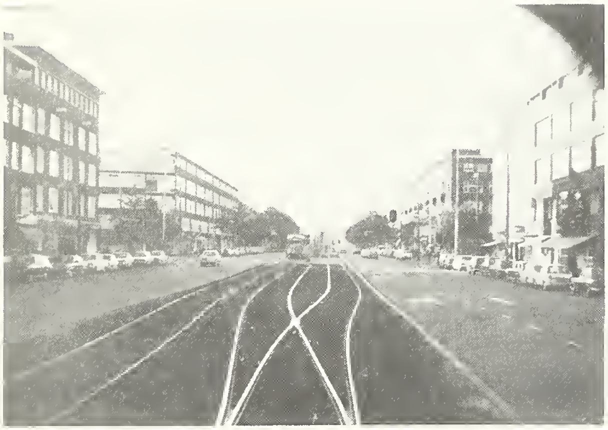
The next phase of control is preferential treatment of light rail vehicles which can be achieved by providing contactors on the overhead wire of the track approaches to signalized intersections. This type of control has been in use, for example, in Düsseldorf for some 15 years.

At the crossings at high speed surface rail lines with streets, usually in the suburbs, light rail vehicles are sometimes given the same priority as railroads: their approach actuates barriers on the highway and the blinking signals sound a warning for highway traffic. Good examples of this exist in Cologne and Düsseldorf.

g. Underpasses. Light rail lines with high frequency service can be placed in underpasses below major surface intersections, thus decreasing delays to automobile traffic and eliminating delays for light rail vehicles. Examples of this solution are found in Gothenburg, Stuttgart, and on the newly constructed Line 2 in South Rotterdam.

Dynamic characteristics of light rail vehicles allow relatively short underpasses since they can easily negotiate up to 5-6% gradients (specially designed vehicles can be used on even higher gradients). However, these underpasses should be constructed in such a manner that they can be connected with tunnels for eventual future rapid transit, if it is contemplated.

P-35. Special signal ("T") for light rail (Rotterdam)



P-36. A third track permits overtaking of a car waiting for left turn (Rotterdam)

P-37. Special switch with long points to allow switching prior to street crossing (Düsseldorf)

P-38. Light rail ROW and underpass (Gothenburg)

P-39. Undercrossing of the mainline railroad (Rotterdam)

P-40. Light rail underpass of a busy intersection (Rotterdam)

h. Overpasses and Viaducts. Where geometric conditions and other factors permit, overpasses and viaducts can be successfully used for light rail lines. This solution is much less objectionable than elevated rapid transit lines or, particularly, highways, since light rail has much lower noise levels and usually has a better appearance. A number of cities have applied this solution in recent years. Cologne has several viaducts, Belgrade opened two such viaducts in 1970, and Rotterdam employed this solution for its new northern section of Line 5. Again, geometric and structural characteristics of the viaducts should be such that they are suitable for future rapid transit operation.

i. Tunnels. Technically, the light rail tunnel cross-section can be identical to that for rapid transit. Actually, most systems are building tunnels in a manner such that they can be utilized by either mode. A typical cross-section of a two-track light rail tunnel has a width of 7.35 m. (24'1") for two tracks and a height of 4.40 m. (13'5"), including a pantograph current collection (Cologne). In some cases lower height can be used by rapid transit so that utilization of tunnels by both systems includes this slightly higher cost than would be needed for rapid transit only. The difference is not, however, great. Tunneling methods - cut-and-cover, boring or cover-and-cut "Milan" methods - can be employed in the identical manner as they are used for rapid transit construction.

A major variation between the two modes may be in the longitudinal alignment. Light rail can have an alignment which is very similar to the alignment in the streets, having small radius curves (e.g. 60 m. (196')) and track crossings at grade.

P-41. Exclusive light rail viaduct (Cologne)

P-42. Viaduct over a canal, freeway interchange and railroad for a new line (Rotterdam)

P-43. Access to a viaduct; pedestrian walk on the right (Belgrade)

P-44. 4-axle car with 4-axle trailer on a new viaduct through freeway interchange (Belgrade)

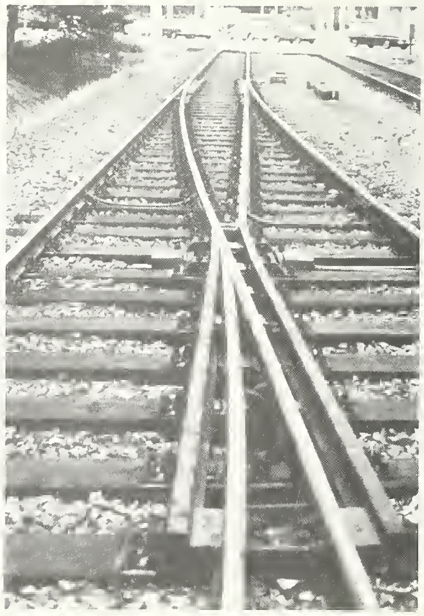
P-45. Exit ramp from a tunnel (Frankfurt)

P-46. Tunnel access ramp (Brussels)

Limitations of running speed due to the alignment and crossings thus remain, although the travel speed and regularity of service are vastly improved in comparison with surface operation due to the completely controlled, free right-of-way. Another type of alignment is where full rapid transit elements are used so that high running speeds can be achieved. Clearly, the latter is superior to the former, although it sometimes involves a considerably higher cost. In Cologne the geometric standards of the tunnels are below the minima required for rapid transit. In addition, at a point where two double track lines converge there is a grade crossing of the opposing tracks. It is claimed that construction of these tunnels to rapid transit standards would have involved 100% higher cost and the time saving on this short section would have been approximately one minute. Although this appears to be an approximate estimate, it clearly indicates that the cost differential for the two types of construction may be quite significant. However, an evaluation of the decision to build with lower standards, at lower cost, and, in most cases, considerably sooner than it would be possible with higher investment, can only be made in the light of later developments. (At present, the lower cost and earlier completion of the facilities are certainly highly beneficial, and the penalty for them is minimal.) If the light rail system continues to use the same type of vehicles, the penalty will remain very small and fully acceptable. If, however, the whole system should later be upgraded and converted into rapid transit, the design bottlenecks in the few sections may be a serious impedance to that progress, and the cost of such lower standard of design may be very high. A further discussion of this point will be given in Chapter VI.

P-47. Modern switch with elastic points

P-48. The latest type of switch: frog also has an elastic point. Straight position



P-49. The same switch in turning out position (Cologne)

3. Stations

Stations in city streets are the greatest obstacle which transit services create to other traffic; at the same time they also represent the most dangerous points with respect to the transit vehicles as well as to the passengers boarding or alighting them.

Transit on private rights-of-way does not have this problem. The minimum standard station consists of a widening of the private right-of-way area. Access to these stations when they are in the medians should preferably be signalized, while at very busy points their access can be provided by pedestrian over- or underpasses, so that the pedestrian-vehicle conflict is completely eliminated.

Light rail stations in subway sections have approaches identical to those for rapid transit. However, important decisions must be made with respect to the length and height of the platform itself. For operation with light rail vehicles it is sufficient to provide platforms long enough to accept two to three vehicles simultaneously; that usually amounts to a length of 50-80 m. (164'-262'). For rapid transit, however, it is necessary to provide at least 100 and desirably 120 m. (328'-394', respectively). There is little compromise that can be made here if light rail is only a transitional system: full length platforms must be constructed. With respect to height, light rail vehicles are built for a platform height of approximately 25 cm. (10") above the top of the rail. Rapid transit requires high-level platforms of approximately 1.00 m (3'3"). In addition, there is a difference in horizontal location of the platform edge when light rail vehicles are narrower than rapid transit vehicles.

Several solutions to this problem of transition can be applied. In Brussels a short section of the platform length, sufficient to accommodate two single-unit cars, has been built

P-50. Stop at a protected island in downtown area (Stuttgart)

P-51. A 4-track light rail facility with stops in a pedestrian area. Highway viaduct on left (Düsseldorf)

P-52. Staggered stops in a median to minimize ROW width (Cologne)

P-53. Protected median ROW and station with grade separated pedestrian access (Cologne)

P-54. Underground station and ramp to surface (Charlottenplatz, Stuttgart)

P-55. Modified surface car in joint operation with wider rapid transit cars (Frankfurt)

P-56. Boarding of a rapid transit train from medium-level platform (Frankfurt)

P-57. Station with a depressed platform section for 'Pre-Metro' (Brussels)

with low-level platform, while the remainder is at the high level. The boarding and alighting of passengers is then identical to that in the street. When rapid transit vehicles are introduced in the future, joint operation with light rail will call for stopping at different sections of the platform; when eventually total conversion takes place, the low part of the platform will be reconstructed to the high level platform, which is indented sufficiently to allow wider vehicles. An objectionable feature of this solution is that the platforms presently used are rather short and narrow and frequently cause congestion at boarding and alighting, while most of the platform length remains unused.

Frankfurt has applied a different solution for its tunnels in which both light rail and rapid transit vehicles operate. Light rail vehicles have been equipped with a movable step so that in their street operation passengers can board from the street level, while in the stations at a higher (although not normal height) level one step less is provided on the vehicles and passengers can again normally step down. On the rapid transit vehicles there is also a small step from which passengers can step either on the platform with the same level or, at some stations at which the platform height is lower because of freight cars which are sometimes transported on this line, passengers step one more step down. It is planned that when high-level platforms are provided, floor of rapid transit vehicles around doors be raised so that all steps are eliminated. – In addition to this level adjustment, light rail vehicles have an added protrusion on their sides which is level with the intermediate platform to prevent the gap between the vehicle and the platform due to their narrower body. This element is not aesthetically pleasing, but the whole solution is technically satisfactory and safe.

In Hannover two new cars are being tested which will be capable of operation at both low-level street stations and high-level platform in the subway stations by automatic opening of doors at either level. The width of cars is also compatible with the future rapid transit stations clearances.

P-58. Surface car with lateral elements for mixed operation with rapid transit

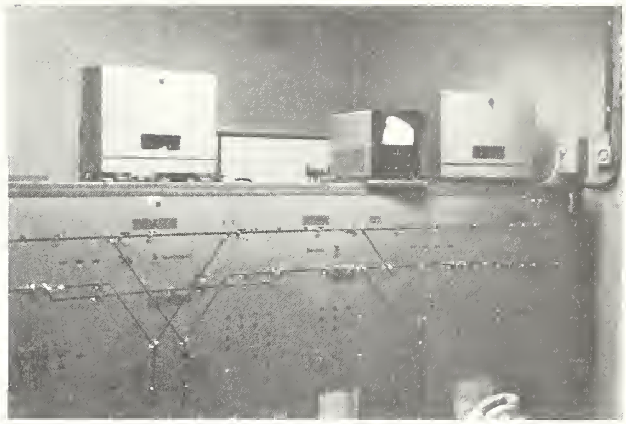
P-59, 60. Two positions of steps providing for low and high-level boarding

Since light rail lines generally operate with smaller units and higher frequency than rapid transit, simultaneous multiple loading at stations is essential for their speed, capacity and reliability of service. In most cities simultaneous stopping of vehicles is employed, even if light rail vehicles operate under full signal control in the tunnels and are separated by blocks. In the stations double signals allow stopping of two or more vehicles at the same time. To avoid confusion of passengers waiting for particular vehicles, automated systems have been introduced (Cologne and Brussels) which, prior to the arrival of each vehicle, display on the platform its destination and its stopping position along the platform.

4. Controls and Communications

The increasing separation of light rail lines from other traffic permits higher running speeds and requires more positive controls of vehicle movements along the line as well as at intersecting points than is provided in street operation.

At complex or dangerous intersections with street traffic modern light rail lines have special signals, as was described under III-A-2-f. Vehicle movement on the surface is based on the driver's control and his visibility, while in tunnels most of the systems have automatic signals varying from classical block systems to some sophisticated systems controlling the maximum speed of each vehicle as a function of the distance from the preceding vehicle. In some cases (Brussels) there is even the fail-safe feature: if the car either overruns a red signal or exceeds the permitted speed, it triggers automatic forced braking. Thus, the safety features of light rail can be as rigorous as those of rapid transit systems, and the choice among the control systems depends on the desired point of the trade-off between line capacity and speed on one side, and cost and safety on the other. By its physical characteristics, however, light rail requires less rigorous safety than rapid transit, thereby allowing higher frequency of service.



P-61. Signal control panel for underground light rail (Cologne)

Departure control at the stations can be exercised either by the station attendant or, with more modern systems, by the driver. There are two procedures for the latter: he can either see the doors in his side-view mirror or, as used in Frankfurt, he activates the doors and after four seconds if the photo cells on the doors have not been interrupted, they close. In addition, to this safety interval, the doors have sensitive edges and will not close if an object is in their way. Door surveillance and decision on departure can, of course, also be performed remotely by closed-circuit TV (Hamburg rapid transit).

Control of vehicle movements along the line from central point has been greatly facilitated by the introduction of radio communications. Many European systems have these installations. For example, in Frankfurt the central control can make announcements at the stations and communicate two-way with station attendants. On the other hand, there is also two-way communication between central control and the driver on each vehicle. The driver can also connect central control directly with the public address system in his vehicle. Significance of such communication systems for regularity of operations, surveillance and fast action in cases of any kinds of emergency is clear.

B. OPERATING CHARACTERISTICS

1. Network-Area Coverage

Investment costs of fixed facilities for light rail (right-of-way, track, overhead, signals, etc.) are sufficiently low that it is feasible to achieve an adequate coverage of medium density areas. They are, however, too high for low density suburban areas. The trend in recent decades has been to consolidate rail lines to fewer higher performance lines rather than many slow lines in the streets. Typically, light rail systems consist of a number of radial lines converging toward the city center into a limited number of trunk lines which have high frequency of service. Due to the limited dimensions of most city centers, it is possible to achieve an adequate area coverage with a relatively short total length of trunk lines. These central sections are then placed in tunnels.

The first tunnels for streetcars were built for downtown sections of transit lines in Boston in 1897. Following Boston's example, Philadelphia, San Francisco, Pittsburgh and Newark built some underground sections for streetcar lines. In modern times, however, there has been virtually no progress with light rail in the United States, while in the Western European cities there is more construction of transit tunnels - light rail and rapid transit systems - than ever before in history. In West Germany alone no less than 15 cities are constructing subways, only four of which are planned for rapid transit in the first stage. All others intend to use light rail vehicles of different types for a number of years to maintain continuity of their networks, and then gradually convert to rapid transit. Brussels and Antwerp in Belgium and several cities in other European countries are also building such systems.

By providing full separation in the center and limited separation (with grade crossings) in suburban areas, many cities are developing networks which are predominantly separated from other traffic. With high frequency of service typical for heavily traveled lines, light rail can operate with as many as five (Brussels, Philadelphia, San Francisco) or six (Cologne) lines merging into one. Rapid transit usually does not handle such configurations. The greater number of lines can provide a much better area coverage than the few usually radial lines typical for rapid transit which are found in many cities (San Francisco BART, Philadelphia, Cleveland).

With cities which have modern light rail as the basic transit mode, city centers are served predominantly (and sometimes nearly exclusively) by light rail, while outside the rail network is complemented by bus lines. As a rule, light rail lines are those with heavy passenger volumes, while buses serve low volume lines. This is obvious from the data in the last column of Table 4: the average number of passengers per unit of line length is three to ten times higher for light rail than for buses. The most drastic example is Bielefeld in which three light rail lines with a total length of 26 km. (16 mi.) carry some 33% more passengers than 21 bus lines with a total length of 185 km (115 mi.).

Recent and current patterns of change in light rail networks consist of the following actions:

- Closing of old-type streetcar lines in narrow streets with difficult traffic conditions in the cities which still have this kind of operation;

- Construction of tunnels, viaducts, or other types of private rights-of-way for light rail lines in high density areas;

TABLE 4

OPERATING STATISTICS OF THE SELECTED LIGHT RAIL SYSTEMS

City	No. of Lines CR[1]	No. of Lines B	Length of Lines km(mi) CR	Length of Lines km(mi) B	Length of Track km(mi) CR	No. of Vehicles CR (Trailers)	No. of Vehicles B	Veh. - km. (-mi.) Mill./yr. CR	Veh. - km. (-mi.) Mill./yr. B	Capacity - km. (-mi.) Mill./yr. CR	Capacity - km. (-mi.) Mill./yr. B	Passengers Mill./yr. CR	Passengers Mill./yr. B	Thous. Annual Pass./km. (/mi.) CR	Thous. Annual Pass./km. (/mi.) B
1. Brussels	37[2]	21[2]	176 (109)	197 (122)	NA	774 (T:197)	491	23.6 (14.7)	14.4 (8.9)	NA		130	47	740 (1,193)	238 (385)
2. Cologne	16	31	269 (167)	332 (206)	136 (85)	310	276	15.6 (9.7)	14.6 (9.1)	3,993 (2,482)	1,555 (966)	112	52	417 (671)	157 (252)
3. Rotterdam	10	33	85 (53) RT:75	304 (189) (4.7)	57 (35)	159 (T:14)	299 RT:43	6.6 (4.1) RT:28	17.9 (11.1) (1.7)	1,223 (760) RT:911	1,605 (998) (566)	59 RT:32.5	62	697 (1,113) RT:4,333	210 (328) (6,915)
4. Dusseldorf	16	48	209 (130)	770 (479)	131 (81)	455 (T:225)	398	19.4 (12.1)	21.9 (13.6)	3,382 (2,102)	1,169 (727)	122	67	583 (938)	87 (140)
5. Frankfurt	25[3]	36	311[3] (193)	333 (207)	133 (83)	576[3] (T:290)	244	25.3 (15.7)	11.0 (6.8)	3,458 (2,149)	961 (597)	147[3]	31	473 (762)	93 (150)
6. Stuttgart	14	45	191 (119)	567 (352)	130 (81)	600 (T:150)	231	26.8 (16.7)	9.6 (6.0)	3,974 (2,470)	856 (532)	113	24	592 (950)	42 (68)
7. Hannover	14	31	181 (112)	420 (261)	86 (53)	420 (T:226)	229	17.8 (11.1)	10.5 (6.5)	2,226 (1,383)	915 (569)	81	24	448 (723)	57 (92)
8. Gothenburg	9	36	115 (71)	285 (177)	NA	339 (T:60)	226	24.2 (15.0)		2,416 (1,502)		87		218 (351)	
9. Bielefeld	3	21	26 (16)	185 (115)	25 (16)	56 (T:16)	73	2.6 (1.6)	3.4 (2.1)	411 (255)	308 (191)	21	15	810 (1,313)	81 (131)

[1]RT - Rapid Transit; CR - Light Rail; B - Bus
[2]As of 1964
[3]Includes A-1 rapid transit line
NA - Not Available

- Separation at grade of light rail vehicles from other traffic in outlying areas: in the medians (Bielefeld, Hannover), laterally, with underpasses, etc. (Rotterdam, The Hague, Gothenburg);

- Extension of light rail lines in outlying areas to connect newly developed residential or commercial centers (Mannheim, Munich, Bern, Bremen, Bielefeld).

This last type of line is built only on private rights-of-way with incidental contacts and crossings with other traffic; fixed facilities are usually designed to rapid transit standards.

The opinion of transportation planners is that such new lines or extensions of the existing ones are justified when the newly developed areas have a population in the order of 20,000 - 30,000.

2. Speed

Travel speeds on the light rail lines largely depend on the conditions of the right of way so that they vary greatly from one section to another. This is clearly illustrated on the sketch of Cologne network with speeds for individual sections. It is interesting to note how the travel speeds increase in the outlying areas (Fig. 1).

Typically, low travel speeds for individual lines average 15 km/h (9 mph), but on some congested sections they may be as low as 8-10 km/h (5-6 mph). Such sections are the first to be placed on private rights-of-way, resulting in drastic increases in speed. A good example is Brussels where travel time on a section had been 20 minutes, with peak travel times reaching sometimes 40 minutes or longer. After the line was placed in a subway, travel time became 8 minutes, and it does not change during peak periods. Most lines average some 20 km/h (12.5 mph), while those which are basically separated from the traffic can reach 27 km/h (17 mph). The highest

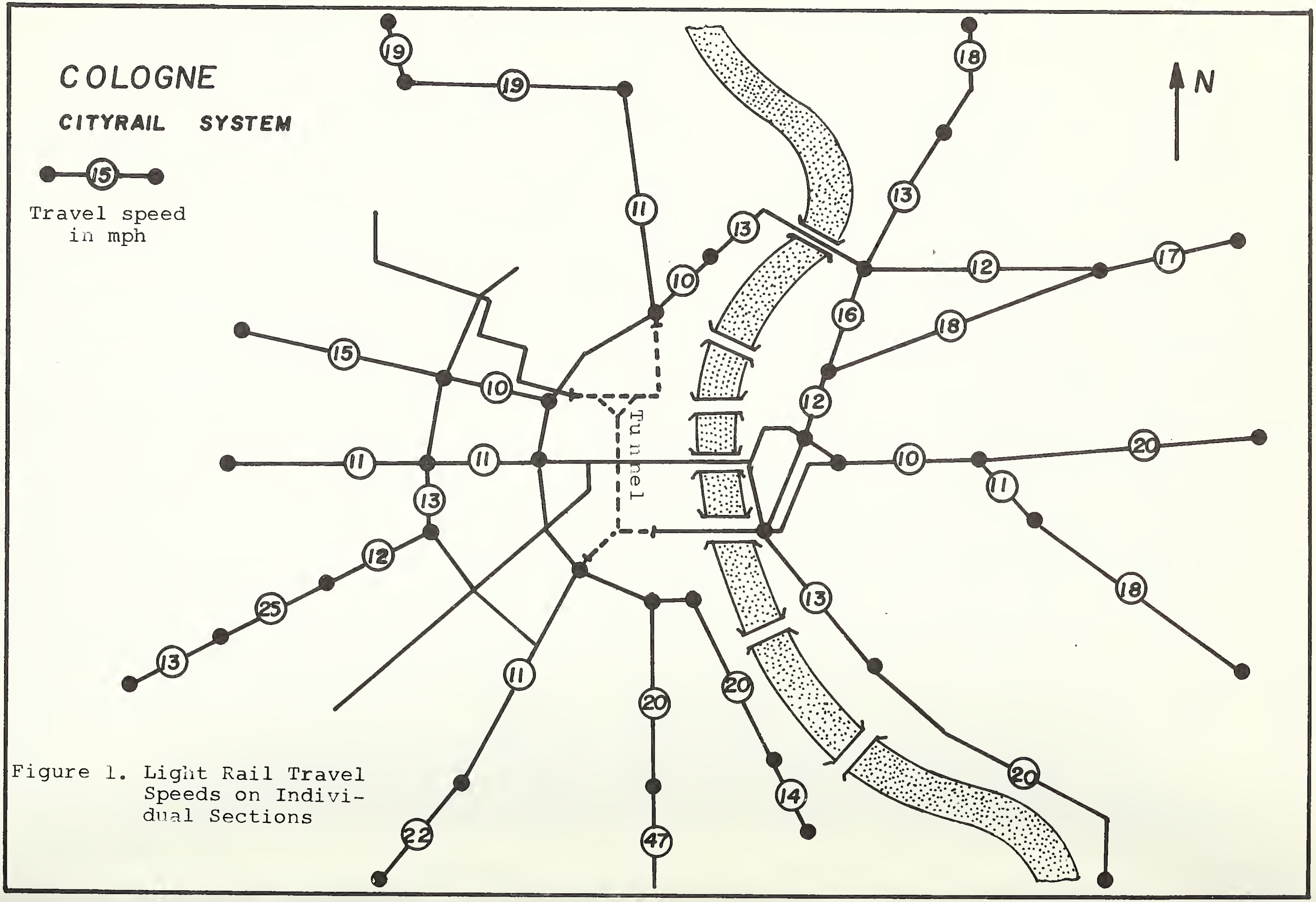


Figure 1. Light Rail Travel Speeds on Individual Sections

average speed for a system is in Hannover: 21 km/h (13 mph). Typical travel speeds in tunnel sections reach 23-26 km/h (14-16 mph), with a good chance for further increase when rolling stock is fully adapted for this type of operation.

The fastest light rail line in Europe is a former railroad line in Gothenburg on which the light rail vehicles operating in up to four car MU trains average 50 km/h (31 mph) on an 8 km (5 mi.) long line. The line is presently being extended through a tunnel to a new suburban development.

With full grade separation and signaling suburban lines with light rail equipment can completely match the speeds of rapid transit.

3. Capacity and Frequency of Service

The numbers given for maximum capacities achieved on a single track in individual cities in Table 5 represent actual numbers of persons transported, rather than design standards or theoretical capacity. Many cities have demonstrated that transporting capacities of 8 - 12,000 persons per hour per direction can be achieved without major operational difficulties. Sixty vehicles of any capacity (including articulated) per hour per direction can be operated under any conditions: in the streets or tunnels, with visual or signal control. The experience in Düsseldorf is that with approximately 80 vehicles per hour some special operational measures have to be taken (multiple loading, actuated signals, etc.). With such measures frequencies as high as 120 vehicles per hour per direction have been actually operated: single-unit vehicles (PCC) on Philadelphia's subway-surface lines, and two-car compositions in the streets in Hamburg. Naturally, like with any operation at capacity, the level of service is affected: speeds are low, comfort is low, and creation of irregularities in service is likely.

TABLE 5

NETWORK CHARACTERISTICS OF THE SELECTED LIGHT RAIL SYSTEMS

City	% Private ROW	Maximum Freq. (veh/h)	Maximum Capacity (pers/h)	Travel Speed km/h (mph)	Average Interstation Spacing m(ft)		Ave. Trip Length km (mi)	Future Rail Modes[1]
1. Brussels	NA	51-72	9,600[2]	NA	402 (1,319)		NA	CR→RT
2. Cologne	63	56-62	13,600	21 (13.1)	CR:615 (2,017)	B[1]:648 (2,125)	5.1 (3.2)	CR(→RT?)
3. Rotterdam	NA	37	4,600	15-21 (9.3-13.1)	400-500 (1,312-1,640)	500-600 (1,640-1,968)	NA	CR+RT
4. Düsseldorf	NA	92	14,000	16-30 (9.9-18.6)	CR:576 (1,889)	B:650 (2,132)	4.7 (2.9)	CR→RT
5. Frankfurt	30-40	23	8,200 11,000[3]	15-26 (9.3-16.2)	CR:450 (1,476)	B:550 (1,084)	4.4 (2.7)	CR+RT
6. Stuttgart	40	40	12,000	16-23 (9.9-14.3)	CR:400 (1,312)	B:550 (1,804)	5.6 (3.5)	CR(→RT?)
7. Hannover	NA	80	18,000	21 (13.1)	CR:549 (1,800)	B:775 (2,542)	5.5 (3.4)	CR→RT
8. Gothenburg	70	88	7,200 12,000[3]	20-25 (12.4-15.5) 50[4] (31.1)	300-500 (984-1,640)		4.4 (2.7)	CR,RT?
9. Bielefeld	40	24	4,300	15-27 (9.3-16.8)	500 (1,640)		4.1 (2.5)	CR+RT

[1] CR - Light Rail; RT - Rapid Transit; B - Buses;
[2] With equipment presently on order;
[3] Rate for 15-30 minute intervals
[4] RR line with modified Light Rail vehicle

NA - Not Available

Probably the most interesting case of high capacity service which has actually been regularly performed is the line to and from the fairgrounds in Hannover. A rate of flow during peak periods of 18,000 persons/hour has been frequently recorded. It is interesting that this is achieved at one station where all loading takes place - rather than joint sections of several lines with boardings elsewhere - and that boarding is not carried out on several tracks (as was done in Brussels during the World's Fair in 1958), but at a single location. Tickets are presold and boarding of a two-car train(capacity of approximately 240 persons) is done through all six doors simultaneously. Headways average 45 seconds.

High capacity of light rail vehicles negatively affects the frequency of service. With smaller vehicle capacity, buses can provide a higher frequency for the same demand. The lower labor requirement, higher capacity of trunk lines and higher passenger comfort are, on the other hand, advantages of light rail. A number of cities operate very large units at 15-minute headways during off-peak periods, shorter headways being provided during the peaks. The main reason for this type of service instead of smaller units with shorter headways is not only labor costs, but in many European countries, lack of personnel. The problem of waiting with 15-minute headways is partly overcome by fixed schedules which provide departures on the same minutes of every hour so that the times can easily be memorized, thus minimizing the possibility that a person has to wait up to 15 minutes for a vehicle.

4. Reliability

The physical guidance and fixed route of rail vehicles makes them inconvenient for street operation in mixed traffic, since any blockage of their path cannot be overcome without removing the obstacle. Although this characteristic discourages parking, loading, etc., in the path of transit, when this does happen, a disturbance is created. On a separated way, on the other hand, rail vehicles are superior to any other, since they have simple guidance, low resistance and require minimum path width.

These characteristics cause rail vehicles to be incompatible with traffic in the streets, so that their service under mixed traffic conditions is often unreliable. This is a major reason for removal of rail vehicles from the streets and creation of the light rail mode. On private rights-of-way, even those in street medians, disturbances by foreign objects is minimal. At intersections and grade crossings, which are extremely costly to eliminate, reliability can be maintained by modern methods of rail vehicle control which minimizes delays and eliminates effects of traffic fluctuations (peak hour congestion, etc.), on transit vehicles.

Breakdowns due to mechanical problems of the vehicle or line are extremely rare, since rail vehicles with electric propulsion are the simplest of all vehicles to maintain. In addition, when a breakdown does occur, it is relatively simple for the following vehicle to push the disabled one to the next turnout. With any other mode on a private right-of-way breakdowns are more likely and once they occur their removal is much more complicated (e.g. buses operating on a single lane or in a tunnel). Consequently, the experience with modern light rail operation is that it is the most reliable surface mode, exceeded only by fully separated rapid transit.

5. Comfort

As already discussed in section III-A-1, passenger comfort in light rail vehicles of modern construction is very high. The vehicles are spacious; their ride is soft and quiet. Many European systems do not provide soft seats because of maintenance costs; the cleanliness is, however, much better than in the typical U.S. transit vehicles. A few light rail fleets have air conditioning (Mannheim), but most do not because of milder climates than typical for the U.S. The experience with air conditioned fleets has been very good since maintenance of electrically powered units is simpler than maintenance of gasoline-powered ones, such as used for buses.

6. Safety

Safety record of light rail vehicles is extremely high since frequent, minor traffic collisions which were a serious problem in street operation do not exist on separated lanes. Spaciousness of the vehicles, width of doors and convenient steps provide for safety of boarding and alighting.

7. Environmental Effects

Modern light rail vehicles running on well constructed and maintained track provide quieter, less intrusive transportation than perhaps any other transit vehicle in use (trolleybuses may be an exception). Even rubber tired rapid transit generates higher noise levels than modern rail vehicles.

Aesthetic effects of the lines depend on their alignment, geometry and structure, but in general, its impact is much less harmful than the effect of a highway or rapid transit. Modern light rail vehicles and rights-of-way are aesthetically pleasing, but the overhead wiring sometimes causes objections. Naturally, community protests due to air pollution by vehicle exhaust do not exist. In a referendum in Bern held in the spring of 1971 the proposed purchase of new light rail vehicles was approved with a margin of 5:1, while the purchase of buses, submitted in the same "package", was rejected 2:1 because of the current concern about noise and air pollution from exhaust fumes.

8. Image and Passenger Attraction

Rail vehicles operating in urban streets were unpopular with motorists due to the congestion they caused. Light rail lines on private rights-of-way, however, enjoy an excellent image and they are, similar to rapid transit, a strong symbol of transit services in the city. Whether this image is created by the guideway and definite path which these vehicles follow or by some other feature of rail vehicles, is difficult to say, but the fact is that buses seldom acquire a comparable system image and major role in urban transportation in a city. In Rotterdam, for example, the introduction of a new light rail line (northern extension of Line 5) replacing a bus line contributed to an increase in patronage of 12 per cent. In Bielefeld a suburban area was served by a bus feeding a Cityrail line. When the Cityrail line was extended to that area offering direct rail service and 30% shorter travel time, patronage on the line during the peak hours showed a fourfold increase.

The opinions of officials and professional experts in those cities operating light rail systems are virtually unanimous that the attitude of the public toward light rail is extremely positive. Passengers like the spaciousness and comfort of the vehicles, speed and reliability of service, distinct image and clear information about the transit system, its quietness and lack of air pollution.

C. COSTS

1. Investment Costs

Cost of fixed facilities for light rail is similar to that of the same type of facilities for rapid transit if both are built to the same standards of alignment. The great cost advantage of the light rail is that it does not need the same facilities for most of its length.

Construction costs for the tunnels vary greatly with local conditions and area, type of tunnel, labor costs, etc. Yet, an analysis of data obtained from Gothenburg, Stuttgart, Düsseldorf, Rotterdam, Hamburg, Bielefeld, Dortmund and Brussels shows rather consistent pattern of costs for all types of ways except for surface rights-of-way; they fall within the following ranges for individual types of construction:

- Double track for light rail at the street level (in pavement or in median): $0.3-1.5 million/mile of double track (the exact figure depending on the allocation of joint costs, whether right-of-way costs are included, etc.).

- Elevated (viaduct) structure: $9-10 million/mile.

- Tunnel: $16-32 million/mile. The lower amount is for tunnels at minimum depth, cut-and-cover method; the cost increases with depth. The maximum cost ($30-32 million) is for deep tunneling construction method. Precise cost figures for both construction methods and different tunnel depths are available for several cities.

- Underground station, platform length 100-125 m. (330-400 ft): $4-5 million.

Consequently, if a light rail line is built completely to rapid transit standards, its construction costs would be approximately the same as those of rapid transit. However, in a typical case a very high quality light rail line may have two miles of tunnel, two miles of viaduct and five miles of running on surface private right-of-way. This would cost, using the average values in the above quoted ranges, $71.5 million (excluding equipment). A rapid transit line of the same length which would consist of four miles of tunnel and five miles of viaduct would cost $143.5 million (excluding equipment). In most cases, however, the difference between the investment costs for the two modes is even more drastic. Consequently, for some lines requiring medium transporting capacity light rail may be 2-3 times cheaper and yet offer not much lower level of service than rapid transit.

Typical costs of light rail vehicles, based on example prices of 1971, are as follows:

- 4-axle vehicle: $120-125,000;
- 6-axle, with four powered and two running axles: $150,000;
- 8-axle, with four powered and four running axles: $180,000 and higher.

These prices are typical average prices for vehicles with a moderate number of special options; they do not include air-conditioning or any other major special equipment. - The portion of costs for electric installations within the vehicle amount to approximately 45%. This amount increases rather sharply with the introduction of motors to more than two trucks. This is one of the reasons that most European systems use 6- and 8-axle cars with only four powered axles. The installation for MU operation is not, however, very expensive. With sophisticated electronic equipment or increased dimensions of vehicles, the prices, naturally, go up. For example, the 6-axle articulated cars for Frankfurt rapid transit with a length of 23 m. (76'6") and width of 2.65 m. (8'8") and with special electronic control equipment carry a price of $180-190,000.

These prices refer to typical vehicles with dynamic characteristics as described in section III-A-1, and which have been proven very successful in operation under normal conditions, including operations on lines with frequent stops. Naturally, in cities with difficult topographic conditions (e.g. Pittsburgh, San Francisco) higher power/weight ratio would be required and the prices would be somewhat higher than those quoted here.

It should be pointed out that there are several very experienced manufacturers of light rail equipment in West European countries. They are competitive and offer several different types of vehicles. Detailed literature on their products can be easily obtained.

2. <u>Operating Costs; Light Rail vs. Bus</u>

Precise figures on the operating costs of different transit modes are difficult to derive, since accounting procedures, particularly the distribution of overhead and joint costs among the modes, vary from one company to another. However, the general relationships of the cost components indicate that the main characteristic of operating costs in Europe is similar to that in the U.S.: the dominance of labor costs. This element amounts to 70% of total costs, while driver costs are 15-40% of the direct operating cost, depending on vehicle capacity. Relationships of other operating costs of light rail and bus are difficult to establish with accuracy required for any generalizations.

For example, in Stuttgart direct operating costs of light rail per unit of vehicle capacity are considerably lower than those of the bus. Cost of driver wages per 100-vehicle capacity miles in that city amounts to 9.3¢ on light rail and 21.6¢ on buses. Cost of maintenance and overhead, however, is higher for light rail so that in Stuttgart the total operating costs for both modes including maintenance but not taxes are approximately the same.

Most companies, including Stuttgart, caution against drawing categorical conclusions on the basis of figures like these, and for good reasons. Cost structures of the two modes - light rail and bus - are such that light rail has a definite advantage on heavily traveled lines, while the cost per offered space-mile on lightly traveled lines is lower on buses. Thus comparing the system averages by mode cannot be very conclusive, since each one represents different type of lines. The only valid comparison would be if the two modes would be considered for similar types of services.

A recent study in this country - Line Haul Service for Henrietta-Charlotte Corridor in Rochester, New York (reference 5) - has done the most thorough comparison, including cost estimation of bus and light rail modes. The study assumed as similar services as the two technologies permit. Costs of the two modes were analyzed for two different patronage levels and a number of variable conditions. The results of the most realistic set of conditions indicate the following:

- Capital cost of light rail would be approximately 26% higher than capital cost for buses ($72.8 vs. $57.6 million).

- Operating cost of light rail would be some 24% lower than bus costs ($2.8 vs. $3.7 million annually), primarily because the light rail would be operated with 59% of the personnel the buses would require (113 vs. 192 men). To be on the conservative side for rail, escalation was assumed not to vary among cost items (faster escalation of labor costs experienced in recent years would increase the cost advantage of rail).

The study shows that relationship of costs of the two modes varies with assumptions about interest rates, types of financing and a number of other factors. Yet, light rail shows a cost advantage for the studied line with daily ridership of 37,800-58,500 for most realistic sets of assumptions. Only for the combination of all assumptions being least favorable for rail the bus gets a small advantage. Consequently, based on these detailed analyses, the study concluded that light rail is advantageous with respect to both quality of service and total cost.

3. Financing Methods

In most European countries the costs of major structures and facilities (tunnels, viaducts, stations) are not charged to light rail (or any other mode for that matter) since they are constructed by the city as a transportation right-of-way. This policy is based on the same principle as the policy toward other modes: costs of streets and highways in the cities are not transferred directly to the users either.

Yet, financing of transit, and particularly major investments required for private right-of-way facilities, is a difficult problem in most countries. Discussions of the problem are long, and the approval of funds is usually made 10-15 years later than provision of such facilities would be justified on the basis of the traffic conditions and the need for improved transportation services. Nevertheless, a number of West European countries are well ahead of the United States in this respect and their resources directed toward improvements of public transportation have been much greater than those made available in our cities.

In smaller countries financing is dependent on special actions of the central government toward individual cities. For example, in Belgium the government decided to separate five large cities (Brussels, Antwerp, Gent, Liege and Charleroi) and finance transit improvements in those cities directly from its resources. These improvements include the subways in Brussels, Antwerp and Gent, which have been either constructed or approved for construction.

In contrast, West Germany is much more similar to our country because of the great number of cities, the federal structure of the country and the distribution of financing among different levels of the government. Their solution of the problem is worthy of careful consideration. A committee of transportation experts appointed by the German Federal Government in the early 1960's submitted a report in 1964 which strongly recommended well formulated specific policies on urban transportation with a major attention given to transit. Based on these recommendations, the government decided to divert a part of gasoline tax receipts to the improvement of urban transportation. At the present time out of the total gasoline costs of 60-65 Pfennig/liter (approximately 70¢/gallon), federal taxes amount to 38 Pf for gasoline and 33 Pf for diesel oil (55-58%). Out of those taxes only 3 Pfennig are earmarked for <u>urban</u> transportation financing; this amounts to approximately $300-million per year. Forty-five percent of this amount goes to public transportation and 55% to streets and highways in <u>urban areas</u>. This 45%, or some $135 million, represents the federal share of the capital investments in public transportation which has to be matched by a composition of state and city contributions, usually amounting to 30%-20%.

Introduction of this financing several years ago caused a major change in urban public transportation: widespread development of light rail and rapid transit facilities began, and it continues at an intensive pace. At this moment 15 cities in the German Federal Republic are constructing rail transit facilities. The positive results of these efforts are only beginning to be felt. Most of the cities will open the first sections of their underground facilities in city centers in the coming years. So far, Hamburg and Berlin have opened a number of lines, while short sections of light rail systems are in operation in Frankfurt, Cologne, Stuttgart, Essen and Bielefeld.

It appears that much can be learned from the method adopted in Germany. At this time in the United States intensive discussions about the diversion of present gasoline taxes are under way. However, the fact is overlooked that these taxes are much lower than gasoline taxes in other countries and have been stagnant for many years. A relatively small increase should not be objectionable to consumers, and it could lead to extremely significant changes and probably reversal of present deteriorating conditions in urban transportation in general, including both transit and automobile facilities. The fact that automobile users presently pay approximately 10 times more for their private vehicles than for the public components of the same system (streets, highways, parking, public transportation) shows the serious deficiencies of our present methods of financing in transportation.

IV. PRESENT LIGHT RAIL APPLICATIONS

A review of cities utilizing light rail transit and an analysis of their characteristics pertaining to this mode will be made in this chapter. The review will serve as a basis for evaluation of light rail and its potential applications in U.S. cities.

It should be emphasized at the outset that an analysis of characteristics of different cities and their transportation systems is a complex task which can give only general conclusions. Population, density, form and character of the city are relevant, but there are also such factors as economy, cost structure, societal values. Some of the most important factors will be discussed here.

The analysis will be made of the cities which have pursued a progressive urban transportation policy leading to a modernization of their transit systems. Cities which have neglected transit are excluded since it is considered useless to analyze obsolete systems. The review will therefore focus on the countries and cities which have modern transit.

A. CITY SIZES AND DENSITIES

In small cities rail transit has been replaced by the bus mode due to the greater economy of the latter for low passenger volumes. There are presently few cities with populations under 150,000 which utilize rail transit. However, most of the conversion of lightly traveled lines to buses has been completed and most cities which now have rail systems intend to maintain, upgrade and in some cases extend them into new suburban developments. As mentioned in Chapter III, several cities have built such extensions in recent years. For example, in Bern, Switzerland extension of an existing rail line and conversion of a bus line to light rail are planned. The new lines will be placed nearly exclusively on private rights-of-way. Figure 2 shows a light rail extension to a new suburban area in the northern part of Rotterdam. Construction of subways for light rail is under way mostly in larger cities (Cologne, Frankfurt, Brussels, Stuttgart), but it is not limited to them. Bielefeld, with a population of only 170,000 (metropolitan area 284,000) opened the first section of its light rail subway in 1971; a similar facility is under construction in Bonn (400,000).

At the other end of the city size range, very large cities gradually replaced surface rail lines by rapid transit. If a number should be given for the upper limit of the city size for surface rail operation, it would approximate two million. However, there are some exceptions to this: light rail with high technical standards is also operated in larger cities (Riverside Line in Boston). Severe climate makes light rail more reliable than buses and increases their use (Soviet cities, including Moscow and Leningrad).

For several decades it was considered that a city should have at least a population of one million to justify construction of rapid transit. However, in the United states some newer cities with populations as high as 5-6 million, but with very low densities, rapid motorization and, above all, complete neglect of transit, do not have any rail transit - or any adequate transit for that matter. In contrast, the trend in Europe has been to plan and build rapid transit even for cities well below one million population (Lisbon - 900,000, Stockholm - 800,000, Oslo - 450,000), because of increasing street congestion and need for reliable, high capacity transportation.

Despite this increasing need for high quality rapid transit, its extremely high investment cost remains the major barrier in European as well as U.S. cities. Consequently, most medium cities have been actively searching for a transit system which

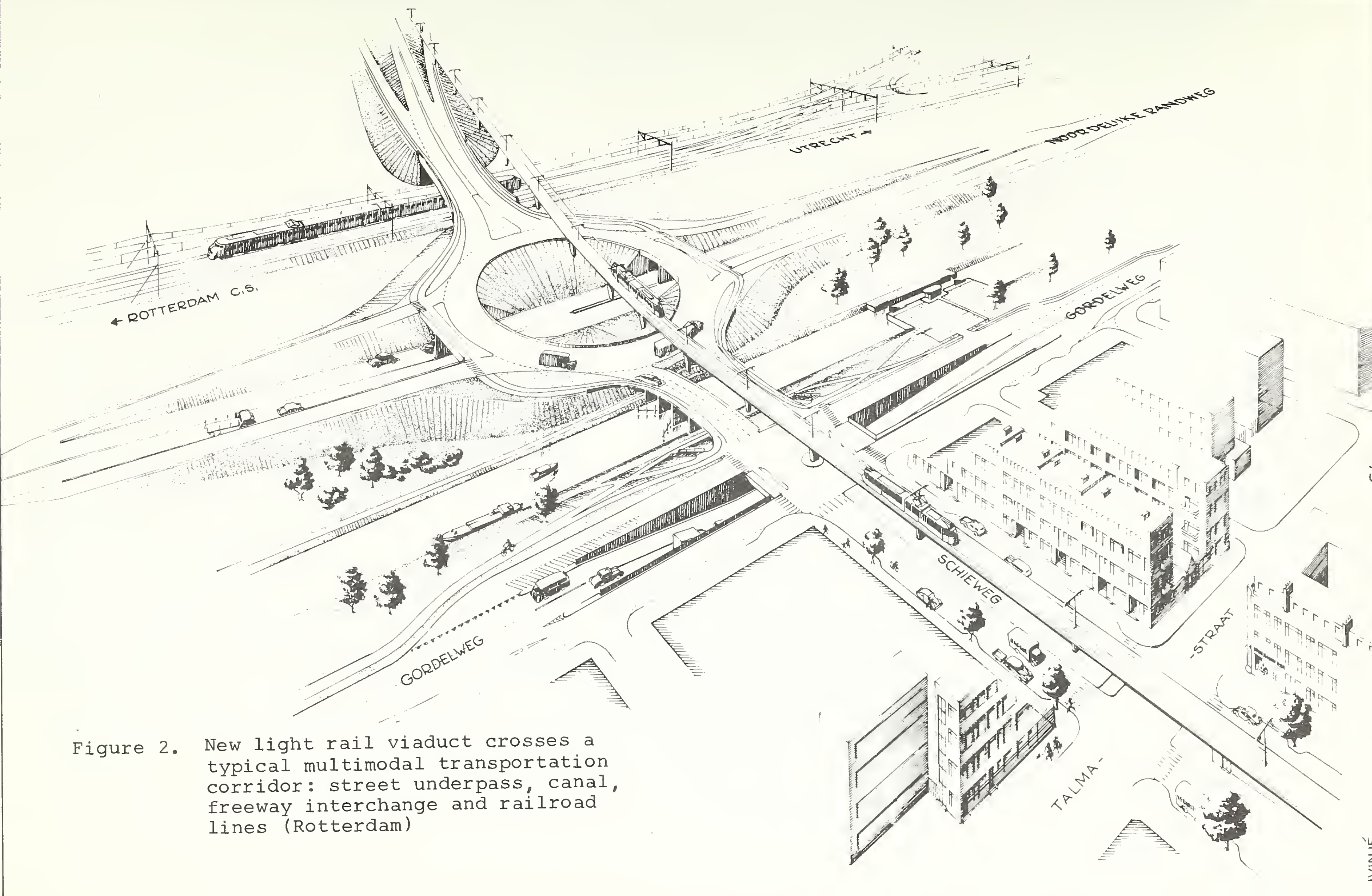


Figure 2. New light rail viaduct crosses a typical multimodal transportation corridor: street underpass, canal, freeway interchange and railroad lines (Rotterdam)

would have a higher level of service than surface streetcars and buses, but a lower investment cost (and somewhat lower level of service) than rapid transit. In many European cities light rail has proved to be the optimum mode for this role, and it is presently under intensive development. In the United States the need for balanced transportation is recognized, but no city of intermediate size has positive, tangible plans for a modern transit system.

It is often believed that U.S. cities cannot support good transit services because of their low population densities. In some studies tables have been made comparing densities of U.S. cities with "foreign" cities. The latter ones give a higher average, but the list usually includes Asian and South American cities (Calcutta, Bombay, Rio de Janeiro) which, naturally, heavily influence the average toward higher density. The analyses of West European cities, however, show that the differences are not great at all. As the figures in Table 2 indicate, the selected cities typical for those utilizing light rail have densities of 8-10,000 persons/mile^2 (with the exception of Gothenburg which has only 3,250), which is quite comparable with a number of U.S. cities. According to the 1960 census, for example, there were 23 cities in the U.S. with densities above 10,000 persons/mile^2. Thus the basic structures of the cities are not as drastically different as often believed.

An interesting comparison of Toronto with Hamburg has been made by Blumenfeld*. He shows that the sizes and densities of both cities are strikingly similar. Yet, the transit riding habit is much higher in Hamburg than in Toronto. The reasons for this may be:

1. Greater density of individual corridors in Hamburg.
2. Later occurrence of high motorization.
3. Better transit service, provided at the early stages of automobile ownership and constantly improved.

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*Reference 2.

The latter two reasons would probably tend to make any transit system somewhat less successful here than in Europe. Yet, based on the experience from individual transit improvements in different cities, it is certain that the introduction in U.S. cities of modern systems similar to those in Europe would significantly increase transit patronage.

B. LINES, NETWORKS AND TYPE OF SERVICE

Light rail has the advantage of lower direct operating cost and higher capacity than buses. Yet, it is in most cases utilized not so much for these reasons as for the fact that it provides a higher level of service and attracts more passengers. Therefore in cities which use it as the basic mode light rail serves not only the heaviest volume lines, but also some branch lines carrying only 3-4,000 persons/day/direction. Thus the network functions as a single system and provides adequate collection-distribution in suburban areas.

The networks are basically radial, but some crosstown lines also exist. The lines weave in the center for better area coverage. In Hannover (Figure 3), the planned network will consist of four basic through lines with not more than two branches on each radial. Frankfurt (Figure 4) has a greater number of connections among lines. At present three of the through light rail lines operate jointly with a rapid transit line, branching into two lines on the south and four lines in the north. A number of cities have been operating up to five-six branches from one line: Cologne, Brussels, Philadelphia, San Francisco. Currently, a new concept is being studied for San Francisco which would provide a high-speed operation on the trunk line even during the peak hours by coupling the cars from different lines at the points of convergence (this operation has been applied at small scale (2 lines) in Gothenburg).

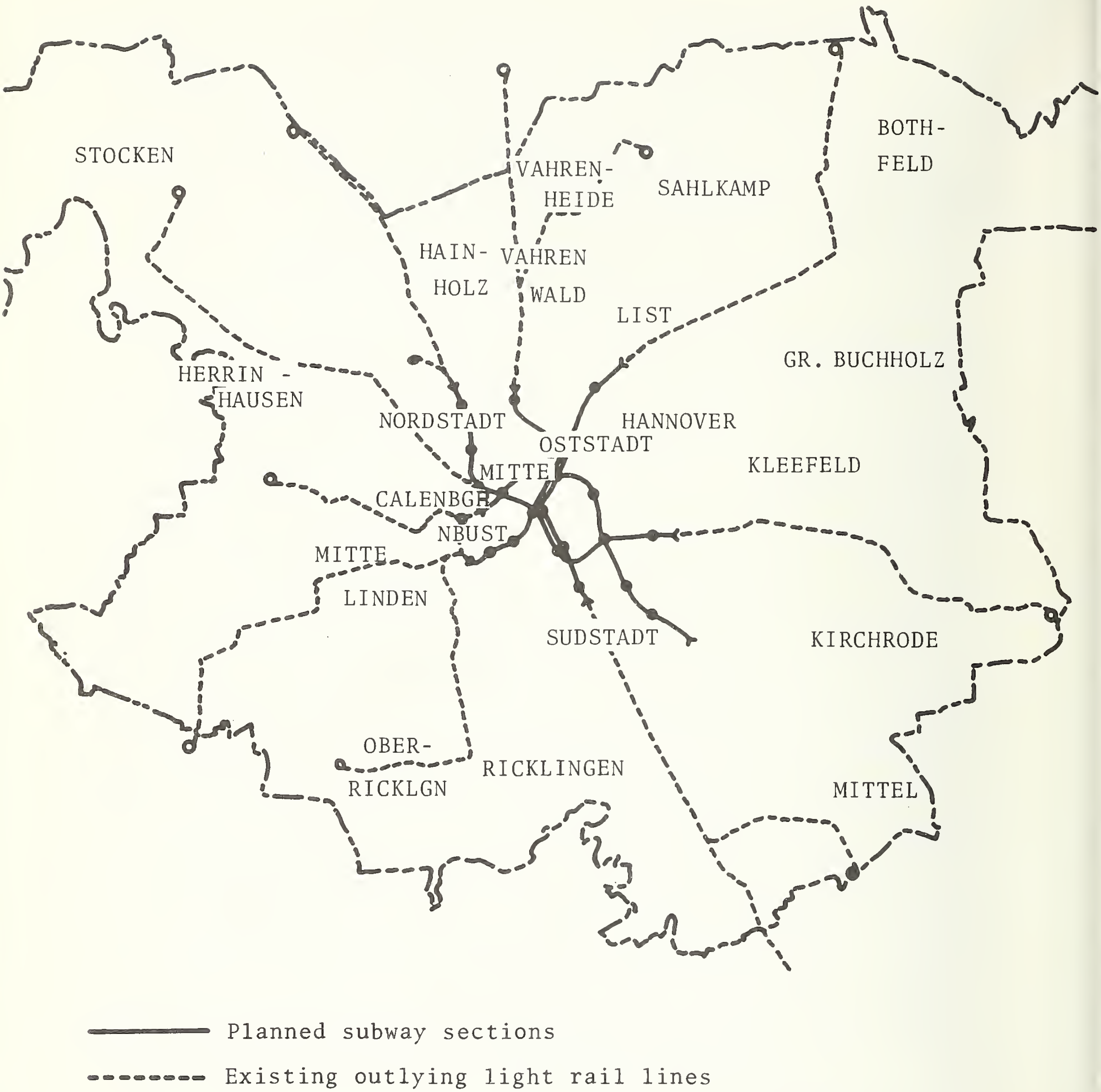


Figure 3. Planned Light Rail Network in Hannover

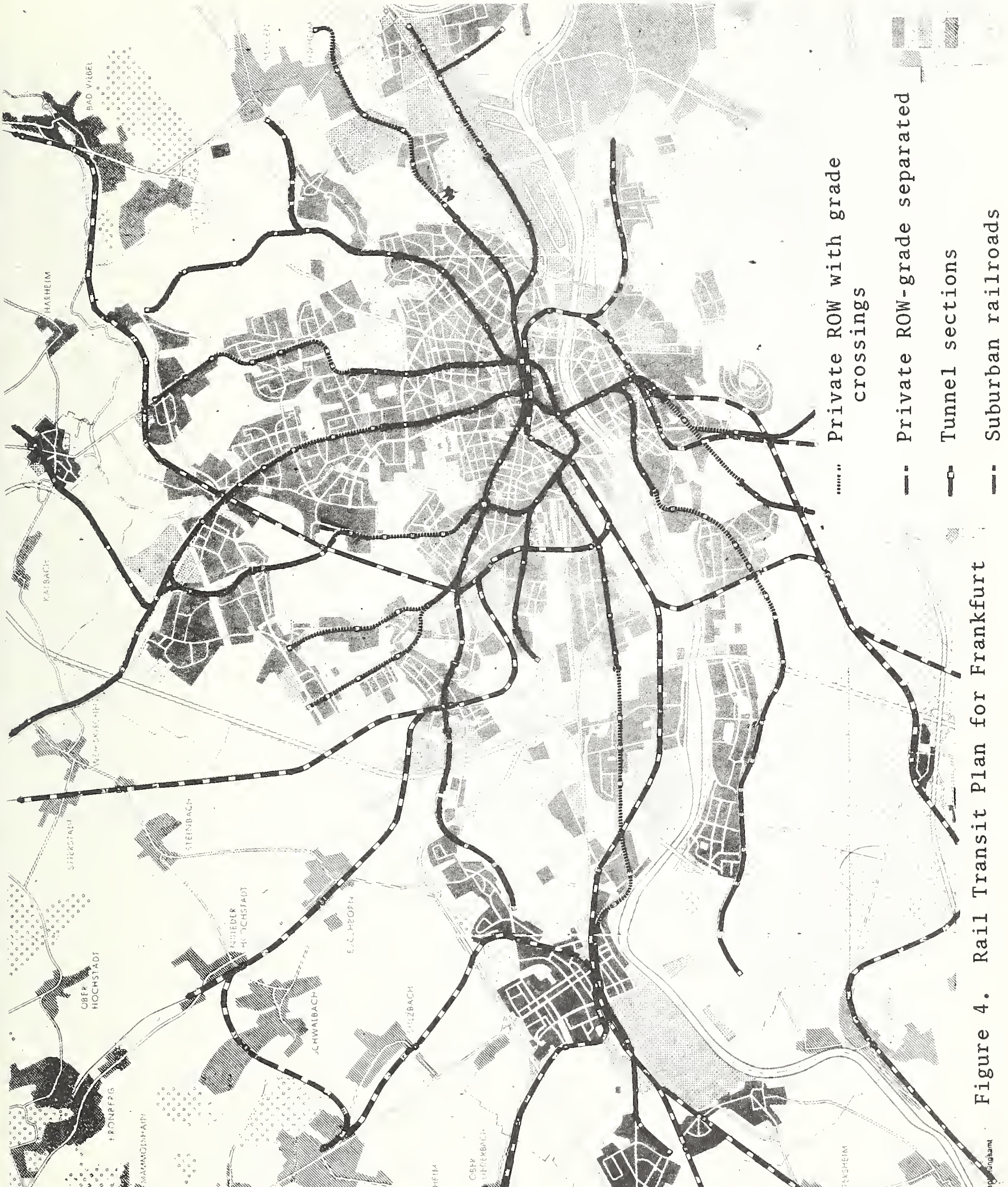


Figure 4. Rail Transit Plan for Frankfurt

Figure 5 shows the Cologne Cityrail network in the immediate future (1974). Gradual separation of lines from other traffic is very clearly shown. Figure 6 shows consolidation of lines into the new Cityrail tunnels in the central area of that city. Figure 7 shows two typical network configurations in city centers (Stuttgart and Ludwigshafen).

All these cities utilizing light rail visualize eventual gradual transition to rapid transit and most of them are constructing new lines with corresponding characteristics. However, they do not intend to introduce rapid transit immediately since it would result in "cutting off" branches and require transfers to feeders, inconveniencing the passengers. This transition is therefore often in the distant future.

As is apparent from these illustrations, from variable speeds shown in Figure 1 and from the photographs, light rail does not represent a single type of system: its characteristics vary widely and give it flexibility of use with a number of different sets of conditions.

C. RELATIONSHIP WITH OTHER MODES

There is no doubt that competition of the private automobile in Europe - as in the U.S. - is very severe. Improvements of streets and highways were carried out in most cities prior to the major improvements of transit systems, so that a significant portion of passengers have been lost to the automobiles.

A more favorable element in European cities is that freeways have not been constructed as extensively for intraurban travel as has been done in most of our cities. This advantage for transit is at least partly offset by the fact that regulation of traffic in some European cities is appreciably better than in the U.S. Several European countries have now more modern traffic engineering and better highway and street design and maintenance than the U.S. cities. - Parking supply

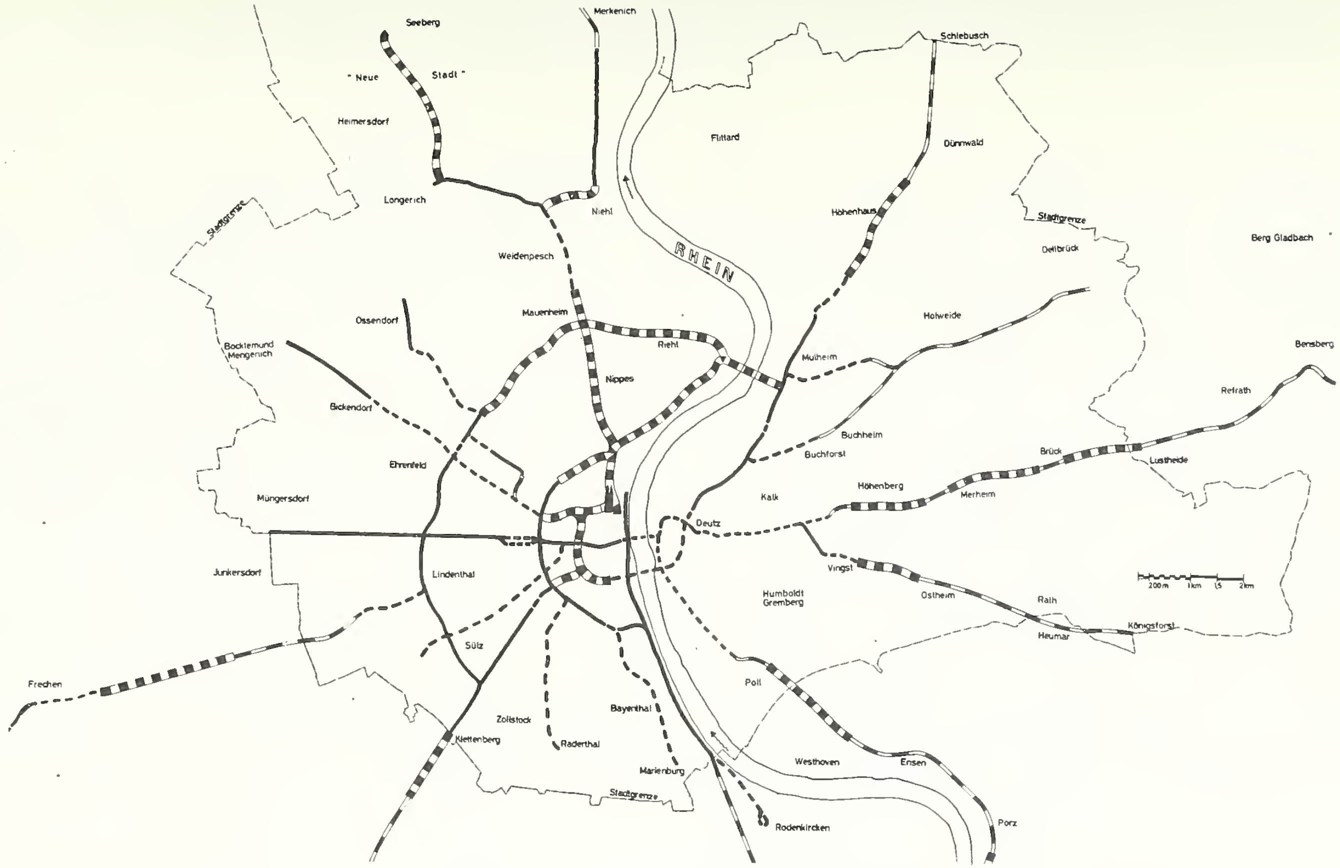


Figure 5. Types of Rights-of-Way in Light Rail Network in Cologne: Plan for 1974

In Street Pavement

Private ROW in Street Medians

Independent Private ROW with Protected Crossings

Private ROW without Crossings (Tunnels, Viaducts)

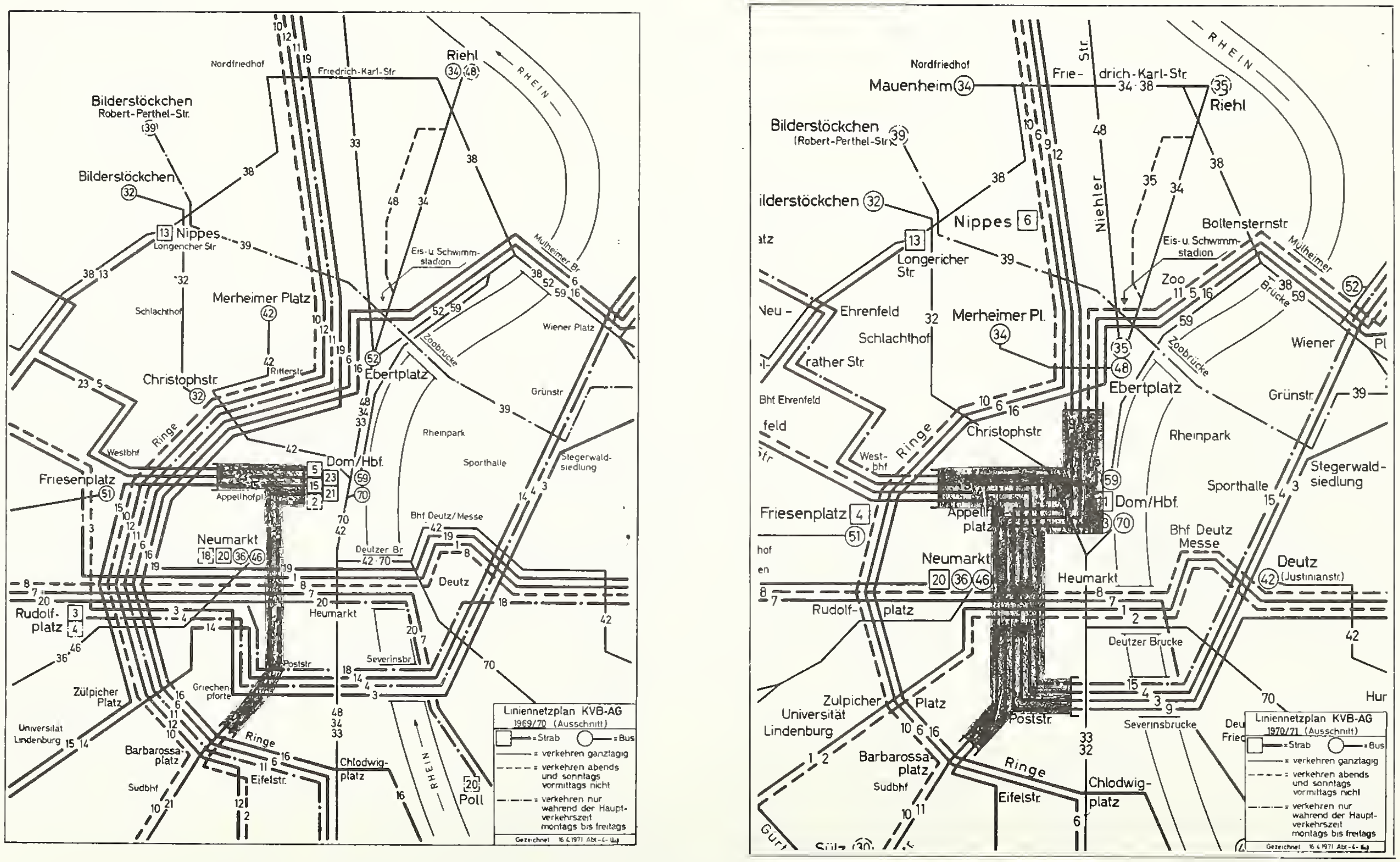
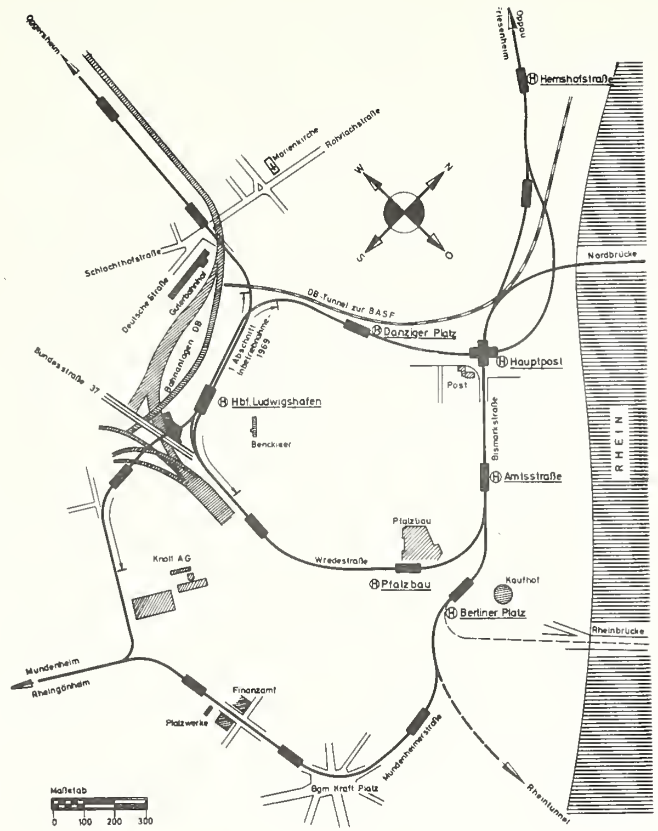
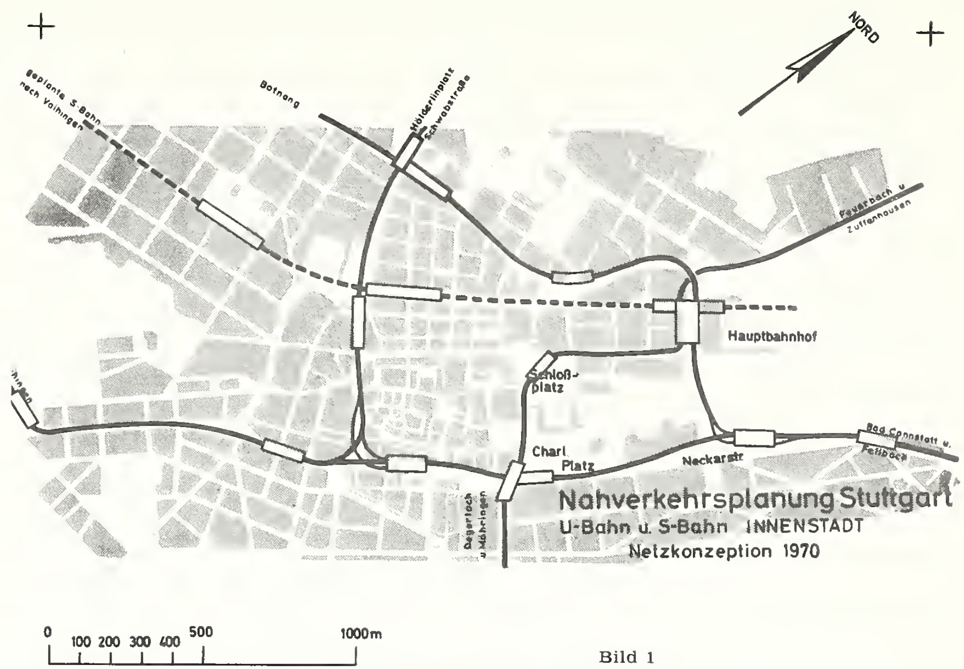


Figure 6. Line Arrangement in Central Cologne before and after the Completion of Light Rail Tunnels in 1970



Ludwigshafen



Stuttgart

Figure 7. Planned Light Rail Networks in City Centers

varies; in some cities it is limited; in others, it is ample: Rotterdam has 26,000 spaces in its central area.

Park-and-ride is being gradually introduced in some cities. Acceptance of it is rather slow, but the experts agree that it will increase when drivers mature with time (the automobile is considered as much as a prestige element and favorite toy as it was considered here in the early 1950's), and when transit systems, through separation currently under construction or in planning, provide decisively faster and more reliable service.

Buses serve the lower-volume lines in the city, to some extent as feeders to light rail, and for long-distance regional routes. They do not duplicate light rail on any of the main lines.

Light rail is sometimes feeder to rapid transit (Rotterdam). The two modes are, however, in most other cases planned as different stages of development of the same system.

D. AUTO OWNERSHIP, PASSENGER CHARACTERISTICS AND TRENDS

Automobile ownership figures in Table 2 show that European cities have reached the level of motorization typical for U.S. cities: 3.0 - 5.0 persons per vehicle. According to recent data* 79% of American families own one or more automobiles; this number, however, varies among areas from 88% for suburban areas of the largest 12 SMSA's to 54% in their central cities. The latter corresponds to the range of 4-6 persons/car. In the Philadelphia Metropolitan Area auto ownership in the late 1960's was 3.5, i.e. very similar to those of Stuttgart, Gothenburg and Bielefeld.

As mentioned in the preceding section, a certain number of transit riders in European cities have been diverted to the automobile and it is difficult to attract them back to transit. Yet, the riding habit remains rather high compared with the U.S. cities. It is interesting to compare the automobile ownership/transit riding trends in the U.S. and, for example, West Germany.

*See reference 1.

During the period between 1960 and 1970 the number of motor vehicles in West Germany increased from 8,004,000 to 16,783,000, i.e. it more than doubled. During that period the total number of transit passengers decreased from 5,2 to 4,5 billion, or 13%. If this is compared with a period during which the number of motor vehicles in the U.S. doubled - for example, 1950-1967 (48.6 to 95.5 million) - statistics show that transit riding decreased from 17.2 to 8.2 billion, or by 53%! Despite the rough nature of this comparison, the difference is drastic. In addition, the decline in transit riding in Germany, which started in 1962, was reversed in 1968 and the last three years have recorded increases. Although there are many physical, economic and social differences between the U.S. and some European countries, it is quite clear that the basic policy toward urban transportation - improving both, public and private modes in a coordinated manner - has already shown distinctly positive results and it is leading toward a stable situation in urban transportation. This deserves a careful study by city authorities in this country who are presently searching ways out of our very serious urban transportation crisis.

Incidentally, placement of the light rail lines on private rights-of-way is not the only method of separation among modes and specialization of streets. In many cities certain downtown streets have been converted into pedestrian areas: various parking restrictions have been applied. The most interesting solution for the whole central area, however, has been so-called "Bremen System." Gothenburg is one of the cities which adopted it: its central area has been divided into five zones, surrounded by an arterial. The zones are delineated by several main streets which automobile traffic cannot cross. Light rail lines follow these streets, so that they are free from cross traffic (see Figure 8). Thus all through traffic in the center has been placed on the ring road and the local streets are freed for local access and internal travel only. Congestion in the central area has been virtually eliminated. The inconvenience to automobile drivers is not great, although taxi drivers dislike circuitous routing for their short trips. Transit speed and reliability have been significantly improved, and pedestrians enjoy several streets converted to pedestrian malls.

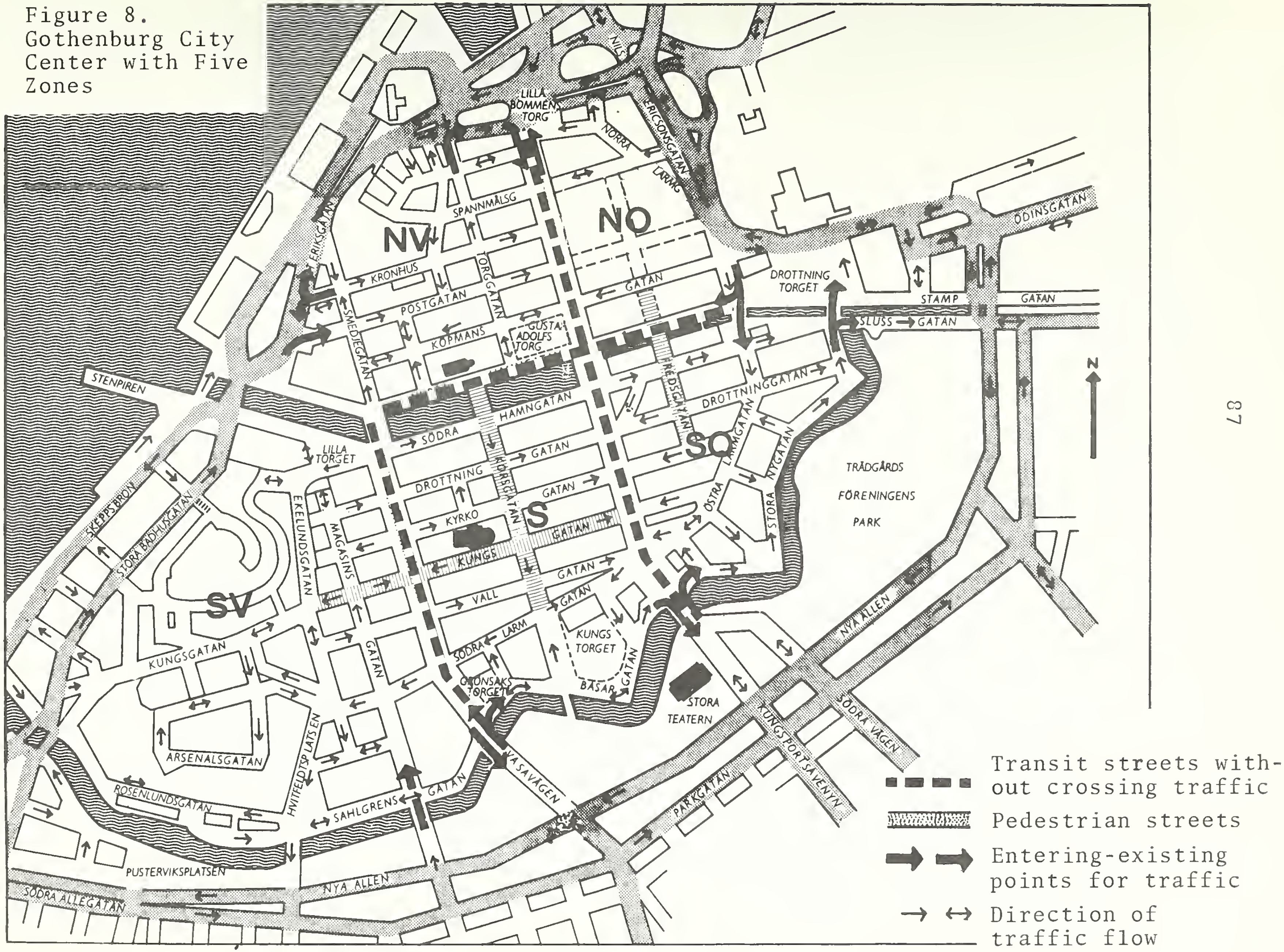
Gridiron street networks, typical for American cities, are particularly convenient for low-cost improvement of transit services through partial separation. Instead of uncontrolled use of every street for private automobiles, transit, deliveries, etc. (which is still common practice in many cities), resulting in inefficiency for all modes, parallel streets should be utilized alternatively for individual purposes. For example, a street with a 30-35 foot wide pavement can provide exclusive transit lanes and accommodate the required deliveries. Intersection control favoring transit vehicles would further reduce delays and secure reliable, fast transit service. Elimination of transit vehicles and stops from other parallel streets would, in turn, improve flow of automobile traffic on them.

The greatest obstacle to introduction of this type of arrangement is opposition by individual groups and difficulty of achieving cooperation of transit company, city traffic authorities, police department and others. Yet, compared with physical and administrative difficulties of constructing a new major facility through an urban area, this should be in most cases a relatively easy task.

E. PLANNING OF NEW LIGHT RAIL SYSTEMS

Light rail systems often suffered from identification with the old-type streetcar or tram systems. Now that this poor image has faded away under excellent experiences with modern

Figure 8.
Gothenburg City
Center with Five
Zones



light rail systems, this mode appears to be getting a more unbiased appraisal based on its technical merits. As already mentioned, several cities with these systems have, or are planning to construct extensions of their lines. In recent years, however, several cities in countries which do not have modern light rail presently in use have included that mode in their transit planning, and reached conclusions which are very favorable for it.

In their study for Sheffield, England, Constantine et al* suggested a light rail system as the most promising mode for providing a high type of public transportation with realistic financial expenditures.

At the end of 1971, the results of the North Tyne Loop Study for improvement of public transportation in the area of New Castle, England, were announced. The Study, performed by Alan M. Voorhees and Associates, Ltd., for the Tyneside Passenger Transport Executive, considered four alternatives: Upgraded existing railroad service, Busway (discontinue rail service and utilize portions of the line for busways), All-bus (buses on existing streets) and Light rail ("Light rapid transit") - substitute electric light rail equipment for the existing service. The fourth alternative - light rail - has been found superior to the first three. Implementation plans for this study are not known at this time, however.

By far the most detailed transit study in a U.S. city which included a light rail system is the plan for Henrietta-Charlotte line in Rochester, New York. The study recommends the light rail over a busway system on the basis of superior performance and lower total cost.

Finally, there may be another major potential application area for some types of light rail systems. A number of cities in the developing countries have a very serious transportation

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*Reference 4.

problem. Good examples are Cairo, Istanbul, Tel Aviv, Tehran, Bangkok, Seoul, Manila and a number of other African, Asian and South American cities. Their populations have soared in recent decades and their densities are high. Yet, many of them have only buses or old-fashioned streetcars for public transportation. Traffic congestion frequently brings all movements in city streets to a standstill. Many of these cities are considering or planning construction of rapid transit systems, but few have realistic chances to secure the necessary financial means in the foreseeable future. It would appear logical that these cities very carefully consider different types of light rail systems as a means for introduction of higher-performance transit in a short run, while providing the option for gradual transition to very high capacity, high speed rapid transit when conditions permit this. Light rail may be in many cases the best, or the only way to make a significant improvement in urban mobility of these cities at a realistic cost.

P-62. Congested cities: cars penetrate even sidewalks (Belgrade)

P-63. Street converted to exclusive pedestrian use (Gothenburg)

V. COMPARISON WITH OTHER MODES

Comparison of different transportation modes is a complex task because the levels of service (including passenger attraction capability) vary among them. Comparison on cost basis, which has frequently been done, can be particularly misleading. In this Chapter a comparison of light rail with other modes will be made on the basis of the main parameters of transit modes.

A. LIGHT RAIL AND BUS

Briefly summarized, in comparison with buses light rail has the following advantages (+) and disadvantages (-):

+ Higher transporting capacity: on the same right-of-way with the same safety and reliability of service, a typical modern light rail line can transport approximately 2-3 times more passengers than a typical bus line.

+ Larger and more stable vehicles provide easier passenger movement.

+ Higher riding comfort (especially for standees).

+ Lower noise levels.

+ No exhaust fumes.

+ Greater reliability (e.g. inclement weather).

+ Higher acceleration rates.

+ Better image and passenger attraction.

+ More durable vehicles, easier to maintain.

+ Operates in tunnels, viaducts or any other right-of-way without exhaust and safety problems.

+ Requires narrower right-of-way (positive guidance).

+ Capable of gradual transition to rapid transit.

- Higher investment cost.

- Less compatible with other traffic: creates problems in street operation.

- Lower flexibility of operation. Cannot be easily relocated - temporarily or permanently; the vehicles cannot be used for off-line charter, etc.

- Less convenient for low density collection-distribution.

- Less frequent opportunity for modernization due to the longer life of vehicles.

It should be emphasized that this is a comparison of the latest types of vehicles and related equipment (including rights-of-way) for both modes. Such comparison of the two modes in U.S. cities is not presently possible since rail systems do not have modern vehicles and equipment.

It is obvious from the above items that with the exception of network density light rail can offer in many situations superior service to passengers compared to that of buses, but some of its features are less desirable for the operator. In a difficult financial situation the operator tends to select the system which involves minimum cost in the short run, often at the expense of the level of service. This was one of the main reasons for abandonment of rail services in many cities even where they had private rights-of-way. Another reason, quite valid, was the incompatibility of rail vehicles with other traffic in the streets. However, the extremely high value given to the so-called "flexibility" of buses was greatly misunderstood. As pointed out in a recent paper analyzing the concept of flexibility*, buses can use path flexibility for temporary re-routings, but they seldom can use it for permanent changes in the network of lines since such changes do not occur often. "Flexible scheduling" is an attractively sounding concept which does not have any significance in standard transit operations: line-haul service should provide for passengers permanent ("inflexible") scheduling which can be memorized easily.

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*See reference 18.

Another strong factor used in favor of buses over rail transit is that buses can mix with other traffic. This is a fact, but that is a laudable feature only if it is desirable to mix the two modes. It has now become increasingly recognized that, as pointed out earlier in this report, mixing of transit with other traffic is the strongest factor causing its deterioration. At the time of total neglect of transit taking of special lanes by rail vehicles was used as one of the strong arguments against that mode. Now special bus lanes are being introduced in some cities, bringing significant improvements to their operations.

How do the latest trends affect the relationship between buses and light rail? The relevant factors are:

+ The greater weight given to quality of service and minimum negative impact is favoring light rail;

+ Acceptance of desirability of private rights-of-way for transit is in favor of light rail.

+ The policy which has been increasingly applied in recent years - that fixed transit facilities be financed by different levels of government - allows introduction of modes which are optimal in a long run rather than on the minimum investment basis, and thus represents a major factor in favor of light rail.

- Price of rail vehicles has been increasing much faster than that of buses: a minus for the light rail system.

- Lowering of urban densities and particularly growth of low density suburbs makes bus services in such areas more economical.

In conclusion, for heavier-volume lines which justify fully or partially separated rights-of-way light rail is definitely superior to buses, its significance for high-performance lines is being increasingly recognized. However, operation of rail vehicles in mixed street traffic should not be planned for the future. Where it now exists, various methods of relocation or special regulatory measures separating transit should be introduced to improve operation of both transit and traffic. For lower-performance, light-volume services, buses are superior to light rail.

B. LIGHT RAIL AND PROPOSED SYSTEMS

Among the numerous proposed transportation systems only those which are functionally similar to light rail can be compared with it. These are the line-haul systems of "intermediate" level of service, such as the Railbus, the Transit Expressway and other automated systems.

Railbus service advantage over buses is that railbuses can run on rail rights-of-way. However, the technology of this mode is not completely developed so that it cannot be considered operationally proven at this time. In addition, the advantage of "no transfer rides" which railbus has over standard buses can be much better matched by light rail than by rapid transit.

Compared with the Transit Expressway and other similar fully automated systems, light rail has the following characteristics:

+ Very significantly lower investment cost;

+ Possibility of gradual introduction of individual sections without interruption of the existing rail service;

+ Vast experience and perfection of all system components;

+ Full compatibility with rapid transit and other high capacity modes;

Analyzing carefully all the proposed systems one can see that there is no system which is truly competitive with light rail, since most systems either offer different cost/level of service packages (buses - lower; fully automated systems - higher), or functionally do not serve the same types of operations. For example, Dial-a-Ride demand-responsive system can probably be efficient only in very low density areas. In the spectrum of transportation systems it falls to the "other side" of buses than light rail. The Transit Expressway does fall between light rail and rapid transit, but it suffers from the above listed characteristics, particularly the much higher investment cost than light rail (demonstrated so clearly in Pittsburgh), and uncertainties about its full automation. However, potentially higher reliability of service (as a result of eventual automation) and lower labor costs may become significant advantages of the system.

C. LIGHT RAIL AND RAPID TRANSIT

The main advantages of light rail in comparison with rapid transit are its much lower investment cost, larger network and better area coverage, and possibility of gradual development. Rapid transit, on the other hand, has lower operating cost, potential for full automation, and higher level of service. Thus, the trade-off between the two systems is, in simplified terms, between the lower cost, sooner operation and more direct (no transfer)service of light rail, and the higher level of service and lower operating cost of the rapid transit.

In cities which have the size and density sufficient to support rapid transit, that mode is the logical choice; in medium-sized cities, however, the logical choice for main lines in many cases should be light rail. In some U.S. cities most of the improvement expected from a planned rapid transit could be obtained through the use of light rail at a substantially lower cost and much sooner. Yet, the option for eventual transition to rapid transit would remain open.

The reason that most medium cities in Europe which intend to eventually have rapid transit are presently buying fleets of new light rail equipment (which will be used for at least 25-30 years) is that a change to rapid transit in the immediate future would result in cutting off of many branch lines and converting them to buses with transfers to rapid transit, a major inconvenience to passengers. Figures 9 and 10 illustrate this problem: the first one shows a typical line configuration of light rail and rapid transit/bus combination. The second indicates the total "costs" or disutility of a trip (including travel and transfer time, inconvenience, etc.) as a function of its length. The slopes of costs for each of the three modes vary, of course, with local conditions. The "cost" of transfer - or time loss and inconvenience caused by it - is also variable, but it is usually of appreciable magnitude. Although not many data on this are available, it is known that a certain number of passengers will not use transit if a transfer exists (e.g. the mentioned dramatic increase of passengers due to provision of direct service in Bielefeld).

In conclusion, rapid transit should preferably be built:

- In very high density corridors;
- As additions and extensions to an existing rapid transit network;
- For lines which would be built with full grade separation on the whole length regardless of the vehicles to be used.

Light rail should preferably be built:

- For intermediate passenger volumes;
- On lines where partial private right-of-way is available (e.g. a railroad spur), while other sections can be placed in street medians, parks, etc.;

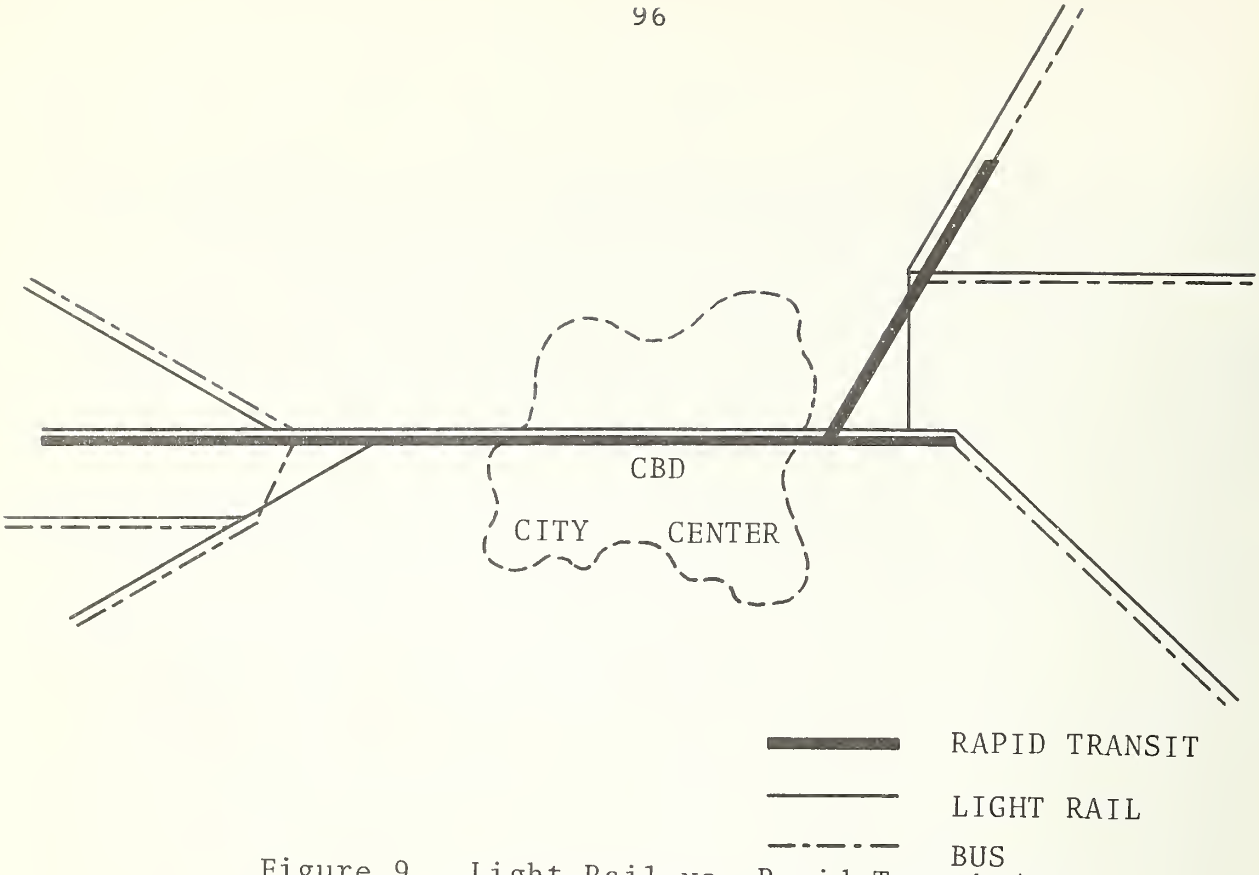

Figure 9. Light Rail vs. Rapid Transit/Bus - A Typical Network Configuration

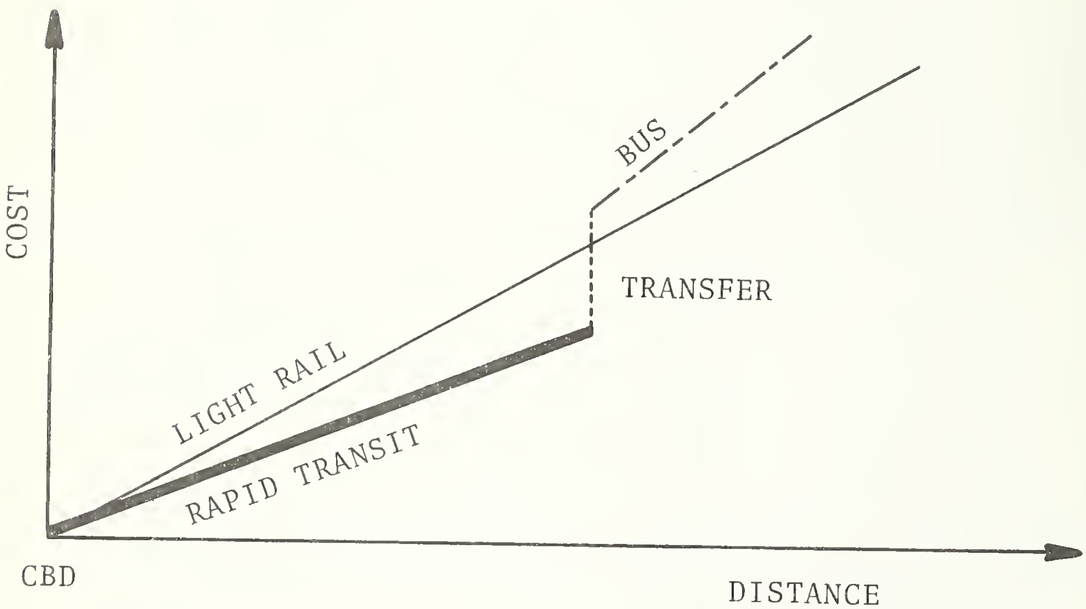

Figure 10. Light Rail vs. Rapid Transit/Bus - Travel Costs

- For lines which serve new urban areas with growing potential but presently have volumes below these justifying rapid transit;

- In areas where several corridors converge into a small number of trunk lines;

- In cities which need higher level of transit service than buses can offer, but which cannot finance rapid transit systems.

P-64. Elevated section of a new rapid transit line (Rotterdam)

P-65. Modern European standard bus (Hamburg)

VI. EVALUATION OF THE LIGHT RAIL SYSTEMS AND THEIR POTENTIAL FOR NORTH AMERICAN CITIES

Based on the preceding light rail description and its comparison with other systems, a general evaluation of the light rail system will be given and its potential use in North American cities will be analyzed.

A. LIGHT RAIL EVALUATION

As an "intermediate" system - between buses and rapid transit, capable of transition into the latter - light rail has all the advantages and disadvantages of such systems. It has superior features for intermediate cost, quality of service and capacity. However, the problem of the system is that it often enjoys few supporters because of the tendency of authorities (including many professionals) to polarize themselves into those who are for "simple" and "flexible" solutions with buses (tending to neglect the deficiencies in the level of service that buses can provide) and those who believe that the "final" or "clean" solution with rapid transit is optimal (regardless of the cost).

Among the cities which were considering upgrading their streetcars into light rail but later decided to build rapid transit, the wisdom of this choice is sometimes discussed. Typical opinions expressed are that, in this perspective, the choice of rapid transit was the correct one. - There is no doubt that it is now better to have a rapid transit rather than a light rail line. However, comparison of these alternatives is erroneous. The question should be: is the existing one rapid transit line better than three to four light rail lines which could have been built for the same cost, so that the city would have had a network of lines with slightly lower type of service?

Several cities (Seattle, Los Angeles) have had their rapid transit proposals with estimated costs of $0.5-2.5 billion, rejected by the voters. It is possible that light rail with its lower costs would have been accepted, and the system - or at least major parts of it - would have been in operation for several years by now. The question in these cases is, therefore, probably: is it better to have rapid transit plans, or light rail in operation?

On the other hand, there are examples of excessively conservative planning based on minimum investment policies which may have appeared wise under given financial constraints, but which are soon recognized as mistakes. An example is the extension of tunnels for subway-surface cars built west of the Schuylkill River in Philadelphia during the 1950's: the alignment of these tunnels is very restrictive at several places even for old-type streetcar operations. The most restrictive points have thus been built into the most expensive structure on the line. Another type of mistake is to "optimize" individual sections of lines; sometimes rail lines are truncated and their branches converted to buses. This defeats a major advantage of the light rail: a continuous network. Ideally, its branch lines should be continued with the growth of the city. Rights-of-way for the extension should be reserved at the time of planning of the suburban developments.

Analyzing a light rail system in a rational way and introducing the relevant pragmatic factors, one can briefly summarize the characteristics of this mode as follows:

1. <u>The Advantages</u>

The main advantages of the light rail mode are:

+ A considerably higher level of service than buses.

+ Investment cost much lower than the cost of rapid transit.

+ Due to the lower initial investment, light rail can be built sooner than rapid transit systems and can later be gradually upgraded.

+ Transition to rapid transit is possible and easy.

+ Popularity with passengers is very high; generates more transit riding than buses.

+ Transporting capacity is adjustable (through variations in vehicle size, composition of trains and frequency of service), so that there is little unused capacity of the lines. Investment is well utilized at each stage of system development.

+ Light rail can have a variety of technical and functional characteristics which allow it to be used for many different services rather than under one exactly specified set of conditions.

2. The Disadvantages and Barriers

The main disadvantages of the light rail are:

- Requires a significant investment, particularly where the mode does not presently exist; therefore it is not suited for low volume lines.

- Provides service which is subject to more irregularities than rapid transit.

- Fixed lines prevent easy changes of alignment which may be desirable, for example, in the parts of the city which are being developed, or in renewal areas.

Obviously, as an intermediate system between buses and rapid transit, light rail has disadvantages in comparison with one or the other. However, the most serious barriers to its introduction in cases where it would be the best choice from technical, economic and functional points of view are:

- The belief that rail modes are "obsolete" and "flexible" systems are modern. This belief is neither based on fact nor on clear concepts,* but it exists, particularly in this country.

- Compared with rapid transit, light rail has the stigma that it is not "real rapid transit", that it is a "lower" type of system and that large, modern cities should have a "metro."

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*See reference 18.

This is also a strongly rooted prejudice which sometimes leads to technically and functionally non-optimal solutions: either to the application of rapid transit where it is economically inferior to light rail, or to a failure to build either system because light rail is not considered and rapid transit is too expensive. Examples of this are not rare. Several European cities with very good, extensive networks of light rail are planning or constructing independent rapid transit systems without transitional stages between the two modes. Since an extensive rapid transit network cannot be constructed in less than 10-20 years, transit systems in those cities will be disintegrated and will require greatly increased intermodal transfers for a number of years.

Examples of this tendency for"grandeur" have also been numerous in this country. One of the "transit modernization" plans for a major city (rejected by voters several years ago) would have created "real rapid transit" resulting in a marginally better service on one truncated light rail line; its outer section and four other light rail lines would have been converted to bus feeders, requiring transfers and increased travel times. Another city still has an extensive network of rail rights-of-way which could be modernized into a very efficient light rail system; yet, that mode has been neglected for several decades and two different modes are now planned to substitute some of its lines. Similar cases are cities which have had their rapid transit projects rejected by voters because of their extremely high costs.

- Another argument against rail systems is that buses allow "better utilization" of their facilities because automobiles are permitted to use their lanes during certain times or under certain conditions. It is true that mixed traffic leads to a higher transporting capacity of the bus lane in many situations, but at the same time it represents a compromise of the most important feature of modern transit - its separation and independence from other traffic; mixing with other traffic results in the loss of reliability, speed, safety, and system image. Studies analyzing the "optimum utilization" of freeway lanes - in most cases finding that a separate bus (or any transit) lane is "not justified" (such as an earlier study of bus lanes on the San Francisco Bay Bridge) - are typical of the narrow approach in transportation analysis. A benefit/cost ratio for a single link without considering the system aspects, can be very deceiving. Such elements as overall travel speed of the bus lines, regularity and reliability of service and, above all, influence of these on the modal split between automobiles and transit are often completely neglected.

It should be emphasized again that in the cities with progressive attitudes toward transportation the important decisions about systems and modes are seldom made on the basis of a narrow analysis of direct benefits and costs: they are usually made on the basis of a policy founded on broad system considerations.

The crisis in the transit industry in the United States is not only financial. An even more serious factor is the lack of qualified people in the planning, design and operation of transit systems. Many aspects of modern transit systems are not known, and many misconceptions are widespread. Overcoming of these may be a more serious barrier to the introduction of light rail (or any other efficient system for that matter) into some U.S. cities than the financial and technical problems.

B. POTENTIAL OF THE LIGHT RAIL SYSTEM FOR NORTH AMERICAN CITIES

Based on the definition of the light rail system, its evaluation and comparison with other transit modes, one can make the following conclusions about its potential for our cities:

- There is a very real potential for modernization and expansion of light rail in all U.S. and Canadian cities which presently operate streetcar or light rail lines; the existing lines should be thoroughly modernized and, in many cases, extended. The very fact that these systems are still in operation, after several decades of neglect, adverse developments and the favoring of competing modes, is the best proof of the inherent value of the services they perform. The largest of these systems, Boston, Cleveland, Philadelphia, Pittsburgh, San Francisco and Toronto, have sound reasons to increase utilization of their systems through modernization projects. San Francisco and Toronto presently lead in such development. Boston has prepared plans for modernization and Philadelphia has begun to study the new vehicles. Cleveland, Newark and Pittsburgh should also take a better advantage of their rail systems.

- At least 25-30 cities in North America could utilize light rail for major improvement of their transit systems. Those are primarily medium-to-large cities, such as Baltimore, Columbus, Dayton, Milwaukee, Minneapolis-St. Paul, Providence, Rochester, Seattle and others which have corridors with densities adequate to support light rail. In some of these cities only a few of the heaviest lines could be upgraded to light rail. In others, fairly large networks could prove efficient. Light rail could be introduced on many unused railroad rights-of-way in urban areas (e.g. Riverside Line in Boston). In addition, conversion of lightly traveled commuter railroad lines to light rail could result in both, cost reduction and increased level (particularly frequency) of service.

- Since light rail can have at-grade crossings or even limited surface running, it is considerably easier to find right-of-way for it than for rapid transit. Specialization of streets is one low-cost approach. Lateral rights-of-way, parks, etc., are another possible solution. Yet, provision of private or semi-private rights-of-way will be in most cases the most serious technical problem of light rail introduction.

- To overcome prejudices against rail, and particularly surface rail systems, light rail should be proposed and promoted as a new system rather than as 'modified streetcars.' A new name is an important item in improving the system's image; light rail or Cityrail, brief and convenient names, are suggested for that reason.

- To help cities which might benefit from light rail, information about this mode should be distributed to all transit and planning agencies.

- Improved information on urban transportation policies as well as technical aspects of progressive European cities would be a major step toward improvement of transit in U.S. cities and eventual recovery of the serious lag between our and European cities in this area.

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APPENDIX

Some Remarks about Transit in the Studied European Cities

Modern light rail systems in the studied cities are not an isolated phenomenon. They represent only one component of modern transit systems which in turn are a product of policies and attitudes considerably different from policies typical for U.S. cities. It appears therefore appropriate to add here several general brief observations about transit in the studied as well as other West European cities with modern public transportation.

Urban Transportation Problems do exist in all major cities. Rapid increase in motorization has resulted in a flood of automobiles in cities with all related problems. Public transportation has increasing financial problems; since it is not considered desirable to maintain direct profitability through increased fares, new sources of financing had to be found

Approaches to solutions of these problems vary, naturally, among cities and countries. Some cities have very serious congestion and slim prospects for any significant improvement in the foreseeable future; others are constantly searching new solutions, from better urban design to detailed refinements in traffic engineering and transit operations. In general, public transportation has been lagging behind highway developments during the last 15-20 years; yet, transit service in most European cities is superior to that in U.S. cities. As a matter of fact, it is generally better now than it ever was before,

P-66. Flood of parked cars (Belgrade)

since it was improved even during periods of decreasing patronage.

Transportation Policy is in many cities defined very clearly. Naturally, many of the basic policy problems, such as intermodal distribution of travel by direction and time of day, methods of influencing it and related economic relationships have not been clearly solved anywhere. But, there is a general concensus that all transportation systems must be improved in a coordinated manner. Public transportation is generally given a high priority, but with different degrees of specificity. For example, Buchanan's report to the British government was very strongly in favor of transit improvements, but it failed to suggest specific actions in that direction. A similar study performed for the German government (authors Hollatz and Tamms) spelled out not only the basic policies, but also specific goals. For example, land use, which should be planned in coordination with transportation, should not create densities of travel which cause congestion; on the other hand, minimum density should not be lower than the density which can support a basic level of transit service; every person in urban areas should have at least one mode of transportation available; area coverage standard is usually that any point within the populated area should have a transit stop within a radius of 5-minute walk; etc.

Capital investments in transit are typically provided from public funds, since transit tunnels and lanes are considered to be public ways, as streets and highways are. Operating subsidies, which exist in a number of cities, are provided usually on an irregular basis from different governments or through merger with utility companies. It should be pointed out that despite its economic problems, transit has never been allowed to deteriorate. Its level of service has remained high.

Thus the main difference between these cities and their American counterparts has been that when intensive motorization and highway construction began, transit service was also continuously modernized so that both modes had a parallel improvement. Certain balance was thus maintained. In our cities improvements of highways have been followed by deterioration of transit and the widening gap accelerated the vicious circle of increasing highway and decreasing transit use.

Transportation Planning is different from planning in U.S. cities in several respects. Again allowing generalizations, one can make the following comparisons:

- Planning process is theoretically much simpler in Europe. Planning models and analytical tools are considerably less sophisticated than those which are applied in our cities. Capabilities for analysis of alternatives are lower.

- Implementation of plans is much better in Europe. Plans developed through cooperation of many municipalities in a metropolitan area are coordinated and once the overall plan is adopted, it is followed rather strictly due to the available planning controls.

- Although use of computers in data collection and analysis is not as widespread as in the U.S., statistical and planning data on population, land use, transportation facilities and operations, etc. are extremely well prepared and easily available. A good example of this are annual reports of transit companies. A typical report (e.g. Hannover, Paris, Rotterdam) contains the data for which one would have to go to several agencies in any of our cities.

- A number of top transit experts take part in urban transportation planning.

Highly Qualified Professionals work for transit companies. Their number is much greater than in the U.S. This is undoubtedly one of the main factors of superior advances in transit that European cities have made.

Modal preferences, and even strong prejudices, do exist also among European experts. For example, there are some who advocate construction of as many freeways in cities as the existing and induced demand would require; some who would ban the automobile from cities; there are opinions that buses should be the dominant transit mode because they are "flexible"; or, that light rail is always better than buses and that rapid transit can only in exceptional cases be more efficient than light rail; finally, many experts in the cities with rapid transit "look down" upon light rail and claim that rapid transit is superior for virtually all cities which require high-quality transit. Yet, these extreme, generalized opinions do not dominate. Among most experts there is a concensus about general optimal areas of application of each mode and one can notice the results: efficient use of all modes. Bus lanes are in use in many cities; busways have been opened in England and are in planning in France and in several German cities. Light rail and rapid transit are under intensive expansion. Coordination of transit with taxis is being prepared in Hamburg. New systems are being studied. Highway systems are being improved and coordinated with parking, while in many cities pedestrian streets and areas are being introduced. Of course, these extremely positive statements refer to the most progressive cities. Many other cities have only some of these positive features and, to be sure, their transportation problem is far from solved. The point is, however, that from the progressive cities it is possible to make many observations which can be extremely

P-67. Pedestrian street (Eindhoven)

useful to U.S. cities in their search for solutions to transportation problems.

Role of Transit remains much greater in European than in U.S. cities. This is not so much a result of the difference in type of cities, ways of living, etc. It is a result of more positive policies toward it in Europe, transit modernization, better service, intensive marketing and public information which starts from instruction in schools about transit systems operation and popular aspects of new construction in the city. In general, popularity of transit is high and population takes a great pride in each major step in its modernization.

Interest of population in public systems and facilities is extremely important for progress of cities. Our urban population also has that interest and pride, but it became often dormant due to lack of activities in that field. A major program of modernization and construction of urban public facilities which improve urban living and activities would easily revive that interest and enjoy strong support of the population. Transit improvements, if properly planned, always fall in this category.

P-68. Attractive pedestrian area in the city center (Rotterdam; City Hall in background)

P-69. Modern and attractive transit facilities: rapid transit station entrance (Hamburg)