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LIGHT RAIL TRANSIT

Technology Sharing

STATE-OF-THE-ART OVERVIEW
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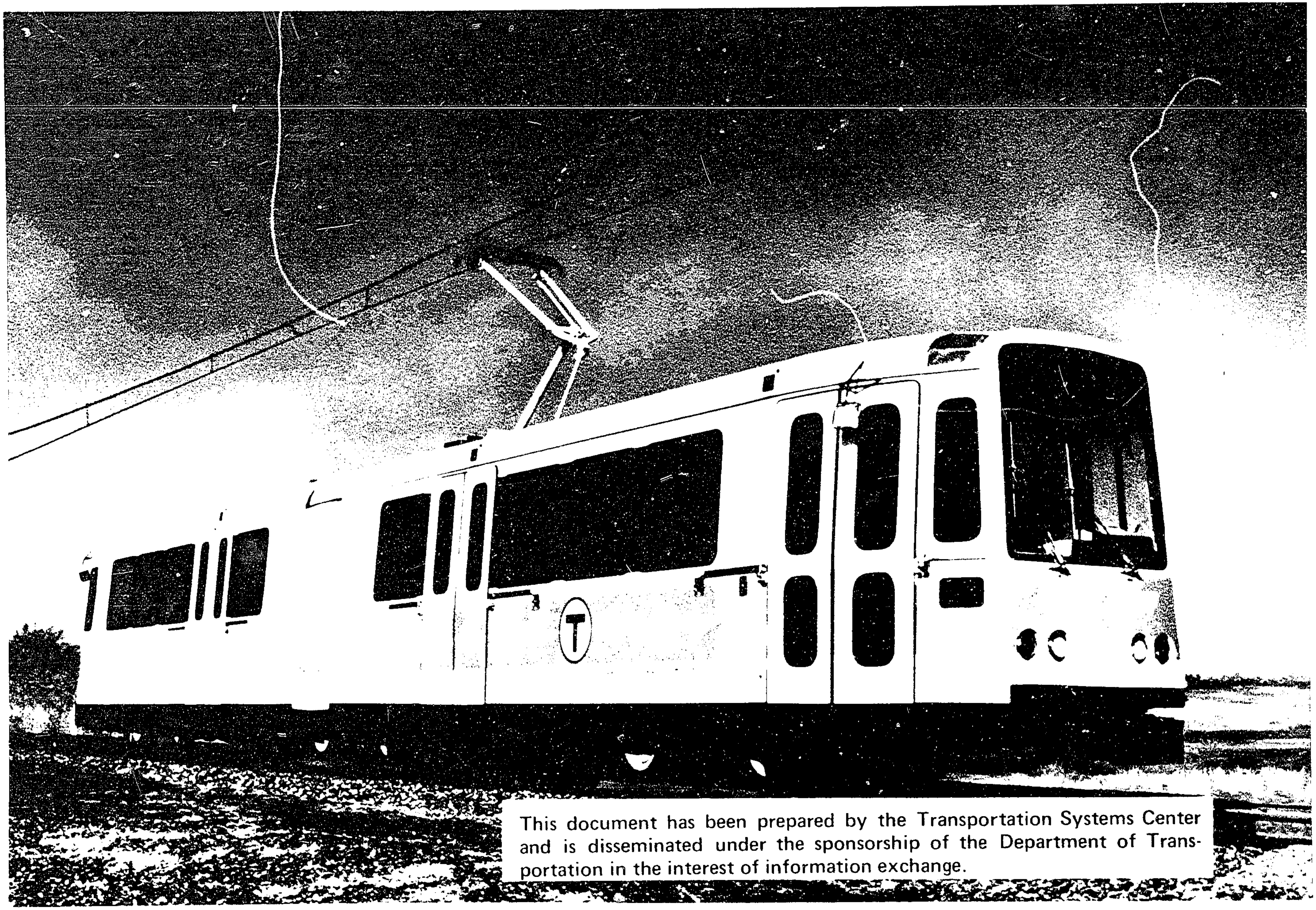

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16. Abstract

This document presents an overview of light rail transit, an urban transit alternative which has the potential to help fill the need for flexibility in public transportation. Existing and proposed U.S. and Canadian light rail transit systems are described with a historical perspective. The technical components and service characteristics of this mode are analyzed. The document also deals with a number of planning and implementation issues, including economics of operation, and various environmental and social concerns.

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FOREWORD

As part of its ongoing commitment to the principle of technology sharing, the U.S. Department of Transportation has initiated a series of publications based on research and development efforts sponsored by the Department. The series comprises technical reports, state-of-the-art documents, newsletters and bulletins, manuals and handbooks, bibliographies, and other special publications. All share a primary objective: to contribute to a better base of knowledge and understanding throughout the transportation community, and, thereby, to an improvement in the basis for decision-making within the community.

This title in the series presents an overview of light rail transit, an urban transit alternative which has the potential to help fill the need for flexibility in public transportation. The document is designed to make more accessible the body of knowledge that now constitutes the state-of-the-art of light rail transit. A special feature is the inclusion of supplementary material to serve as a source-book for further information.

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A special acknowledgment is made to the light rail transit operators and planners and to the Transportation Research Board's Committee on Light Rail Transit whose review of and comment on this document is greatly appreciated.

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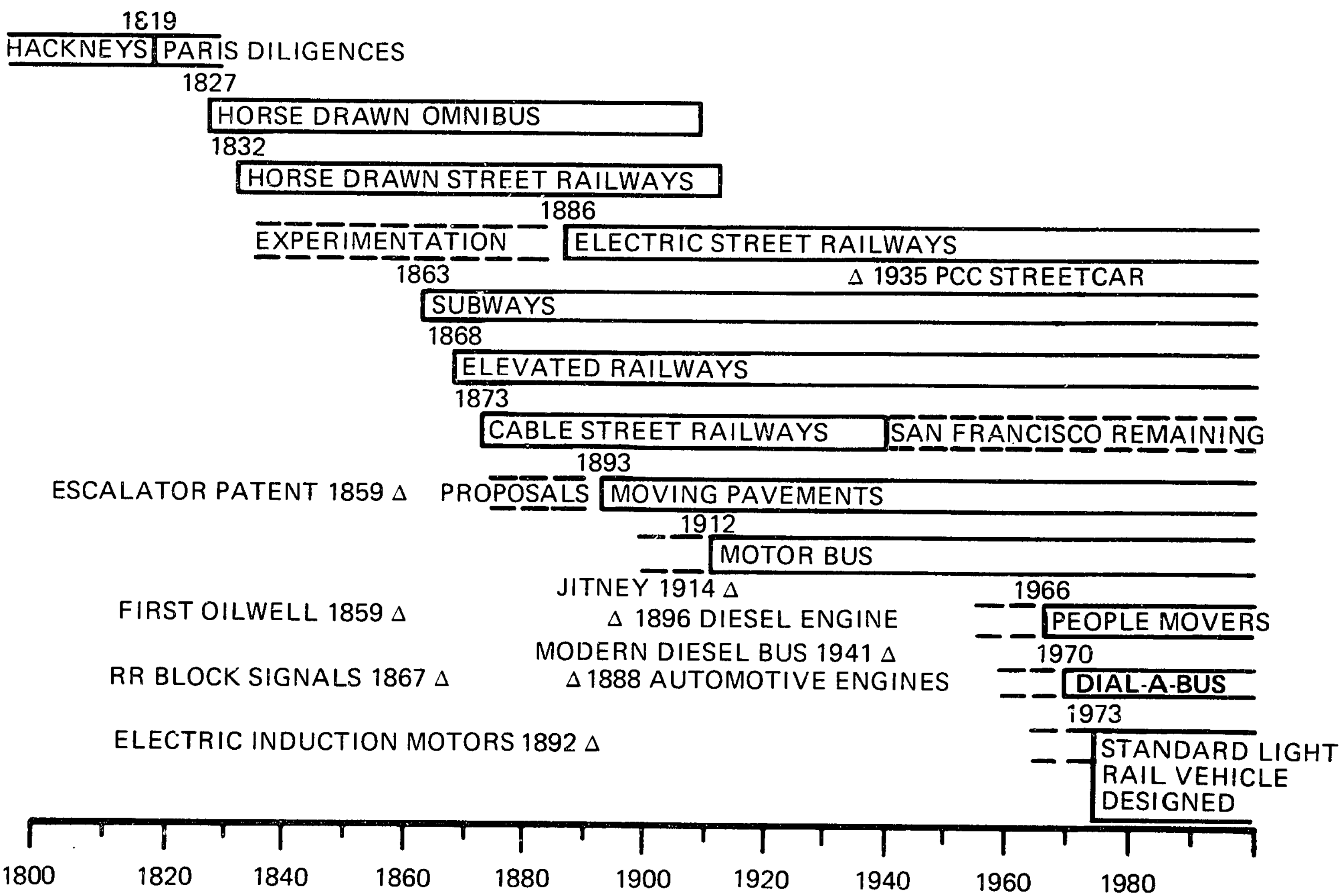

Source: Adapted from N.D. Lea Transportation Research, Lea Transit Compendium, Vol 1 No. 1, 1974

I OVERVIEW OF LIGHT RAIL TRANSIT[1]

revived interest in light rail transit

IN RECENT YEARS, the growing need to move people in and around urban areas economically and with minimum disruption to the quality of urban life and environment has stimulated an interest in various transit alternatives. In light of the national interest in energy conservation, the need for transit alternatives has become even more pronounced.

In the realm of conventional mass transit, both new and extensions to existing rail rapid transit systems are being planned and constructed. Improvements in bus and commuter rail services are also being planned and implemented in many urban areas. The interest in transit alternatives has also focused on techniques for making better use of existing transportation resources such as the designation of exclusive lanes for buses and carpools, and the establishment of demand responsive transportation services, specialized services for the transportation disadvantaged, and subscription bus service. Evaluation of these transit alternatives, as they relate to specific applications, is necessary if citizens are to receive the best transportation service for their tax dollars.

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[1]This state-of-the-art overview, derived largely from documented research and personal contacts, concentrates on streetcar and light rail transit systems as they exist in the U.S. and Canada. For a detailed assessment of light rail transit (including European systems), the reader is referred to Reference 55.

It is this renewed interest and evaluation of various transit alternatives which has intensified the interest in another alternative, light rail transit, a generic name for a transit mode consisting of electrically powered steel-wheeled rail vehicles operating predominantly on exclusive rights-of-way. This latter characteristic is the primary feature which distinguishes light rail transit from the electric streetcar – streetcars typically share right-of-way with other vehicular traffic on public, often congested roadways.

Light rail transit is an intermediate-capacity, intermediate-speed mode capable of operating at passenger volumes, and service levels, between those of fully-separated rapid transit and those of transit operating on public streets or roadways in mixed traffic. It is characterized by flexibility which provides planners with a variety of options in locating and/or relocating routes, and in selecting and utilizing a number of different operating procedures.

advantages

Light rail transit has the potential of meeting transportation needs within many urban areas. Recent reports have cited a number of advantages of light rail transit, *in contrast to several of the other possible alternatives* (references 47, 52, and 54, DeGraw). The attributes most often cited are:

- Light rail transit offers flexibility in right-of-way selection. It can be used underground in subways, at grade either on exclusive rights-of-way or in mixed traffic, or on elevated structures. The primary reasons for this flexibility are that passenger loading is possible at both high-level and low-level platforms, and that electrical power collection is generally from an overhead wire rather than the third rail of most rail rapid transit systems – a safety consideration allowing operation in mixed traffic. Various characteristics of three rail transit modes are shown in Figure 1.
- Light rail transit has an intermediate carrying capability ranging in between that of conventional bus and rail rapid transit systems and can be upgraded to a full-scale rail rapid transit system (if carefully planned for in the original construction), should future passenger volumes warrant. Experience indicates that bus systems have difficulty operating efficiently when passenger volumes exceed 4000 to 6000 persons per hour per direction (pphpd), while the minimum volumes to warrant a rail rapid transit system have been reported to be 20,000

Figure 1. Characteristics of Three Rail Transit Modes

	Streetcar	Light Rail Transit	Rail Rapid Transit
FIXED FACILITIES			
Exclusive Right-of-way	Minimal	Variable	100 Percent
Way Control	Mostly Visual/Some Signal	Mostly Visual/Some Signal	Signal
Fare Collection	On-Vehicle	Mostly On-Vehicle/Some At-Station	At-Station/Some On-Vehicle
Power Supply	Overhead	Mostly Overhead/Some Third Rail	Mostly Third Rail/Some Overhead
Stations: Platform Height	Low	Low or High	High
VEHICLE/TRAIN CHARACTERISTICS*			
Typical Train Composition (number of vehicles)	1-2	2-4	1-10
Vehicle Length (ft/m)	46-50/14-15	50-75/15-23	49-75/15-23
Vehicle Capacity (seats/vehicle)	22-55	22-68	32-86
Vehicle Capacity (total/vehicle) (for 2.7 ft^2 (0.25 m) per standee)	74-180	110-200	100-307
OPERATIONAL CHARACTERISTICS*			
Operating Speed (mph/kph)	6-15/10-25	12-30/20-45	15-40/25-60
Typical Frequency Peak hour joint section(/h)	30-60	20-60	20-40
SYSTEM ASPECTS*			
Network and Area Coverage	Dispersed, Good Area Coverage	Good CBD Coverage; Branching	Predominantly Radial; Some CBD Coverage
Station Spacing (ft/m)	800-1600/250-500	1000-2500/350-800	1600-5000/500-1500
Average Trip Length	Short to Medium	Medium to Long	Medium to Long
Relationship to Other Modes	Can Feed Higher Capacity Modes	Park & Ride, Kiss & Ride, Bus Feeders Possible, Can Feed Higher Capacity Modes	Park & Ride, Kiss & Ride, Bus Feeders

*Figures shown are typical ranges for existing U.S. and Canadian vehicles and systems.

Source: Adapted from reference 90.

to 24,000 pphpd (references 9 and 47). Light rail transit, with single-vehicle operation, can transport up to 8000 pphpd, and has the flexibility to be converted quickly to multiple-vehicle operation, when requirements dictate, resulting in a maximum capacity range of approximately 18,000 to 20,000 pphpd (reference 54, Vuchic, Vigrass).

- Since light rail transit is a relatively permanent system, it can stimulate land use development & use of transit modes such as feeder bus lines, along the light rail transit routes. Evidence has shown this factor instrumental in establishing and retaining high patronage levels (reference 54, Tennyson).
- The construction costs for a light rail transit system can be lower than rail rapid transit, and the system can often be implemented in less time (references 54, Thompson, Vigrass, and 107). These advantages accrue because there is less need for the large civil works necessary for rail rapid transit grade separation. This is significant since fiscal constraints at all government levels are prohibiting proliferation of high capital intensive transportation alternatives.
- Since light rail vehicles are electrically powered, they offer a clean and quiet ride not available from diesel powered vehicles. In addition, light rail transit permits a wide choice of energy sources which may be cheaper and more available than petrochemical energy. Light rail transit has also been reported to be an efficient user of energy (reference 54, Thompson).

historical perspective

Assessments of light rail transit technology reveal it to be a versatile transportation mode with potential for fulfilling many urban transportation needs. A brief review of past events relative to the development of urban public transportation in the U.S. helps to place light rail transit in proper perspective with respect to technological, sociological and economic determinants.

Light rail technology had its beginnings in the late 1880's when the electric streetcar was developed as a logical successor to the horsecar, largely as a result of the experiments and research of Thomas A. Edison and Frank J. Sprague. In the late 19th and early 20th centuries, electric rail transportation usage grew extensively throughout the U.S. in the form of electric street railways and interurban railways. This growth period peaked around the time of World War I, after which the development and popularity of the automobile and motor bus began to flourish. Subsequently, and through the 1920's, demand for urban public transportation service was divided among electric railways, buses, and automobiles, with the high ridership levels once enjoyed by the street railways steadily eroding due largely to their slow performance in mixed street traffic and dramatically increased automobile ownership. The decline in ridership naturally affected the profitability of many street railway companies, whose ability to generate capital for replacement of obsolete equipment was severely inhibited. Fares generally could not be increased due to franchise restrictions. On many lines equipment condition deteriorated due to deferred maintenance, making alternate transportation modes even more attractive. This general decline in the fortunes of most of these companies continued into the 1930's, when the great depression further contributed to their economic problems.

By the end of the 1950's, only a remnant of streetcar/light rail transit service remained in the U.S. and Canada. In Europe, however, the technology survived. In fact, after World War II, many European cities converted what were streetcar or tramway lines into fast, efficient light rail transit systems. In essence, the steady decline of streetcar/light rail transit in the U.S. had little to do with whether or not it had those attributes needed as a functional mode of transportation for fulfilling urban mass transportation needs. Instead, its decline was primarily due to its inability to produce profit for its owners in an era when urban transportation was a private business enterprise.

The research, development, and experimentation with urban transportation modal alternatives over the last decade is partly responsible for present day interest in light rail transit. During the 1960's, the great interest was directed toward conventional rail rapid transit. Since rail rapid transit service is best suited for high ridership ranges, as well as being capital intensive, it is applicable for only a limited number of American cities (reference 91). Experimentation and high initial cost associated with new transit modes such as monorails, rubber-tired guided cars, and personal rapid transit systems has not yet been successful enough to generate momentum leading to their widespread use. Other services and techniques, such as demand-responsive transportation and preferential treatment for buses and carpools, are being implemented in a number of urban areas. In addition, the recent energy crisis has also been a factor in the intensified interest in quickly-implemented transportation solutions which made more efficient use of existing transportation facilities. In this respect, light rail transit is becoming a recognized transportation alternative because:

- it is suited to ridership ranges which make it a workable alternative for many urban areas;
- it can be less capital intensive than rail rapid transit;
- it can often be implemented more quickly than rail rapid transit;
- it can utilize existing highway medians or little-used railroad rights-of-way in urban areas.

Figure 2. U.S. and Canadian Streetcar and Light Rail Transit System Descriptions, 1976

CITY	NAME AND ADDRESS OF OPERATING AUTHORITY	NUMBER OF LINES	SYSTEM LENGTH (ROUTE MILES)	AVERAGE SPEED (MPH)	LIGHT RAIL VEHICLE DATA						
					TYPE	QUANTITY	CAPACITY		LENGTH (FEET)	WIDTH (FEET)	HEIGHT - RAIL TO ROOF (FEET)
							SEATING	STANDING			
Boston	Massachusetts Bay Transportation Authority (MBTA) 50 High Street Boston, MA 02110	5	28 5	15	PCC	294	42	76 100	46 47	8.7 8 8	10 8 11.8
Cleveland	Greater Cleveland Regional Transit Authority 1404 East Ninth Street Cleveland, OH 44114	2	13 1	23	PCC	57	62	35	50	9	10 2
Fort Worth	Tandy Corp (Dillard's Dept Store M&O Subway) 2727 West 7th St Fort Worth, TX 76107	1	1 2	16	PCC	6	50	50	46	8 5	10 0
New Orleans	New Orleans Public Service 317 Baronne Street New Orleans, LA 70160	1	5 5	9 3	Conventional Streetcar	37	52	33 50	47 7	8 5	14 6
Newark	Transport of New Jersey 180 Boyden Ave Maplewood, NJ 07040	1	4 2	20	PCC	30	55	70	46 4	9	10 2
Philadelphia	Southeastern Pennsylvania Transportation Authority (SEPTA) 12 South 12th Street Philadelphia, PA 19107	CT 12* RA 3	82 0 27 0	10 13 27	All PCC Non PCC	364 55	51 53 58 61	40 60 40 60	46 46 7 48 3 55 2	8 3 9 9 2	10 0 10 3 10 0 12 7
Pittsburgh	Port Authority of Allegheny County (PAT) Beaver and Island Ave Pittsburgh, PA 15233	5	24 9	12	PCC	95	50	40	48	8 5	10 1
San Francisco	San Francisco Municipal Railway (MUNI) 949 Presidio Ave San Francisco, CA 94115	5	36 0	9 3	PCC	110	55	65	50 5	9	10 1
Toronto	Toronto Transit Commission 1900 Yonge Street Toronto, Ontario, Canada M4S 1Z2	11	68 5	10	PCC	389	48	77	46 4	8 3	10 3

*CT - City Transit Division
RA - Red Arrow Division

Source: Adapted from references 50 and 118 and phone conversations with each system.

A recent stimulant to interest in light rail transit was the need by Boston and San Francisco to replace their existing light rail fleets, both of which are well over twenty years old. This has led to the development of the U.S. Standard Light Rail Vehicle (SLRV) currently being built for both transit systems by the Boeing Vertol Company.

Further present day interest in light rail transit is brought to focus by the new systems being planned for several U.S. and Canadian cities, as detailed below. These events indicate that light rail transit has become a significant urban transportation alternative.

existing and proposed U.S. and Canadian light rail transit systems

There are nine U.S. and Canadian light rail transit systems in operation today. These systems, ranging from large-scale metropolitan area operations to small, special purpose lines, are described in Figure 2. Although there is considerable interest and activity in light rail transit in Europe, this report will concentrate on these nine existing U.S. and Canadian systems.

During the last 20 years, two new light rail transit operations were implemented. One was the Riverside Line in Boston which began operations in 1959, making use of a former commuter railroad line. This line was rerouted to tie in with existing light rail transit lines. The other is a private line in Fort Worth, Texas carrying riders to a downtown department store from an outlying parking lot approximately one mile away.

As of 1976, light rail transit had been proposed or planned in the following U.S. cities:

- Austin, Texas
- Aspen and Denver, Colorado
- Baltimore, Maryland
- Buffalo and Rochester, New York
- Dayton, Ohio
- Erie and Harrisburg, Pennsylvania
- Hartford, Connecticut
- Honolulu, Hawaii
- Los Angeles and San Diego, California
- Kansas City, Missouri
- Memphis, Tennessee
- Miami, Florida
- Portland, Oregon
- Washington, D.C.

Figure 3. Geographical Distribution of Existing and Proposed U.S. and Canadian Light Rail Transit Systems, 1976

In Canada, a new light rail transit system is under construction in Edmonton with startup due in 1978. Systems for Vancouver, Calgary, and Winnipeg are in the planning stages. A possible extension of one of Toronto's light rail transit lines has also been studied. Figure 3 is a map indicating the location of the existing and proposed light rail transit systems in the U.S. and Canada.

II TECHNOLOGICAL COMPONENTS AND SERVICE CHARACTERISTICS

THE IMPLEMENTATION AND OPERATION of a light rail transit system requires a thorough understanding of its technological and service characteristics. This chapter briefly discusses such technological components as the light rail transit vehicle, track structure, power distribution, and right-of-way requirements.[1] Among the service characteristics identified are the various components of system capacity such as speed and frequency of service, light rail's interface with other modes, and safety.

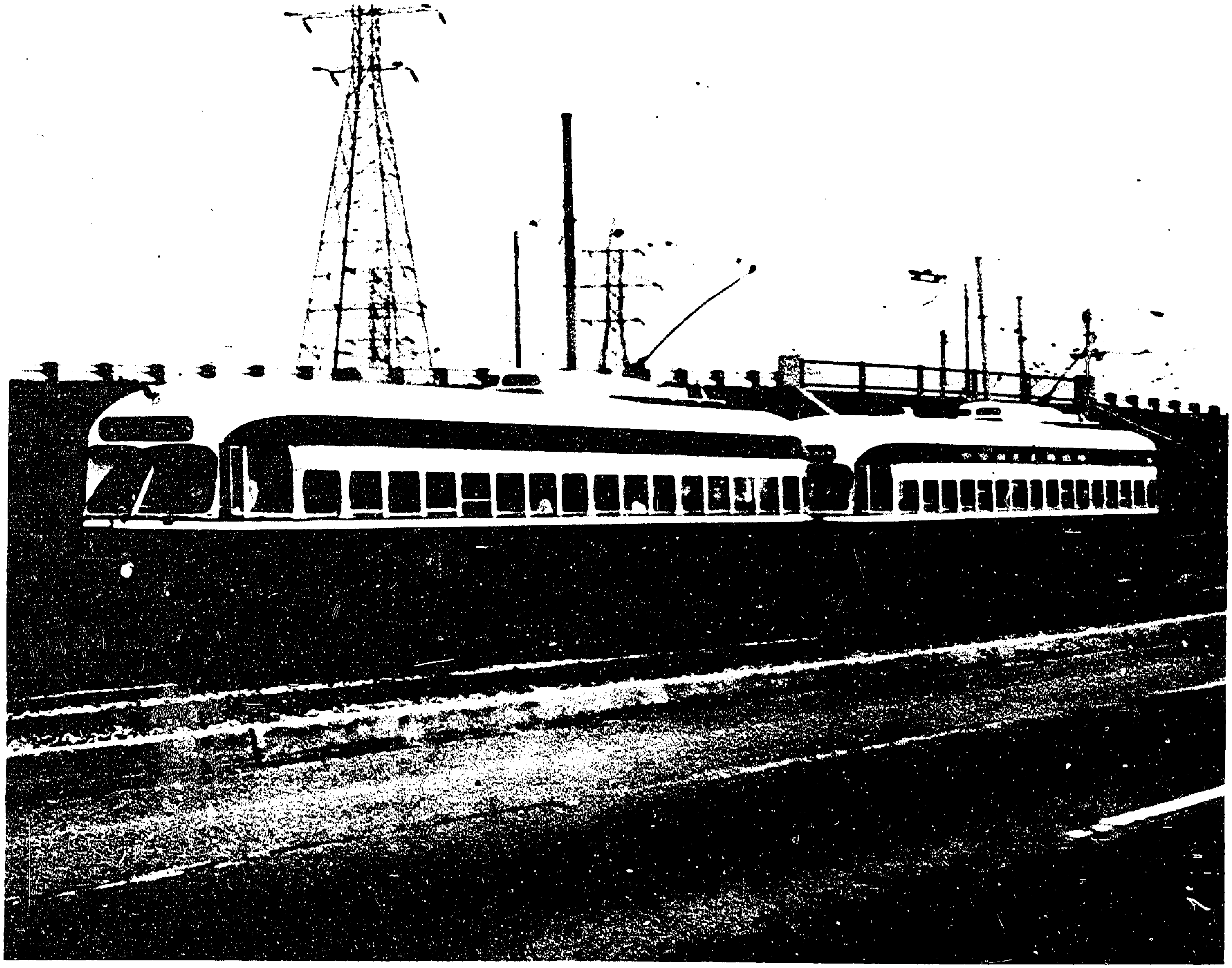
technological components

VEHICLES. The vehicle which has dominated U.S. and Canadian streetcar and light rail transit operations is the Presidents' Conference Committee (PCC) car. The PCC car was developed in a research and development project by a committee of street railway officials who recognized the necessity for an advanced, less costly, and standardized street railway vehicle in the 1930's. The first PCC cars were delivered in 1935 and the last new PCC cars were built in 1952 by St. Louis Car Co. for use in San Francisco (another late builder of PCC cars was Pullman-Standard).

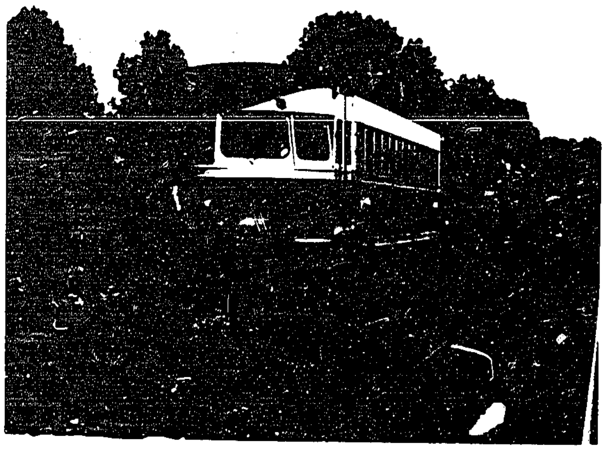
Approximately 5000 PCC cars were built in North America and about 1300 are still in use. Only two U.S. light rail transit systems do not use PCC cars. One is New Orleans, where well-designed and maintained (1920's vintage) vehicles built by the Perley Thomas

[1] More detailed information may be found in references 54 and 55.

PCC Cars in Toronto



Examples of Non-PCC Equipment



Brill Bullet Car, Philadelphia

Conventional Streetcar, New Orleans

Car Co. are used. The other is Philadelphia's Red Arrow Division which uses all non-PCC vehicles. PCC cars are also being operated in locations other than the U.S. and Canada, such as Mexico City.

The basic design features of PCC cars are simple; a single-body car about 50 feet long and weighing about 20 tons. The car has two powered trucks and runs on 600-volt DC electric power obtained from an overhead trolley wire.

Cars which met the PCC specifications were produced in a variety of interior and exterior designs at essentially the same purchase price. These usually have the capacity to seat about 50 patrons with room for approximately 50 - 70 standees. There are usually two double doors on the right-hand side of the car, and in the case of Boston, one double-door on the left-hand (driver's) side in the center. Some cars are double-ended, meaning that there are operator's controls on both ends and an equal number of doors on both sides, so that the car does not have to be physically turned at the end of a route--just reversed. Seats in such cars are normally reversible so that passengers can always face the direction of travel. However, most PCC cars are single-ended with controls on one end only; such cars are turned at the route terminal via a loop track or a wye.

The PCC car can negotiate curves with minimum radius of approximately 40 feet, and can climb 12-percent grades. PCC cars are also capable of being operated in trains, i.e., in multiple units. In this way, system capacity can be varied by running trains of three or four vehicles each during peak periods, and running one or two vehicles during periods when transit requirements are not as great.

Current Developments: Recognizing advances in transit technology and the need by many cities for higher capacity vehicles, the Urban Mass Transportation Administration (UMTA), in cooperation with Boston, San Francisco, Philadelphia and other light rail transit operators, sponsored a program to develop the Standard Light Rail Vehicle (SLRV). The Boeing Vertol Company is currently manufacturing the SLRV for Boston (MBTA) and San Francisco (MUNI) (Figure 4 is a photograph of the SLRV). There are two differences between the MBTA and MUNI cars. The first is that air conditioning will be provided for the MBTA cars while MUNI (because of San Francisco's year-round moderate temperature) will have an air ventilation system. The other difference is the provision for convertible high-low level passenger loading for MUNI operation in the Market Street subway.

A basic change that the SLRV offers to U.S. light rail transit operation is articulation. A single articulated vehicle is comprised of two single-body sections joined by a swivel hinge which allows passengers to pass between car halves. This hinge, supported by a single truck, allows a relatively long light rail vehicle to negotiate very sharp curves. Whether or not a light rail transit system employs articulated cars will depend on the unique needs and characteristics of that system.

Figure 4. The Standard Light Rail Vehicle

One advantage of articulated vehicles is that only one operator is required for a large number of passengers. For example, the vehicles being built for Boston will seat 52 with room for 167 standees while the San Francisco car design will seat 68 passengers with provision for 125 standees. This total of 219 or 193 passengers per unit for both systems is approximately twice the capacity of many PCC cars, yet only one operator is required.

In addition to the efforts in the U.S., two recent developments concerning light rail vehicles in Canada should also be noted. The first is Toronto's decision to replace part of its PCC car fleet with 200 new cars from the Urban Transportation Development Corporation which has developed specifications for a non-articulated vehicle called the Canadian Light Rail Vehicle (CLRV). (Reference 15 has a description of the CLRV). The design of the CLRV will reduce both internal and external noise levels compared to the PCC. Safety features of the CLRV include energy absorbing front and rear bumpers and four-way flashers activated automatically when the doors are opened. The second development is Edmonton's decision to order 14 Duwag U2 cars from West Germany for their light rail transit system which is currently under construction. (Detailed specifications for a variety of light rail vehicles may be found in reference 55.) A comparison of four types of light rail vehicles can be found in Figure 5.

TRACK. Light rail transit vehicles operate on rails where the gauge, or distance between the rails, varies among different systems. There are two basic track gauges used in the U.S. and Canada: standard gauge (4'8-1/2"), which is used by most U.S. and Canadian railroads, and broad gauge (5'2-1/2"), which is used in Pittsburgh, and a variation (5'2-1/4") in Philadelphia. Meter gauge, with 1 meter (or approximately 3'3-1/3") between rails, is common in Europe; however, standard gauge is also in wide use there. Standard gauge is advantageous because it facilitates use of a railroad line by light rail transit and it allows the light rail transit line to have a freight railroad connection where equipment can be moved over the line. Standard freight equipment can also be used to haul ballast for track construction and maintenance work and to take delivery of large parts and equipment items for various locations on the system.

The rail and ties used for the track of a light rail transit system are common track materials. In light rail transit operations, continuous welded rail (CWR) is preferred over jointed rail. Jointed rail is comprised of standard 39-foot sections joined at the ends by metal joint bars. The advantages of CWR are that it provides a smoother and quieter ride by eliminating the vertical and horizontal shocks as well as the noise associated with jointed rail. CWR can also reduce maintenance costs by reducing rail wear at joints. The ties used are usually standard 8½-foot ties with cross sections of 7-by-9 inches with centers usually 24 inches apart. The ballast, or roadbed on which the track rests, is usually composed of crushed rock; industrial slag is also used by some systems.

Efficient, bi-directional light rail transit system operation usually requires two tracks.

Figure 5. Comparison of Four Light Rail Vehicles

VEHICLE	PCC CAR	DUWAG U2	STANDARD LRV	CANADIAN LRV
Approximate Design Year	1930-1934	1965	1973	1975
Axles/Articulation	4/0	6/1	6/1	4/0
Length, Feet/Meters	43.5 to 50.5/ 13.2 to 15.4	75.5/23.0	71.5/21.8	50.5/15.4
Width, Feet/Meters	8.33 to 9.0/ 2.54 to 2.74	8.70/2.65	8.85/2.70	8.32/2.54
Floor Height, Feet/Meters	2.72/.83	3.18/.97	2.82/.85	–
Roof Height, Feet/Meters	10.1/3.08	10.8/3.28	11.5/3.51	10.6/3.25
Seats, Number/Layout	49 to 69/ 2+1 or 2+2	64/2+2	68/2+2	41 or 51
Doors, Number per Side	2 or 3 double	4 double	3 double	2 double
Type	Folding	Folding	Plug	Folding
Steps	Low	High	High/Low	Low
Maximum Speed, MPH/KPH	50/80	50/80	50/80	50/80
Acceleration Loaded, Feet/Second^2	6	3.3	4.1	4.9
Deceleration Loaded, Feet/Second^2	–	3.9	5.1	5.1
Emergency Deceleration Loaded, Feet/Second^2	–	10	8.8	10
Empty Weight, 1000 lbs.	33 to 42	66	68	45
Maximum Grade (Percent)	13	4.4	9.0	–

Source: Adapted from Reference 55

Single-track operation is possible but, since vehicles would have to stop at sidings and wait for opposing vehicles to pass, it may not be the most efficient arrangement. In places where uni-directional flow occurs, or where headways are sufficiently long, single-track operation is feasible, particularly at the outer ends of branches. However, single-track lines used for light rail transit urban operations will have built-in track capacity limitations.

RIGHT-OF-WAY. The flexibility in planning light rail transit routes makes it well suited for implementation in existing rights-of-way. In well-developed areas, where land may be at a premium, a mass transit mode which uses existing rights-of-way becomes an attractive alternative. The various types of routes over which light rail can be implemented are detailed below.

Roadway Median Routes: Locating a light rail transit line in the median strip of a roadway is a common practice. Since the right-of-way is already there, the need for large-scale civil works is minimized. The light rail transit line then becomes visible to motorists, with motivation to use the system reinforced each time light rail vehicles roll by autos standing in traffic. A light rail transit line in a median strip can cross other streets at grade. Wherever this situation exists, traffic signals activated by the light rail transit vehicle may be arranged to give the light rail vehicle preference over auto traffic.

Median strips must be at least 25-feet wide to accommodate a two-track light rail transit line. However, where a median strip is wide enough, landscaping can be employed to enhance the esthetic appeal of the system.

Grade-Separated Routes: Grade-separated routes are a good means of insuring operating reliability since conflicts with vehicular traffic are eliminated. A grade-separated route in an urban area is usually run either on an embankment or in a depression. When embankments are used, automobile cross-traffic passes beneath the transit route. Therefore, each street crossing requires a bridge structure. When depressed rights-of-way are used, the transit route is below ground level. This configuration necessitates cross-street bridge structures for automobile traffic. Benefits of the depressed right-of-way are that the sound-absorption qualities of the walls of the depression act to reduce transit noise, and that there is also the possibility of converting a depressed way into a subway by decking over the route. However, these routes are expensive to build, require careful drainage design, and are likely to require frequent cleaning. Furthermore, depressed lines (more so than embankments) are vulnerable to vandalism by individuals throwing objects at moving trains.

Subway Routes: The use of subways for downtown distribution is common; Philadelphia, Boston, Newark, and Fort Worth all operate light rail transit service in subways, and San Francisco is in the process of completing a new subway. Downtown subway distribution is faster and more reliable than downtown street-level distribution. As an additional system benefit, when light rail transit capacity reaches the saturation point,

Roadway Median Route, Boston

Exclusive Right-of-way, Philadelphia

the subways can be economically upgraded from light rail to rail rapid transit standards (if properly planned for in the original construction).

Elevated Routes: Elevated structures for light rail transit are used when a subway, exclusive right-of-way, or street-running operation is not feasible. Community acceptance of elevated structures varies: i.e., Boston, Chicago, and New York are eliminating them where possible; on the other hand Miami has plans to build new elevated structures, and the new BART system in San Francisco has 23 miles of elevated structure. Modern construction techniques employ concrete structural shapes for esthetically designed elevated structures. It is the older girder-steel elevated structures which are commonly being eliminated.

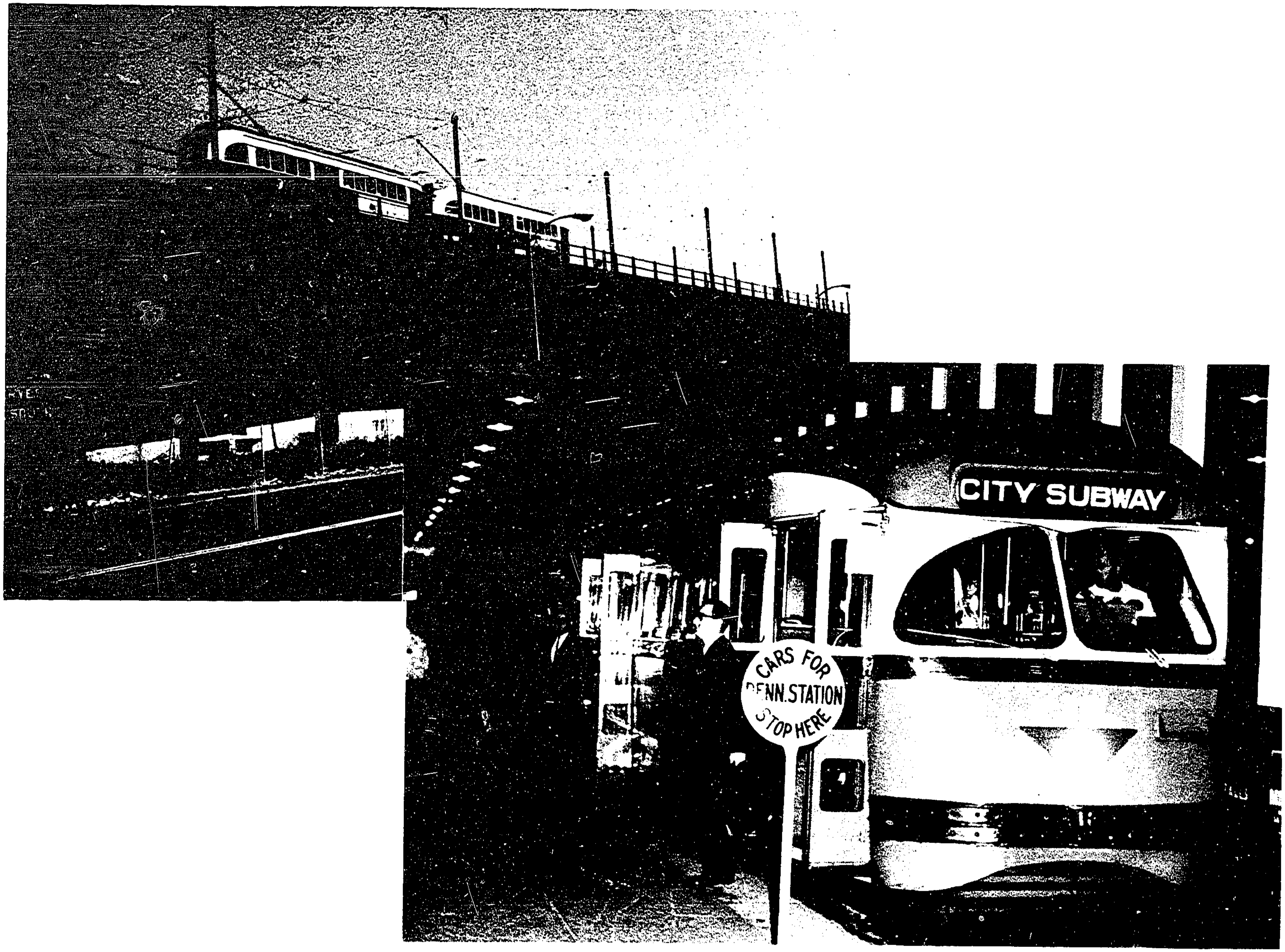
Shared Right-of-Way, or Track Over Existing Rail Lines: An important feature of light rail transit is that its cars can be operated over existing railroad rights-of-way. In cases where an abandoned or unused right-of-way is employed, it is only necessary to upgrade the track, add electrification, and build station platforms. Additional trackage for maintenance shops and storage would, of course, be required. The MBTA's (Boston) Riverside Line is a good example of an abandoned railroad right-of-way purchased and converted into a light rail transit line.

In cases where railroad freight operations are to be continued on a shared right-of-way, the interface of light rail transit can be accommodated with no major operational problems. There are no urban light rail transit lines in the U.S. which share rights-of-way with operating freight trains; however, the planned systems for Dayton, Ohio, Portland, Oregon, and Rochester, New York incorporate shared rights-of-way. Joint light rail transit and freight service is provided in certain locations in Europe.

When light rail transit and railroad freight share the same tracks, freight operations are usually conducted during hours when light rail transit cars are not in operation. This, of course, may restrict implementing late night and pre-dawn light rail transit service, but it must also be understood that the freight traffic over which a light rail transit line operates is usually very light. Light rail transit vehicles cannot feasibly share tracks with freight lines over which fast and frequent, or scheduled line-haul freight operations are conducted. If a rail freight right-of-way is wide enough for a two-track exclusive light rail transit line to be used without interference from cross-tracks for switching, then such a line may be adaptable for light rail transit use.

Sharing a freight right-of-way can present other problems. First, the overhead electric power lines for the light rail transit cars must be placed high enough to clear freight cars and oversized shipments. Second, a line used for both freight switching and light rail transit is likely to contain many turnouts and crossovers leading to wayside industrial locations. This results in complicated track work, depending on the number of industries, and also might affect ride quality if strict standards of maintenance are not followed.

Light Rail Transit on Elevated Structure (Boston) and in Subway (Newark)



In addition, joint operation may result in institutional problems for regulatory agencies. Thus, all these positive and negative factors should be considered before joint operation is proposed.

Street-Running Routes: Street-running routes can be used by light rail transit vehicles for passenger boarding and alighting, and can be designed so that patrons are not subject to hazards of automobile traffic. An example of successful street-running is in Toronto, where, because of prominent paint striping and strict traffic-law enforcement, motorists avoid the light rail transit vehicle paths and respect the right of pedestrains to cross the street to board or alight the cars. On a short portion of the Boston MBTA's Arborway Line, as well as in many European cities, the street rail line is raised above the pavement surface by about six inches, discouraging motorists from driving on the tracks. It is also possible to paint striping on pavement sectors to designate areas where light rail transit vehicles have traffic priorities.

One technique for improving transit service, practiced both in the U.S. and in Europe, is to close specific streets to automobile traffic and to allow access only to pedestrians, transit vehicles, and emergency vehicles. This arrangement is often called a transit-pedestrian mall. Another option for street-running distribution might be to locate light rail tracks next to the curb, thus isolating light rail transit operation in the curb-side lane, now usually reserved for automobile parking. This arrangement has been used effectively in Europe.

Since the 1920's the trend has been one of abandoning street-running segments and maintaining exclusive routes. Light rail transit is indeed most desirable, and is perhaps most efficient, when operated on a completely exclusive right-of-way. However, there may be cases where limited street running for distribution is required, and planners can take advantage of light rail's flexibility to adapt to this mode of operation. Not only is this evidenced by U.S. and Canadian light rail transit experience, it is also the case in Europe where the trend is toward building both replacement subways for downtown street-running and exclusive rights-of-way to replace street-running in fringe and suburban locations. European cities are also making use of transit-pedestrian malls in downtown areas where subway construction has been either deferred or rejected.

POWER DISTRIBUTION. Light rail transit vehicles typically operate on 600-volt direct-current electrical energy, usually delivered by means of an overhead wire. The wire is fed from sub-stations that receive power from distant generating stations. Electrical power for light rail transit can either be purchased commercially or generated on-line. In either case, the primary power from the generating station is used to feed sub-stations which, due to the nature of direct-current electricity, typically are placed every two or three miles over the route.

Island Platform Loading for Street-Running Operation, San Francisco

The simplest support method for the overhead wire uses single utility poles adjacent to the track to support the power wire. Other support methods employ single poles between two tracks with rigid arms on each side of the poles, suspended over each track. Still other methods use support stringers between opposed single poles on both sides of the tracks, or a rigid support over the tracks. Poles typically are placed every 100 feet along straight (tangent) track, and closer together along curved track to make the power wire follow the curve of the track.

Third rail electrical power collection for light rail transit is not commonly used. This is because many light rail transit lines are at-grade where the wayside power rail represents an unacceptable safety hazard because the public has access to the right-of-way. The only application of third-rail power collection in the United States is SEPTA's Norristown Line, a grade-separated light rail transit line in the Philadelphia area.

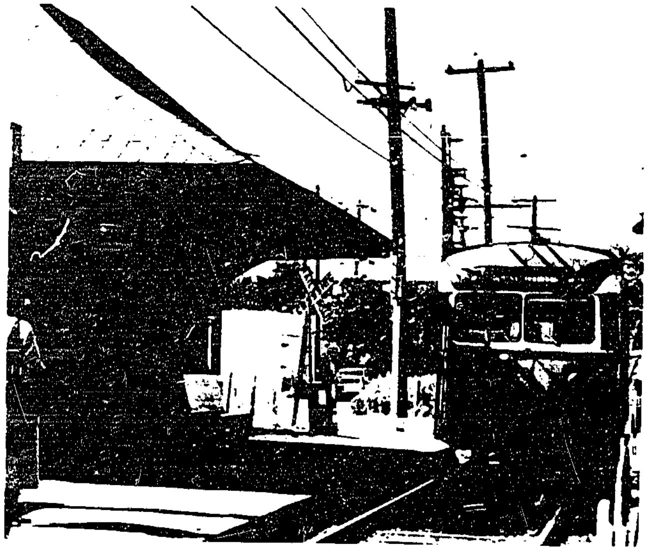
STATIONS. Experience indicates that there are great variations in the types of stations which are used for light rail transit (see reference 54, Landgraf). They range from small areas of cleared ground to large terminal buildings with provision for transfer to subways. The type of station needed is a function of such variables as passenger volumes, train headways, climate, fare collection methods, and civic attitudes in the immediate area. However, it is important to note that planners of new light rail stations should consider the possibility that modest stations might have to be upgraded in the future if passenger volumes grow sufficiently.

Stations for light rail transit surface operations are often quite simple. A street-level loading platform, with or without a shelter, can be sufficient. When street-running is employed such platforms can be located in a pedestrian safety zone for passenger safety. Platforms are also commonly used as stations for highway median light rail transit routes. On exclusive rights-of-way, a platform with a complementary shelter or even a station building can be used. For example, the Boston MBTA's Riverside Line uses the former railroad passenger stations located on the line.

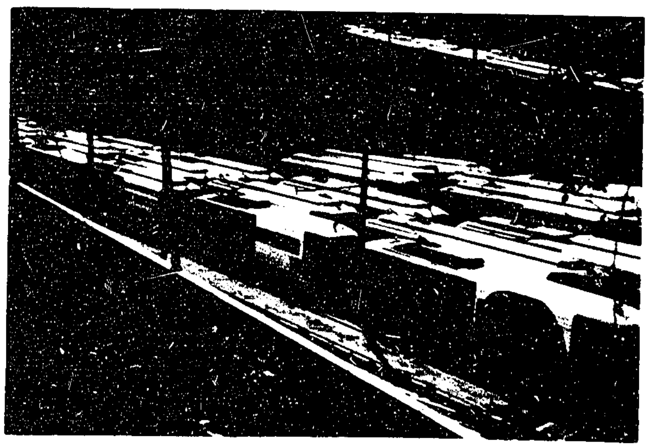
Light rail transit stations used in subways are quite similar to rail rapid transit subway stations, except that low-level loading can be employed. In places where the subway ridership is very high, convertible high/low-level steps can be used on the vehicles to provide optimum access for both street-level loading and subway-platform loading. High-level loading is easier and faster for passengers because they do not have to climb steps to enter the car. To date, only the San Francisco MUNI system in the U.S. plans to employ high-level loading in the light rail transit subway. The new light rail transit system being built in Edmonton, Alberta will employ high-level loading.

Light rail transit surface stations can include automobile parking facilities, bus loading areas, or along-the-platform interfacing with rail rapid transit as between the Shaker Division light rail transit line and the Cleveland Division high-platform rail rapid transit line.

Light Rail Station on Philadelphia's Media Line



Storage Facility, Pittsburgh



SHOPS AND STORAGE FACILITIES. Light rail transit lines require maintenance, cleaning, spare parts, and storage facilities for their vehicles and other equipment. The storage facilities required for light rail transit vehicles do not necessarily include an enclosed building; the vehicles can be stored outdoors. Accordingly, storage yard tracks are all that are needed for overnight storage. Maintenance shops are best located on-line so that light rail transit vehicles can operate directly into them; central or satellite locations are common.

TRAFFIC (SIGNAL) CONTROL. Traffic or signal control for light rail transit lines is similar to, and often simpler than, conventional control systems used in rail rapid transit operations. Signal control systems are generally not used on street-running operations, but are required on exclusive right-of-way routes where light rail vehicles move at higher speeds. In subways, the lack of visibility calls for sector control, particularly at curves and blind junctions, where the operator cannot see whether or not he has a clear route without first proceeding into the critical area.

In systems without signals, vehicles operate under visual control of the operator in the same manner as a bus system; i.e., a car dispatched at a scheduled time from an originating terminal proceeds down the line making appropriate passenger stops. Lines with frequent stops, particularly surface lines, generally operate like this because visibility is good and traffic moves in only one direction on each track.

In order to increase the average speed of light rail vehicles and improve schedule reliability on highway median and street routes, preferential traffic signals which give light rail vehicles priority through intersections can be employed. Such control devices are used in several European cities. Without preferential signals, light rail transit vehicles must observe the normal signal indications and proceed accordingly.

Light rail vehicles may be equipped with radios for emergency purposes. It is uncommon on light rail transit lines to use radios for vehicle traffic control.

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service characteristics

FREQUENCY. Service frequency on light rail transit lines can vary considerably with service demands. Typically, service frequencies can be classed as peak, base, and off-peak service. Although variations do exist, generalized definitions of these service classifications are:

- Peak service is designed to accommodate the heaviest passenger loads occurring during rush hours, usually 7 AM to 9 AM, and 4 PM to 6 PM. Light rail transit headways (time between arrival of successive trains) usually range from one to five minutes. Typically, system capacity is increased during peak periods by running two, three, or four-car trains.

- Base service is the routine service operation of the line and is provided at other than peak periods during daytime hours; i.e., from 9 AM to 4 PM. During this period, light rail transit typically operates with single vehicles and headways of 10 to 15 minutes.
- Off-peak service is that which is provided during the evening hours of 6 PM to 12 midnight. Off-peak also means all-night service (owl) and that which is provided on weekends and holidays, when regular commuter traffic does not occur. Many light rail transit companies do not provide all-night service, but use that time to perform system and track maintenance.

SPEED. The average speed of light rail transit vehicles largely is dependent on the number of stops and on the extent to which the route shares city streets with automobiles. Another factor affecting light rail vehicle average speed is right-of-way alignment; vehicle speeds will be adversely affected by extremes of grade and curve radii. Also, if a highway median strip serves as a light rail transit right-of-way, grade crossings may cause delays should they become obstructed by cross-traffic. As previously mentioned, traffic control devices which give light rail transit vehicles priority through such intersections can reduce the deleterious effects of cross-traffic.

SYSTEM CAPACITY. Light rail transit system capacity is a function of vehicle capacity and speed, frequency of service, train length, and passenger loading time. Assuming a double-track system, signaled, with a peak headway of 90 seconds (easily attainable, according to reference 54, Vigrass) between single light rail vehicles, and using vehicle capacities of 120 passengers for a PCC car and 200 for the SLRV, the resultant route capacities would be 4800 to 8000 pphpd, respectively. If the light rail vehicles are operated as three-car trains, the theoretical capacities would increase by three times to 14,400 and 24,000 pphpd, respectively. A maximum passenger capacity range of approximately 18,000 to 20,000 pphpd will allow for acceptable spacing between trains with occasional above-peak passenger loading. Since the time required at station stops increases with heavier passenger loads, queuing of trains would result if greater volumes were carried. With ridership ranges higher than 20,000 pphpd, either rail rapid transit technology should be seriously considered or, alternately, the system could use articulated, high-platform loading light rail vehicles with several doors to reduce station dwell times.

Light rail transit can also be an economical and attractive transit alternative for lower passenger volumes; for example, some existing light rail systems carry 10,000 to 15,000 passengers per day (reference 54, DeGraw, Vigrass). These low all-day figures result in peak-hour volumes of 2000 to 4000 passengers, which are easily accommodated with one or two-car trains running every 5 to 10 minutes. These light rail transit systems can upgrade their service in the future if passenger volumes increase significantly. The upgrading process might involve increasing train length (which may also necessitate lengthening stations), increasing power substation capacity, and, in the case of single track lines, adding a second track. Another alternative would involve decreasing headways, which might mean a significant alteration in the signal system. An analysis of each of these alternatives would be needed to determine if the solution should be longer trains with long headways or shorter trains with short headways.

EXPRESS AND LOCAL SERVICE. Light rail transit service is typically local, with a light rail transit vehicle stopping at every station along a route. Stops are sometimes made only on demand, with alighting passengers signaling a desired stop by actuating bell signals.

Another type of light rail transit operation is express service, variations of which exist in Cleveland, Philadelphia, and Pittsburgh. Express runs may skip intermediate stops, and usually run non-stop over some portion of their route. For example, an inbound express may stop at the outmost group of stations, then run express non-stop until it reaches the downtown area, where it distributes the passengers locally. This same mode can be employed with a variation called "skip-stopping", in which alternate trains stop at every other station, with some common station stops.

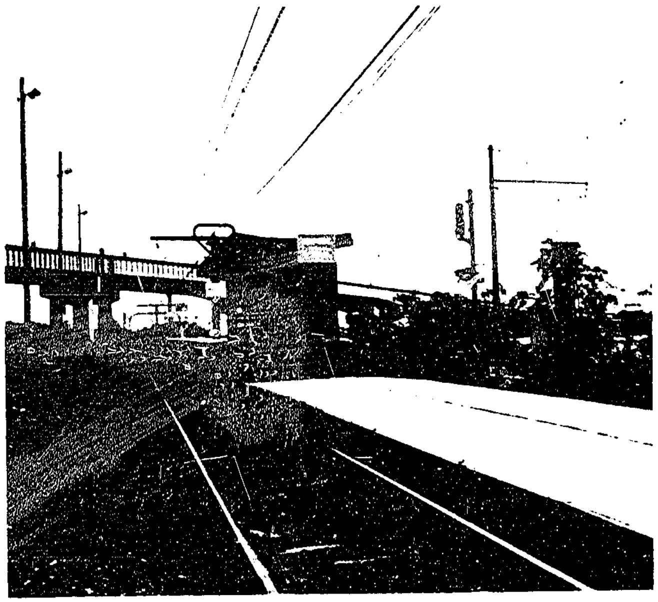
INTERMODAL INTERFACE. Interface between light rail transit and other modes of transportation such as bus service, rail rapid transit, and automobile parking facilities is common. Interface with automobile transportation, for example, can be effected by locating parking lots adjacent to light rail transit stations. Interface with buses can be done on the platform level. Interface with rail rapid transit often requires at least a change in platforms. One example of light rail/rail rapid transit interchange is in San Francisco, where the light rail transit line (MUNI) is on the top level of a two-level subway, with the rail rapid transit (BART) using the bottom level. Another example is the East 34th Street Station in Cleveland where easy connection can be made between the low-level light rail platform and the high-level rail rapid transit platform.

SAFETY. Light rail transit technology provides for safe system operation. The use of appropriate signaling on high-speed routes ensures safe operation between elements of the system. Safety on street-running and median routes is facilitated by use of appropriate highway traffic control devices preventing collisions between automobiles and light rail transit vehicles. The vehicles themselves are usually of steel construction and can withstand moderate impacts. Fencing of exclusive rights-of-way discourages human encroachment and its attendant hazards. To provide for safe boarding of passengers on street and median routes, pedestrian safety islands are often employed.

Light rail transit passenger safety in urban areas depends to a certain extent upon motorist's behavior. Therefore, effective traffic law enforcement is necessary to ensure the safety of passengers boarding and alighting vehicles, and also to avoid congestion between light rail transit vehicles and automobiles on city streets.

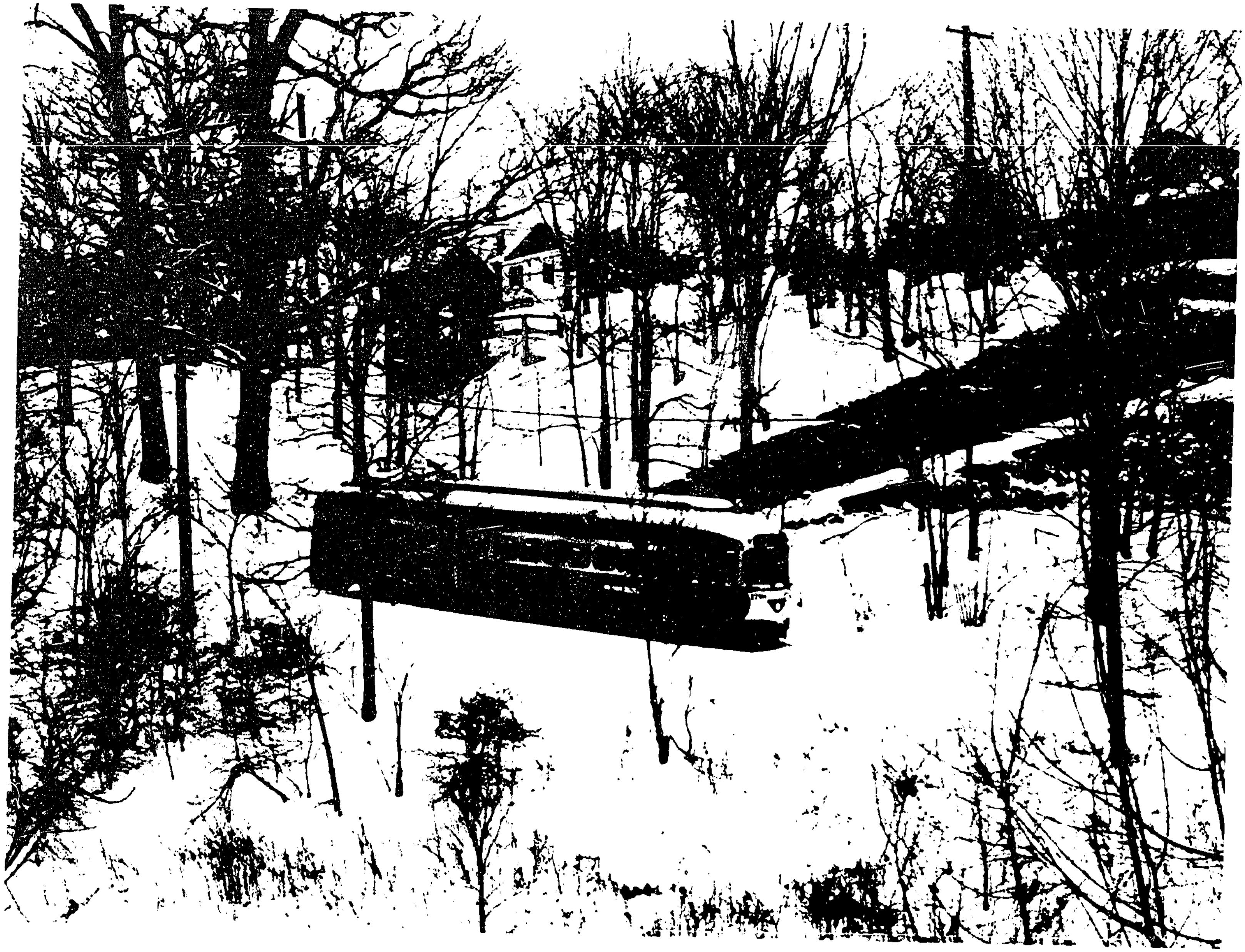
Bus and Light Rail Interface, Boston

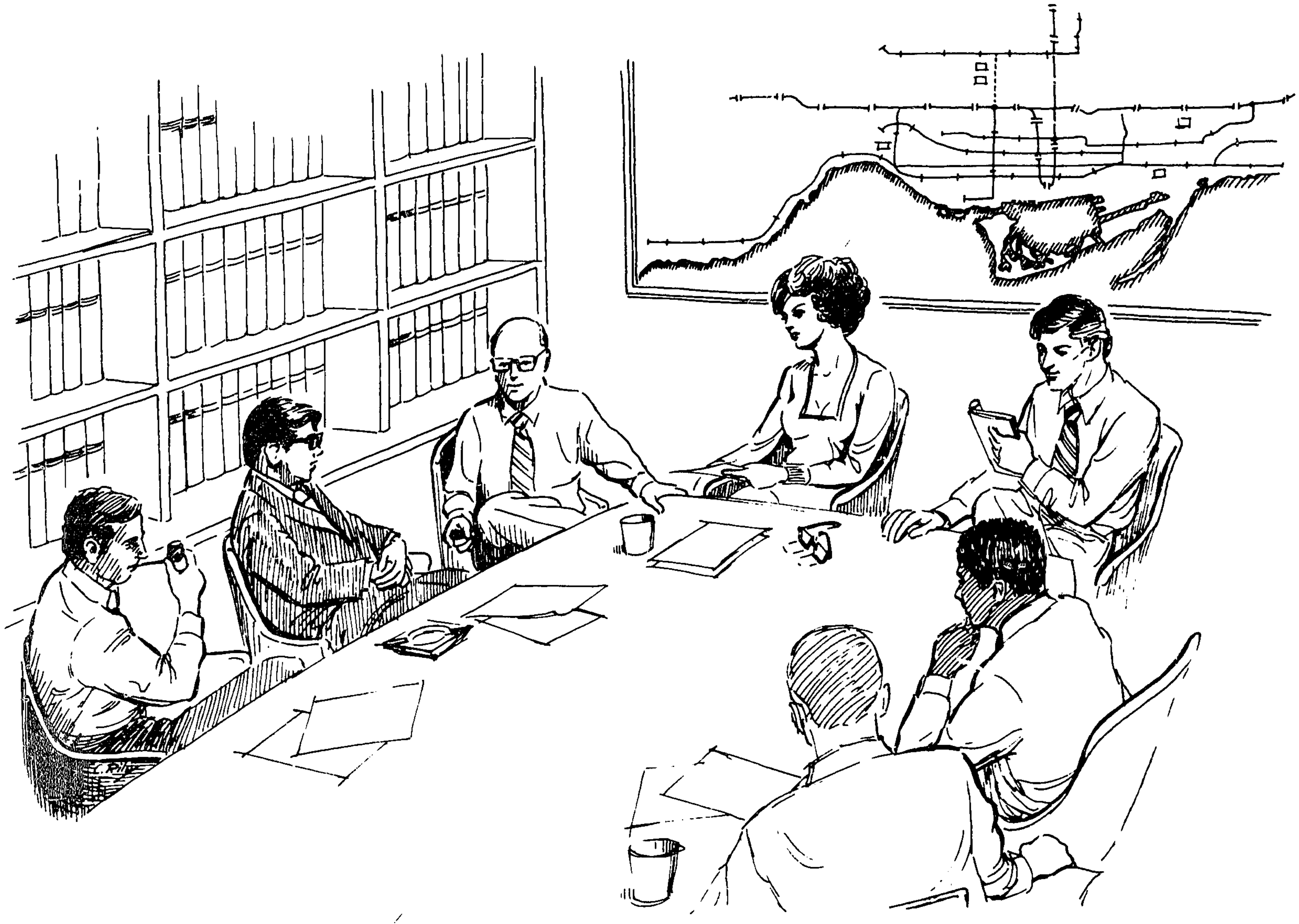
Rail Rapid and Light Rail Interface, Cleveland



In addition, when light rail vehicles operate underground in subways, they often require many of the rail rapid transit safety elements (reference 54, Parkinson). Thus, where long subway sections are planned, ventilation control, power supply redundancy, and a means to evacuate passengers are needed. However, in short tunnels, the expenses for the implementation and maintenance of these measures may not be justified because of natural ventilation and/or short station spacing.

Pittsburgh PCC Car





III PLANNING AND IMPLEMENTATION ISSUES

WHEN PLANNING AND IMPLEMENTING a light rail transit system, a wide variety of issues should receive consideration. Some of the more important issues addressed in this chapter are: the level of service to be provided, initial construction and annual operating costs, and the environmental and social impacts on the community.

planning criteria

The issues influencing the selection of light rail transit cover a wide range of topics. Implicit in the light rail transit selection process are the following important considerations:

- Intensity and growth prospects of the proposed service area.
- Historic and potential area reliance on public transportation.
- Suitability of utilizing existing rights-of-way and highway medians for possible conversion to light rail transit roadbeds, or of sharing existing rights-of-way with railroads.
- Flexibility to adapt to a variety of rights-of-way provides more options in planning future route extensions.

- Coordination of light rail transit with existing rail rapid transit lines and feeder bus operations.
- Flexibility to convert light rail transit to rail rapid transit if passenger volumes warrant; this requires careful consideration in the planning and design stages.
- Local definition of the ridership range, which justifies the light rail transit system based on the unique needs and characteristics of the urban area.
- Station spacing most suitable to demand levels.
- Overall urban impact of the light rail transit system in terms of environmental, social, and land use considerations.

The above points are general planning criteria. A number of other issues are addressed in the paragraphs to follow which center on light rail transit application possibilities, capital and operating costs, implementation period, and urban impacts.

APPLICATIONS. A review of existing and proposed U.S. and Canadian light rail transit systems reveals various applications for this transit mode. Typically, light rail transit has been used for radial service to the CBD, downtown distribution, and as a feeder line for rail rapid transit service. In addition, light rail transit can be used for numerous other special applications.

Radial Service to the CBD: A common application of public transportation in urban areas is service to radially-oriented commuter work trips between central business districts and suburban communities. During peak periods, commuters may walk or drive to light rail transit stations, park, and then ride the light rail transit line downtown. During base and off-peak periods, shopping, recreational, and personal trips prevail. Downtown shopping areas and recreational centers such as parks, theaters, and restaurants then become readily accessible to the light rail transit user.

An example of radial service to the CBD is Cleveland's light rail transit line which connects downtown Cleveland with suburban Shaker Heights, Ohio. The line makes six stops in Cleveland on six miles of exclusive grade-separated right-of-way, terminating in a downtown station where riders may transfer to a high-platform rail rapid transit line. Five of the six stations are flag stops, which are skipped both by express and by some local trains. At the outer suburban stop on the main line, the system splits into two distributor lines which travel in boulevard median strips. This system essentially provides the suburban community of Shaker Heights with limited-stop, express service to downtown Cleveland.

Downtown Distribution: When planning for downtown distribution, the four options for light rail transit are:

(1) Street running in median strips or with other vehicles;
(2) Subways;

(3) Exclusive rights-of-way at grade;
(4) Elevated structures.

Any combination of these options is also possible. In the U.S. and Canada, the following methods are employed by the existing systems:

City	Downtown Distribution
Boston	Lines feed into downtown central subway.
Cleveland	Exclusive right-of-way into downtown rail terminal.
Fort Worth	Subway into department store.
Newark	Downtown subway.
New Orleans	Street-running.
Philadelphia	Street-running and a downtown central subway fed by 5 of the 12 lines.
Pittsburgh	Street-running.
San Francisco	Downtown subway under construction to replace street-running.
Toronto	Street-running.

No system in the U.S. or Canada exclusively employs elevated light rail transit structures for downtown distribution. However, a small section of one of Boston's light rail transit lines does use an elevated structure in part of the downtown line. The systems in the U.S. and Canada which operate on downtown streets share such streets with motor vehicle traffic.

Light Rail Transit Feeder to Rail Rapid Transit: An example of a light rail transit line feeding a rail rapid transit line is the MBTA's (Boston) Mattapan-Ashmont route, which is an isolated light rail transit line connecting two non-CBD locations with intermediate stops. The light rail transit line interchanges at Ashmont with the rail rapid transit line, which goes into downtown Boston. This feeder line was built on an abandoned railroad right-of-way, thereby demonstrating how such rights-of-way can be used. Another example is the Red Arrow Division of SEPTA (Philadelphia), in which three light rail transit lines feed the rail rapid Market Street Line at Upper Darby.

Circumferential Transportation: Radial routing is the most common configuration for mass transit routes. Only in the downtown areas do the routes diverge and form circumferential distribution patterns. However, with circumferential routing in the fringe and suburban areas, transit would become available for users who wish to ride to destinations other than the downtown areas. The flexible routing capabilities of light rail transit make such circumferential routing feasible, but low usage demand forecasts make such routing unlikely.

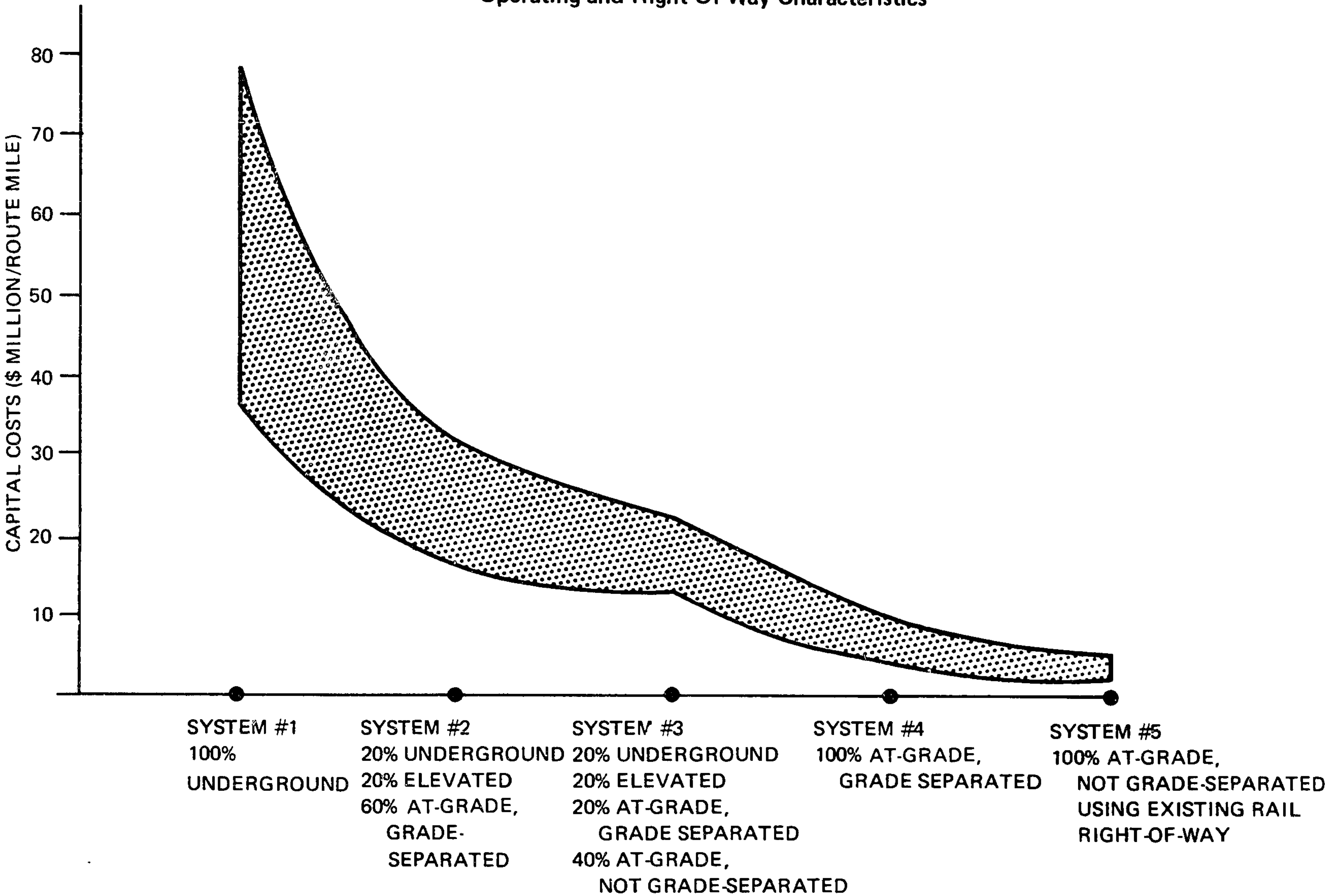
Special Applications - Airport and Shopping Center Access: Light rail transit use for airport access is being considered in Aspen, Colorado. No other airport access light rail transit system is either planned or in use in the U.S. at this time.

The M&O Subway in Ft. Worth, Texas, is a unique application in which a department store is connected to an outlying parking lot with light rail transit service. The volume on this system is 3000 to 6000 riders per day. This application demonstrates the flexibility of light rail transit and shows that it is not limited to high passenger-volume locations.

COST REQUIREMENTS. If light rail transit is built to the same standards as fully grade-separated rail rapid transit, the costs will be comparable (reference 107). However, since light rail transit does not usually require the same degree of grade separation and number of fixed facilities as rail rapid transit for most of its length, there may be a significant cost savings in initial construction. In addition, the potentially high labor productivity element for light rail transit will result in a favorable annual operating cost comparison with buses for similar types of transit service.

Capital (Implementation) Costs: Capital cost is of primary interest when planning and implementing fixed-guideway mass transit systems and can vary substantially depending upon such factors as system design and the availability of existing rights-of-way. While some of the dollar figures involved may seem high, light rail transit capital costs can be relatively low when compared with rail rapid transit. *This depends on the specifics of the site at which light rail transit is implemented,* for example, whether it is underground, at-grade, or elevated. Figure 6 shows that the variations in light rail transit capital costs are largely dependent on its operating and right-of-way characteristics. Additional and more detailed capital cost information may be found in references 24, 54, and 55.

Figure 6. Example of Light Rail Transit Capital Costs For Various Operating and Right-Of-Way Characteristics*



*NOTE: THIS GRAPH SHOULD NOT BE USED WITHOUT THE SUPPORTING MATERIAL CONTAINED IN REFERENCE 55, FROM WHICH THE GRAPH WAS ADAPTED.

Operating Costs: In general, it is very difficult to derive and compare the operating costs of various transit modes. This is also the case with light rail transit (reference 107). The variations in accounting procedures, especially the distribution of such elements as the overhead and maintenance costs, is one reason for this difficulty. Another difficulty is local variations in work rules and operating procedures for light rail transit systems. However, it can be stated that labor costs represent the major portion of a light rail transit system's operating cost (reference 54, DeGraw). It has been reported that driver costs can be as high as 40% of the direct operating costs (reference 107).

Comparisons of the operating costs of buses and light rail transit have recently been made. However, these comparisons are rarely conclusive since the two modes generally represent different types of service. Thus, only when the two modes are compared for the same type of service could a valid comparison be made.

A recent comparison of light rail transit and bus service for as similar a type of service as the technologies would permit, was made on the Charlotte-Henrietta corridor in Rochester, New York (references 18 and 54, Morris). This study showed that although the total system capital costs of light rail transit and a busway were comparable, there was a significant (approximately 25%) operating cost saving for light rail transit. The study noted that this potential superior cost performance was due to light rail transit's ability to operate trains controlled by only one operator and the higher passenger capacity of light rail transit vehicles when compared to buses.

IMPLEMENTATION PERIOD. Another feature of light rail transit is its potentially short implementation period. As mentioned previously, light rail transit is easily adapted to highway median strips and to railroad rights-of-way. This means that the construction of light rail transit lines need not be complicated, time consuming, or disruptive to the community.

There are two examples of this comparatively short lead time for construction. One is the MBTA's Riverside Line, built over a former railroad right-of-way; the line took only one year to modify and upgrade. Another example is Edmonton, where construction of the first segment of a new light rail transit system began in 1974; it is anticipated that the first line will be ready in 1978 (reference 55);

ENVIRONMENTAL AND SOCIAL ISSUES. Light rail transit has potential for fulfilling a number of urban transportation needs with minimal adverse environmental impact. For example, unlike automobiles and buses, light rail transit vehicles do not pollute their local environment because they run on comparatively clean and quiet electric power.

The flexible and inconspicuous nature of light rail transit alignments enables it to blend in with the surrounding environment. The fact that highway median strips and existing rail rights-of-way can be used for light rail transit increases its environmental advantage because existing resources can be used without additional construction or reshaping of the local landscape.

Light rail transit construction is also more likely to be favorable with respect to social impact on neighborhoods. Such construction does not require large structures and attendant property acquisition, which could have a negative effect on the social and demographic characteristics of a city by breaking up neighborhoods and creating abnormal population relocation requirements.

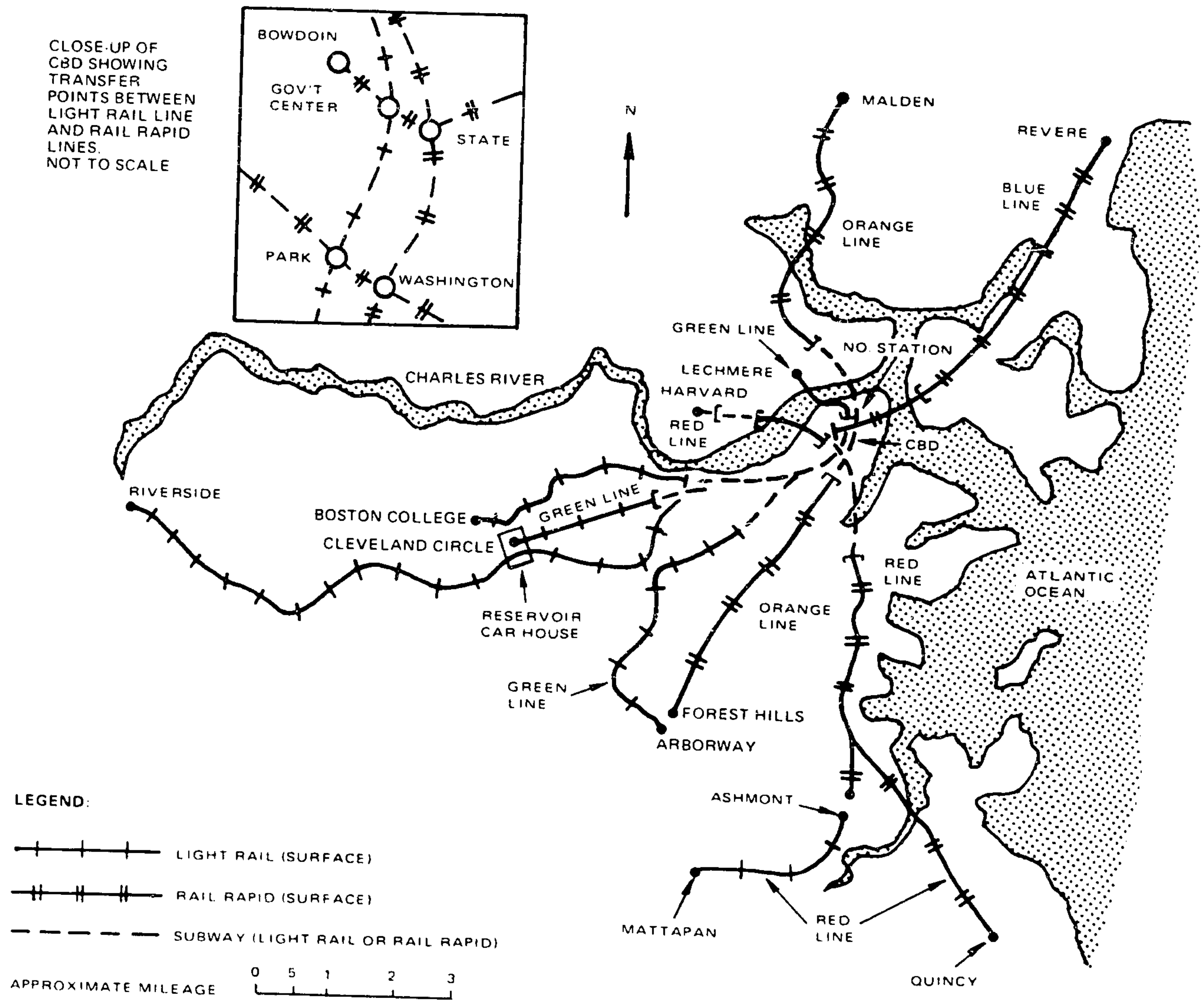
Another positive factor regarding light rail transit concerns the extent to which it affects land use. For example, a light rail transit line's visibility gives it a unique identity. People know where the light rail transit line is because they can see it, whereas they might be unaware of bus route locations and stops unless they are familiar with a particular route beforehand. It is also unlikely that a light rail transit line will be as easily removed or changed as a bus route. The knowledge that a transit system is there, and will probably still be there in the future, is attractive to those who would develop the land area in the vicinity, or who choose to live there for reasons related to the long-term accessibility of public transportation. Thus, light rail transit is a potential catalyst for urban development.

summary

From its beginnings in the last years of the 19th century, and for some 30 years thereafter, streetcar and light rail transit (primarily as street railways) grew enormously through the U.S. and Canada. Its growth peaked with the advent of the automobile and bus. Now, after four decades of decline, light rail transit is enjoying a resurgence of interest as an urban mass transportation mode. This increase in interest has been credited to the combined results of several motivating factors which include: (1) high level of service afforded to passengers; (2) low capital costs and ease of implementation relative to alternative modes; (3) widespread concern about urban, environmental and energy situations.

In a number of medium-density areas, light rail can offer a high level of service at a significantly lower capital cost than rail rapid transit. It can be built on an incremental basis - a few miles at a time. State-of-the-art experience indicates that light rail's adaptability results in it providing solutions to a variety of transit problems. Its ability to be implemented (when necessary) on streets with other vehicles, as well as on exclusive rights-of-way and in subways, provides an operating flexibility for a number of local situations and requirements. Recognizing these advantages, the Urban Mass Transportation Administration (UMTA) recently issued a policy statement on light rail transit (reprinted as Appendix D). In this policy statement, UMTA affirms that it has no modal favorites and will continue to support the choice of a transportation system and mode which emerges as the best solution from the locally conducted alternatives analysis. However, the statement does announce UMTA's intention to aid in the deployment of light rail transit in the city or cities where the proper conditions exist.

SUPPLEMENTARY MATERIAL



Boston (MBTA) Light Rail Transit Service

APPENDIX A*

DETAILS OF EXISTING U.S. AND CANADIAN STREETCAR AND LIGHT RAIL TRANSIT SYSTEMS

BOSTON

Operator

Massachusetts Bay Transportation Authority

Route Characteristics

Four routes feed the Central Subway, comprising what is now referred to as the Green Line. Two of the Green Line routes entering the subway utilize street running and boulevard median strip running extensively (the Boston College and Cleveland Circle routes). The Arborway route terminates in the area of the Forest Hills Orange Line rail rapid transit terminal, providing interface between rail rapid, light rail transit and bus service. The Riverside branch of the Green Line is on an exclusive right-of-way (formerly the Boston and Albany Railroad), and is the longest of the Green Line routes.

A fifth route, the Mattapan-Ashmont route, does not enter the Central Subway and is physically isolated from the other light rail transit lines. This line feeds the Red Line rapid transit at its southern end, providing exclusive right-of-way light rail transit service with an across-the-platform connection at Ashmont for rail rapid transit into the Central Subway. The isolated Mattapan-Ashmont high-speed line connector is officially a part of the Red Line. It is a short route, three miles long, with loops at each terminal, and is built on a former New Haven Railroad branch. Several intermediate shelter-type stations are provided.

At the north end of the Central Subway, a short elevated structure passes North Station and crosses the Charles River to Lechmere Square in Cambridge. Cars can be turned at several downtown points in the Central Subway. Several routes use the various downtown loops as well as loops at North Station and Lechmere Square.

Statistical details regarding the MBTA light rail transit lines are presented in Table A-1.

Market Characteristics

Approximately 165,000 passengers are carried per typical weekday on Boston's Green Line. Approximately 25,000 person-trips originate on the Boston College and Cleveland Circle routes, 13,000 on the Riverside route, and 13,000 on the Arborway route. The remainder are accounted for in local ridership, Mattapan-Ashmont trips, and passengers coming from Lechmere and North Station. The Central Subway is operated with one-, two- and three-car trains, and its rush hour capacity, as presently operated, is equal to approximately 58 three-car trains.

Equipment

PCC cars are now in use for light rail transit service on the MBTA system. However, 175 new articulated (SLRV) cars are being manufactured to replace the bulk of the PCC fleet (which averages about 30 years old). It is anticipated that the newest group of PCC cars (dating from 1951) would be retained to compensate for traffic growth.

Almost all of the MBTA's cars are air-electric, and are single-ended. Some 25 double-ended cars were purchased from Dallas in 1958-1959, but their use is confined primarily to the Mattapan-Ashmont Line and the Arborway Line.

Approximately 15 cars are assigned to the Mattapan-Ashmont Line, with the remainder used on the Green Line routes. Most cars are equipped for multiple-unit operation. None are air conditioned. For subway service, left-side doors are provided. MBTA cars employ modified seating arrangements, with single seats, either inward- or forward-facing, provided ahead of the center door, and with conventional forward-facing two-passenger seats in the rear. Standees are common during peak hours.

One main repair shop located at Cleveland Circle (connecting to the Riverside and Boston College Lines, as well) handles major maintenance. Inspection stations are located at other route terminals, and heavy repair work is performed at the main shops, which are located in Everett. Cars are moved to Everett, and to the Mattapan-Ashmont Line, by flat-bed truck. The main repair shop at Cleveland Circle is known as "Reservoir Car House." This facility is common to the Riverside Line, where the stop is called Reservoir, rather than Cleveland Circle.

A new facility for heavy repair is presently under construction at Riverside. This will accommodate the new SLRVs as well as the older PCC cars.

*Data adapted from reference 118 and reviews by each transit system.

Table A-1
Boston - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF-PEAK		
Commonwealth Ave. - Boston College	Boston College, Park Street Station, Lechmere	Highway Median, Subway, Elevated	7.5	Local	6	7	10 - 15	50	10.0
Beacon Street - Cleveland Circle	Cleveland Circle, Park Street Station, Lechmere	Highway Median, Subway, Elevated	6	Local	6 - 7	7	10 - 15	48	10.2
Riverside	Riverside, Park Street Station, North Station	Grade Separated Right-of-way, Subway	12.7	Local	7 - 8	8	10 - 15	58	15.8
Arborway - Huntington Ave.	Arborway, Park Street Station	Street Running, Subway, Elevated	6.5	Local	3 - 7	5	10 - 15	39	10.8
Mattapan - Ashmont	Mattapan-Ashmont	Exclusive Right-of-way with Grade Crossings	3	Local	2	6	8 - 30	15	12.0

CLEVELAND (SHAKER HEIGHTS)

Operator

Greater Cleveland Regional Transit Authority
Shaker Division

Route Characteristics

The Shaker Division (light rail transit) operates two routes. One of these, the Shaker Line, operates west from Green Road to Shaker Square over the median strip of Shaker Boulevard, and is all double-tracked. Several small shelters and substantial parking facilities exist at certain stops along this route.

The second route, the Van Aiken (formerly Moreland) Line, extends west from Warrensville Center Road to Shaker Square, using the median of Van Aiken Boulevard. Similar in many respects to the Shaker Line route, there is a 30-car storage yard at the outer terminal. At Shaker Square, the routes combine into a fully grade-separated double-track line on an exclusive right-of-way with stops averaging one mile apart, to the junction with the Cleveland Division high-platform rail rapid transit line at Kinsman Road. A tunnel structure provides grade-separated interface. Immediately south of this junction is the Kingsbury Run shop of the Shaker Division lines. From this point to Union Terminal both rapid transit divisions share the double trackage. At one intermediate station, East 55th Street, the high-level loading platforms of the Cleveland Division are outside while the low-level loading platforms used for Shaker Heights trains are in the center (island fashion).

At the second intermediate stop, East 34th Street, to facilitate interchange, both divisions employ island platforms end-to-end with different stopping sections for the different equipment.

At the terminal at Public Square, the high-platform and light rail trains again diverge, and the Shaker Division trains terminate on two low-level loading platforms, beyond which there is a loop. Storage is provided at this terminal for all cars. There is no direct passenger connection in the terminal to the high-level loading platforms of the Cleveland Division, except through the station concourse.

Frequent service is provided on both routes every day, except during late night hours, with all trains originating or terminating at Union Terminal. Many downtown bus connections exist at Union Terminal and some suburban bus routes connect at outlying points. Except for the Union Terminal, few enclosed buildings are used for stops, although all have shelter facilities. The terminal trackage in Cleveland is underground; all other trackage is on the surface or is open cut or fill. Route statistics are presented in Table A-2.

Market Characteristics

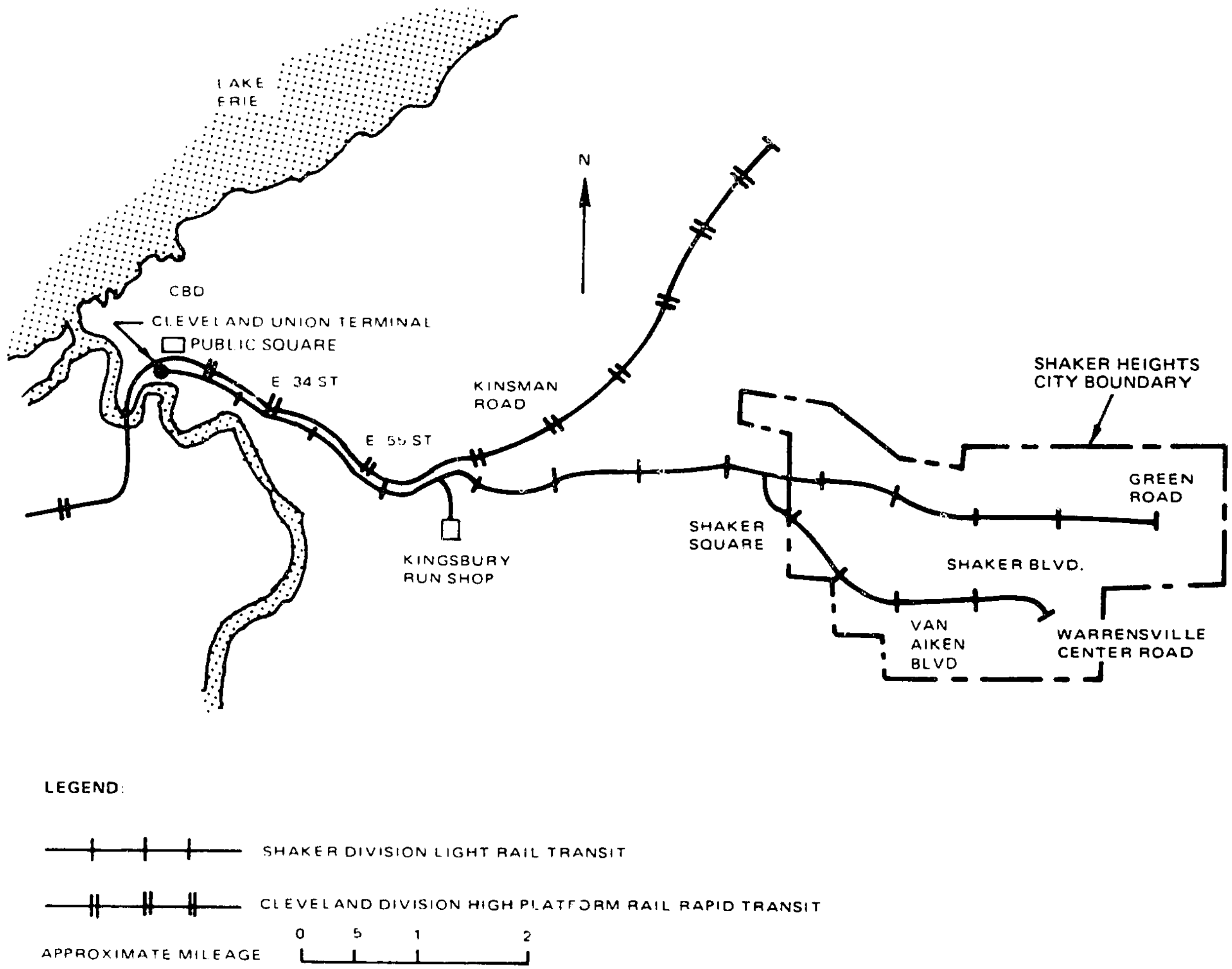
Ridership is predominantly downtown-commuter oriented, with a reasonably high percentage of local shopping, school and other trips contributing significantly to the total.

16,500 weekday rides are typical, with approximately 6,000 on Saturday and 1,500 on Sunday. Total annual ridership is approximately 4.6 million trips. Of the two routes, the heavier ridership is on the Van Aiken route. In the past few years headways have increased, with a reasonably frequent periodic service still provided. An increase in drive-in traffic has been spurred by the development of parking lots adjacent to many of the stops. There is no charge for parking.

Equipment

All 57 revenue cars are of PCC design; 25 were built new for Shaker Heights in 1947, 10 cars of 1946 construction were bought from St. Louis Public Service in 1959, and 20 (built in 1946-1947) were bought from the Twin Cities in 1953. Two double-end cars built in 1949 for Illinois Terminal Railroad are operated under lease. The cars built new for Shaker Heights were equipped with left-hand center doors, although these have always been inactive and sealed. All but five cars are equipped with multiple-unit couplers and controls, with two and three-car trains common.

All cars are all-electric, and air conditioning is not provided. The cars are maintained by the shop at Kingsbury Run. Cars are stored at Van Aiken Terminal (Warrensville Center Road) and at Cleveland Union Terminal. Turnback loops without storage facilities are located at Shaker Square, at the Warrensville Center Road stop on the Shaker branch route, and the Green Road Terminal. A rebuilding and upgrading program for the cars is presently underway.

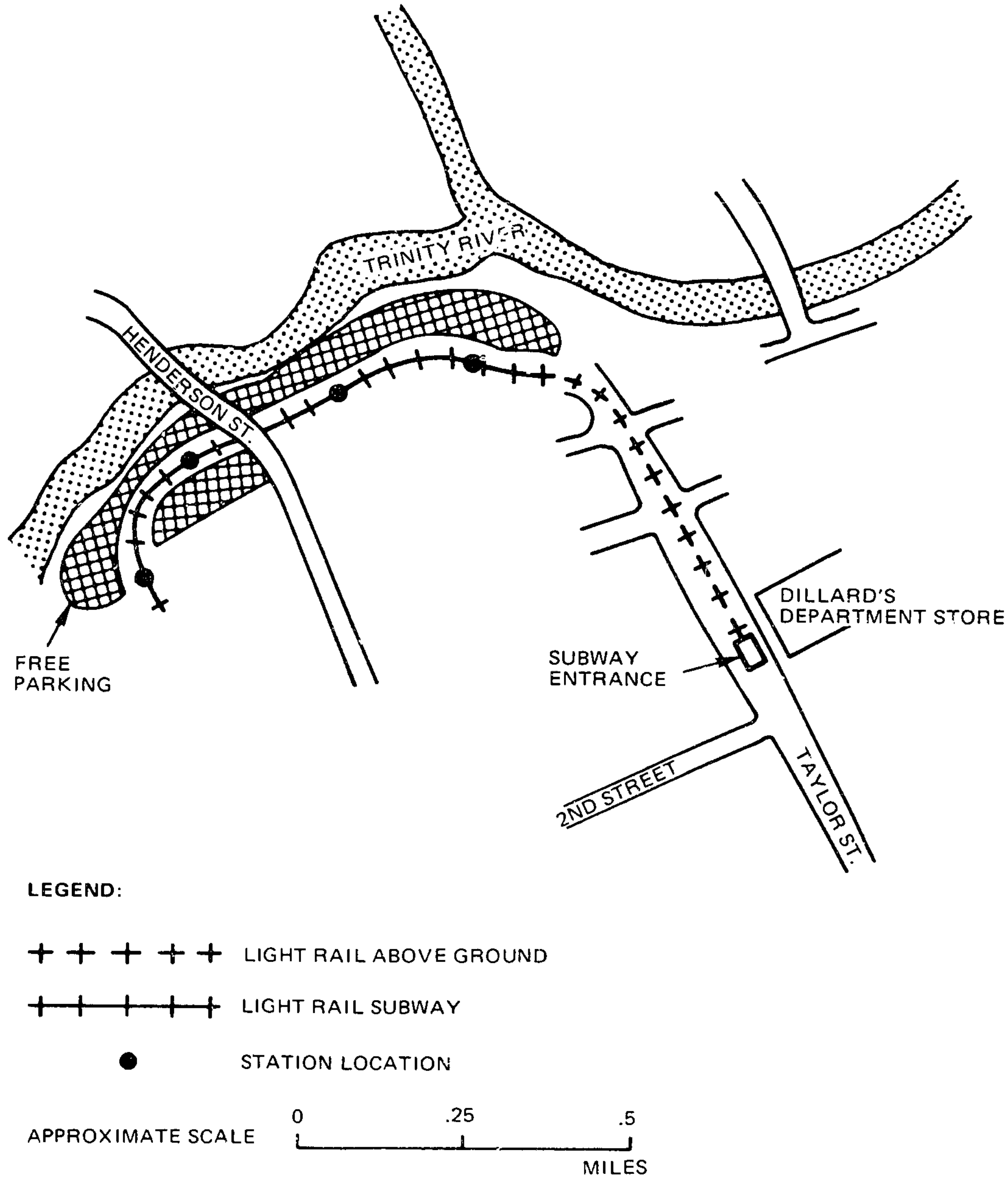


Cleveland (Shaker Division) Light Rail Transit Service

Table A-2

Cleveland (Shaker Division) - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF-PEAK		
Shaker Boulevard Line	Green Road, Shaker Square, Cleveland	Grade Separated and Median Strip in Highway	9.8	Local and Express	4 - 10	20	60	25	24
Van Aiken Line	Warrensville, Shaker Square, Cleveland	Grade Separated and Median Strip in Highway	9.3	Local and Express	4 - 10	20	60	25	22



Fort Worth Light Rail Transit Service

Operator

Tandy Corporation
Dillard's Department Store - M&O Subway

Route Characteristics

The light rail transit line is on an exclusive right-of-way, and is double tracked except for terminal stations, which are single stub tracks. All stations (two terminal and two intermediate) have high-level loading of passengers. There is one intermediate stop provided for inbound and one for outbound cars (platform provided on one side only). The downtown terminal is the only stop not located in the Dillard's parking lot. At the edge of the lot the two tracks enter a subway of approximately one-half mile, terminating at Dillard's basement. The car storage facility is located immediately beyond the outer terminal. The parking lot area is separated from the Central Business District by a small hill, under which the subway passes. Total route length is less than two miles. M&O Subway light rail transit line route statistics are presented in Table A-3.

Market Characteristics

Due to the unique nature of the line, traffic fluctuates widely. An estimated 3,000 - 6,000 riders use the system per day, with this number increasing during peak retailing seasons. Commuters are not a significant factor in ridership, since there are less than 1,000 riders during rush hours. The line operates six days a week, starting at 7:00 AM and continuing until either 7:00 PM or 10:00 PM, depending on store hours. The majority of riders are patrons of Dillard's, with the second largest group being general downtown shoppers.

Equipment

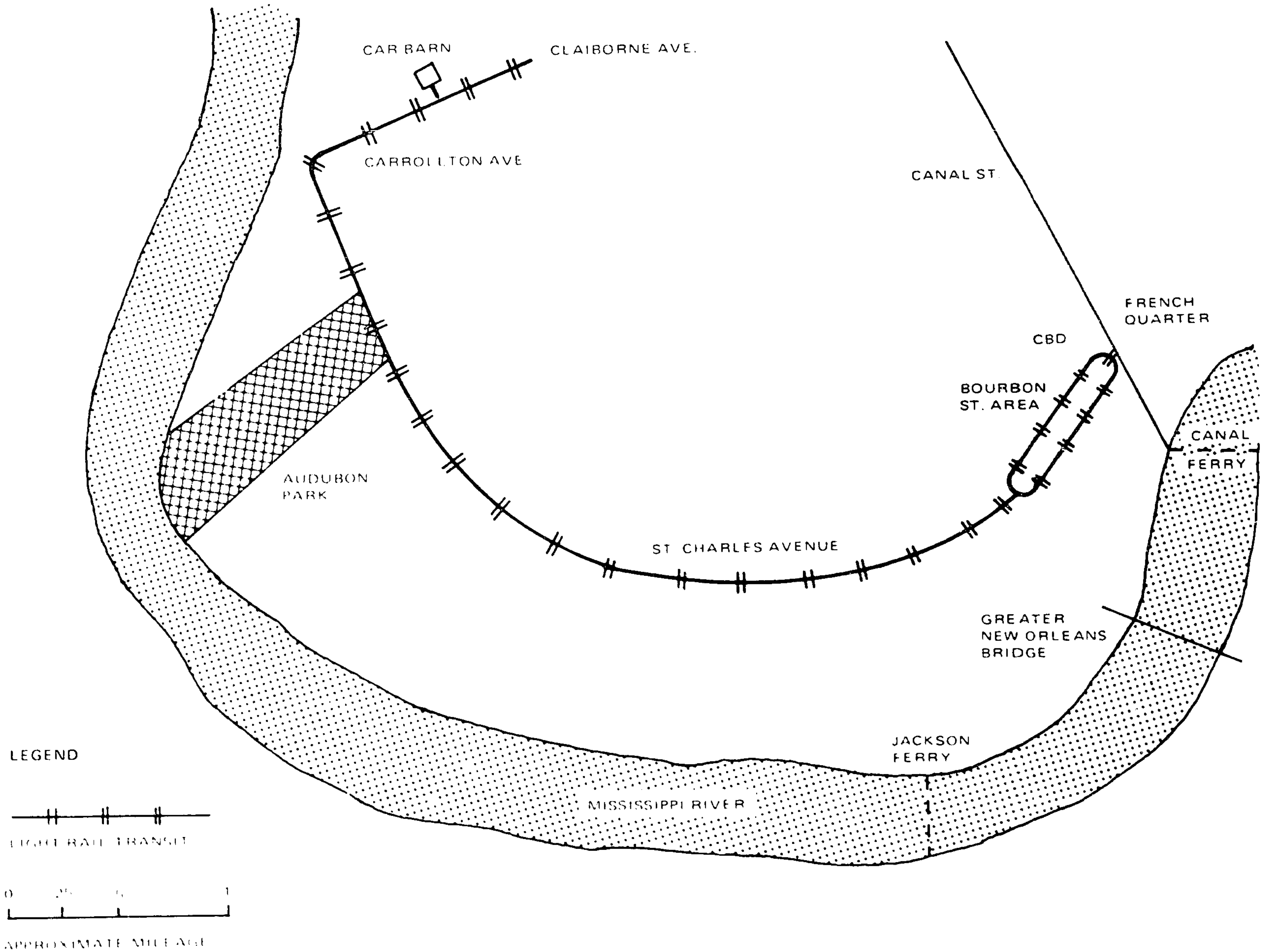
All six cars presently used are former Washington D.C. Transit PCC cars. Built in 1944-1945, these cars were sold to Leonard's Department Store, the former operator of the system, in 1962 and were given an extensive refurbishment. These standard air-electric cars were converted to double-ended streamliners, with the addition of extensive skirting; all are air conditioned. Seats are at the sides and are inward-facing, with consequent reduction in capacity. This is hardly a detriment considering the short ride length, frequency of service, and large number of parcels brought on board by shoppers. All cars were modified for high-level loading of passengers.

Several additional cars were cannibalized to provide spare parts for the six active cars, only three of which are normally utilized at any given time.

Table A-3

Fort Worth - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF-PEAK		
M&O Subway	Parking Lot to Dillard's Department Store in the CBD.	Exclusive Right-of-way, Both Surface and Subway	1.2	Transport to and from Parking Lot	2	12	–	4 - 5	16



New Orleans Light Rail Transit Service

NEW ORLEANS

Operator

New Orleans Public Service, Inc.

Route Characteristics

The six and one-half mile route is predominantly set in the center reservation of St. Charles and Carrollton Avenues. Its access to the Central Business District is via city streets, with some one-way street running, forming a loop. Bordering on the French Quarter at Canal Street (the downtown terminal), the line runs on a sod-covered right-of-way bordering, from Jackson Avenue to Louisiana Avenue, the Garden District, an exclusive neighborhood of large private residences. The line passes Audubon Park and terminates only three miles from its origin; its circuit following the arc of the Mississippi River, which it parallels.

The downtown end is composed of a loop, while the Carrollton Avenue end is a double-track stub with crossovers. The car barn (storage area) is located near the outer end of the line, only one block from the route. Route statistics are provided in Table A-4.

Market Characteristics

Frequent service and low fares have kept light rail transit popular in New Orleans. About 25,000 riders use the service each weekday; more than eight million passengers ride the line yearly.

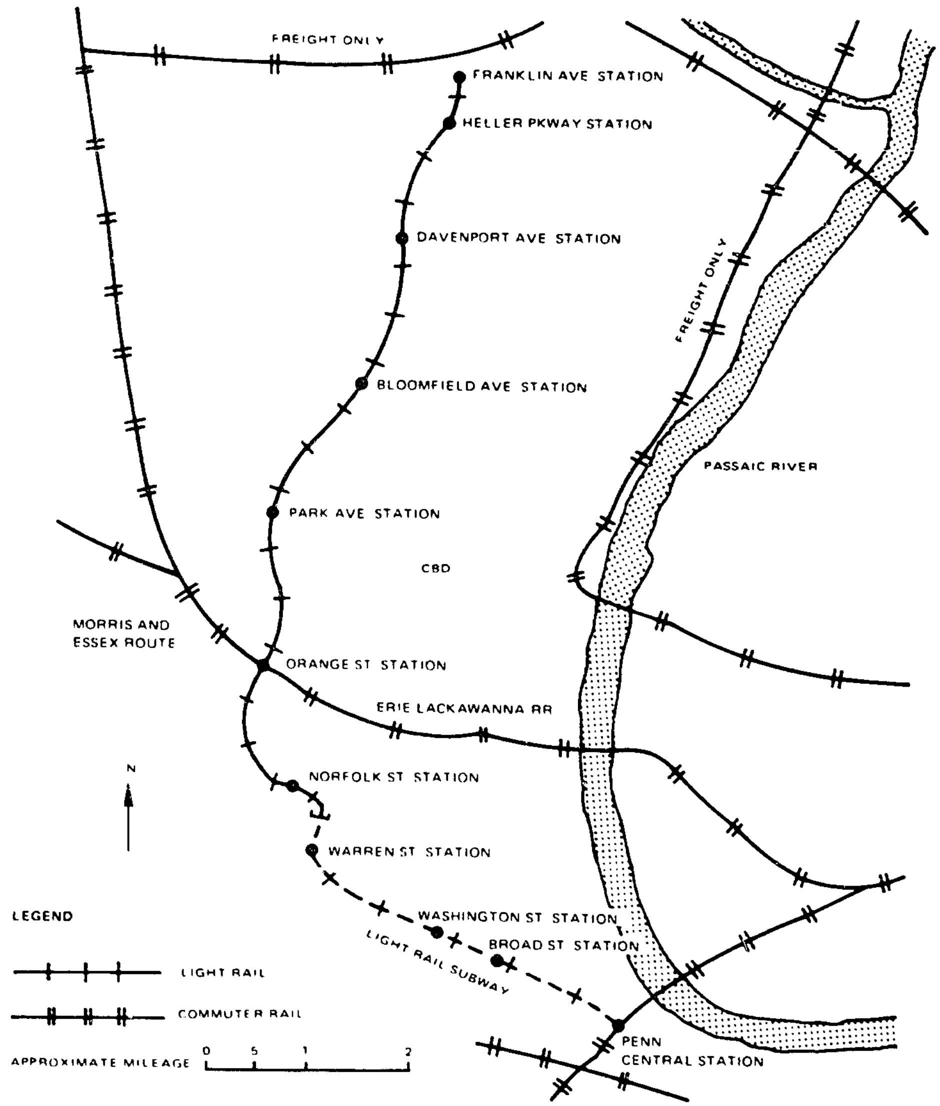
Equipment

The New Orleans cars, built by the Perley Thomas Car Co., are now about 50 years old. The cars are double-ended, and all have wooden bench seating. The seats are walkover except at each end, where they are inward facing. A large vestibule at each end provides a control station, with doors on each side. Many replacement parts must be made in the repair shop. The cars have been extensively upgraded and all cars are presently in good condition.

Table A-4

New Orleans - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF-PEAK		
St Charles Ave	Downtown New Orleans	Street Median	6.5	Local	3.5	4.5	18.5, 60 on Owl	90	9.3



Newark Light Rail Transit Service

Operator

Transport of New Jersey

Route Characteristics

Of the 4.1 miles of route on this line, about one and one-half miles are subway. The entire route is double-tracked and is completely signaled. A large underground terminus is provided at Penn Central Station, the south end of the line where provisions for fleet storage and maintenance are located along with several platforms. At Broad Street Station there is an underground connection to a now unused short subway which was formerly served by other routes. At several intermediate stations on the open segment, unused stub connections provide access to former street routes. Route statistics are shown in Table A-5.

A joint bus-rail transfer station is provided for the north terminal, which is located at Franklin Avenue. Bus feeders provide connections at several intermediate stops, although no other physical transfer stations are used. The line crosses (overhead) the Morris and Essex route of the Erie-Lackawanna Railway, although no station connections exist. At Penn Central Station, covered passage is provided to Port Authority Trans-Hudson (PATH) rapid transit service to downtown New York City, Central Railroad of New Jersey, Penn Central and AMTRAK trains, as well as to the Greyhound Bus Terminal.

Four subway stations and seven surface stations are served. All stations have provisions for precollection of fares, and most have a shelter, although none have station buildings or waiting rooms.

Market Characteristics

Approximately 8,000 weekday riders regularly use this line. This is a substantial reduction from past years, which is primarily due to the economic decline of the City of Newark. Although the light rail transit line is still utilized as a downtown distributor for suburban bus routes, through service on the bus routes in peak hours carries much of the heavy volume. Furthermore, the local areas served directly by the City Subway, as the line is known, have changed greatly in their characteristics over the years. Very little local traffic is available, in comparison to other North American light rail transit operations. Approximately 2,000,000 annual rides are provided. Some element of reverse commutation is offered, with rail commuters arriving at Penn Central Station and dispersing to downtown Newark on the subway. An incentive fare has promoted this travel.

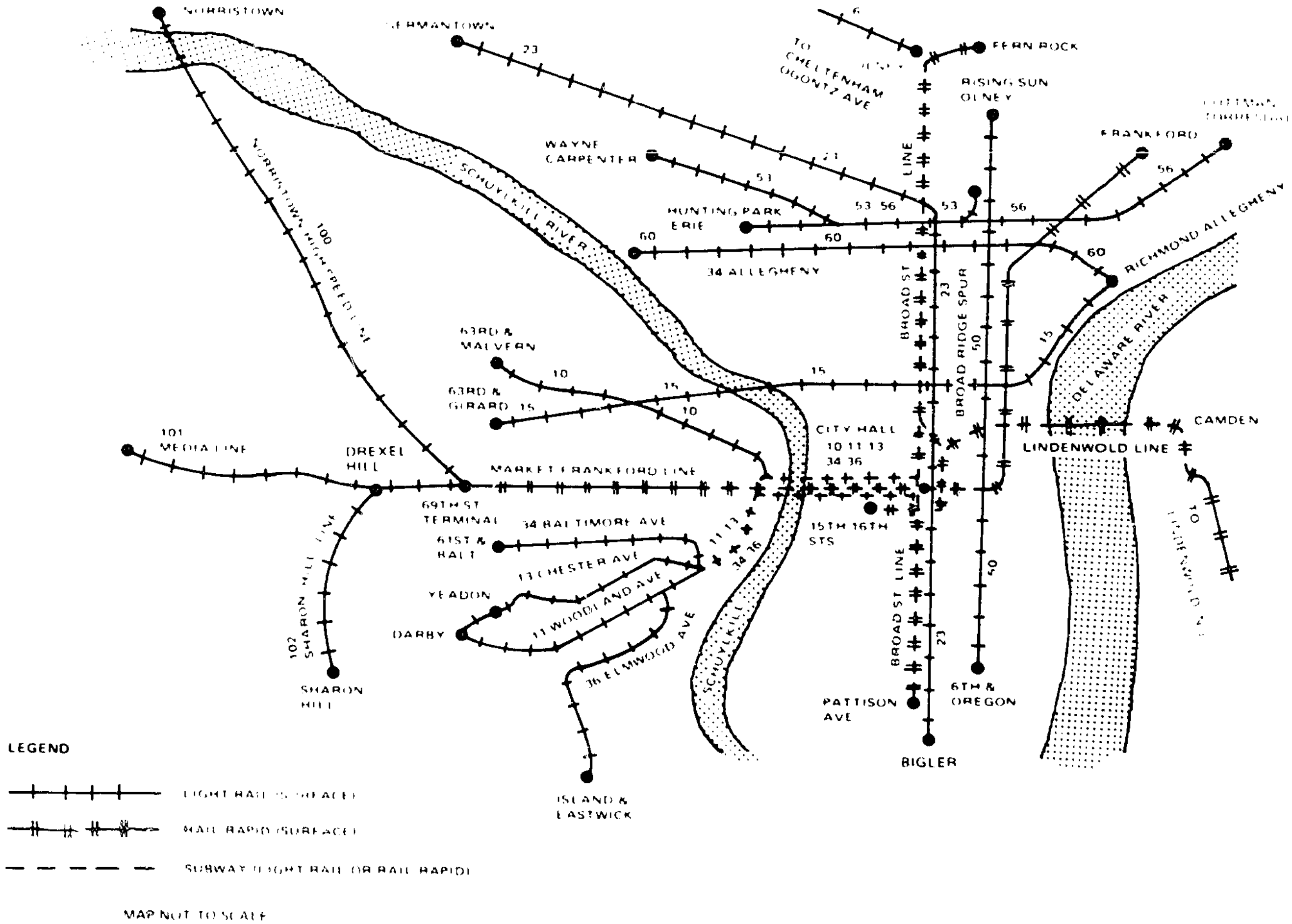
Equipment

Since 1954, all service has been provided by a fleet of 30 former Twin Cities (Minneapolis) PCC cars. These cars were built in the 1946-1949 era and, although old, are well maintained and capable of lasting for several more years. Cars are all-electric, and are non-air conditioned, with two and one seating across in the forward half of all cars. All maintenance activities are performed in the Penn Central Station facility.

Table A-5

Newark - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF PEAK		
7 City Subway	Franklin Ave Penn Central Station	Exclusive Right of way, Subway	4.1	Local	3	15 20	20 30	12	20



Philadelphia Light Rail Transit Service

Operator

Southeastern Pennsylvania Transportation Authority

Route Characteristics

The Southeastern Pennsylvania Transportation Authority's (SEPTA) City Transit Division operates seven streetcar routes, and five subway-surface (i.e., light rail) routes. These lines remain from a system which once operated 86 routes over 678 track miles in Philadelphia. SEPTA's Red Arrow Division operates two light rail lines and the Norristown High-Speed Line. Statistical data for the Red Arrow Division and the City Transit Division is presented in Tables A-6 and A-7, respectively.

The City Transit Division's surface lines are double-tracked with a single uni-directional track in the center of downtown one-way streets. All routes connect, except for the Route 6 (Ogontz Avenue) line, which uses non-revenue trackage to reach the remainder of the system. An extremely heavy North-South line, Route 23 (Germantown Avenue), connects the extreme northwest corner of the city with the older areas of South Philadelphia. Other routes are mostly east-west, connecting with one or both of the main subway lines, and numerous bus routes. Downtown trackage is generally on narrow one-way streets, with but a single uni-directional track in the street center.

The subway-surface routes enter downtown on the two outer tracks of the Market Street subway, looping around City Hall Plaza underground. They radiate from the tunnel portals in the southwest and northwest directions. Several subway stations are provided, two connected by a common concourse with rapid transit stops. All subway-surface routes are double-tracked, with some exclusive right-of-way on rush hour extensions in the southern city limits area (one line was part of a suburban route once extending to Chester). The portals, and confluence of the street portions are located in the university area just west of the Schuylkill River. The subway is three miles in length, although one line uses a portal one mile east of the final exit.

The Red Arrow routes are suburban in nature, almost entirely on exclusive rights-of-way, and combine signaled portions of single and double-track, with passing stretches. They run together on shared double-track at the side of Garrett Road, west from the 69th Street Terminal, and split at Drexel Hill. At this point, the Media Line proceeds west through parks and hilly terrain to the town of Media, and the Sharon Hill Line turns south and slightly east. Both terminate on single track, with no loops required, as all cars are double ended. The 69th Street Terminal, however, incorporates a loop with two departure tracks, an arrival track, and a small adjacent storage yard. Many stops have shelters, and a few have small adjacent parking lots.

The Norristown Line strikes out northwest from its separate terminal at 69th Street (separated from the terminal by the Market-Frankford subway station), which incorporates three stub tracks. It has sharp curves and a graded route but the tracks are designed with superelevation and spirals to allow high-speed operations. Operations up to 90 miles per hour were commonplace in previous years, although power and equipment maintenance now limit the top speed to approximately 70 miles per hour. All stations have short, high-level platforms and shelters, with the 69th Street Terminal having an enclosed waiting room. The Norristown Station is at the end of a long viaduct over the Schuylkill Valley, on the second floor of a commercial building. An enclosed waiting room is provided. Several stations have parking lots, and two have turnback tracks between the inbound and outbound main tracks. The viaduct and Norristown Station is the only single track on the route.

Two trips during each evening rush hour are serviced by Liberty Liner equipment, operating on Norristown express schedules. These are four-unit articulated streamliners which provide luxurious seating and beverage service Some rush hour trips on all Red Arrow routes utilize two-car multiple units. Express service is provided on all these routes.

The City Transit routes are served by four storage car houses. Woodland, on the subway-surface routes in Southwest Philadelphia, houses cars for Routes 11, 13, 34, and 36. The remaining subway-surface route, Route 10, shares Callowhill Depot, in West Philadelphia, with Route 15. The heavily utilized Route 23 solely occupies Germantown Depot, while Luzerne Depot in North Philadelphia houses Routes 6, 50, 53, 56, and 60. A single service area, with a repair shop on opposite sides of the Norristown Line, is located at Victory Avenue near the 69th Street Terminal.

Except for the subway stations, no City Transit routes use station facilities, other than an occasional shelter at a terminal.

Market Characteristics

All routes are heavily utilized, with all-night service provided on most of the City Transit Division routes. Commuters ride to schools such as Temple, Drexel, and the University of Pennsylvania, as well as to work. Heavy use is made of all lines for local travel demands and for access to Center City, the downtown area which is still the economic and cultural center. The Red Arrow routes serve the upper- and middle-class western suburbs in Delaware County and along the fashionable Main Line. Most commuters on these routes are white-collar workers and school children, with a substantial reverse movement of employees of the scattered industrial areas. Although shopping centers are served by the Red Arrow routes, high auto usage for shopping trips, and the availability of competing SEPTA-sponsored rail commuter services on the Penn Central and Reading railroads have curtailed the use of the light rail transit for these trips.

Ridership on the City Transit Division surface routes is heaviest, with 130,000 weekday rides, or almost 40 million annually. The Route 23 line alone accounts for 44,000 weekday trips. The subway-surface lines generate 65,000 weekday trips, or almost 20 million annual trips. Red Arrow trolley routes carry 14,000 passengers on a weekday, and almost this number ride the Norristown high-speed line (4 million and 2-3/4 million annually, respectively).

Equipment

All City Transit vehicles are PCC cars built between 1941 to 1948. Some were bought from Kansas City Public Service in 1954. Both all-electric and air-electric cars are used. Many of Philadelphia's cars are now being refurbished. Seats are two and one across the front and conventional in the rear, all forward facing.

Red Arrow cars are a mixed lot of older equipment which still provides exceptional performance, equal to that of new cars. These lines all use double-ended non-PCC equipment, although the most recent group of 1949 cars resemble PCC cars. A group of prewar cars were built as the last effort of J.G. Brill, a leading electric railway carbuilder responsible for many of the pre-PCC cars in this country, and for many of the remaining Red Arrow cars. This group, based on lightweight designs similar in some respects to PCC equipment, is called Brilliners. Earlier Brill cars (from 1932) are some of the last cars to use manual, rather than pedal, type controls. Two earlier heavyweight, center-entrance cars are maintained for historical purposes, although these have been used in recent years during heavy snow. All cars have doors on both sides of the cars.

All the Red Arrow cars are equipped for high-speed operation on ballasted track. All have walkover type seats, and all are equipped with wooden drop seats used when a door is not in service (they span the door stepwell).

The Norristown Line cars are in three groups. The oldest were built in the 1924-1929 era and are used in rush hours only. A later group, the famed Brill Bullet cars, was built in 1931 after a great deal of research, including wind tunnel testing. Designed for high speeds with low power consumption, they have comfortable, walkover bucket seats, and a sizeable platform at each end, with folding doors. The latest group of Norristown cars are the Liberty Liners. Two of these four-car articulated trains were bought from the Chicago, North Shore and Milwaukee Railroad, where they had served since construction in 1941 on high-speed intercity runs between Chicago and Milwaukee. Using deluxe seats, and containing a tavern lounge and bar section in one car, the trains are popular, but are used only in peak periods due to their high capacity and inordinate drain on the line's electrical distribution system.

Table A-6

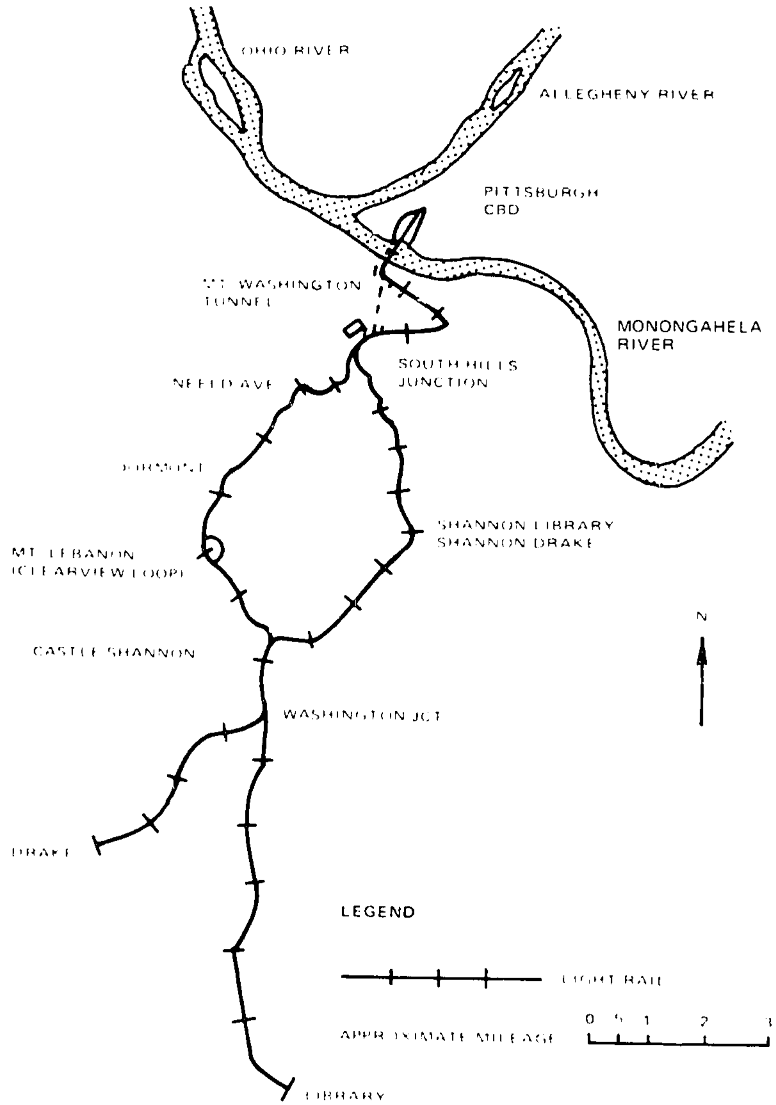
Philadelphia (Red Arrow Division) - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	HEADWAY (MINUTES)				SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
				SERVICES	PEAK	BASE	OFF-PEAK		
Route 100 Norristown High Speed Line	Norristown 69th Street Terminal	Grade Separated Right of way	13.5	Local, Express, Skip Stop	4.5	15	30	26	31
Route 101 Media Rail Line	Media 69th Street Terminal	Exclusive Right of way with Partial Street Running	8.5	Local and Express	4.0	20	30	30	17
Route 102 Sharon Hill Rail Line	Sharon Hill 69th Street Terminal	Exclusive Right of way with Partial Street Running	5.3	Local and Express	3.5	20	30	22	14.5

Table A-7

Philadelphia (City Transit Division) - Streetcar and Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF PEAK		
Route 6 Ogontz Ave	Ogontz & Cheltenham Broad & Olney	Street Running	2.8	Local	8	15	30 60	15 - 17	9.0
Route 10 Lancaster Ave	63rd & Malvern - City Hall Via Subway	Street Running to 34th Street Subway to City Hall	5.8	Local	6	12 20	30	25 - 33	9.4
Route 11 Woodland Ave	9th & Main Streets, Darby City Hall Via Subway	Street Running to 39th Street Subway to City Hall	6.7	Local	4	12 - 20	30	29 - 36	11.0
Route 13 - Chester Ave	Yeadon & Darby City Hall Via Subway	Street Running to 39th Street Subway to City Hall	5.7	Local	3	12 20	30 - 60	24 - 32	11.3
Route 15 Girard Ave	63rd & Girard Richmond & Westmoreland Street	Street Running	7.6	Local	5	15	30	45 - 55	7.3
Route 23 Germantown Ave	Germantown Ave & Bethlehem Pike 10th & Bigler	Street Running	12.8	Local	4	15	30	60 - 75	8.0
Route 34 - Baltimore Ave	61st & Baltimore, City Hall Via Subway	Street Running to 39th Street Subway to City Hall	5.0	Local	4	12 - 20	30	21 - 27	11.5
Route 36 Elmwood Ave	80th & Eastwick City Hall Via Subway	Street Running to 39th Street Subway to City Hall	8.1	Local	4	15	30	30 - 40	12.3
Route 50 5th Street Line	6th & Oregon Rising Sun & Knorr	Street Running	10.8	Local	9	15	30	70	9.3
Route 53 - Wayne Ave	10th & Luzerne Wayne & Carpenter	Street Running	4.3	Local	10	15	20 40	20 - 25	10.7
Route 56 Erie Ave	23rd & Venango Torresdale & Cottman	Street Running	7.5	Local	4	15	30	35 - 40	11.1
Route 60 Allegheny Ave	35th & Allegheny Richmond & Westmoreland	Street Running	4.9	Local	4	12 - 15	30	20 - 27	8.9



Pittsburgh Light Rail Transit Service

PITTSBURGH

Operator

Port Authority of Allegheny County

Route Characteristics

There are five light rail transit routes in Pittsburgh. All routes originate in the Central Business District, looping on a number of one-way streets to provide downtown coverage. Three configurations of the downtown loop are used. All lines merge on double track which crosses the Monongahela River on the Smithfield Street Bridge.

One line, used as a detour route, climbs over a hill south of the bridge on street trackage. The remaining routes use the tunnel under Mount Washington which exits at South Hills Junction, the major operating headquarters and car repair shop (Tunnel or South Hill Car House). The street trackage on the tunnel bypass route rejoins the main route here.

From South Hills Junction, the Mt. Lebanon via Beechview Line heads Southwest over a long viaduct through Beechview and Dormont to Mt. Lebanon. Some rush hour cars continue on exclusive right-of-way to Castle-Shannon. The Mt. Lebanon Line is double-tracked, with cut-back points at Neeld Avenue and Dormont. The extension to Shannon is single-tracked with sidings.

The Shannon-Library and Shannon-Drake routes continue South from South Hills Junction on double and single-track exclusive right-of-way with passing sidings. The line is signaled. At Castle-Shannon they intersect the extension of the Mt. Lebanon Line, and continue south to Washington Junction. Here, the double-track route to Library continues southeasterly on an exclusive right-of-way, and the single-track route to Drake continues southwest.

The exclusive right-of-way portions of the lines employ shelters at key stops, but no formal station facilities are provided. Several parking lots provide free parking along the Drake and Library routes. Service is provided all night. During peak hours, certain Library route cars operate express over portions of the line. During peak hours, cars are run as short turns to various points along the routes. Statistical data relative to the Pittsburgh light rail transit routes are presented in Table A-8.

Market Characteristics

The system is used by some 15,000 passengers on a typical weekday. Most of the riders are commuters working in the Golden Triangle and other parts of the downtown area. A substantial amount of traffic uses the system as one element of a multi-modal trip, usually involving a bus. Heavy use of the routes during off-peak hours has enabled frequent service to be maintained on all routes, with service on the outer end of the Shannon-Library and Shannon-Drake Lines every half-hour during base periods.

Equipment

PCC cars are used in Pittsburgh; some are all-electric, and others air-electric. The earlier cars were built in 1944-1945, and the latter all-electric cars were constructed in 1947-1948. No multiple-unit operation is employed, and no air conditioning is provided. Some of the cars are equipped with special headlights and horns for use on the longer routes, although cars are generally intermingled in assignment. In a recent overhaul program, many cars have been upgraded, with various colorful exterior schemes.

Table A-8

Pittsburgh - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF-PEAK		
Route 35 Shannon Library	Library, Bethel Park, Pittsburgh	Exclusive Right of way with Partial Street Running	12.8	Local and Express	5	15 30	30 45	41 48	16.0
Route 36 Shannon Drake	Drake, Bethel Park, Pittsburgh	Exclusive Right of way with Partial Street Running	10 8	Local	7	20	30 - 60	37 42	15.5
Route 37 Castle Shannon	Castle Shannon Pittsburgh	Exclusive Right of way with Partial Street Running	7 0	Local	5	15	40 - 60	25 - 35	12.0
Route 42/38 Mt Lebanon Via Beechview	Mt Lebanon, Beechview, Pittsburgh	Exclusive Right of way with Partial Street Running	5 7	Local	5	15	30	35 - 40	8.6
Route 49 Arlington Warrington	S. Hills Junction, Pittsburgh	Exclusive Right of way with Partial Street Running	3.0	Local	30	60	60	22 - 30	7.0

Operator

San Francisco Municipal Railway (MUNI)

Route Characteristics

All five light rail transit routes of the San Francisco system are double-tracked, and share Market Street trackage in the downtown area. Presently originating at the East Bay Terminal (the focal point for inter-urban bus service to East Bay cities), they continue on Market south-westerly to a point west of Van Ness where the J (Church) Line swings south on a mixture of street and exclusive right-of-way trackage, and the N (Judah) Line swings due west, through the short Sunset Tunnel to street trackage leading almost to the ocean front. The remaining lines enter the Twin Peaks Tunnel at Market and Castro, and continue south-westerly through two stations to the junction at the West Portal stop. The L (Taraval) Line branches off at this point and continues west to the ocean and city zoo along street trackage, while the K (Ingleside) and M (Ocean View) Lines split at St. Francis Circle. Both then arc to the southeast; the K Line terminates just short of the BART Balboa Park rapid transit station, and the M Line terminates at Broad and Plymouth, using both street and exclusive right-of-way trackage. The main heavy repair shops lie just beyond the present K Line terminus, connected by non-revenue trackage. Each of the five routes connect the downtown business district with residential areas to the west and south.

A new subway under Market Street will route the lines from a terminal at the Embarcadero near the foot of Market Street to the Duboce Portal, where the J and N Lines will emerge to street level, then separate at Church St. Outer-end routing will remain, except that the K and M Lines will terminate at a new extension - adjacent to the BART Balboa Park station. Statistical data relative to these routes is presented in Table A-9. (Note: A-9 lists present terminals.)

Market Characteristics

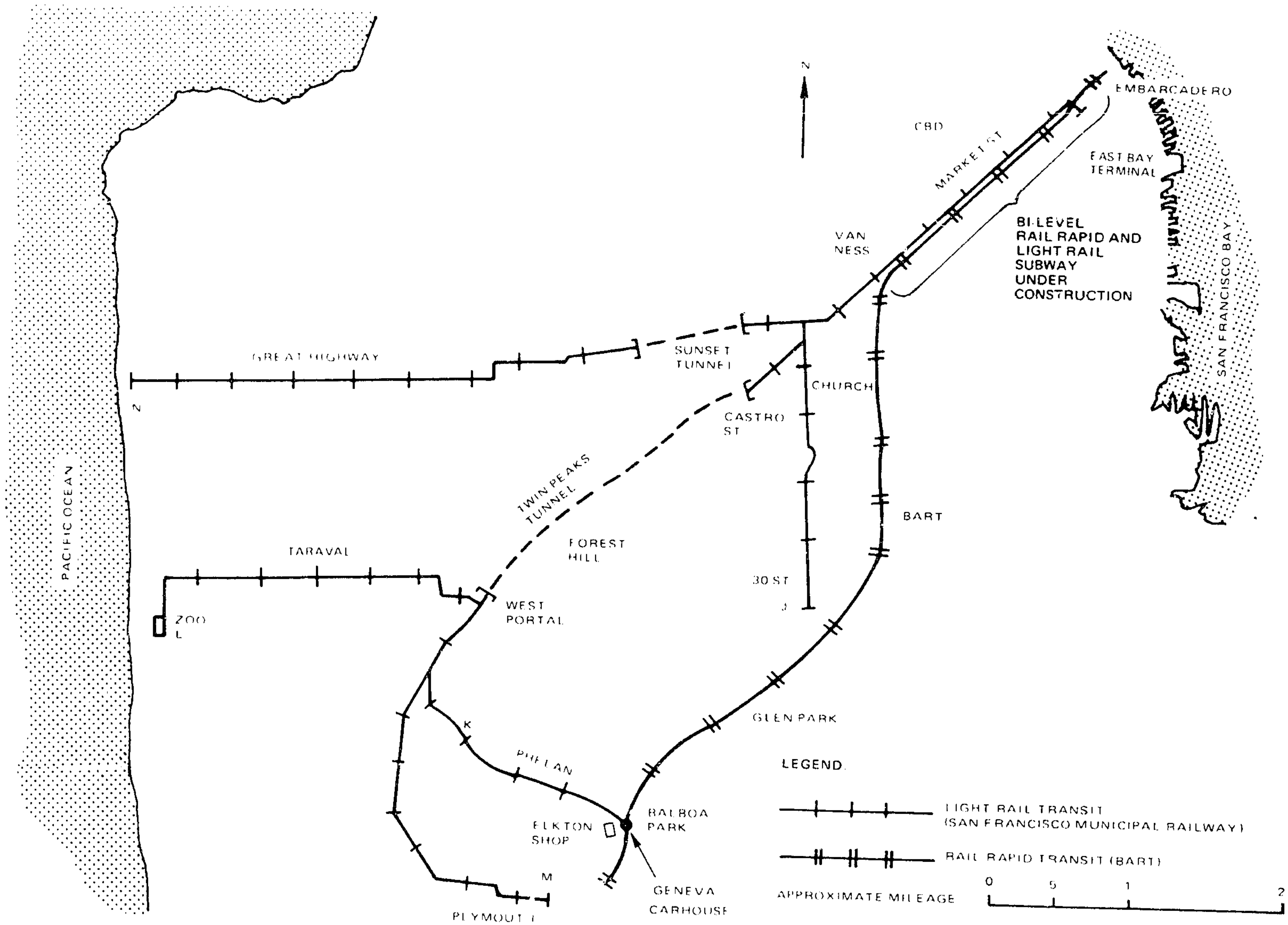
The five light rail transit routes have heavy peak-hour ridership, and lighter weekend traffic. Approximately 35,000 rides are taken on a typical weekday, and approximately 10,000,000 riders per year use the system. Ridership per capita is high on all public transportation in the San Francisco Bay Area, and these routes serve tightly-knit areas in which congestion and terrain make the automobile a less than desirable mode of transportation.

Equipment

All vehicles are PCC cars running as single units, and are all-electric. Most of the cars now in service were bought second-hand, either from St. Louis (bought in 1957-1962) or, most recently, from Toronto (1974).

Ten cars purchased new (1949) for this system were originally equipped for two-man operation, and were later converted to one-man operation. Twenty-five additional one-man cars were purchased new in 1952, from St. Louis Car Co., the last PCC cars to be manufactured in the U.S. All cars have backup controls and poles, two termini being wye-equipped (rather than having loops). Air conditioning is not used. The cars are in reasonably good condition, but are scheduled to be replaced with new articulated cars now under construction by Boeing Vertol Company. These cars will be double-ended.

The operating (Geneva) car house and main heavy repair shop (Elkton) for the system are located beyond the K Line terminus adjacent to the BART Balboa Park Station. A new MUNI Metro Center will replace the Geneva-Elkton facilities in 1977.



San Francisco Light Rail Transit Service

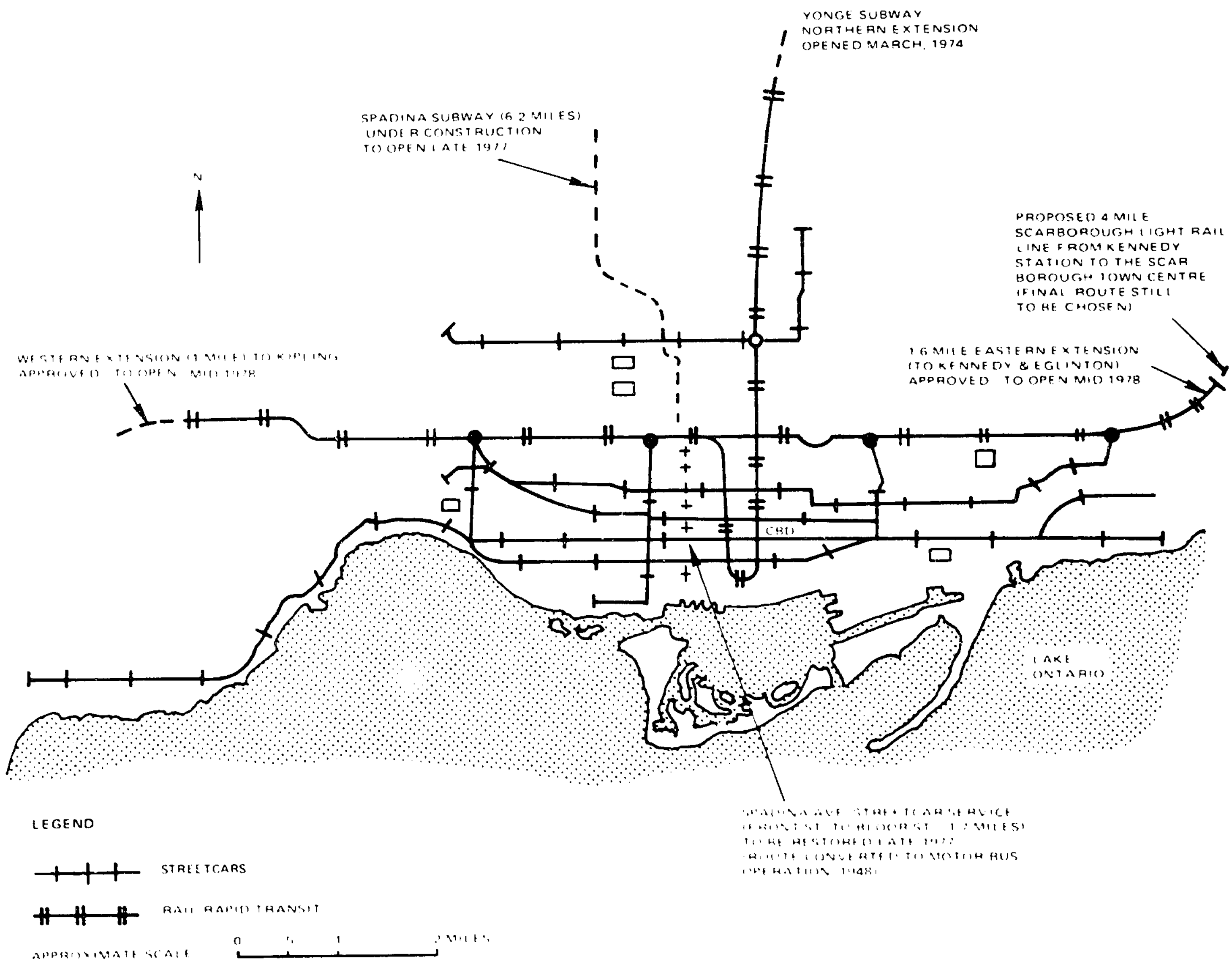
Table A-9

San Francisco - Light Rail Transit Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES) **			SCHEDULED TIME TO TRAVERSE ROUTE * (MINUTES)	AVERAGE ROUTE SPEED* (MPH)
					PEAK	BASE	OFF-PEAK		
J Church	30th & Church	Street Running and Exclusive Right of way	8.8	Local	4.5	7	12	60	7.6
K Ingleside	Ocean & Phelan	Street Running and Exclusive Right of way (2.1 mile tunnel)	15.3	Local	4.5	7.5	12	78	9.9
L Taraval	46th & Wawona	Street Running and Exclusive Right of way (2.1 mile tunnel)	16.[illegible]	Local	3.5	7.5	12	85	9.8
M Ocean View	Broad & Plymouth	Street Running and Exclusive Right of way (2.1 mile tunnel)	17.1	Local	7	8.5	12	90	9.8
N Judah	Judah & La Playa	Street Running and Exclusive Right of way (0.8 mile tunnel)	14.2	Local	3	5.5	12	74	9.6

* Includes recovery time at outer terminals. Street speed at 15 - 20 mph

**PEAK 7-9 AM, 4-6 PM
BASE 9 AM - 4 PM
OFF PEAK 6 PM - 1:00 AM



Toronto Streetcar Routes

Operator

Toronto Transit Commission

Route Characteristics

The routes are typical of streetcar operation. All have double track, loops at each end and numerous turnback points, and there is considerable emergency use downtown trackage. The Queen Line has a section of reserved right of way. In addition, there are several terminal loops entirely within the confines of rail rapid transit stations providing a weather protected transfer between modes. Route statistics are shown in Table A-10.

While the suburban development in the metropolitan region has been great, the inner city portion has not declined in proportion to other regions' experience. As a result, patronage continues to be very heavy. Headways are short and two-car trains are used on Queen Street during the peak hours. Two lines, Earlscourt, and Kingston Road peak-hour "short line" services of longer routes, are providing extra service on the densest portion of the line. About 45 route-miles are currently in operation with eleven routes.

The entire physical plant of the Toronto streetcar system is in excellent physical condition. The Commission has had jurisdiction over the routes for many years, having consolidated several private railway operations as early as 1921.

Three car houses service the routes, and a heavy repair shop is connected by service track to the regular routes. This same service track, along Bathurst Street, connects the St. Clair/Earlscourt and Mt. Pleasant operations with the remainder of the routes, which would otherwise be isolated. The main shop is Hillcrest, which also houses a bus repair shop. Roncesvalles, on the King and Queen Lines, and Russell on the Queen Line and St. Clair Line, just off the St. Clair/Earlscourt routes, are the car houses. Hillcrest Shop houses the operating administration building and Transit Control Center, the main supervisory facility for communications, power distribution and subway signalling.

Regular car lines, which bear no route numbers, are designated Bathurst, Carlton, Downtowner, Dundas, Earlscourt, King, Kingston Road, Long Branch, Mt. Pleasant, Queen, and St. Clair. Numerous short turns are operated, as are night combinations.

Market Characteristics

The high level of ridership is bolstered by a generally high per capita use of transit resulting in part from low fares, high service level, traffic congestion, and the generally high regard in which public transportation is held in Toronto. Service is offered commensurate with ridership, and the frequent service continues until the late hours, with all-night service on many routes. Two routes, Earlscourt (basically a duplication of another route) and Kingston Road (essentially a branch of the Queen and King routes) operate primarily in peak hours. The other nine regular routes operate every day (Downtowner, weekdays only).

Some 65 million rides* are taken on the streetcars each year, a number that has remained relatively constant, considering the effects of route alterations to suit the expanding rapid transit system. Approximately 200,000 weekday riders* utilize the eleven routes.

Much of the streetcar traffic is connecting traffic, destined to or from areas served by connecting subway, bus and trackless trolley lines. This is a byproduct of the grid pattern of routes, combined with the free universal transfer offered, the ease of subway transfers, and the lack of resistance to the inconvenience of a multi-vehicle ride engendered by the frequency of service and general transit orientation.

Equipment

All regular route equipment is PCC type, either bought new or second-hand.

Fewer than 400 cars of a one-time fleet of almost 800 PCC cars remain. About 300 are required for peak-hour service. Cars seat about 50, and are predominantly all-electric; all the air-electric cars having been the oldest of the groups, and consequently, the first retired. Some cars have been sold to other properties - notably 140 cars to Alexandria, Egypt and recently, 10 cars to San Francisco.

In recognition of the decision to retain streetcar operation indefinitely, a large-scale car rebuilding program has been undertaken, with 172 of the newer PCC cars having been outshopped by the end of 1975. In this modernization program, the cars receive interior refurbishing, structural repairs, and electrical overhauls.

New single-unit cars to replace the PCC cars have been designed and on August 19, 1975 the Commission placed an order with the Urban Transportation Development Corporation for 200 new CLRV's. The first 10 cars will be built in Switzerland and delivered in 1978-1979.

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*Fares collected, does not include transfers.

The new car design draws heavily on features of the newest European cars and the United States SLRV. Because of physical constraints on the Toronto track system and at Hillcrest Shop, an articulated design of larger proportions was not deemed feasible and hence a 51-foot double-truck car, similar in size to the PCC was selected. This vehicle can easily be adapted for use in true light rail transit operation, such as the planned Scarborough Light Rail Line which will link the eastern terminus of the Bloor-Danforth subway (to be Kennedy Station opening 1978) with the new Scarborough Town Centre.

Since only one route operates with multiple units, only about a third of the fleet is so equipped. Seating in the cars is primarily forward facing, two-and-one forward of the center doors, and conventional to the rear. The extra-wide front door opening is characteristic of PCC cars and a stanchion-type divider is utilized to direct passengers toward the farebox, and into the car. Air conditioning is not used.

Table A-10

Toronto Streetcar Route Statistics

ROUTE NUMBER AND/OR NAME	DESTINATIONS	TYPE OF ROUTE	ROUTE MILEAGE	SERVICES	HEADWAY (MINUTES)			SCHEDULED TIME TO TRAVERSE ROUTE (MINUTES)	AVERAGE ROUTE SPEED (MPH)
					PEAK	BASE	OFF PEAK		
King	Broadview Stn. Dundas W. Stn.	Street Running	16.0	Local	2	7	9	45	10.6
Queen	Queen & Neville The Queensway and Humber River	Street Running and Exclusive Right of way (1.75 Mi. in Median)	30.8	Local	4*	4	5	55	11.4
Dundas	Dundas W. Stn. Broadview Stn.	Street Running	13.2	Local	5	5	8.2	45	8.8
	Dundas W. Stn. Dundas & Church	Street Running	8.6	Local	2.5	5		30	8.6
Downtowner	Kingston Road & Bingham Queen & McCaul	Street Running	12.2	Local		7		35	10.4
	Kingston Road & Bingham Bathurst Stn.	Street Running	16.2	Local	5			50	9.7
Bathurst	Bathurts Stn. Exhibition Grounds	Street Running and Exclusive Right of way (¼ Mi. R/W in Grounds)	5.9	Local	2.5	4	5	18	9.3
Long Branch	Lakeshore Rd. & Brown's Line - The Queensway and Humber River	Street Running	9.8	Local	6	10	10	25	11.7
Carlton	High Park - Main Station	Street Running	18.6	Local	2.5	4	5	54	10.3
St. Clair	St. Clair & Keele St. Clair Station	Street Running	8.2	Local	4	4	6	26	9.3
Mount Pleasant	St. Clair Stn. - Mt. Pleasant & Eglinton	Street Running	3.5	local	6	8	10	12	8.7
Kingston Road	Kingston Road & Bingham - King and Roncesvalles	Street Running	18.4	Local	6	-	-	54	10.2
Earlscourt	St. Clair and Lansdowne - St. Clair Station	Street Running	6.4	Local	4	-	-	22	8.7

*2-car MU trains in rush hours

NOTES: 1. Owl service provided on the following routes - KING, QUEEN, LONG BRANCH (through-routed), CARLTON and ST. CLAIR - MT. PLEASANT (through-routed).

2. Trippers and short working extras provide additional rush hour service (to that shown above) on all routes except LONG BRANCH, MT. PLEASANT, KINGSTON ROAD and EARLSCOURT.

APPENDIX B

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APPENDIX C

SUGGESTED PERIODICALS AND OTHER SOURCES OF CURRENT INFORMATION

This list represents the more important trade journals and other periodical literature, that are known to contain certain articles and information on light rail transit. These sources are available by subscription or at major public and university libraries.

Electric Traction (Australian Electric Traction Association)

Headlights (Electric Railroaders Association)

Lea Transit Compendium

Mass Transit

Modern Tramways and Light Railway Review

Railway Gazette International

Railway Age

Rollsign (Boston Street Railway Assn., Inc.)

Traffic Quarterly

Transit Journal

Transitrends

UITP Review

PROCEEDINGS

American Electric Railway Association (AERA)

American Electric Railway Engineering Association (AEREA)

American Public Transit Association (APTA)

Transportation Research Board (TRB)

APPENDIX D

UMTA POLICY STATEMENT ON LIGHT RAIL TRANSIT

During the past year light rail transit has come to be viewed as a serious alternative to buses and rapid transit in meeting the transportation needs of our metropolitan areas. Several cities with existing light rail systems are taking steps to modernize their vehicle fleets and upgrade service. A number of other cities are contemplating the possibility of introducing light rail to supplement existing bus service. However, no new light rail lines have been built in recent years in this country, with the result that capital and operating data on modern light rail technology is not available.

In light of the growing interest in light rail transit, and in answer to numerous requests, the Urban Mass Transportation Administration is issuing this statement of policy in order to provide the clearest possible expression of its position toward light rail transit.

UMTA considers light rail transit as a potentially attractive concept for many urban areas. The features that distinguish it most strongly from conventional rapid transit are the flexibility with which it can be adapted to a variety of urban settings, and its potentially lower cost. In congested downtown areas light rail transit can be operated in underground subways. In lower density areas it can be operated at grade in existing roadway medians, reserved freeway lanes, and in abandoned rail and other exclusive rights-of-way. At heavily traveled intersections and in busy arterials grade separation can be achieved through underpasses or elevated structures. However, with preemptive signals and barriers, surface grade crossing and operation in mixed traffic might be tolerated in some situations. Because much of the track can be built at surface level, the need for costly tunneling and elevated guideways can be minimized and substantial economies in capital expenditure can potentially be achieved.

Light rail transit has also other merits. It is a technologically proven concept that requires no costly development program. It can be introduced into a community with a minimum of disruption and can be operated with minimum intrusion in residential areas. It may offer a capability for conversion to higher capacity service, thus allowing a city to match its initial investment to existing and near-term demand and to stage subsequent investment as and when it is required. Because light rail transit holds promise of an economic, versatile and environmentally attractive form of mass transportation, the Urban Mass Transportation Administration believes that it deserves serious consideration by localities bent on improving the quality of their transportation service.

This is not to say that light rail transit will be prescribed as a preferred alternative in any specific local situation. UMTA has no preferences among mass transit technologies and will continue to support the choice of system and mode which emerges as the right transportation solution from the locally conducted alternatives analysis.

But while UMTA has no modal favorites, the burgeoning demand for mass transit assistance, together with the escalating costs of transit construction and operation, has put a serious strain on the available public resources, making it essential to fully explore any cost effective approaches. Therefore, the Urban Mass Transportation Administration announces its intention to assist in the deployment of modern light rail transit in a city or cities where proper conditions for this type of service are found to exist. In pursuit of this objective UMTA will carefully review all alternatives analyses and capital grant applications which are pending or which will be submitted in the coming months to determine which urban area or areas can make a convincing case for Federal support of light rail projects.

December 16, 1975

APPENDIX E

GLOSSARY

Automatic Train Control
A system in which a predetermined operational pattern is established on a given line so that all cars are accelerated, braked, etc., automatically in accordance with curve and grade conditions.

Air-electric Vehicle
A vehicle using compressed air as well as electricity to operate brakes and/or accessories.

Articulated Car
A car consisting of two or more full-size units free to swivel, the inner ends being carried on a common center truck.

Ballast
The bed of crushed stone in which the track rests.

Base Service
Level of service during non-peak daytime hours.

Bi-directional
The ability to simultaneously operate both inbound and outbound vehicles on a given route.

Bogey
The apparatus for suspending or supporting and laterally controlling the vehicle with respect to a guideway.

CBD
Acronym for Central Business District, the section of an urban area characterized by intensive business activity.

Capacity
The maximum number of vehicles or passengers in a single direction during a specific time period.

Capital Costs (Transit)
Nonrecurring costs required to construct transit systems, including costs of right-of-way, facilities, rolling stock, power distribution and the associated administrative and design costs.

CLRV
Acronym for Canadian Light Rail Vehicle, new light rail vehicle being built by the Urban Transit Development Corporation for Toronto.

Commuter Rail Transit
That portion of passenger railroad operations which carry passengers within urban areas; differs from rail rapid transit in that passenger cars are heavier and average trip lengths are longer than for rail transit, and the operations are generally run by railroad companies as part of their overall passenger and freight service.

Double-ended Car
A vehicle with controls at both ends, permitting reversal of direction without turning of the vehicle.

Elasticity of Ridership
The percentage change in level of ridership resulting from a 1% change in a particular service attribute.

Express Service
A type of operation providing higher speed with fewer stops than generally exists on local transit lines.

Fares
The authorized amount (cash or token) paid or valid transfer, pass, etc., presented for a transit ride.

Gauge
Distance between the rails; standard gauge is 4'8½", broad gauge is 5'2½".

Grade Crossing
An intersection at which vehicles of the same or different modes of transportation cross at the same level.

Headway
Scheduled time between vehicles on a line or route.

APPENDIX E (CONT.)

High-level Loading
Passenger loading from a platform at the same height as the vehicle floor.

Interurban Railway
An electric railway serving two or more urban areas.

Jointed Rail
Rail laid in 39 foot sections and joined by metal joint bars.

Level of Service
The combination of attributes of a system which collectively determine the attractiveness or utility of the particular system.

Light Rail Transit
A generic name for a transit mode consisting of electrically-powered steel wheeled rail vehicles operating predominantly on exclusive rights-of-way and characterized by flexibility in planning routes and operating procedures and an ability to provide intermediate capacity service in between that of many bus and rail rapid transit systems.

Local Service
A type of transit operation involving frequent stops and low speeds, the purpose of which is to deliver and pick up passengers as close to their destinations or origins as possible.

Low-level Loading
Passenger boarding from a platform below the height of the vehicle floor, requiring steps.

Off-Peak Service
The lowest level of service offered to transit users.

Operating Costs
Recurring costs incurred in operating transit systems, including wages and salaries, maintenance of facilities and equipment, fuel, supplies, employee benefits, insurance, taxes, and other administrative costs.

Park and Ride
The transfer point of an intermodal trip where the driver of an automobile parks and changes to a transit mode.

PCC
Presidents' Conference Committee car, a standard street railway vehicle developed in the 1930's and used extensively in the U.S., Canada, and abroad.

Peak Service
Service designed to handle the heaviest traffic load, in rush hours.

Rail Rapid Transit
Electrically-powered passenger rail cars operating singly or in trains of two or more cars on fixed rails in separate rights-of-way from which all other vehicular and foot traffic is excluded.

Single-ended Car
A vehicle which can be operated in one direction only, and therefore must be turned around to reverse direction of service.

SLRV
Acronym for Standard Light Rail Vehicle.

Transit-Pedestrian Mall
Street(s) closed to private vehicles for use only by transit vehicles and pedestrians.

Truck
The general term covering the assembly of parts comprising the structures which support a car body at either end and also provide for attachment of wheels and axles.

Two-and-one Transverse Seating
A pattern of seating consisting of a single seat on one side of the aisle and a two-person seat on the other side.

Walkover Seat
A type of seat with a moveable back, so that the seat can face in either direction, used in double-ended trains.

Welded Rail
Rail laid in continuous sections which are welded together to give a continuous smooth surface.

Wye
A y-shaped track arrangement used for reversing the direction of trains.

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