What's New in North American Light Rail Transit Projects?

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This paper summarizes North American light rail transit (LRT) progress during recent years. Existing system rehabilitation and new project planning, design, construction, and start-up activities are discussed. To depict the significant effects of recent changes in the North American LRT situation, the text and data update the author's paper Evaluations of Operating Light Rail Transit and Streetcar Systems in the United States, published in TRB Special Report 182 (1978). Since then, U.S. LRT/ streetcar cities (Boston, Newark, Philadelphia, Pittsburgh, Cleveland, New Orleans, Fort Worth, and San Francisco) have replaced old cars or rebuilt fixed facilities or both. Similar changes have occurred in Toronto and Mexico City. Seven cities have opened new LRT systems since 1977: Edmonton (1978), Calgary and San Diego (1981), Buffalo (1985), Portland (1986), and Sacramento and San Jose (1987). All these projects have been positive and productive additions to the transit networks in their respective areas. LRT is under construction in Los Angeles and in an advanced state of planning or design in more than a dozen other places. These projects encompass urban areas where LRT may be a natural "step up" from an all-bus transit system, as well as cities that have discarded proposals for other guideway technologies. With old system reconstruction and a flurry of new starts, LRT has become the guideway mode of choice for an increasing number of cities. LRT provides adequate levels of service, speed, and comfort for realistically projected passenger flows; it is affordable to build and run; it enhances urban development without "Manhattanization"; and it is a sensitive, environmentally compatible neighbor to the communities it serves.

FROM A TURN-OF-THE-CENTURY position of dominance among urban transport modes, surface electric railways—i.e., city streetcar systems plus suburban and intercity "interurbans"—dwindled nearly to the point of extinction. Although new rapid transit systems were begun, only three

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significant trolley projects were undertaken from the end of World War II through the late 1960s:

- 1955: Extension of Philadelphia's surface car subway from 23rd and Market streets to the University of Pennsylvania;
- 1959: Conversion of Boston's Riverside line from diesel-powered commuter rail to light rail; and
- 1963: Opening of Leonard's M&O (now Tandy) subway in Fort Worth.

By this time, the streetcars-to-buses changeover had largely run its course. Except in Philadelphia and Toronto, most of the remaining trolley lines had substantial portions of their routes on a right-of-way (ROW) separated from rubber-tired traffic; and in all cases, political pressure was growing to prevent their closure. During the latter 1960s and through the 1970s, it became increasingly clear that operators faced a choice of either refurbishing and modernizing their systems or weathering a public outcry if electric rail operations ceased.

THE LRT CONCEPT EMERGES

The light rail transit (LRT) concept emerged during this same period. It was applied with great success by European authorities to upgrade aging streetcar systems to modern, efficient transit services. By 1976, enough thought had been given to the subject in North America that the TRB Committee on Light Rail Transit adopted a concise definition for this new mode of urban transportation based on thoroughly proven electric railway technology (*1*, p. 1):

> Light rail transit is a mode of urban transportation that uses predominantly reserved, but not necessarily grade-separated, rights-of-way. Electrically propelled vehicles operate singly or in trains. Light rail transit provides a wide range of passenger capacities and performance characteristics at moderate costs.

Not all of the remaining North American trolley systems fit the new definition. Lines in North Philadelphia, San Francisco, and Toronto retained the look and performance of streetcars (little track reservation, frequent stops, slow running, and/or old cars). New Orleans continued to run streetcars dating from 1924 on a right-of-way that, though separated from parallel traffic, resulted in slow service speeds due to very frequent stops and minimally protected grade crossings. Other systems, though benefiting from substantial sections of reserved ROW, all used aging fleets of President's Conference Committee (PCC) or similar cars.

WHAT MAKES LRT UNIQUE?

As with any definition, TRB's is subject to interpretation. It has been, and no doubt will continue to be, the topic of spirited debate among experts. As used here, the definition is taken to mean that to qualify as LRT, a system: (1) must run on track mostly separated from vehicular traffic, (2) be capable of operating through grade crossings, and (3) use "straight electric" duo-rail vehicles. Table 1 compares some of the key aspects of LRT with other types of transit and indicates LRT's position as a medium-cost, medium-capacity mode. The range of new projects demonstrates the broad variations in service and costs that may be achieved with LRT and, more importantly, that adequate-to-superior performance and appropriate capacity can be provided on available or newly created ROW without breaking the bank.

TABLE 1 KEY CHARACTERISTICS DIFFERENTIATING LRT FROM OTHER TRANSIT MODES

Characteristic	Light Rail	Bus	Commuter Rail	Automatd Guideway	Rapid Rail*
System Costs:					
Initial	Moderate	Low/Moderate(a)	Low-to-High	High	Very High
Operating & Maintenance, per Passenger Mile(b)	---	Higher	Higher	Similar	Lower(c)
Attributes:					
Schedule Reliability	Excellent	Fair	Good	Superior	Excellent
Grade Separation	Varies	Less	More	100%	100%
Automatic Operation	No(d)	No	No(d)	Yes	Maybe(d)
Entrained Vehicles	Yes	No	Yes	Maybe	Yes
Public Perception:					
Comfort, Ride Quality	Good	Fair	Good	Good	Good
Route Comprehension(e)	Easy	Hard	Easy	Easy	Easy/Hard
Social Acceptability	High	Low	High	High	(f)
Railroad Involvement:					
Operating Labor	No	No	Yes	No	No
Freight Coordination	Maybe(g)	No	Maybe(g)	No	No

* Also called "Heavy Rail" and/or "Metro"
(a) But, busway/HOV lane cost per mile can equal or exceed LRT construction cost/mile.
(b) Other modes in comparison to LRT
(c) Not always; San Diego Trolley (which is LRT) has lowest O&M $/Passenger Mile of any transit system in U.S.
(d) May have automatic train stop (ATS), without full automation
(e) Generally, a surface or aerial guideway is visible and therefore easier to comprehend than a bus route on public streets or guideway in tunnel.
(f) Higher for new systems, but lower for old systems operating in depressed or deteriorating urban areas
(g) Yes, if joint track use or grade crossings with freight railroads

WHAT TRANSIT SERVICES CAN LRT PROVIDE?

Depending on local needs, city size, ROW availability, and financing capability, LRT systems can be developed to serve three principal classes of urban travel:

- Line haul transit from city or suburban residential areas to central business districts (CBDs) and other employment zones;
- Feeder service to rapid transit or commuter rail; and
- Local area transit within a portion of an urbanized area or activity center, including CBD distribution.

As indicated in Table 2, the North American systems all perform one or more of these functions. The ability to perform multiple transit functions is an advantage of LRT, which combines some operational characteristics of both bus and rapid transit modes. LRT can approach rapid transit commercial speeds to attract line haul traffic; but ease of access to simple at-grade stations and typically shorter station spacings also allow LRT to attract local ridership.

In Portland, for example, the Metropolitan Area Express (MAX) was conceived as an arterial trunk commuter line to downtown. But it also carries local passengers between suburban origins and destinations: along East Burnside Street and in Gresham, between downtown and Lloyd Center (downtown's extension on the east bank of the Willamette River), and on short hops within downtown Portland. In suburban Philadelphia, the lines to

TABLE 2 PRINCIPAL FUNCTIONS OF NORTH AMERICAN LRT AND STREETCAR SYSTEMS

Line haul/express/commuter service between employment zones (particularly central business districts) and residential areas, including coordination with feeder buses, auto passenger drop-offs, and/or park-&-ride:

> Boston (Green Line), Calgary, Cleveland, Edmonton, Newark, Philadelphia (Subway-Surface), Pittsburgh, Portland, Sacramento, San Diego, San Francisco, San Jose

Feeder service to rapid transit and/or commuter rail:

> Boston (Mattapan-Ashmont), Philadelphia (Media-Sharon Hill); secondary function for Boston (Green Line), Cleveland, Newark, Philadelphia (Subway-Surface and Streetcars), San Francisco, San Jose, Toronto

Local area circulation within a portion of an urbanized area or activity center, and/or CBD distribution:

> Fort Worth, Philadelphia (Streetcars), Toronto, and "Vintage Trolleys" in Detroit, Lowell, New Orleans, Seattle; secondary function for all other systems listed above

Media and Sharon Hill primarily feed the Market-Frankford rapid transit line at 69th Street Terminal. But they also carry students, shoppers, and others to destinations along the two routes.

LRT IN THE LATE 1970s

Ten years ago, there were 11 definable LRT and streetcar systems in eight U.S. cities, plus the streetcar systems in Toronto and Mexico City. The author's research (*2*, pp. 94–103) classified the U.S. properties according to system average operating speeds (V_{avg}):

- Light Rail Transit—Group I, $V_{avg} \geq 24$ km/hr (≥ 15 mi/hr): Cleveland, Newark, Philadelphia (Media-Sharon Hill), and Fort Worth;
- Light Rail Transit—Group II, $V_{avg} \geq 16$ to <24 km/hr (≥ 10 to <15 mi/hr): Pittsburgh, Boston (Green Line and Mattapan-Ashmont), and Philadelphia (subway-surface); and
- Streetcars, $V_{avg} <16$ km/hr (<10 mi/hr): San Francisco, New Orleans, and Philadelphia (streetcars); and Toronto's streetcar system.

By 1977, several cities had taken initial steps toward upgrading their LRT systems, a new 7.2-km (4.5-mi) LRT line was being built in Edmonton, and other North American cities were in various stages of LRT planning and design.

NORTH AMERICAN LRT SYSTEMS TODAY

Virtually all the systems running in 1977 have since been modernized or refurbished to some degree, and seven new projects have begun revenue service. Today, 19 definable systems serve 16 U.S. and Canadian cities.

Lines operated have grown in 10 years from 368 km (229 mi) to 541 km (336 mi), a 47 percent increase. Though impressive against the LRT mode's previous decline, average kilometers (miles) built per year have remained small (see Table 3).

Characteristics of Present U.S. and Canadian Systems

Table 4 lists the existing, physically separable LRT and streetcar systems operating in North America. Line lengths, number of revenue cars, rides per weekday, and two productivity indicators are shown.

TABLE 3 TEN-YEAR GROWTH IN NORTH AMERICAN LRT SYSTEMS

	United States	Canada	North America
LRT km (mi) in 1977	295(183)	73(46)	368(229)
LRT km (mi) in 1987	430(267)	111(69)	541(336)
Percent increase	46	50	47
Average km (mi)/year	13.5(8.4)	3.8(2.3)	17.3(10.7)

Systems included meet TRB's definition of LRT or are streetcars providing all-year service as part of a larger, integrated transit system. Omitted are lines using vintage trolleys as local distributors (Detroit, Seattle) and seasonal tourist services (Lowell, San Francisco's Trolley Festival), as well as systems requiring 100 percent grade separation [the Southeastern Pennsylvania Transportation Authority (SEPTA) Norristown High Speed Line] and automatic operation (Vancouver's SkyTrain).

Based on system average operating speeds (V_{avg}), the distribution of North American LRT and streetcar systems is as follows (italics indicate new starts):

- Light Rail Transit—Group I, $V_{avg} \geq 24$ km/hr ($\geq$15 mi/hr): *Calgary*, Cleveland, *Edmonton*, Newark, Philadelphia (Media-Sharon Hill), *Portland*, *Sacramento*, *San Diego*, and *San Jose*;
- Light Rail Transit—Group II, V_{avg} $\geq$16 to <24 km/hr ($\geq$10 to <15 mi/hr): Boston (Green Line and Mattapan-Ashmont), *Buffalo*, Fort Worth, Philadelphia (subway-surface), Pittsburgh, and San Francisco; and
- Streetcars, V_{avg} <16 km/hr (< mi/hr): New Orleans, Philadelphia (streetcars), and Toronto.

Kilometers and miles of line, size of car fleets, and weekday rides (boardings) are distributed among the three categories of systems as shown in Table 5.

Group I headways tend to be longer and speeds faster; therefore, fewer cars per kilometer of line are required as compared with the more urban Group II and streetcar systems:

	LRT		
	Group I	*Group II*	*Streetcars*
Revenue Service Cars/km (mi)	1.7 (2.8)	3.9 (6.3)	2.6 (4.2)

TABLE 4 LINE LENGTHS, CAR FLEETS, AND PRODUCTIVITY

City/System	Parameters km(mi) of Line	Parameters Cars	Parameters Rides/ Weekday	Statistics Cars/ km(mi)	Statistics Weekday Rides/ km(mi)	Statistics Weekday Rides/ Car
LRT-Group I:						
Calgary, C-Train(a)	27.5(17.1)	83	83000	3.0(4.9)	3018(4854)	1000
Cleveland, Shaker Rapid(b)	21.1(13.1)	48	17500	2.3(3.7)	829(1336)	365
Edmonton, Northeast LRT(a)	10.5(6.5)	37	25000	3.5(5.7)	2381(3846)	676
Newark, City Subway(b)	6.9(4.3)	24	14100	3.5(5.6)	2043(3279)	588
Philadelphia:						
Media-Sharon Hill(b)	19.2(11.9)	29	9600	1.5(2.4)	500(807)	331
Portland, MAX(a)	24.3(15.1)	26	20000	1.1(1.7)	823(1325)	769
Sacramento, RT Metro(a)	29.4(18.3)	26	13200	0.9(1.4)	449(721)	508
San Diego Trolley(a)	32.8(20.4)	30	27000	0.9(1.5)	720(1157)	787
San Jose, Guadalupe(a,e)	32.8(20.4)	50	12000	1.5(2.5)	366(588)	240
Subtotals	204.5(127.1)	353	221400	1.7(2.8)	1083(1742)	627
LRT-Group II:						
Boston:						
Green Line(b)	40.1(24.9)	235	210000	5.9(9.4)	5237(8434)	894
Mattapan-Ashmont(b)	4.3(2.7)	12	7000	2.8(4.4)	1628(2593)	583
Buffalo, MetroRail(a)	10.3(6.4)	27	29000	2.6(4.2)	2816(4531)	1074
Ft Worth, Tandy	1.6(1.0)	8	5900	5.0(8.0)	3688(5900)	738
Philadelphia:						
Subway-Surface(b)	35.9(22.3)	112	49700	3.1(5.0)	1384(2229)	444
Pittsburgh,						
South Hills(b)	36.2(22.5)	102	27300	2.6(4.2)	754(1213)	268
San Francisco,						
Muni Metro(c)	32.2(20.1)	130	130000	4.0(6.5)	4037(6468)	1000
Subtotals	160.6(99.9)	626	458900	3.9(6.3)	2857(4594)	733
Streetcars:						
New Orleans, St Charles	10.5(6.5)	35	21000	3.3(5.4)	2000(3231)	600
Philadelphia, Streetcars	92.4(57.4)	110	51300	1.2(1.9)	555(894)	466
Toronto, Streetcars	73.4(45.6)	318	298300	4.3(7.0)	4064(6542)	938
Subtotals	176.3(109.5)	463	370600	2.6(4.2)	2102(3384)	800
Totals	541.4(336.5)	1442	1050900	2.7(4.3)	1941(3123)	729

(a) New start opened since 1977; (b) Major reconstruction/rehabilitation since 1977; current peak requirement is 60 cars, 33 LRV + 27 PCC; (c) Upgrade from Streetcar system since 1977; (d) East Line has no bus feeders; will update figures after 1/88 bus cut-over; (e) 10.5 km (6.5 mi) to be in service 12/87; Rides/Weekday - current projection for 1991 opening of full line

TABLE 5 NORTH AMERICAN LRT SYSTEM STATISTICS BY CATEGORY

	Extent of Line			Cars		Weekday Boardings	
	Kilometers	Miles	Percent	No.	Percent	No.	Percent
LRT—Group I	204.5	127.1	38	353	24	221,400	21
LRT—Group II	160.6	99.9	30	626	43	458,900	44
Streetcars	176.3	109.5	32	463	32	370,600	35
Total	541.4	336.5		1,442		1,050,900	

For the most part, LRT systems in Group I tend to link downtown employment with relatively distant, lower density residential neighborhoods 8 to 24 km (5 to 15 mi) away, while Group II LRTs and streetcars tend to serve neighborhoods closer to the core, 8 to 10 km (5 to 6 mi) or less away. Obvious exceptions are Newark (Group I), and Boston and Pittsburgh (Group II).

In keeping with divergent functions, the more suburban Group I systems tend to have stations spaced farther apart:

	No. of Stations	*Avg Spacing, km (mi)*
LRT—Group I	234	0.9 (0.5)
LRT—Group II	469	0.3 (0.2)
Streetcars	1,233	0.1 (0.1)

To serve their longer routes, the faster Group I systems run about as many car kilometers per year as each of the other two categories, but work their fleets harder:

	Car-km (Car-mi)/Year (millions)	*Annual km (mi)/Car (thousands)*
LRT—Group I	20.8 (13.0)	59 (37)
LRT—Group II	22.6 (14.1)	36 (23)
Streetcars	19.1 (11.9)	41 (26)
Total	62.5 (39.0)	43 (27)

Group I systems tend to be more commuter-oriented; therefore, as a group, they attract fewer rides per kilometer of line than the typically shorter, more urban lines of the Group II and streetcar systems (see Table 6).

By careful design, most of the new-start systems fall into Group I. Within the multiroute systems included in Group II, some individual lines meet the >15 mi/hr criterion and, if considered separately, would be in Group I (e.g., Boston's Riverside Line). Especially noteworthy is the upgrading of San

TABLE 6 WEEKDAY BOARDINGS PER KILOMETER, PER MILE, AND PER CAR

	Per Kilometer		Per Mile		Per Car	
	Range	Avg	Range	Avg	Range	Avg
LRT—Group I	366–3,018	1,083	588–4,854	1,742	240–1,000	627
LRT—Group II	754–5,237	2,357	1,213–8,434	4,594	268–1,074	733
Streetcars	555–4,064	2,102	894–3,384	3,384	466–938	800

Francisco from Streetcar to LRT—Group II in light of the system's metamorphosis as the Muni Metro with new light rail vehicles (LRVs) and the tunnel beneath Market Street, an important increase in reserved trackage (37 percent in 1977 to 44 percent now).

To achieve competitive average operating speeds at moderate costs, the new systems all are built on primarily reserved but not necessarily grade-separated ROW:

	Percent of Line-km (Line-mi)	
	Reserved	*Mixed Traffic*
LRT—Group I	97	3
LRT—Group II	67	33
Streetcars	10	90

In most cases, downtown construction in reserved lanes or transit malls has avoided costly subways, while making the new LRT systems in Group I at once more easily understandable and hospitable to riders. They employ one-person operation of multicar trains and self-service proof-of-payment (POP) fare collection to minimize operating labor requirements. As a result, the new all-surface or mostly surface LRT lines are able to provide rapid transit or commuter rail types of services at levels of investment and operating support appropriate for and affordable by the medium-sized cities they serve. Spacing of surface stops makes these new LRTs more accessible, though typically somewhat slower than grade-separated rapid transit systems. Each of the new LRT lines provides the backbone of a multimodal bus and rail transit system.

By and large, the new and rebuilt LRT systems have proven their worth in the marketplace. They attract substantially more riders than the previous all-bus systems they have replaced (or streetcar system in the case of San Francisco); and, where operating jurisdictions have allowed, the ability to run LRT with a small staff has resulted in economical operation.

Comparing Different Groups of LRT Systems

Table 7 displays some key statistics of the LRT and streetcar systems currently carrying passengers in North America. Compared with urban LRTs (Group II) and streetcars, the Group I—LRT systems extending furthest from downtown provide trunk line "arterial route" service and generally exhibit

TABLE 7 KEY DESCRIPTIVE STATISTICS

City/System	% R/W Reserved	Avg Sta Spacing km(mi)	% Dbl Track	# Thru Routes	# Cars: 4-Axl (a)	# Cars: 6-Axl (b)	System Av Speed km(mi)/h
LRT-Group I:							
Calgary, C-Train	100%	0.9(0.6)	100%	3	0	83	29(18)
Cleveland, Shaker Rapid	100%	0.8(0.5)	100%	2	0	48	30(18)
Edmonton, Northeast LRT	100%	1.3(0.8)	100%	1	0	37	30(19)
Newark, City Subway	100%	0.6(0.4)	100%	1	24	0	34(21)
Philadelphia:							
Media-Sharon Hill	87%	0.4(0.2)	71%	2	29	0	26(16)
Portland, MAX	99%	1.0(0.6)	89%	1	0	26	30(19)
Sacramento, RT Metro	90%	1.0(0.7)	40%	1	0	26	34(21)
San Diego Trolley	100%	1.5(0.9)	99%	2	0	30	29(18)
San Jose, Guadalupe	100%	1.0(0.6)	95%	2	6(c)	50	32(20)
Subtotals/Averages	97%	0.9(0.5)	86%	15	53	300	
LRT-Group II:							
Boston:							
Green Line	89%	0.5(0.3)	100%	4	0	235	16(10)
Mattapan-Ashmont	100%	0.5(0.3)	100%	1	12	0	20(12)
Buffalo, MetroRail	100%	0.7(0.5)	100%	1	27	0	20(12)
Fort Worth, Tandy	100%	0.4(0.3)	100%	1	8	0	17(11)
Philadelphia:							
Subway-Surface	16%	0.2(0.1)	100%	5	112	0	18(11)
Pittsburgh, South Hills	97%	0.4(0.3)	90%	4	47	55	22(14)
San Francisco, Muni Metro	44%	0.3(0.2)	100%	5	0	130	18(11)
Subtotals/Averages	67%	0.3(0.2)	<100%	21	206	420	
Streetcars:							
New Orleans, St. Charles	88%	0.2(0.1)	100%	1	35	0	15(9)
Philadelphia, Streetcars	5%	0.2(0.1)	100%	7	110	0	14(9)
Toronto, Streetcars	4%	0.1(0.1)	100%	9	318	0	15(9)
Subtotals/Averages	10%	0.1(0.1)	100%	17	463	0	
Totals	60%	0.3(0.2)		53	722	720	

(a) Non-articulated, rigid body
(b) Articulated
(c) Vintage trolley cars for downtown loop, not included in totals

- More reserved ROW, to achieve higher speeds and schedule reliability;
- Longer distances between stations to increase schedule speeds;
- Less double track where longer trains provide sufficient peak capacity at longer headways;
- Fewer through service routes, relying on bus feeders and automobile park-and-ride for suburban distribution;
- Propensity to use large six-axle articulated cars to gain more carrying capacity while retaining the capability to negotiate sharp turns; and
- Higher system average speeds.

More detailed information on these and other LRT and streetcar system characteristics may be found in Tables 8 through 12 covering ROW location; station and grade crossing frequency; track traffic patterns, signal systems, and electrification; revenue service vehicles; and operating statistics.

LRT Progress in the 1980s

North America's LRT progress has been hard won and has been achieved in the face of severe obstacles:

- Continuing preference for automobile travel, seemingly at any cost, and corresponding antipathy to group transportation (reinforced by government funding allocations to the various transport modes);
- The present federal tilt against new rail transit systems; and
- The challenge of financing the capital costs of fixed-guideway transit, whether heavy rail, automated-guideway, or even some LRT systems.

These obstacles notwithstanding, new system construction during the 1980s has demonstrated that LRT can indeed provide "a wide range of passenger capacities and performance characteristics at moderate costs" (*1*, p. 1). Table 13 lists the recent North American projects, their initial cost, and total cost per kilometer of line constructed. Cost ranges for recent LRT capital projects are:

- New starts, \$5.4 million/mi (San Diego-South Bay) to \$82.8 million/mi (Buffalo);
- Extensions, \$7.6 million/mi (San Diego-Euclid) to \$42.5 × 0.75 ± ~\$31.9 million (Canadian)/mi (Toronto-Harbourfront); and
- Reconstructions, \$1.0 million/mi (Fort Worth) to \$51.6 million/mi (Pittsburgh—Stage I).

These expenditures have been for systems with a wide range of physical, operational, and service characteristics, as shown in the tables.

TABLE 8 RIGHT-OF-WAY LOCATIONS

City/System	km(mi) of Line Subway/Tnl	Exclusive (a)	Pvt R/W (b)	Median (c)	Lanes/Mall (d)
LRT-Group I:					
Calgary, C-Train	1.9(1.2)	1.3(0.8)	13.2(8.2)	8.7(5.4)	2.4(1.5)
Cleveland, Shaker Rapid	---	11.3(7.0)	---	9.8(6.1)	---
Edmonton, Northeast LRT	2.3(1.4)	---	8.2(5.1)	---	---
Newark, City Subway	2.1(1.3)	4.8(3.0)	---	---	---
Philadelphia:					
Media-Sharon Hill	---	---	16.3(10.1)	---	0.3(0.2)
Portland, MAX	---	8.7(5.4)	3.7(2.3)	8.4(5.2)	3.4(2.1)
Sacramento, RT Metro	---	9.5(5.9)	12.4(7.7)	1.0(0.6)	3.7(2.3)
San Diego Trolley	---	---	30.1(18.7)	1.6(1.0)	1.1(0.7)
San Jose, Guadalupe	---	15.8(9.8)	1.8(1.1)	14.1(8.8)	1.1(0.7)
Subtotals	6.3(3.9)	51.4(31.9)	85.7(53.2)	43.6(27.1)	12.0(7.5)
LRT-Group II:					
Boston:					
Green Line	7.2(4.5)	17.1(10.6)	---	11.4(7.1)	---
Mattapan-Ashmont	---	4.3(2.7)	---	---	---
Buffalo, MetroRail	8.4(5.2)	---	---	---	1.9(1.2)
Fort Worth, Tandy	0.6(0.4)	---	1.0(0.6)	---	---
Philadelphia:					
Subway-Surface	4.0(2.5)	---	---	1.6(1.0)	---
Pittsburgh, South Hills	3.8(2.4)	9.7(6.0)	20.9(13.0)	0.8(0.5)	---
San Francisco, Muni Metro	10.2(6.4)	---	1.2(0.8)	2.6(1.6)	---
Subtotals	34.2(21.4)	31.1(19.3)	23.1(14.4)	16.4(10.2)	1.9(1.2)
Streetcars:					
New Orleans, St. Charles	---	---	---	9.0(5.6)	0.2(0.1)
Philadelphia, Streetcars	---	---	---	---	4.2(2.6)
Toronto, Streetcars	0.3(0.2)	---	---	2.6(1.6)	---
Subtotals	0.3(0.2)	---	---	11.6(7.2)	4.4(2.7)
Totals: km/ (mi)	40.8/ (25.5)	82.5/ (51.2)	108.8/ (67.6)	71.6/ (44.5)	18.3/ (11.4)

(a) Aerial or surface with no grade crossings
(b) Surface, LRT private R/W with grade crossings
(c) Surface, reserved medians of highways and streets with grade crossings
(d) Surface, reserved lanes (other than medians) and LRT/pedestrian malls

Table 14 summarizes changes in the North American LRT scene since 1977. Developments from 1977 through 1985 were reviewed at TRB LRT conferences in 1982 and 1985. The remainder of this paper discusses the specific progress made by North American LRT systems, new starts, and would-be new starts since TRB's last conference in May 1985. Much has happened in this short time.

TABLE 8 *continued*

City/System	km(mi) of Line: Mixed Tfc (a)	km(mi) of Line: Total	% of Line: Grade Sep	% of Line: Surf-Rsrvd	% of Line: Mixed Tfc
LRT-Group I:					
Calgary, C-Train	---	27.5(17.1)	12%	88%	---
Cleveland, Shaker Rapid	---	21.1(13.1)	53%	47%	---
Edmonton, Northeast LRT	---	10.5(6.5)	22%	78%	---
Newark, City Subway	---	6.9(4.3)	>99%	<1%	---
Philadelphia:					
Media-Sharon Hill	2.6(1.6)	19.2(11.9)	---	87%	13%
Portland, MAX	0.1(0.1)	24.3(15.1)	36%	>63%	<1%
Sacramento, RT Metro	2.8(1.8)	29.4(18.3)	32%	58%	10%
San Diego Trolley	---	32.8(20.4)	---	100%	---
San Jose, Guadalupe	---	32.8(20.4)	48%	52%	---
Subtotals: km/ (mi)	5.5/ (3.5)	204.5/ (127.1)	28%	69%	3%
LRT-Group II:					
Boston:					
Green Line	4.4(2.7)	40.1(24.9)	61%	28%	11%
Mattapan-Ashmont	---	4.3(2.7)	>99%	<1%	---
Buffalo, MetroRail	---	10.3(6.4)	81%	19%	---
Fort Worth, Tandy	---	1.6(1.0)	40%	60%	---
Philadelphia:					
Subway-Surface	30.3(18.8)	35.9(22.3)	11%	5%	84%
Pittsburgh, South Hills	1.0(0.6)	36.2(22.5)	37%	60%	3%
San Francisco, Muni Metro	18.2(11.3)	32.2(20.1)	32%	12%	56%
Subtotals: km/ (mi)	53.9/ (33.4)	160.6/ (99.9)	41%	26%	33%
Streetcars:					
New Orleans, St. Charles	1.3(0.8)	10.5(6.5)	---	88%	12%
Philadelphia, Streetcars	88.2(54.8)	92.4(57.4)	---	5%	95%
Toronto, Streetcars	70.5(43.8)	73.4(45.6)	<1%	>3%	96%
Subtotals: km/ (mi)	160.0/ (99.4)	176.3/ (109.5)	<1%	9%	>90%
Totals: km/ (mi)	219.4/ (136.3)	541.4/ (336.5)	23%	36%	41%

(a) Street lanes shared by LRT and other traffic; "streetcar" operation

TABLE 9 STATION AND GRADE CROSSING FREQUENCIES

City/System	Psgr. Stops (a)	Grd Xngs/ Intrsctns (b)	Spacing km(mi)	No. With Priority (c)	Grade Separations
LRT-Group I:					
Calgary, C-Train	30	43	0.6(0.4)	40	15
Cleveland, Shaker Rapid	28	24	1.1(0.7)	0	26
Edmonton, Northeast LRT	8	9	1.2(0.7)	9	3
Newark, City Subway	11	1	3.4(2.2)	1	8
Philadelphia:					
Media-Sharon Hill	50	4	0.4(0.2)	25	2
Portland, MAX	25	52	0.5(0.3)	52	20
Sacramento, RT Metro	27	72	0.4(0.2)	70	15
San Diego Trolley	22	77	0.4(0.3)	57	5
San Jose, Guadalupe	33	51	0.6(0.4)	51	21
Subtotals	234	333		332	115
LRT-Group II:					
Boston:					
Green Line	84	52	0.8(0.5)	0	28
Mattapan-Ashmont	8	2	2.2(1.4)	0	5
Buffalo, MetroRail	14	7	1.5(0.9)	7	N/A
Fort Worth, Tandy	4	3(d)	0.5(0.3)	0	2
Philadelphia:					
Subway-Surface	167	4	1.4(0.9)	1	0
Pittsburgh, South Hills	82	43	0.8(0.5)	30	18
San Francisco,					
Muni Metro	110	39	0.1(0.1)	0	2
Subtotals	469	150		38	55
Streetcars:					
New Orleans, St. Charles	50	98	0.1(0.1)	0	1
Philadelphia, Streetcars	573	14	0.3(0.2)	0	0
Toronto, Streetcars	610	3	0.9(0.5)	0	1
Subtotals	1233	115		0	2
Totals	1936	598		370	172

(a) Stations and Car Stops
(b) Line segments except Street-Mixed Traffic
(c) Railroad-type gates &/or flashers, plus traffic lights w/LRT pre-empts, priority, green wave, etc.
(d) 1-vehicular & 2-pedestrian crossings

TABLE 10 TRACK TRAFFIC PATTERNS, ELECTRIFICATION, AND SIGNALING

City/System	Double Track km(mi) (a)	Double Track %	Trctn Power (VDC)	Substatns No.	Substatns Rating (mW)	Type of Overhead (b)	Signals Blk (c)	Signals Tfc (c)
LRT-Group I:								
Calgary, C-Train	27.5(17.1)	100%	600	17	≤2	Both	91%	9%
Cleveland, Shaker Rapid	21.1(13.1)	100%	600	6	(d)	Catenary	85%	47%
Edmonton, Northeast LRT	10.5(6.5)	100%	600	6	(d)	Catenary	100%	--
Newark, City Subway	6.9(4.3)	100%	600	4	0.75	Trolley	100%	<1%
Philadelphia:								
Media-Sharon Hill	13.7(8.5)	71%	635	4	(h)	Trolley	50%	25%
Portland, MAX	21.6(13.4)	89%	750	14	0.75	Both	52%	49%
Sacramento, RT Metro	11.7(7.3)	40%	750	14	1	Both	70%	32%
San Diego Trolley	32.7(20.4)	99%	600	20	1	Both	91%	9%
San Jose, Guadalupe	30.9(19.2)	95%	750	15	1.5	Both	58%	42%
Subtotals	176.6(109.8)							
LRT-Group II:								
Boston:								
Green Line(f)	40.1(24.9)	100%	600	11	3-6	Trolley	61%	39%
Mattapan-Ashmont(g)	4.3(2.7)	100%	600	1	6	Trolley	100%	--
Buffalo, MetroRail	10.3(6.4)	100%	650	5	2	Catenary	81%	19%
Fort Worth, Tandy	1.6(1.0)	100%	600	1	(h)	Trolley	--	--
Philadelphia:								
Subway-Surface	35.9(22.3)	100%	600	(e)	--	Trolley	11%	89%
Pittsburgh, South Hills	32.6(20.3)	90%	650	6	6	Both	90%	10%
San Francisco,								
Muni Metro	32.2(20.1)	100%	600	12	2-8	Trolley	19%	81%
Subtotals	157.0(97.7)							
Streetcars:								
New Orleans, St. Charles	10.5(6.5)	100%	600	(h)	(h)	Trolley	--	100%
Philadelphia, Streetcars	92.3(57.4)	100%	600	(e)	--	Trolley	--	100%
Toronto, Streetcars	73.4(45.6)	100%	600	(h)	(h)	Trolley	--	100%
Subtotals	176.2(109.5)							
Total	509.8(317.0)							

(a) Includes paired 1-way street single tracks functioning as double track
(b) Type of Construction: Catenary, Trolley, or Both
(c) % of Line km (mi) Equipped: Blk-Block Signals; Tfc-Traffic Lights; May not add to 100% as some segments have no signals, others both Blk & Tfc
(d) 1.5 and 3.0 mW
(e) 28 major substations serve all electric transit in City of Philadelphia
(f) 4 of 11 substations also serve other lines
(g) Substation also provides power to Red Line rapid transit
(h) Data not available at time of publication

TABLE 11 REVENUE SERVICE VEHICLES

City/System	Car Types (a)	Builder	Fleet	Accelrtn (b)	Max Spd (c)	Length (d)	Weight (e)
		Characteristics of Car Equipment:					
LRT-Group I:							
Calgary, C-Train	LRV-6-A	Siemens	83	1.0(2.2)	80(50)	24(80)	32(35)
Cleveland, Shaker Rapid	LRV-6-A	Breda	48	1.3(3.0)	88(55)	24(80)	40(45)
Edmonton, Northeast LRT	LRV-6-A	Siemens	37	1.0(2.2)	80(50)	24(80)	31(34)
Newark, City Subway	PCC-4-R	St Louis	24	1.8(4.0)	72(45)	14(46)	17(19)
Philadelphia:							
Media-Sharon Hill	LRV-4-R	Kawasaki	29	1.3(3.0)	100(62)	16(53)	27(30)
Portland, MAX	LRV-6-A	Bombardier	26	1.3(3.0)	88(55)	27(89)	42(46)
Sacramento, RT Metro	LRV-6-A	Siemens	26	1.1(2.5)	80(50)	24(80)	36(40)
San Diego Trolley	LRV-6-A	Siemens	30	1.0(2.2)	80(50)	24(80)	33(36)
San Jose, Guadalupe	LRV-6-A	UTDC	50	1.3(3.0)	88(55)	27(89)	45(49)
Subtotals			353				
LRT-Group II:							
Boston:							
Green Line	LRV-6-A	Kinki	100	1.3(2.8)	80(50)	22(72)	38(42)
(Also In Service)	LRV-6-A	Boeing	135	1.3(3.0)	88(55)	22(72)	30(33)
Mattapan-Ashmont	PCC-4-R	Various	12	1.8(4.0)	72(45)	14(46)	17(19)
Buffalo, MetroRail	LRV-4-R	Tokyu	27	1.3(3.0)	80(50)	20(67)	30(33)
Fort Worth, Tandy	PCC-4-R	St Louis	8	1.8(4.0)	72(45)	14(46)	17(19)
Philadelphia:							
Subway-Surface	LRV-4-R	Kawasaki	112	1.3(3.0)	80(50)	15(50)	26(29)
Pittsburgh, South Hills	LRV-6-A	Siemens	55	1.3(3.0)	80(50)	26(84)	36(40)
(Also In Service)	PCC-4-R	St Louis	47	1.8(4.0)	72(45)	14(46)	17(19)
San Francisco,							
Muni Metro	LRV-6-A	Boeing	130	1.3(3.0)	88(55)	22(72)	30(33)
Subtotals			626				
Streetcars:							
New Orleans, St. Charles	VTL-4-R	Perley-Thos '24	35	0.8(1.7)	43(27)	14(48)	19(21)
Philadelphia,							
Streetcars	PCC-4-R	St Louis	110	1.8(4.0)	72(45)	14(46)	17(19)
Toronto, Streetcars	LRV-4-R	UTDC	196	1.5(3.2)	85(53)	16(53)	23(26)
(Also In Service)	PCC-4-R	Various	122	1.8(4.0)	72(45)	14(46)	17(19)
Subtotals			463				
Total			1442				

(a) See Note (a) on next page. (b) Initial acceleration: meters/sec/sec (mi/h/sec). (c) km/h (mi/h). (d) Meters (feet) overall, to nearest full unit. (e) Metric tons (short tons).

TABLE 11 *continued*

City/System	Car Types (a)	Characteristics of Latest Car Equipment: Endedness	Train (b)	Seats	Capacity (c)	AC? (d)	ATS/ATO
LRT-Group I:							
Calgary, C-Train	LRV-6-A	Double	3	64	144	No	ATS
Cleveland, Shaker Rapid	LRV-6-A	Double	2	84	144	Yes	ATS
Edmonton, Northeast LRT	LRV-6-A	Double	3	64	144	No	ATS
Newark, City Subway	PCC-4-R	Single	1	54	83	No	No
Philadelphia:							
Media-Sharon Hill	LRV-4-R	Double	2	50	95	Yes	No
Portland, MAX	LRV-6-A	Double	2	76	160	No	ATS
Sacramento, RT Metro	LRV-6-A	Double	4	64	144	Yes	No
San Diego Trolley	LRV-6-A	Double	4	64	144	(e)	No
San Jose, Guadalupe	LRV-6-A	Double	2	75	160	Yes	No
LRT-Group II:							
Boston:							
Green Line	LRV-6-A	Double	3	50	130	Yes	No
Mattapan-Ashmont	PCC-4-R	Single	1	52	83	No	No
Buffalo, MetroRail	LRV-4-R	Double	3(f)	51	121	Yes	ATS
Fort Worth, Tandy	PCC-4-R	Double	1	60	83	Yes	No
Philadelphia:							
Subway-Surface	LRV-4-R	Single	1	51	90	Yes	No
Pittsburgh, South Hills	LRV-6-A	Double	2	62	151	Yes	ATS
San Francisco, Muni Metro	LRV-6-A	Double	3	68	130	No	No
Streetcars:							
New Orleans, St. Charles	VTL-4-R	Double	1	52	68	No	No
Philadelphia, Streetcars	PCC-4-R	Single	1	50	83	No	No
Toronto, Streetcars	LRV-4-R	Single	1	46	95	No	No

(a) LRV-Light Rail Vehicle, PCC-Presidents' Conference Committee, VTL-Pre-PCC Vintage Trolley; # Axles, 4 or 6; R-Rigid, Non-Articualted, A-Articulated
(b) Maximum Cars/Train in Regular Operation
(c) Car Length (Feet) * 1.8 - comfortable load of seats + standees at $\pm 4/m^2$
(d) Air Conditioning
(e) 6-Yes, 24-No
(f) 4-Car Trains for Special Events

EXISTING SYSTEMS UPGRADED

The process of renewing and upgrading older LRT systems is largely complete. Since 1985, nine cities have made major accomplishments.

Boston

Most visible has been delivery of 100 new LRVs from Kinki-Sharyo. Similar in size and configuration to the Boeing-Vertol cars delivered in the late 1970s, but specified to prevent a repeat of their reliability problems, these LRVs will

TABLE 12 OPERATING STATISTICS

City/System	Anl Car km (mi) (mil)	Annual Train Hours(a) (000s)	Anl km (mi)/Car (000s)
LRT-Group I:			
Calgary, C-Train	4.3(2.7)	79	52(33)
Cleveland, Shaker Rapid	3.1(1.9)	66	65(40)
Edmonton, Northeast LRT	2.1(1.3)	29	57(35)
Newark, City Subway	0.9(0.6)	39	38(25)
Philadelphia:			
Media-Sharon Hill	1.0(0.6)	52	34(21)
Portland, MAX	1.6(1.0)	36	62(38)
Sacramento, RT Metro	1.6(1.0)	36	62(38)
San Diego, Trolley	3.3(2.1)	56	110(70)
San Jose, Guadalupe	4.5(2.8)	140	90(56)
Subtotal/Averages	20.8(13.0)	533	59(37)
LRT-Group II:			
Boston:			
Green Line	7.6(4.7)	384	32(20)
Mattapan-Ashmont	0.5(0.3)	23	42(25)
Buffalo, MetroRail	1.5(1.0)	35	56(37)
Ft Worth, Tandy	0.2(0.1)	9	20(13)
Philadelphia:			
Subway-Surface	4.5(2.8)	297	40(25)
Pittsburgh, South Hills	3.5(2.2)	183	34(22)
San Francisco, Muni Metro	6.5(4.1)	400	50(32)
Subtotals/Averages	22.6(14.1)	1331	36(23)
Streetcars:			
New Orleans, St Charles	1.1(0.7)	83	31(20)
Philadelphia, Streetcars	3.5(2.2)	274	32(20)
Toronto, Streetcars	14.5(9.0)	968	46(28)
Subtotals/Averages	19.1(11.9)	1325	41(26)
Total/Averages	62.5(39.0)	3189	43(27)

(a) Train km(mi) and Train Hours essentially the same as Operator Platform km(mi) Hours for systems with one-person train operation.

supplement the existing fleet and ultimately replace a majority of the remaining PCC cars on the Green Line. However, rebuilt PCC cars will continue to serve the Mattapan-Ashmont route feeding the Red Line.

LRT facility improvements continue to be made. Reconstruction of Central Subway tracks and signaling began in 1985 and will continue through 1989. Surface line rehabilitation also has continued in several locations. Particularly intriguing was a 1987 agreement with a private developer to reconstruct the Riverside Line's Newton Center station as retail shops, a fine reuse for this structure dating from the line's steam engine commuter train days.

TABLE 13 COSTS OF NEW LRT PROJECTS AND MAJOR LRT RECONSTRUCTION

City/System	Line km(mi)	Project	Year Open	Capital Cost Initial ($Mil)	Capital Cost Per km(mi) ($Mil)
LRT-Group I:					
Calgary, C-Train					
South Line	12.7(7.9)	New Start	1981	$C174	$C13.7($C22.0)
Additional LRVs	N/A	---	1982	$C53	N/A
Northeast Line	9.3(5.8)	Extension	1985	$C169	$C18.2($C29.1)
Northwest Line	5.5(3.4)	Extension	1987	$C104	$C18.9($C30.6)
Cleveland, Shaker Rapid	21.1(13.1)	Reconstrctn	1981	$150	$7.1($11.5)
Edmonton, Northeast					
Northeast Line	7.2(4.5)	New Start	1978	$C65	$C9.0($C14.4)
Clareview Extnsn	1.7(1.0)	Extension	1981	$C10.5	$C6.2($C10.5)
Corona Extension	1.6(1.0)	Extension	1983	$C110	$C68.8($C110.0)
Newark, City Subway	6.8(4.2)	Reconstrctn	1985	$20	$2.9($4.8)
Philadelphia:					
Media-Sharon Hill	19.2(11.9)	Reconstrctn	N/A	Unknown, work ongoing	
Portland, MAX	24.3(15.1)	New Start	1986	$213	$8.8($14.1)
Sacramento, RT Metro	29.4(18.3)	New Start	1987	$176	$6.0($ 9.6)
San Diego Trolley					
South Bay-Phase I	25.6(15.9)	New Start	1981	$86	$3.4($ 5.4)
South Bay-Phase II	N/A	Add Dbl Trk	1983	$31	$1.2($ 1.9)
East Line-Euclid	7.2(4.5)	Extension	1986	$34	$4.7($ 7.6)
East Line-El Cajon	18.5(11.5)	Extension	1989	$101	$5.5($ 8.8)
Bayside	2.1(1.3)	Extension	1990	$40	$19.0($30.8)
San Jose, Guadalupe	32.7(20.3)	New Start	1991	$500	$15.3($24.6)
LRT-Group II:					
Boston					
Green Line					
Riverside Carhse	N/A	New Facil	1975	$37	N/A
Commonwealth Av	~6.8(~4.2)	Reconstrctn	1982	$5	$0.7($1.2)
Reservoir Carhse	N/A	Reconstrctn	1984	$37	N/A
100 Kinki LRVs	N/A	New Cars	1988	$112	N/A
Central Subway	~7.2(~4.5)	Track Rcnstrctn	1989	$26	$3.6($5.8)
Traction Power	N/A	Improvements	1991	$37	N/A
Mattapan-Ashmont	4.2(2.6)	Reconstrctn	1981	$8	$1.9($3.1)

TABLE 13 *continued*

City/System	Line km(mi)	Project	Year Open	Capital Cost Initial ($Mil)	Per km(mi) ($Mil)
Buffalo, MetroRail	10.3(6.4)	New Start	1985	$530	$51.5($82.8)
Ft Worth, Tandy Subway	1.6(1.0)	Reconstrctn	1978	~$1	$0.6($1.0)
Philadelphia Subway-Surface	35.9(22.3)	Reconstrctn	1983	Data unavailable	
	N/A	New Cars	1983	$589	~$0.5 mil/car
Pittsburgh, South Hills	36.2(22.5)				
Stage I	16.9(10.5)	Reconstrctn	1987	$542	$32.1($51.6)
Stage II	19.3(12.0)	Reconstrctn	F	~$300	12.0($19.4)
San Francisco, Muni Metro	33.3(20.7)	Reconstrctn	1981	$330	$9.9($15.9)
Streetcars:					
New Orleans, St Charles	10.5(6.5)	Reconstrctn	1991	$43	$4.1($6.6)
Philadelphia, Streetcars	110 PCCs	Rehab Cars	198?	$16	~$0.1 mil/car
Toronto, Streetcars					
4-Axle LRVs	N/A	New Cars	1981	$C98	~$C0.5 mil/car
Articulated LRVs	N/A	New Cars	1988	$C82	~$C1.6 mil/car
Harbourfront LRT	2.1(1.2)	Extension	1989	$C51	$C25.5($C42.5)

$ - U.S. dollars in expenditure year
$C - Canadian dollars in expenditure year
F - Future project, no firm timetable established

Relocation of North Station area trackage and the Lechmere terminus are in final design. Construction of a new LRT maintenance facility at the latter location is in the planning stage. In conjunction with its automatic vehicle identification (AVI) system, to be installed over the next 18 months, the Massachusetts Bay Transportation Authority (MBTA) is working with Boston on providing LRT prioritization at some intersections along surface lines.

Newark

Rehabilitation of the tunnels, tracks, subway and surface stations, and PCC cars was completed in 1985. With bus services reconfigured to feed LRT, the system now carries 14,100 per weekday. Several extensions continue to be evaluated; and in 1987, a feasibility study was initiated for a new station at Summit Street in conjunction with a major redevelopment project. LRT as an extension to the city subway is one of several alternatives being considered to link Newark with its airport and the adjacent city of Elizabeth.

TABLE 14 CHANGES IN NORTH AMERICAN LRT AND STREETCAR SYSTEMS, 1977–1987

City/System	Code (a)	Changes Since 1977
LRT-Group I:		
Calgary, C-Train	NVX	Opened South Line 1981, Northeast Line 1985, Northwest Line 1987; total system is 27.5 km (17.1 mi)
Cleveland, Shaker Rapid	RV	48 new LRVs, new shop, completely rebuilt facilities; currently planned: Van Aken Project (twin office towers above station)
Edmonton, Northeast	NVX	Opened 1978, and since extended to 10.5 km (6.5 mi)
Newark, City Subway	R	Rebuilt PCCs and facilities
Philadelphia, Media-Sharon Hill	VR	29 new LRVs and rebuilt facilities
Portland, MAX	NV	Opened 1986, 24.3 km (15.1 mi)
Sacramento, RT Metro	NV	Opened 1987, 29.4 km (18.3 mi)
San Diego Trolley	NVX	Opened South Bay Line 1981, Euclid line 1986; total system is 32.8 km (20.4 mi)
San Jose, Guadalupe	NV	Partially open December 1987, 10.8 km (6.7 mi). Extension to downtown scheduled June 1988; full line in operation mid-1991
LRT-Group II:		
Boston		
Green Line	RV	235 new LRVs, new shops, rebuilt PCCs and facilities
Mattapan-Ashmont	R	Rebuilt PCCs and facilities
Buffalo, MetroRail	NV	Opened 1985 and 1986, 10.3 km (6.4 mi)
Fort Worth, Tandy	R	Rebuilt PCCs (second time) and refurbished facilities
Philadelphia: Subway-Surface	VR	112 new LRVs, new shop and refurbished facilities
Pittsburgh, South Hills	VRX	55 new LRVs, new shop, 40 rebuilt PCCs and rebuilt 16.9 km (10.5 mi) line including two new subways
San Francisco, Muni Metro	VRX	140 new LRVs, new shop, new Market Street subway, line extension and rebuilt facilities
Streetcars:		
New Orleans, St. Charles	R	Designated National Historic Landmark
Philadelphia, Streetcars	R	110 rebuilt PCCs; some track reconstruction
Toronto, Streetcars	VRX	196 new CLRVs, first of 52 ALRVs under test, Harbourfront LRT begun Sep '87, 2.1 km (1.2 mi); ongoing track renewal, 19.8 km (12.3 mi) in last two years

(a) N–New Start, R–Rebuild/Rehab Facilities, V–New Vehicles, X–Extension

Philadelphia

The Media-Sharon Hill lines were served by buses during summer 1987 so that the 69th Street terminal loop facilities and tracks in Terminal Square could be rebuilt. Much of the surface track was renewed in 1984–1986. This work follows acquisition of 29 Kawasaki LRVs and rehabilitation of track, the traction power system, and the line's attractive stone waiting shelters.

The five subway-surface lines have enjoyed a ridership increase of about 42 percent since being reequipped with Kawasaki LRVs in 1983. These cars are serviced in the new Elmwood Depot completed in the same year.

The North Philadelphia streetcar system is in a period of retrenchment, primarily because the useful life of the fixed plant has been completely consumed, and capital resources are lacking for either renewal or upgrading to LRT standards. Because there is little reserved trackage, except on Route 15-Girard Avenue, service speeds are low. Buses have replaced PCC streetcars on several routes, some permanently and others on a sporadic basis in response to car availability problems, deteriorated track, and street and sewer reconstruction projects. In 1987, the City of Philadelphia initiated a congressionally mandated review to see if certain lines previously converted to bus would have the potential for reintroduction of rail service. Special focus was placed on creation of a reserved ROW LRT line on Allegheny Avenue that would feed both the Broad and Market-Frankford rapid transit lines. City and SEPTA officials are weighing future options for these services.

Pittsburgh

An ambitious reconstruction of about half this system was completed in mid-1987. The 10.5-mi Phase I South Hills LRT line includes new tracks, electrification, and signaling over its entire length, 13 high-and-low platform stations, 23 low-level car stops, 1,600 park-and-ride spaces spread among five stations, 55 new Siemens LRVs, and 2 new subways—1.1 mi under downtown Pittsburgh and 0.2 mi under suburban Mount Lebanon. Both replace former mixed-traffic street operations in areas subject to severe congestion. As a result, average speed between the Mount Lebanon station and downtown Pittsburgh has increased 22 percent, from 17.1 to 20.9 mi/hr. Weekday ridership averaged 27,300 from June 1987 through February 1988.

Up to 45 PCC cars are under consideration for rehabilitation. Eight have been rebuilt to date. Future plans include possible reconstruction of the South Hills Junction-Castle Shannon trunk line via Overbrook, and the branches to Library and Drake.

In addition, an alternatives analysis is in progress to evaluate various LRT options in the "Spine Line" corridor linking downtown with the Northside, Oakland, and Squirrel Hill.

Cleveland

The 48 Breda LRVs delivered in the early 1980s continue to serve the reconstructed Blue/Green (former Shaker Rapid) LRT system and are maintained with the Red Line rapid transit cars in the opulent new Central Rail Maintenance Facility. An award-winning renovation of Shaker Square station, at the junction of the Shaker and Van Aken branches, was completed in 1986.

Current work focuses on key stations. The Van Aken Project, a cooperative effort with the City of Shaker Heights using an UMTA grant, will relocate the Warrensville Road LRT platforms to permit construction of twin office towers and a parking garage.

Renovation of the downtown Tower City LRT and rapid transit stations will include across-the-platform transfers. Rail transit patronage in Cleveland is inhibited because Tower City, the only downtown stop, is not centrally located. The Dual Hub Corridor alternatives analysis currently in progress is addressing the problem of transit distribution through the Cleveland CBD to the city's Cultural Center at University Circle. LRT is emerging as a prime candidate.

New Orleans

The St. Charles streetcar line was designated a National Historic Landmark in 1973. System rehabilitation is in progress, including the tracks, maintenance facility, and the fleet of 35 vintage streetcars built in 1924.

New Orleans also is studying the feasibility of introducing modern LRT, with interest currently focused on a reincarnation of the Canal Street line. Work also is progressing on a 2-mi Waterfront Vintage Trolley.

Fort Worth

The Tandy Subway has not changed since 1985 but continues to function as an efficient connector between peripheral parking and the Fort Worth CBD.

San Francisco

Of all the system renewals, San Francisco's best exemplifies the upgrading of an old streetcar system using modern LRT service standards. Located in a densely developed urban core city, this achievement required substantial capital expenditure, though much less than other rail options.

During Bay Area Rapid Transit (BART) planning in the mid-1950s, a two-level rail tunnel under Market Street was adopted, with Muni trains running above BART's. Consultants proposed a Muni heavy rail system, all in-tunnel, consisting of the new Market Street tunnel plus Muni's existing Twin Peaks and Sunset tunnels, and a new subway under Geary Street, all to be fed by buses.

By the late 1960s, this costly proposal had foundered, and the Muni Metro concept emerged: use subway-surface rail cars (the term LRV was not yet invented) to provide no-transfer service directly to the CBD on the existing five streetcar lines and through the new subway. This system was implemented by the early 1980s. The public response has been a 32 percent increase in rides to about 130,000 per day.

Current projects include extending the J Line 2.2 mi to the Muni Metro Center to expand LRT service and avoid a long, circuitous deadhead route. Construction is to begin in October 1988. An Environmental Impact Statement is being prepared for a new Embarcadero ramp and surface turn-around loop at the Ferry Terminal. Further in the future is an extension from the Ferry Terminal to the area south of Market, where several major land development projects are under construction or planned.

An environmental assessment is being prepared for the F Line. This service will run from Market and Castro via the now-to-be-retained Market Street surface trackage to the Ferry Terminal, then continue on a former freight line to the Fisherman's Wharf area. The project includes rehabilitation of 20 PCC cars.

Toronto

Toronto's large streetcar network was upgraded in the early 1980s with 196 4-axle UTDC LRVs. Track reconstruction usually is in progress along one or more line segments, with 19.8 km (12.3 mi) renewed in the last 2 years.

Since 1985, the system has tested a prototype articulated LRV from UTDC based on the Canadian Light Rail Vehicle (CLRV) design and has ordered 52 production cars. Work on a 2-km (1.2-mi) Harbourfront LRT line began in September 1987. Expected to cost $51 million (U.S. $38 million), the line includes a short tunnel and segregated surface street lanes linking Union Station and a redevelopment zone to the south and west.

NEW STARTS OPENED

Most exciting to LRT advocates has been the opening of several new systems. From 1977 to 1985, four all-new LRT projects were opened for revenue service: Edmonton (1978), Calgary and San Diego (1981), and Buffalo (1985). Since then, three more systems have opened: Portland (1986), and Sacramento and San Jose (both 1987).

Four of these projects—Edmonton, Calgary, San Diego, and Sacramento—all use variants of the Siemens/Duewag U2 LRV. Since the joint Boston-San Francisco order with Boeing, this is about as much "standardization" as the

North American LRT scene has been able to achieve. Of these four projects, only Sacramento used U.S. federal funding.

Edmonton

Edmonton opened its initial 4.5-mi line in 1978. Since then, LRT has been extended on both ends, to the new town development of Clareview in 1981, and further through the CBD (in subway) in 1983. A new shop opened in 1984.

Currently, a 2.4-km (1.5-mi) extension to the University of Alberta is under construction, including a new bridge over the North Saskatchewan River and tunnels on both the CBD and University sides of the river. This short but expensive segment is consuming Edmonton's present LRT financing capabilities, but it is a necessary prelude to one or more longer, lower-cost per kilometer surface extensions to the southern suburbs planned for construction after 1990.

Calgary

By avoiding subway construction through its downtown, Calgary has been able financially to expand its LRT system coverage at a faster rate than its sister city to the north. After the 1981 opening of the South Line, which is mostly in a jointly used railroad ROW, Calgary turned to its Northeast Line. This required a new bridge across the Bow River and, north of that point, tracks laid primarily in the median strips of Memorial Drive and 36th Street NE. The Northeast Line opened in 1985.

September 1987 saw the start of revenue service on Phase I of the Northwest Line, three months ahead of schedule and $3 million (U.S. $2.24 million) under budget. This latest line extends 5.5 km (3.4 mi) to the University of Calgary. It was a key element in Calgary's transport strategy for the 1988 Winter Olympics in which transit played a major role. On the heaviest single day, the LRT system alone carried 262,000 rides, more than three times its normal weekday load.

Further plans call for extending the Northwest Line another 8.5 km (5.1 mi) along Crowchild Trail. The next kilometer (0.6 mi) is in final design, with construction expected to start in summer 1988.

Long-term plans call for building lines to the west and, eventually, the north. When completed, the South/Northwest and Northeast/West lines will operate as two through-routed services.

San Diego

As the first new U.S. LRT system to open since Fort Worth's subway, the start of revenue service on the 25.6-km (15.9-mi) San Diego Trolley in 1981 was a landmark event. San Diego opted for a "no-frills, low-budget, reuse what you have" approach. The payoff has been a system relatively inexpensive to build and operate, popular with riders, and readily expandable. Since opening the initial line, San Diego, like Calgary, has demonstrated how LRT can be expanded in affordable increments.

The first improvement was full double tracking of the initial South Line, begun in late 1981 and finished in 1983. Then work began on the East Line in two phases. Phase I extends 7.2 km (4.5 mi) to Euclid Avenue and was opened in March 1986. A few months later, the South Line's new Bayfront/E Street station in Chula Vista was opened, providing access in what had been a gap of about 3 km (1.8 mi).

As a result of these improvements, patronage has grown from 11,000 per weekday in 1981 to about 27,000 in 1988. Only about 16 percent of total riders are tourists.

Now work is proceeding on the nearly 18 km (11 mi) of Phase II to El Cajón, scheduled for a 1989 opening. A 2.1-km (1.3-mi) "Bayside" line from the Santa Fe Depot to the Imperial & 12th Transfer Station is in final design and should open in 1990. At the latter location, major reconstruction is in progress, including a 10-story MTS Tower office building set to open in January 1989.

The Metropolitan Transit Development Board (MTDB) also is purchasing another 41 Siemens LRVs, which will bring the total fleet to 71.

Future extensions include El Cajón-Santee and Santa Fe Depot-Old Town, each about 5 km (3 mi) long and in preliminary engineering, and lines from Old Town to the north and into the Mission Valley, both in the planning stages.

Buffalo

After years of planning, Buffalo's MetroRail finally started running in spring 1985, not as the heavy rail subway-elevated line originally planned, but as a light rail rapid transit system. Alone among the new North American LRT projects, Buffalo opted for four-axle nonarticulated cars (from Tokyu Car).

Buffalo's 1985 opening was partial. Finish work continued around trains along the 1.2-mi Main Street Mall and service stopped short of the two outer end stations. Nonetheless, antirail critics were quick to pounce and loudly proclaimed Buffalo "another rail transit failure." They were a little too fast off the mark.

At the end of November 1986, all the work was completed, and the system fully opened from end to end. Patronage, which has been growing, now has settled in at 29,000 on weekdays. Productivity in passengers per kilometer of line and per LRV is quite high (Table 4).

Buffalo, too, has plans for extensions: completion of the initial line to Amherst and a branch to the Tonawandas. But funding is difficult, and the timing for these improvements remains indefinite.

Portland

The genesis of Portland's successful MAX LRT project was a local decision in the late 1970s to drop a planned segment of Interstate highway, the so-called Mount Hood Freeway. The 24.3-km (15.1-mi) MAX line represents $212.7 million of a $319 million project, the $107 million difference representing reconstruction of 7.2 km (4.5 mi) of Interstate 84, the Banfield Freeway. Even the LRT cost includes substantial road works: building-to-building reconstruction of streets and sidewalks along 3.5 km (2.2 mi) in downtown Portland and Lloyd Center, and complete reconstruction of suburban East Burnside Street for 8.5 km (5.3 mi). Opened to revenue service in September 1986, MAX was an instant hit, for these reasons:

- LRVs are perceived as fast, quiet, reliable, and comfortable.
- Bus connections are crisp and comprehensive; because MAX is integrated with the rest of the transit system, all-day use is assured.
- Park-and-ride lots are adequately sized (but not overbuilt).
- MAX is one link in a 20-year chain of public and private investments made to keep downtown Portland vital; these efforts continue.

In September 1987, Portland completed its new three-theater Performing Arts Center only three blocks from MAX. Engineering for a Vintage Trolley service to complement MAX downtown is under way. Now the region is beginning preliminary engineering for a Westside MAX line to Beaverton; and ROW is reserved for extensions from the midpoint of the Gresham Line north to the airport and south to a major regional shopping and suburban office complex.

Sacramento

Like Portland, Sacramento turned in an unwanted segment of Interstate freeway, some of which had been built but never opened, and parlayed the substitution funding from 8.5 km (4.5 mi) of highway to 28.4 km (18.3 mi) of

LRT. Included in the $176 million project were conversion of downtown's unsuccessful K Street pedestrian mall to a transit mall, creation of a second mall on O Street, three major arterial street/freight railroad grade separations, and numerous smaller street improvements and repavings. Nonetheless, by such stratagems as using the built but unused freeway for a park-and-ride and existing bridges to avoid having to construct several major new structures, Sacramento achieved the lowest initial cost to date for a rail project using federal funds—under $10 million/mi.

As noted above, Sacramento uses the latest modified version of the Siemens/Duewag U2. From the passengers' perspective, the major addition is air conditioning, but there also have been changes in the braking system and in the car body end construction (steel instead of fiberglass).

As of April 1988, the fourth month of full LRT and feeder bus operation, Regional Transit's RT Metro averaged 13,200 boarding rides per weekday. This LRT ridership reflects overall transit use less than forecast during LRT planning due to the drastic drop in oil prices since 1981, shorter operating hours, and less feeder bus service because of RT budget constraints, and downtown parking that is cheaper and more abundant than forecast. As Sacramento's rapid growth continues and traffic congestion worsens, this LRT system built for the future may be expected to become more productive.

San Jose

In common with the preceding federally funded U.S. projects, San Jose's Guadalupe Corridor is the survivor of a long planning process. Conceived in 1973, the system began revenue service on the north end of its line in late 1987 to ensure eligibility for a sale/lease-back deal on some of the 50 UTDC LRVs. Construction on the south end will continue until the full system is completed in mid-1991. This $750-million (*3*) project includes:

- LRT system—33 km (20 mi) long at a cost of $500 million or $15.2 million/km ($25.0 million/mi),
- Freeway—14 km (9 mi) long at a cost of $200 million or $14.3 million/km ($22.2 million/mi), and
- Downtown Mall—0.7 km (0.4 mi) long at a cost of $50 million or $71 million/km ($125 million/mi).

The new downtown transit mall will be shared with buses, automobiles, and pedestrians. Vintage trolleys will supplement LRT service.

Supplemental environmental reviews and project redesign work associated with the decision to build a freeway instead of a surface "expressway" south of downtown San Jose caused the project's extended completion date. This change also is a major contributor to increased LRT costs, because freeway median stations now must be grade-separated and equipped with stairs, escalators, and elevators instead of being constructed as simple surface facilities.

Planning is under way for two extensions. A Phase 2 alternatives analysis (AA) is evaluating LRT and other options in the Fremont-South Bay Corridor. Milpitas-Sunnyvale subcorridor LRT options would use the existing Guadalupe LRT trackage along Tasman Drive from North First to Old Ironsides. Simultaneously, a Phase 1 AA is being conducted on the Vasona/ Highway 17 Corridor extending southwest from downtown San Jose. This study will lead to selection of a small set of alternatives, of which LRT is likely to be one, for further evaluation in a Phase 2 AA.

NEW STARTS—CONSTRUCTION IN PROGRESS

Construction on a new-start LRT project is under way in only one city: Los Angeles. On the Long Beach-Los Angeles (LB-LA) line, ROW structures and the central maintenance facility are taking shape; track laying has begun; and 54 six-axle LRVs have been ordered from Nippon Sharyo. These cars will provide initial service on the LB-LA line and, perhaps, the Norwalk-El Segundo line.

The latter line also is under construction. Grading and structures for a transit line in the Century Freeway median are being built by Caltrans as part of freeway construction. Guideway facilities will be placed in this prepared ROW as in Portland's earlier construction and following the example of San Jose's current work. The El Segundo segment of the route is in final design, including 5.6 km (3.5 mi) of elevated line, and a satellite light maintenance and storage facility. The Los Angeles County Transportation Commission's (LACTC's) latest thinking is that this line will be automated, in which case it will no longer meet TRB's criteria for LRT since full grade separation will be mandatory and operation of the vehicles through grade crossings will not be possible.

LB-LA is expected to open in 1990, Norwalk-El Segundo in 1993. The scheduling of future lines is less certain; but plans call for LRT to Pasadena, Marina del Rey, and the San Fernando Valley.

PLANNING AND DESIGN UNDER WAY

Numerous cities have been considering LRT in planning studies; and several have progressed into system design. Indeed, during the 1980s, both LRT construction and interest in further new starts have increased, fueled by growing urban transportation problems, the clear successes of the new LRT systems opened so far, and shrinking budgets that rule out higher-cost solutions such as rapid rail and automated guideways.

This section describes projects well along the planning and design path. It is organized to show new-start LRT projects in—or ready to enter—the following categories: final design, preliminary engineering, and planning.

Final Design

In Dallas, planning and preliminary engineering have been completed for a 150-km (93-mi) system. If or when a public consensus is reached, construction can start on 23.3 km (14.5 mi), linking Oak Cliff and Park Lane via downtown Dallas. A further 23.2 km (14.4 mi) would open in increments thereafter to serve Parkland Hospital, Oak Cliff, West Oak Cliff, and Park Lane to Texas Instruments. Completion of the full system would not occur until 2010 or later.

St. Louis anticipates signing a full-funding agreement with UMTA later this year. This step will signal the start of final design on Metro Link, a 28.2-km (17.5-mi) LRT line using mostly railroad, freeway, and airport ROW to connect East St. Louis and downtown St. Louis with the Central Midtown and its hospitals, Forest Park, the University of Missouri, Lambert International Airport, and McDonnell-Douglas world headquarters.

Preliminary Engineering

In Baltimore, the Maryland Mass Transit Administration recently selected consultants to oversee design and construction of a South Line to Anne Arundel County and Baltimore-Washington International Airport, and a North Line to Hunt Valley. The 43.5-km (27.0-mi) system includes a 2.0-km (1.2-mi) downtown transit mall on Howard Street. State funds were approved this spring. The full system is expected to be in operation by the early 1990s.

The Hennepin County Regional Railroad Authority has completed a 20-year LRT development plan for Minneapolis. Preliminary engineering for Stage I is expected to begin in 1988. The initial system is likely to include four lines totaling about 40 km (25 mi) and radiating from downtown to the northwest, southwest, southeast, and University of Minnesota. ROW combines railroad lines, land acquired for a now-defunct freeway, and exclusive street lanes.

Planning

Planning, including UMTA-sponsored alternatives analyses (AAs) as well as locally funded feasibility studies, is in progress for at least 19 other LRT proposals. Potential projects include all types of LRT service capabilities (line-haul transit, feeder service, and local area circulation) in a variety of settings and route lengths.

Austin

An AA is ongoing in the Northwest Corridor; the city and transit agency have purchased a railroad ROW extending both northwest and east from downtown.

Brooklyn Waterfront

A local circulation system has been proposed as part of a major redevelopment planned for this formerly active, but now largely disused, docks area.

Charlotte

LRT is one option in an AA study to evaluate how this fast-growing sunbelt city can cope with worsening traffic congestion.

Chicago

An AA is starting to plan a Downtown Connector. The central core is separated from the two major commuter rail stations and a major redevelopment area west and north, respectively, of the Chicago River.

Denver

Planning continues on a regional guideway system. LRT is a strong contender for the initial Southeast Line, to be developed with substantial private participation, but support for automated-guideway transit (AGT) also is strong.

Detroit

Interest in LRT has been renewed. Woodward (priority corridor) and Gratiot avenues are being considered in the context of a regional bus and rail plan, which may lead to a referendum on dedicated funding.

Houston

Guideway plans were boosted by voters' January 1988 approval of the $2.6-billion Phase 2 Mobility Plan. A key element is a 32-km (20-mi) guideway system, perhaps LRT, linking four major employment centers.

Kansas City

Planning for LRT continues. An initial downtown distributor line of about 5 km (3 mi) is being considered as a first phase that will fit available resources.

Manhattan West Side

Alignments being considered include a rail freight line stretching from northern to downtown Manhattan, as well as adjacent streets, 11th and 12th avenues, and easterly extensions across 42nd Street and to Penn Station. Preliminary indications are that initial development efforts may focus on the midtown segments.

Memphis

A 26.2-km (16.3-mi) LRT line has been planned in the Poplar Corridor, about 56 percent in public thoroughfares and 44 percent along an existing rail alignment. A local decision-making process is under way to choose among LRT and various non-rail system improvement alternatives.

Miami

An AA is nearing completion on ways to connect the Metro with Miami Beach. A 10-km (6-mi) surface LRT option would use an existing causeway to bridge the channel separating Miami from Miami Beach.

Milwaukee

An AA completed in 1987 identified a North/Northwest LRT line 16 to 29 km (10 to 18 mi) long. Interim express bus improvements are proceeding, because LRT capital is not likely to be available in the near future.

Norfolk/Virginia Beach

A 31-km (19-mi) LRT line has been proposed using railroad ROW, with about 1.6 km (1.0 mi) of street operation at each end. City councils are expected to consider local funding options this summer.

North Jersey Waterfront

Plans for renewing this former shipping hub include a 24-km (15-mi) LRT/bus north-south transitway. The system would link new office and residential developments with other transportation: trans-Hudson links, commuter trains, and the New Jersey Turnpike.

Phoenix

A plan for a regional guideway system has been developed for consideration by voters in this fast-growing area. Modal options included LRT, aerial AGT, and commuter rail, with the latter two being recommended. Public review meetings on the draft plan are scheduled this year, with a sales tax referendum in early 1989 seeking to raise nearly $5 billion over 20 years.

St. Paul

Ramsey County's railroad authority has reviewed alignment options to extend Hennepin County's University Connector to downtown St. Paul. Further activity awaits local and state funding decisions.

Salt Lake City

An AA nearing completion includes an LRT option extending 26 km (16 mi) south from downtown. Decisions on a preferred alternative and funding plan may be adopted in late summer or early fall 1988.

Silver Spring, Maryland

Montgomery County is studying transit options, including LRT, to connect and feed two Washington Metro lines using 6.6 km (4.1 mi) of the former B&O Railroad's Georgetown Branch.

Tampa

A three-line fixed-guideway system up to 65 km (40 mi) long using either LRT or AGT is being evaluated in a technology assessment. In addition, local business interests have proposed a vintage streetcar system as a downtown distributor.

DEVELOPMENTS IN MEXICO

Work continues in Mexico City to modernize the remaining two streetcar lines to Xochimilco and Tlalpan. These lines are mostly on reserved ROW, and feed the Metro at Tasqueña. Facility improvements include high-platform stations, renewed track, and overhead lines. A fleet of 30 eight-axle, double-articulated LRVs is being rebuilt from PCC cars. The system ultimately is expected to serve over 30,000 riders daily.

In Guadalajara, a turnkey contractor is building a new 16-km (10-mi) LRT system on a route previously worked by trolley buses. The first 10 km (6 mi) are to open in November 1988. The work includes provision of 16 six-axle, articulated LRVs (with local assembly in Mexico), as well as installation of track, power, signals and maintenance equipment, and staff training.

Finally, the northeastern city of Monterrey is evaluating proposals for an 8-km (5-mi) LRT route. The mostly elevated alignment would serve 12 stations.

CONCLUSIONS

With old systems largely rebuilt and a flurry of new-start successes, LRT has become the guideway mode of choice for an increasing number of cities. The operating systems frequently host groups of would-be emulators gathering ideas for LRT projects being planned at home.

LRT provides adequate levels of service, speed, and comfort to accommodate realistically projected passenger flows. It is affordable to build, operate, and maintain. It can enhance urban development without "Manhattanization" and is a sensitive neighbor to communities served. Light rail should continue to enjoy a bright future.

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