When and Where Does LRT Work?

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This paper determines that LRT can and does work in a variety of situations and analyzes the conditions necessary to support its successful implementation. To be effective, light rail service must meet the requirements of a substantial number of the tripmakers along its route. Travel time must be shortened to attract riders who have the option of traveling by private auto. Alternatively, travel volume must be so high that a low transit modal split will still yield high ridership in absolute numbers. Exclusive or preferential rights-of-way help minimize LRT's trip time and relieve highway congestion. Shared or converted railroad alignments, center boulevards, exclusive lanes, and short aerial or underground structures are the usual means of accelerating LRT to improve trip time. Simple, traditional street operation is effective only when travel volume is sufficient to justify LRT on its productive efficiency rather than its speed. For maximum efficiency, LRT must often closely integrate its service with that of a local bus network, but on long, fast radial lines serving a central business district, integration, although desirable, may not be a necessity. Conditions under which LRT works best range from long, fast, low-density suburban lines to short, slow, high-density inner-city lines. Some LRT installations are high-capital, high-efficiency operations; others require less capital to achieve superior results. LRT can only be used where it is the best transit mode for the specific application.

San Diego, San Francisco, Calgary, and Edmonton have recently and successfully implemented new or vastly improved light rail transit systems, and construction is under way in Buffalo, Pittsburgh, and Portland. Final plans for construction are being drawn in Baltimore, Denver, Detroit, and Sacramento. Studies have been done in Rochester and San Jose with favorable results. All this activity and interest in light rail transit (upgraded street railway) raises the question: Why and how?

HISTORY

Light rail operations over the past 25 years stand out in bold and happy contrast to the results experienced by surface transit generally, which lost 64 percent of its passengers during that period of metropolitan growth.[1] The shift from the 6-day work week of the World War II period to a 5-day week was completed in 1952 when banks inaugurated Saturday closings. The years from 1953 to the first energy crisis of 1973-74 provide a stable period for comparison of LRT trends to those of the surface transit industry generally. Major changes in light rail operations in many cities limit valid comparisons to the systems in Cleveland (Shaker Heights), Newark, and San Francisco, whose services were operated almost without change during the 20-year period.

Compared with the 64 percent decline in surface transit generally, these unchanged light rail systems lost only 10 percent of their riders; most of this loss was experienced when the Newark operation was shut down temporarily and when subway construction began to inhibit operation in San Francisco. Light rail in these three cities clearly had an attraction for riders superior to that of other surface transit systems. This attraction justifies light rail's existence, but there also must be economic justification such as that demonstrated by Boston's Transit Authority. In 1959, it opened a major new long line to Newton and Riverside, which immediately demonstrated a 900 percent increase in transit use. Previous service in the corridor was provided by a desultory commuter train and parallel feeder bus service to other, shorter LRT lines.

WHY?

Why does light rail transit service have such a superior attraction for riders?

First, the systems discussed had the following elements in common:

- High acceleration electric propulsion,
- Higher than average transit speed,
- Larger vehicles than motor buses,
- Exclusive transit lanes over part of the route,
- Protection from the weather,
- Train signals on exclusive right-of-way,
- Outlying parking for passengers (except San Francisco),
- Bus transfer privileges (except Cleveland),
- Overhead trolley power supply,
- Petroleum conservation and no on-line emissions, and
- Absence of air conditioning.

Second, these light rail systems were proved efficient. Passenger-mile data in Cleveland and Newark provide the following specifics: each light rail line needed only 2.1 or 2.2 employees per vehicle to support the total operation, including power systems and routine track maintenance; each passenger car produced 1900 passenger miles (3060 passenger kilometers) per weekday for a total employee productivity rate of 900 passenger miles (1450 passenger kilometers) per employee.

Comparable figures for a typical city bus is 550 passenger miles (887 passenger kilometers) for express service and 530 passenger miles (855 passenger kilometers) in general service.[2]

Express service usually has a low midday use rate, but it outperforms local service at peak hours. The light rail efficiency as demonstrated above affects either fares, or operating assistance required, or both.

A third, but less objective, reason for passenger preference for LRT is found in the following amenities:

- No on-board engine noise or smell,
- No air pollution along the route,
- No unexpected swerving or sudden stops,
- More interior space per passenger,
- Passengers can read while commuting,
- Fixed and self-proclaiming route,
- Smooth ride (assuming proper track maintenance),
- Double doors to speed loading and unloading,
- Multi-car operation possible to handle large volumes,
- Different from routine transit travel, and
- Urban development adjacent to fixed right-of-way.

A fourth, and crucial, reason is the avoidance of the higher capital costs of rail rapid transit and the higher operating costs per passenger of low-capital alternative modes.

There are also problems with light rail transit but, although real and sometimes vexing, their effect is small and more than outweighed by the advantages. One problem is that transit management often perceives light rail as a system that requires more attention than a bus operation. Some other problems include the following:

- Lack of flexibility;
- Dependence on a single power source;
- Nonstandard transit operation;

- Difficult spare parts supply; and
- Objections of motorists, police, and traffic engineers more interested in moving vehicles than people.

HOW?

There are five ways to implement light rail operation; these methods can be combined for use on different segments of the same line, thus giving light rail greater flexibility than other transit modes. The methods are:

- Using a long, exclusive right-of-way from suburbia to the central business district (CBD) (Riverside MBTA, Shaker Heights, San Diego);
- Creating a short, densely used exclusive right-of-way in the CBD or other major traffic center (Buffalo, Newark, Woodland Avenue in Philadelphia, Edmonton, Pittsburgh);
- Routing to avoid constricting traffic congestion (Calgary, New Orleans, Red Arrow SEPTA, Skokie Swift);
- Allowing priority street space for high-volume lines (Buffalo, Calgary, Canal Street in New Orleans, San Diego, Toronto); and
- Providing fast feeders to a heavier rail mode (Mattapan MBTA, Red Arrow SEPTA, Skokie Swift).

All these methods use the light rail technology of standard or trolley gauge street trackage, direct low voltage electric power supply from overhead wires (to permit street interface and pedestrian safety), 220 to 400 horsepower (165 to 300 kw) vehicles, manual control with block signal override when appropriate, and easy, direct passenger access from the right-of-way. The light rail vehicle is truly flexible; it is capable of aerial, underground, exclusive, or railroad right-of-way, as well as mixed street traffic operation, without design change or changeover delay. A single, one-way trip can include a subway operation in the central business district, a mixed traffic street operation enroute, and a private right-of-way operation at the outlying end of the route. This ability to use whatever right-of-way is available is the prime factor in making light rail a less capital-intensive rail transit alternative, although a light rail subway system may be no less expensive than a similar heavy rail rapid transit undertaking.

A VOLUME MARKET

Light rail transit cannot be economical to low-volume markets. The fixed cost of its unique infrastructure requires volume travel to amortize the investment over many trips, but there is no specific break-even point because of the wide investment range for different light rail applications. The longer and faster a line becomes, the lower the traffic volume needed to assure its economic viability. In San Diego, a peak volume of 1200 passengers, one way per maximum hour, is economical because of steady all day use and a low capital investment. Only 11 articulated rail units are required to operate the service schedule. The bus route that previously provided the service—#32 to San Ysidro—would have needed 23 buses to carry the same peak volume. The economy of light rail service is exceeded only by its attractiveness.

Even at midday, the San Diego-San Ysidro bus service required 10 articulated buses with standees, but 10 light rail vehicles will carry more passengers with plenty of seats, inducing still more ridership. The economics are clear: the same speed that attracts more riders and augments revenue will simultaneously cut costs significantly.

Shorter lines with less speed opportunity need more volume to justify investment in LRT. Toronto has the continent's most successful transit system; streetcars preempt the center street lanes and speed movement nearly 10 percent faster than do curb-loading buses. In this case, the economy of light rail comes primarily from vehicle size and efficiency, with speed a secondary factor. With a 3-minute peak headway (for example) on a 90-minute round trip cycle, 30 rail cars (unarticulated) are required to meet the schedule and move 28 passengers per minute past the maximum load point. These 30 vehicles, with 15 percent spares, require 108 employees, including maintenance people and management.[3]

To serve the same route by bus, a 2.25-minute headway will be required to move 28 passengers per minute, and the round trip cycle will approach 99 minutes as buses are delayed detouring into the curb, then seeking street space to pull back into traffic. This will require 44 buses, plus 15 percent spares, and 128 employees, including maintenance and management, with an 18 percent higher cost level than for light rail operation for the same volume of travel.[4] Labor costs are approximately 75 percent of all transit expense.

As travel volumes decline, it is not possible to reduce light rail infrastructure employees in proportion. At some point of lower volume, bus operation will become more economical than light rail, but superior passenger attraction will still give light rail some advantage at the break-even point. The economic advantage of light rail disappears when the peak headways fall below 6 minutes. However, if tracks are in good condition and relatively maintenance free, light rail will maintain its superiority until major repairs are required.

In such situations as in San Diego or Calgary, where street operation is combined with exclusive suburban right-of-way, no flat rule can be applied. Each specific situation must be analyzed on its own merit.

Light rail transit should not be specified for peak-hour volumes one way for more than 16 000 passengers per hour. Heavy rail rapid transit or commuter railroad service with larger vehicles and longer trains on exclusive rights-of-way are required. To move 16 000 passengers per hour with 1985 amenities would require 131 articulated light rail cars. Even with 3-car trains, a 1.3-minute headway would be required, and such speeds would fall to very low levels with trains on such close headways; congestion would negate any perceived light rail advantages. With 4-car trains on a 1.8-minute headway and no branch lines to skew loading near the maximum load point, LRT could handle 16 000 peak passengers per hour, but heavy rail would do it much better and more economically. (In 1957, Philadelphia operated a 27-second light rail headway in the subway by means of multiple berthing at stations with single cars, but speeds in the subway fell to 12 miles (19.5 km) per hour, further slowed by frequent delays.)

Where trade-offs become necessary, as with high volumes in center city but dispersed low volumes in the suburbs, it may be necessary to utilize heavy rail rapid transit on the trunk line with light rail on the branches (Red Arrow, Mattapan, Skokie Swift).

RIGHTS-OF-WAY

Light rail service can efficiently utilize six kinds of right-of-way, depending on cost, availability, and condition. Circumstances will dictate which type, or what combination, should be applied to a given corridor or route. The six kinds are the following:

- Center street operation, with as much transit priority as feasible;
- Park strip, median, or boulevard right-of-way (similar to above but exclusive and with crossing safety features);
- Joint use of light density railroad trackage;
- Power line or abandoned railroad rights-of-way;
- Aerial structures at highway crossings, with private right-of-way between crossings; and
- Subway, or below grade, right-of-way.

In general, the easier a right-of-way is to obtain, the less satisfactory it may be. Center street operation in central business districts brings speed down below 10 miles (16 km) per hour but should not be dismissed for this reason alone. In many central business districts, bus speeds fall to 5 or 6 miles (8 to 10 km) per hour or lower during peak periods. Light rail may be able to provide a 50 percent improvement in speed if conditions are favorable, even if that speed is only 8 or 9 miles (13 to 14 km) per hour. The only real advantages of street operation are that passengers are delivered conveniently and the right-of-way is available, but these can be major advantages, as they are in Toronto. New investment required for such rights-of-way may approach $1 500 000 per double track mile ($930 000 per km), including power supply and vehicles, assuming minimum utility relocations underground. San Diego and Calgary offer recent examples of this type of right-of-way.

Park strip, median, or boulevard operations, as in Shaker Heights, New Orleans, and elsewhere, are highly advantageous except for one major factor—crossing safety. Intersection hazards can be extreme. Low crossing volumes with adjacent rail stops for passengers, bans on left turns, or sophisticated signalling devices will be necessary to permit this type of operation where crossings are not grade separated. New Orleans copes with slow speed cars and frequent stops. Shaker Heights has a wide median, station locations at crossings, signals, and patience. Toronto's Queensway is a high type example of median operation with few crossings. New investment for this type of right-of-way will approach $1 250 000 per mile, excluding rolling stock and power supply ($775 000 per km).

Joint use of light-density railroad track will not cost less than new construction on a median strip, because signals and switch locks will be required. The track may need extensive rehabilitation. However, the results can be highly advantageous if the right-of-way is in a good location.

Joint operation should avoid mixing freight trains with LRT trains during such periods of frequent operation as 6 a.m. to 10 a.m., 2:30 p.m. to 6:30 p.m., or midday if frequent midday service is scheduled. Employees must be highly trained and skilled in switching operations and signaling functions not normally encountered on homogenous transit operations. San Diego is an excellent example of joint use, and, in past years, the Chicago Transit Authority, the Illinois Terminal Railroad, the New York City Transit Authority, and Pennsylvania-Reading Seashore Lines successfully operated joint light rail and freight service on common trackage.

Power line and abandoned railroad rights-of-way can be economical locations for light rail alignments if they are in areas of potential passenger traffic. Power lines and electric rail lines share common rights-of-way successfully in many places. The primary consideration is available patronage rather than physical feasibility. Construction cost for light rail on these rights-of-way will average $1 500 000 per double-track mile ($930 000 per km), excluding rolling stock and substations. On ungraded power line rights-of-way, this cost may increase 33 percent or more if grading is necessary. If grade crossings are separated, the new investment will increase dramatically, depending upon the terrain.

Light rail aerial structures have aesthetic and cost disadvantages when compared to ground level rights-of-way, but aerial structures can potentially offer the best passenger service, without the grade crossings and underground stations disliked by some of the public. The cost should be less than half that for underground alignment, or roughly $30 million per mile ($18.5 million per km).[5] Costs can be substantially reduced if short sections of single track for two-way operation are used, as in Pittsburgh and San Diego. Extreme care must be exercised to avoid service delays when single track is used. It is not feasible on close or irregular headways, although Pittsburgh has maintained a busy operation in spite of this handicap.

The aesthetic problem of overhead power wires on aerial structures can be relieved by locating the supporting poles between the two tracks with bracket arms, rather than at the sides of the structure with span wires. This reduces their visibility from the ground. Light rail operations can usually tolerate 6 percent grades with little difficulty, particularly when ascending to station stops and descending to accelerate. Such grades can bring the track down from an aerial structure to sight level (4 feet above the ground) in 300 feet, so city blocks over 600 feet long need not have the visual intrusion of aerial structures in midblock. Such grades are also energy savers. But if railroad freight is present, the heavier, less powered movements require gentler gradients.

Subways, or below-grade alignments, are ideal from a city planner's viewpoint but are otherwise undesirable. In addition to high cost, passenger dislike of underground passages mitigates against such construction unless it is unavoidable. Well-designed subways, integrated with adjacent commercial development, can transform a subway's disadvantage to a great advantage, as in Edmonton or San Francisco, but Edmonton kept the subway very short. In Pittsburgh, an existing railroad subway is to be converted to light rail use, retaining a single-track section to avoid costly new construction, but this single track can accommodate only one-third of the movements. A short, strategic new double-track subway is required for trips to another portion of the downtown area, where it will be closely integrated into new office buildings now under construction.

TRANSIT SYSTEM INTEGRATION

A high-density, urban area light rail system must have free or nominally priced interchange (transfers) with other rail and bus lines serving the local area. As many as two-thirds of all high-density riders transfer at points where highest ridership is obtained.[6] Transfers are an essential element of high ridership, not because they are popular, but because individual bus routes cannot connect enough origin and destination points. With universal transfers, many economies can be effected in route structure on bus lines parallel to light rail transit where the LRT service is superior, i.e., faster and/or more economical. Such transfers would not be convenient between slow, long headway bus lines.

Long, fast, suburban light rail lines have less need for transfer privileges if they serve the central business district adequately, as in Cleveland and Pittsburgh. The Cleveland to Shaker Heights light rail line had its highest passenger volume (20 000 per weekday) 30 years ago when it had no transfer privileges. Feeder buses in low-density suburban areas often have only a few captive or necessity riders. Automobile owners usually prefer to drive or be driven to the car stop. This does not eliminate the desirability of transfers, but it does suggest the possibility of a successful suburban light rail operation if two independent operating agencies cannot agree on transfer arrangements.

OPERATIONAL ASPECTS

To be justified, light rail must be the fastest, or the most efficient, alternative for specific patrons. A speed of only 8 or 9 miles per hour can be justified in heavy central business district traffic if most other transit speeds are even slower. LRT schedule speeds of 15 miles (24 km) per hour are possible on exclusive rights-of-way with closely spaced stations and grade crossings, and increase to 20 miles (32 km) per hour as stations are spaced a third-of-a-mile or more apart. In Edmonton, Calgary, and San Diego light rail lines reach schedule speeds of 30 miles (48 km) per hour where stations are 1 mile apart but require formal stops; this is possible only in tolerant areas. An average speed of 40 miles (64 km) per hour is technically possible on very long lines with few stations averaging 2 or more miles (3 km) apart. A 12-mile (19-km) suburban trip would be possible in 18 minutes with this type of operation, as light rail has been successfully operated in regular service at speeds up to and exceeding 70 miles (112 km) per hour.[7] Certain recently abandoned railroad lines could provide the opportunity for such operation.

Speed may be less important, however, in terms of miles of line than it is in terms of minutes per passenger. It is good practice to delay a lightly loaded vehicle by stopping to pick up more passengers who are at points not convenient to widely spaced stops, as long as the majority of riders benefit.

Express and local light rail trains can enhance both speed and economy. Normally, cars or trains cannot pass each other unless costly, additional right-of-way and trackage is provided, but it is possible to alter a 4-minute headway to operate on staggered 6- and 2-minute headways. Only 4 minutes can be saved by the express, but, psychologically, it is worth 8 minutes and, economically, it permits segregation of loads; locals can be turned short of end of the line, with considerable savings and increased revenue.

COSTS

The construction cost of light rail line, including rolling stock and substations, can vary from $6 million per mile in optimum circumstances, to $90 million per mile ($3.5 million to $55 million per km) in the most difficult subway situations. There is no abstract economy for light rail in subways, where heavy rail will usually be more efficient and economical. The only justification for a light rail subway would be for completion of an otherwise less capital-intensive project with no feasible alternative for reaching the central business district. Edmonton is an excellent example of this situation.

Because of wide and varied investment requirements, each light rail project must be studied separately with emphasis given to avoiding subway construction wherever possible. In congested central business districts, however, there may be no satisfactory alternative.

The capital investment in light rail cannot be meaningfully compared with the cost of a fleet of buses or with an exclusive bus road that fails to penetrate the central business district. Total traffic capacity and speed of movement must be considered. For example, a light rail line that costs $250 million and serves 40 000 weekday riders comfortably will provide peak-hour capacity equivalent to 32 lanes of arterial street or 8 lanes of freeway. Less statistically and more realistically, half of a new light rail line's patronage may be former local transit riders enjoying the improved service and half may be former automobile commuters; therefore, the light rail line will have abolished the need for 16 more arterial lanes or 4 more lanes of freeway in costly, congested areas. Nearly 8000 fewer costly downtown parking spaces will be required. In many cases, providing equivalent highway and parking facilities costs far more than the light rail system without providing its economy or civic benefits.

While costs vary widely in specific situations, a conservative assumption is that a new highway lane, in a high value area, cannot be built for less than $10 million. Four such lanes, extending over 4 miles, would thus cost $160 million; parking space needed to accommodate the highway users, another $40 million; highway vehicles that can be replaced by light rail, $40 million on short amortization schedules. Thus, light rail could easily be the low cost alternative for the needed capacity, even without considering such increases in community values as are now taking place in Pittsburgh in the light rail construction area.

Light rail operating costs are more consistent and amenable to analysis than construction costs. With reduced federal funding for urban transit, operating costs will become more important in decisionmaking. Single-unit light rail cars on high-volume lines require 3.1 employees per vehicle to maintain, operate, power, and manage them if frequent midday service is maintained. As off-peak service becomes less a factor in an operation, the employee per vehicle ratio will drop toward the 2.1 ratio once achieved in Shaker Heights.

In 1982, each employee's compensation will average $27 000 per year, including fringe benefits. Materials, supplies, rent, and insurance will add 50 percent to this employee cost, raising the total annual cost of light rail vehicle operation to $125 500 per single-unit vehicle ($27 000 x 1.5 x 3.1), or $42 per vehicle hour. Although it is 15 percent higher than the cost of bus service per unit, it is considerably lower in terms of cost per passenger mile. Because of its larger size and higher speed, the productivity of a light rail car, applied in its proper sphere of operation, should exceed bus productivity by 30 to 50 percent.

Each articulated car under similar circumstances will require 4.5 employees at a total cost per unit of $182 250 per year ($27 000 x 150 percent x 4.5). The saving in operators' platform wages is partially offset by the added maintenance required by the articulated unit, a slightly lower speed because of higher passenger loads, and fewer units over which to distribute the right-of-way costs. The 1982 per hour cost for articulated units will be approximately $60.75, 3 percent less per passenger at peak hours than for single-unit cars, but bus costs increase during light traffic hours when too many empty seats prohibit reasonably frequent service. With appropriate volume, LRT operating costs per passenger mile will average 30 to 50 percent below those of articulated buses.

REVENUE-COST RATIOS

Single-unit LRT vehicles can produce 1900 passenger miles (3000 psgr km) per weekday at a 1982 cost of $420 ($42 per hour x 20 hours), which equals 22.2 cents per passenger mile (13 cents per km). With base fares of 50 cents for short rides, plus 12 cents per mile for longer rides through fare zones, fares will average 16 cents per passenger mile (10 cents per psgr km), resulting in 72 percent of cost covered by passenger revenue and another 1 percent by concession income. This is well above the current transit industry average of under 50 percent. Where there is relatively high midday ridership, as in Calgary or in San Diego, full coverage of costs from fares is possible. Tighter scheduling can also boost the revenue ratio and reduce the amount of taxpayer assistance needed. An LRT vehicle operating 10 hours per weekday can approximate 75 passengers per hour, 100 per peak hour (not all on-board simultaneously), and 50 base. The resulting 750 average weekday passengers per vehicle averaging 4 miles (6.5 km) each, as in Pittsburgh, will generate 3000 weekday passenger miles (4800 psgr km) per vehicle. At this optimum but achievable rate, costs will drop to 14 cents per passenger mile (8.5 cents per psgr km). The revenue-cost ratio will rise to 114 percent and abolish the need for any operating subsidy. Not all operations can achieve this goal, but in fairness to riders and taxpayers, all must try.

To cities considering light rail transit, where current transit operations cover only 35 to 45 percent of the cost from revenues, the economic possibilities of LRT should be attractive, even if the optimum cannot be obtained.

COMPARING LIGHT RAIL SYSTEMS

Light rail experiences in the United States and Canada include a variety of types and operations. They have been analyzed in order to provide relevant comparisons. Because accounting practices differ, the avoidable operating costs shown below are estimated from the data in this paper to improve comparability. Some operations may not keep records by vehicle type; some are too new to have compiled a full year's results; and some allocate system fixed costs in a manner unrelated to actual light rail costs. The data used here are believed to be sufficiently accurate for comparison purposes. Capital costs for rehabilitation programs are excluded; only operating costs are included.

Light Rail Systems Data (Estimated)

The variation in light rail operations makes both analysis and comparison not only difficult but risky. Schedule speeds vary from 8 miles per hour (13 km) in Philadelphia to 38 mph (61 km) on Skokie Swift, yet both are successful in their own different ways. A typical new line averages 24 mph (38 km) per hour. Passenger mile per car mile (or km) productivity ranges from 45 in Chicago and San Diego to 15 in Philadelphia, but in all cases exceeds the urban motor bus average of 13.[2]

The passenger miles per car year productivity ranges from 2 250 000 (3 600 000 km) in San Diego with its articulated cars to 393 000 (628 800 km) in Philadelphia with its single cars on slow congested routes.

The revenue/cost ratio does not meaningfully measure efficiency because different communities have different fare policies, not subject to management or technical control. For example, the electorates in certain cities have voted funds to hold fares at noncompensatory levels as a public service. The cost per passenger mile (km) is the only meaningful unit of comparison, and it declines in inverse proportion to distance traveled. Long (intercity) trips cost approximately 10 cents per passenger mile (6 cents per km) but have an initial service and/or boarding cost of at least 15 cents for zero distance, bringing the cost of a 1-mile ride to 25 cents, or 35 cents for 2 miles (21 cents for 1 km and 27 cents for 2 km). Few transit systems achieve these optimum rates, partly because of traffic delays and peaking problems not frequently found in intercity travel.

Boston

The Massachusetts Bay Transportation Authority operates 4 radial LRT routes that disperse from the central subway (the nation's oldest) and an aerial viaduct that extends the subway a short distance in the opposite direction to a feeder bus interchange terminal (Lechemere). The 12-mile suburban Riverside line, converted from a commuter railroad line in 1958, has the best suburban penetration in the system. The Commonwealth Avenue line to Boston College has equally heavy use, is considerably shorter, and operates primarily on the median of the highway. The Beacon Street line lies between the Riverside and Commonwealth lines but is shorter than either, and performs more accessible, median area, local service to relieve the longer Riverside line of short-haul travel. It is a train type operation and uses both PCC cars and new LRT articulated vehicles. The Arborway line is primarily a street operation outside the subway, parallel to the Forest Hills elevated rapid transit line. A high-speed LRT shuttle is also operated from Mattapan to Ashmont—only 2 miles—where it connects with the red rapid transit line. It runs entirely on private right-of-way and attracts ridership requiring a 2-minute peak headway. A sixth LRT line, which runs over city streets to Watertown, is not currently in passenger operation because of rolling stock problems.

In Boston, LRT carries heavier loads than heavy rapid transit lines, but this practice is not recommended.

Calgary

The Calgary Transit System opened its first LRT route in May 1981 with extremely heavy patronage. As in San Diego and on Buffalo's proposed line, it travels on preferential street lanes downtown, then tunnels briefly to reach a reserved strip of Canadian Pacific Railway right-of-way in order to serve the southern portion of the city. It places heavy emphasis on feeder buses and wide station spacing. A 5- and 10-minute peak and base headway is operated with 2-car articulated trains.

Cleveland

Until the recent delivery of large new Breda articulated cars, the Shaker Heights Rapid Transit utilized a mixture of multiple- and single-unit PCC cars. Two 10-mile lines with 6 miles of common trackage radiate east from Cleveland's Terminal Tower. First they travel through abandoned railroad yards, then down the medians of suburban boulevards—one with residential character and one with high density development. Service is fast, and no street operation is in mixed traffic. Peak headways are frequent, with 15-minute base headways on the denser Van Aken line and 30 minutes on the residential Shaker Boulevard line. Sunday service is hourly. The Shaker Heights operation is perhaps the most aesthetically attractive anywhere. Before its amalgamation with Cleveland Transit in 1975, the Shaker Heights Rapid Transit had no transfer arrangements, but now, as part of the Greater Cleveland Regional Transit Authority, it has universal transfers.

Before 1930, the line entered downtown Cleveland over city streets and had good but slow distribution. With the move to faster, off-street service to the single Terminal station on Public Square, some patronage was lost because distribution was not as good. Following World War II, voters approved construction of a subway to improve the distribution, but the county highway engineer in charge of the project refused to build it.

For 5 miles, the Shaker Heights LRT shares its tracks with the heavy rail trains of the former Cleveland Transit System, reconfirming LRT's operating flexibility.

Chicago

The Skokie Swift of Chicago's Transit Authority is classified here as light rail because it uses vehicles upgraded from PCC streetcars, operates at grade-over-grade crossings, and obtains power from overhead trolley wires. It runs on the right-of-way of a former interurban electric railway and operates as a rapid transit feeder line shuttling passengers between Skokie and the Howard Street Rapid Transit Terminal. Some articulated cars are used. The service originated from a federal demonstration grant. Multi-car trains are not employed. No intermediate stops are made.

Edmonton

The Edmonton Transit System built a short downtown subway to provide central business district access for the light rail line, built along the Canadian National Railway right-of-way to serve the northeast corner of the rapidly growing oil city. Recently extended, only 3 years after its opening, the line depends largely on feeder buses for outlying access. Stations are a mile apart and have high-level platforms. Two-car articulated trains operate on 5-minute peak headways and 10-minute midday headways. Subway extensions to the west are under construction, and a more extensive system is planned. Grade crossing protection systems are synchronized with the rail block signal system to prevent trains from interrupting highway traffic.

Fort Worth

The Tandy Corporation operates the former M&O Subway as a public convenience for its commercial center and adjacent department store. It is totally a park-and-ride operation that uses extensively rebuilt PCC cars on a 1-mile line. It has attracted more riders than any other transit route in Fort Worth. The half-mile subway portion of the line was built with private funds for approximately $1.5 million nearly 20 years ago.

Newark

Transport of New Jersey operates the city-owned subway from the central business district to the northwest city limits, with 3 miles of parkside trackage and 1.5 miles of subway (5 km and 2.5 km). The right-of-way was obtained from an abandoned canal. The subway portion was overbuilt with an arterial highway. Bus transfers from competing, not feeder, routes supply much of the peak-hour traffic, for which a 2-minute headway is provided with large PCC cars. A reduced, reverse direction downtown fare is offered. Off-peak bus riders do not save enough time to induce them to transfer to the subway, but a 6-minute headway is offered walk-in riders. As transit riding declined generally, the Newark subway has become the most heavily traveled transit route in the state, measured at the maximum load point.

New Orleans

New Orleans Public Service operates the St. Charles streetcar line primarily on reserved median space, with grass between the rails. Grade crossings are frequent, and several blocks of street operation are used downtown. When a similar route was converted to bus 15 years ago, the peak-hour congestion caused by smaller vehicles, with fewer doors, on closer headways, slowed movement to 3 or 4 miles per hour (5 or 6.5 km) in the central business district, despite exclusive bus lanes. Residents and riders prefer keeping the grassy rail right-of-way to having the street widened for heavier vehicular traffic. The rail line has become a historic monument and still operates cars built in 1926.

Philadelphia

The Southeastern Pennsylvania Transportation Authority (SEPTA) operates three types of light rail service. The agency was created, in part, for this purpose. Five busy lines serve the central business district in a common 2.5-mile (4 km) subway, similar in principle to Boston's but without multiple-unit capability. With a 1-mile exception, street operation prevails outside the subway. At one time, a 27-second headway was operated with multiple berthing at stations, but population declines have lengthened these headway intervals.

Seven other lines operate throughout the city on longer but lower volume routes that run entirely on city streets. The longest route, 13 miles each way, traverses hills where residents object to the throbbing of buses' overworked diesel engines. Much of the trackage on this line was recently rebuilt. PCC cars are also being extensively overhauled. New cars have been purchased for the subway lines. One of the 7 surface lines is a rapid transit subway feeder, and all surface lines connect with the major subway. Exclusive lanes are provided where possible. In certain respects, these 7 lines resemble the Toronto light rail operation.

SEPTA's fastest light rail lines are in the suburbs where operations are similar to the Ashmont-Mattapan LRT service feeding rapid transit. One such line extends 6 miles to Sharon Hill and the other 8 miles to Media (9.5 and 13 km), with 2 miles (3 km) of common trackage. Combined headways reach 2.5 minutes at peak hours, with a 10-minute base midday. The largely exclusive right-of-way permits higher speed operation—faster than auto travel over certain segments. Several years ago, experiments were conducted with buses equipped with rail guide wheels, but the tests were unsuccessful. New cars have now been purchased from Kawasaki for 60-mph (96-km/hr) operation and double-end controls. Some two-way operation on single track is involved on the outer ends of the lines, as is some street trackage. Known as the Red Arrow Lines, its suburban ridership has continued over the years as automobiles and suburban shopping centers have decimated transit ridership in other areas.

Pittsburgh

The Port Authority of Allegheny County operates 4 light rail lines from downtown Pittsburgh to Drake Road Route #36, Library Route #35, Mount Lebanon and Castle Shannon Route #42/38, and Arlington Avenue Route #49. Except #49, all routes operate through the Mount Washington transit tunnel with much exclusive right-of-way beyond the city. Route #49 is a short, partially single-track tunnel bypass, with a cliffside view of the rivers and the city. Like San Diego and Calgary, the Drake and Library lines (11 and 13 miles, or 17 and 21 km) operate exclusively on private rights-of-way outside the Golden Triangle (downtown). The heaviest trunk line, #35 and #36 together, operates on a 2-minute peak headway with single-unit PCC cars, but the operation is constrained by several sections of single track. This may be the busiest section of single track anywhere. Congestion and, occasionally, tieups occur at peak hours. The topography has deterred double tracking. Only intolerable highway congestion induces the 2-car families served by these lines to patronize them. Ironically, these lines have some of the few paid park-and-ride lots in the nation. Pittsburgh's light rail lines generate nearly half of all park-and-ride activity in the Pittsburgh metropolitan area, although they serve only 5 percent of the transit vehicle miles.[8]

Elected officials recognize these severe handicaps to efficient system operation. Construction has started on major improvements to remedy these intolerable conditions and modernize the system. A redundant railroad bridge over the Monongahela River and its connecting subway under the east edge of the Golden Triangle have been acquired for conversion to light rail use. A short, strategic subway will be constructed under Sixth Avenue to serve the department stores and Gateway Center, at the point of the triangle. This will convert Pittsburgh to an elongated, Edmonton-type operation. The bucolic Mount Lebanon to Castle Shannon extension of Route #42/38 will be upgraded and double tracked to connect with an extension from the Drake line to South Hills Village Regional Shopping Center, where a new car shop will be located. Reverse flow diversions will become possible to relieve some of the congestion on the single track used by Routes #35 and 36.

At present, 1-minute peak-hour headways are operated on the joint portion of the system across the Monongahela River into downtown Pittsburgh. Street congestion in the city, however, is a severe restraint.

In spite of its debilities, the Pittsburgh system has survived in the highway age because of passenger volume. Throughout Pittsburgh and the nation, transit ridership has dropped 64 percent or more since the end of World War II except on Pittsburgh's light rail routes. Ridership is still at 1945 gasoline-rationed levels during peak hours, but off-peak use has experienced some of the decline common to transit everywhere. After the war, the light rail lines attracted suburban development, which built peak-hour patronage, congested highways, and thus sustained patronage as midday travel to the city was diverted to suburban shopping centers.

Currently, with modernization of the LRT system, downtown Pittsburgh is undergoing its greatest building boom. Almost all open parking lots are being converted to office buildings, with total value exceeding $1 billion. A new trade and convention center has recently been completed near the downtown terminal of the light rail system.

San Diego

The San Diego Trolley, Inc., operates a 16-mile line over a lightly used railroad bed from the edge of downtown San Diego to the Mexican border at San Ysidro. Downtown, 1.7 miles of new double track was constructed via Twelfth and C streets to deliver passengers to within 1 block of the length of Broadway. The railroad portion of the line serves the edges of National City, Chula Vista, and Imperial Beach; local feeder buses connect to the residential areas. Park-and-ride space is also provided. Service began in July 1981.

San Diego's busiest bus route, #32, which served this same corridor, was cut back to serve as a feeder and for local, neighborhood travel. The bus route required a 2.5-hour cycle. The LRT will reduce this to 1.25 hours, a 50 percent saving in time, equal to 35 minutes each way. Many passengers must transfer, which reduces the time saved for some, but the net benefit is still great. Five trains with 5 operators can provide twice as much capacity as 10 bus drivers with articulated buses.

San Francisco

The San Francisco Municipal Railway operates 5 light rail lines under Market Street; this is similar to the pattern in Philadelphia, except that articulated cars are employed in train operation. Two old trolley tunnels under Twin Peaks are utilized to extend the exclusive right-of-way to heavily developed residential areas. End-to-end, 2 of the 5 lines duplicate BART (Bay Area Rapid Transit), but there is no competition. BART is much faster over a shorter route. Light rail serves the intermediate territory with frequent-stop service, and on a different alignment. The trunk subway is served by 2-minute headways with 2-car trains. The 5 branches have 1- and 2-car trains on less frequent headways. Ridership increased markedly as lines were diverted to the new subway. Additional LRT vehicles are being purchased to accommodate the patronage, which may reach 50 percent more than that of surface operation. Subway service was inaugurated in 1980 on a partial basis; full service was inaugurated in 1981.

Toronto

Unlike any other light rail operation, Toronto Transit Commission depends for its success on street operation, using fast, well-maintained PCC cars. New Canadian light rail vehicles (CLRV) are now replacing 200 of the older PCC cars. Others were replaced several years ago by the new subway on Bloor and Danforth. Toronto is unique for having built patronage over the years while most other systems were losing it. Light rail has been a part of Toronto's success, preempting the best part of the street for transit. There is no legislated preemption. The presence of the rail cars on frequent headways discourages other vehicles from using the same space.

The subways, however, have become the mainstay of transit in Toronto. Efforts to phase out light rail a decade ago were met with such stong public opposition that new vehicles were ordered instead, and track was upgraded. It appears that where transit service is good, the public will support it. Toronto recovers over 60 percent of its operating cost from the fare box—one of the best ratios on the continent.

CONCLUSION

The energy supply is dwindling. The cost of petroleum is certain to rise further. Transportation is energy-dependent; it is also costly. It has resulted in severe and undesirable congestion and air pollution. It has decimated large areas of our cities. Better solutions to urban transportation problems are needed. New technology is, by definition, not the answer, although it may be of limited assistance where applicable.

There is no ideal solution, but for urban public transport, light rail transit, in its proper place, has emerged as a superior performer—holding on to former, higher ridership levels, developing new ridership, sustaining revenue, and cutting the cost per passenger, if not the cost per vehicle. Light rail cannot be used indiscriminately; it has unique advantages for unique situations. Many cities are using it, and many more can use it to improve urban conditions. For relatively fast, efficient, overall service, a subway operation downtown and a suburban, exclusive right-of-way with controlled grade crossings are the best choices, as in Edmonton, Newark, Shaker Heights, or on Boston's Highland Branch. Light rail is not recommended for very high-volume operation. Rapid transit trains on totally separate rights-of-way are required for capacity and efficiency. Light rail cannot be expected to carry over 16 000 passengers at peak hours. Light rail services's value is below rapid transit levels, where buses have inadequate capacity, speed, attraction, or efficiency.

The sheer cost of downtown subways often precludes the ideal light rail configuration. A good, practical, alternative is the Calgary or San Diego pattern, where a downtown street is preempted for transit and exclusive right-of-way provided for transit outside downtown. New Orleans' pattern is similar but has too many grade crossings. Low volumes of movement, relative to subways, can be served economically and effectively by use of this pattern.

A third pattern of light rail operation involves a downtown subway, as in the first pattern described above, and surface street operation in outlying areas, where exclusive rights-of-way are not obtainable. Five Philadelphia lines, San Francisco lines, and certain Boston lines employ this pattern. It is obviously successful, but less desirable than exclusive right-of-way where available.

A fourth pattern of light rail operation is that demonstrated by Skokie Swift, the Ashmont-Mattapan line in Boston, and the Red Arrow lines west of Philadelphia, where light rail has exclusive right-of-way for use in shuttling passengers to a high-capacity, full-scale rapid transit line. The public may not appreciate the advantage, as this pattern requires a transfer. But the speed of service compared to buses, and the economy of operation compared to heavy rail for light volume, are such major advantages that it is the only feasible way to provide good service. It is extremely wasteful of both money and energy to operate long, heavy rail rapid transit lines deep into the suburbs because of the dwindling occupancy as the trains move further from the city. With express tracks and very high volumes, this disadvantage can be overcome, but for most applications, the light rail feeder is best.

The fifth and last common light rail pattern is the street railway, as employed in Toronto and on several Philadelphia lines. Although traffic engineers seldom see advantages in on-street operations, there are several, and speed is not one of them. Direct access to traffic generators is a prime advantage; preemption of the traffic stream by transit is another. Vehicles are not dependent upon petroleum; total street capacity is increased. However, the prime advantage is the efficient and economical handling of volume. For 2000 passengers per peak hour one-way, 30 buses would be required to serve the maximum load point during the hour; a better job can be done on a trunk line with just 23 light rail cars, reducing costly platform time by 23 percent. Such an operation 10 miles long (5 miles each side of downtown) would cost $7 million per year to operate with buses, with 50-cent fares covering 86 percent of the cost. Using light rail, the cost would be only $6 million, with no subsidy needed. (This is an ideal condition, assuming no half fares for senior citizens and no transfers at reduced revenue, but the point is still valid.)

As energy supplies dwindle and prices escalate; as federal aid is reduced; as cities redevelop; and as inflation pressures on transit management, taxpayers, and riders increase, it is mandatory to find better and more effective ways to move people in centers. Light rail cannot do all or even most of the work, but it does offer such great value for specific situations that its intrinsic merit should force a wide application to urban transit in the years ahead.

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Factors Influencing Light Rail Transit Feasibility

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As part of its regional transportation plan update for the post-1990 period, the Puget Sound Council of Governments (PSCOG) commissioned a study to assess the feasibility of a light rail transit system. The study found there would be sufficient demand to warrant some form of light rail for the Central Puget Sound Region of Washington by the year 2000. The feasibility study weighed the advantages and abilities of LRT and an all-bus transit system to meet future demand and found the cost of LRT, in the highest demand corridors, would be comparable to that of an all-bus system of the same capacity. LRT operating costs might be lower, and it would use less energy. LRT is a particularly attractive solution to Seattle central business district transit problems and has a potential for cost savings that could offset higher construction costs on other segments. The study identified two high-capacity regional corridors connecting with the CBD as the most feasible and cost-effective for LRT. PSCOG is working with the City of Seattle, Metro Transit, and the Downtown Seattle Development Association (private sector) to develop the scope and process and to obtain funding for further study.

The Puget Sound Council of Governments has recently completed an update of its regional transportation plan to the year 2000. A key recommendation is to consider light rail transit as an alternative transit mode in selected regional corridors in the post-1990 period. This recommendation was based on the results of a study conducted in fiscal year 1981 to determine the feasibility and justification of including fixed-guideway transit as a component of the long-range regional transportation plan.

The decision to consider fixed-guideway transit was made within the context of the following factors:

- Expanding areawide economy,
- Increased public acceptance and use of transit,
- Lack of support for major new highway projects,
- Need for energy conservation, and
- Regional development policies.

Forecasts of employment growth have been adjusted upward substantially in recent years. The ratio of transit ridership per capita in the Seattle urban area is one of the highest in the nation for urban areas of comparable size. The unique topography of the region has limited the mileage and capacity of the freeway system and compressed travel demand into a few well-defined corridors.

THE REGION

The Puget Sound Council of Governments is the Metropolitan Planning Organization (MPO) for the Central Puget Sound Region of Washington, consisting of the 4 counties of King, Kitsap, Pierce, and Snohomish. The population of the region is 2.2 million; 80 percent live in the urbanized areas of the 3 largest counties. The major population center is King County with a population of 1.3 million, including its central city, Seattle.

Like most urban regions, its transportation system was developed under diverse circumstances over many decades by numerous jurisdictional entities. In addition, the region has unique attributes and problems that offered opportunities and imposed constraints on past development of the region's transportation system and will influence determination of its future transit needs.

The region is both the victim and the beneficiary of its geographic location and topography. While the Puget Sound waterway, large inland lakes, and glacially formed topography that characterize the region provide unusual scenic beauty and numerous economic attributes, they also create an unusual setting for an urban transportation system. Generally, urban development has been a series of linear corridors, mostly north-south. Topography is a moderate to severe obstacle to most east-west corridors and, overall, has added significantly to the cost of providing the transportation facilities necessary to serve the area.

The north-south corridor runs for about 60 miles between the cities of Tacoma and Everett, with the Seattle CBD located midway. It is served by Interstate Route 5. New growth in King County has tended to locate in a 5- to 8-mile band due east of Seattle across Lake Washington. Transit service in the cross-lake corridor will be concentrated on Interstate Route 90, yet to be completed. These geographic features and the resulting pattern of urban development are particularly relevant to assessing the feasibility of light rail transit.

The Central Puget Sound Region has a dynamic economy because of its role as the preeminent business and financial center for the Pacific Northwest and Alaska. Population has increased commensurate with employment opportunities stemming from this economic growth. From 1950 to 1980, the region's population grew at an average annual rate of 2.1 percent compounded while the overall U.S. population increased at an annual average rate of 1.36 percent. The growth has consisted of about 55 percent net in-migration, a ratio expected to continue. There are many indications that the long-term growth of the region will continue at a rate greater than that of the nation as a whole by a margin at least as great as in the past. Growth forecasts figure prominently in the assessment of light rail feasibility.