Value of Light Rail Transit as a Major Capital Investment

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Most current urban public mass transit projects are funded primarily with federal aid furnished by the Congress through the Urban Mass Transportation Administration of the U.S. Department of Transportation. A local contribution of 25 percent or more is required to qualify under the law.

The success of most existing light rail systems in retaining patronage (1) and the success of new systems in generating it (2) have multiplied applications for funding new light rail systems. At the same time, traffic congestion, air pollution problems, and ever-higher costs of moving people by bus have brought similar demands for extensive, expensive subway and aerial transit systems in addition to plans for the light rail type (3). There are applications and pending applications for $19 billion for such projects. Clearly, there is no way that Congress can fund so many projects simultaneously unless it revises its budget priorities away from anything currently contemplated.

To avoid holding good, valid, and necessary projects too long, while they wait their turn behind previously filed applications for less urgent or too expensive projects, the Urban Mass Transportation Administration has expanded its past policy statements to include a new (May 1984) policy statement on new major urban capital investment policies (4).

There is much logic behind the new policy. It seeks to prefer projects that produce the greatest benefits per dollar invested. Such a policy is both sound and rational. The input criteria are also well chosen. The new incremental capital investment, the new incremental operating costs, and the value of travel time saved are all to be evaluated to determine the net annual economic benefit, if any, that will result from implementation of a proposed project.

The dollar figure thus determined is then to be divided by the incremental gain (if any) in passengers carried to determine the net annual cost per passenger. This is neither as logical as it may first appear nor as equitable as was intended.

The numerator is a function of the size (or length) of the project. A longer line or route, other things being equal, will have higher capital and operating costs than will a shorter project. The denominator, however, bears little relationship to the length of the line or route. As the gravity model theory indicates, trip making varies inversely with the square of the distance traveled. With the denominator determined by the net increase in passengers, there is a real mathematical possibility that the rating index, or net cost per added passenger, could rocket toward infinity despite the possibility that the project might both be the least costly way to move riders in the corridor under analysis and have low per unit construction costs.

A short downtown people-mover to scurry people around on their lunch hour will almost always rate higher than typical line-haul facilities simply because there are fewer miles to pay for. A line-haul facility may be absolutely necessary to bring people to the central business district for work trips or shopping at reasonable operating costs, in reasonable time, and without undue congestion. However, the UMTA rating system, as first devised, will seldom recognize that fact as long as any short downtown people-movers are in the competition for funds.

It is at this point that light rail projects, of one particular type, can gain high ratings from the proposed rating criteria. In Buffalo, Calgary, San Diego, San Jose, and Sacramento (and perhaps Portland), the light rail projects not only serve, or will serve, the longer haul or trunk radial movements but will also serve as downtown circulators (people-movers) with short-trip fares and closely spaced stations right on the street to attract the short, more discretionary trips. This considerably increases the number of passengers to be carried without adding much to the cost of operation or construction. The same seat can be sold twice on the same trip. To the extent that the rating criteria force designers to accommodate short downtown trips on the trunk facility, this may be a good and valuable incentive to lower the cost per passenger, but it makes no more sense to equate a short downtown trip to a longer suburban trip than it would for Greyhound or Trailways (or Amtrak) to have a flat fare for any length of trip, such as the Post Office does with first class mail within the United States. Clearly and obviously, passenger-miles, not passengers, must be the denominator in this equation for rating projects if equity is to prevail.

An example may help illustrate this principle. On the basis of recent experience in several cities, a light rail line (without subway) 7 mi long may cost $150 million to design and construct. Based on UMTA's published examples (5) this may well be equivalent to $9 million per year. Annual operating costs may be $2 million less than continued surface bus service over the same route because of the larger, faster vehicles with greater labor productivity. It is possible that 3 million additional passengers per year might be attracted. Travel time savings could approximate 1 million passenger-hours worth $4 million per year (6,p.39). The cost-effectiveness index would then be $9 million, less $2 million operating savings, less $4 million in time savings, divided by 3 million additional passengers. The result is $1. A $1 rating places it extremely high on UMTA's list of examples. It implies that the imaginary light rail project will not have as much net cost as do most other projects.

If a downtown people-mover is proposed for the same city, or a competing city, it may typically be a 2-mi loop that will cost two and one-half times as much per mile as the longer light rail line, or $100 million in the aggregate. Annual operating costs may be $2 million per year, but few savings will result because most line-haul bus (or light rail) lines must continue to operate full schedules connecting suburban areas with downtown. The time savings may aggregate 250,000 hr, enjoyed by 3 million annual passengers, 2 million of whom are new riders making short discretionary trips that were previously made on foot or not made in the central business district (CBD). The cost-effectiveness index would be $6 million, plus $2 million added operating cost, less $1 million time saving, divided by 3 million annual passengers. The result is $2.33. Although this is not as favorable as the typical light rail example given previously, it is far more favorable than several of the initial project ratings announced by UMTA (5).

If passenger-miles were used instead of passengers to reflect work actually performed, the results would be quite different. Instead of the hypothetical 3 million passengers, the light rail example would add 12 million passenger-miles, again using typical data. The cost-effectiveness index would drop to $0.25.

The typical people-mover, a 2-mi loop, would probably average 1 mi per passenger, so the cost-effectiveness index would remain at $2.33. The relative rating of the two projects would change by a factor of 4, $0.25 versus $2.33 instead of $1 versus $2.33. In many, perhaps most, cases, this would make a great difference in the relative ranking of the projects seeking assistance.

Although the quantitative values assigned to the two cases just described are hypothetical, they are quite close to the real-time experience in Calgary, Detroit, Edmonton, and Shaker Heights.

CAPITAL INVESTMENT

The most important value in the numerator of the cost-effectiveness equation is the net capital investment in the preferred alternative compared with the next best alternative. Light rail, when judiciously applied, may have several attributes that could qualify it for a favorable comparison on the basis of net investment.

Compared with other types of fixed guideway, the construction of an electric railroad, by itself, is not particularly capital intensive. In 1982-1983 the Deseret Western Railroad was built over a distance of 35 mi between Colorado and Utah for $70 million excluding nonrail aspects of the project. The first cost of $2 million per track-mile included grading rough terrain, all aspects of track construction for heavy loads, and electrification. Neither stations nor signals were provided (7).

It is most unlikely that any other form of exclusive right-of-way for transit could be built for much less, less future salvage value, if equal life span is required. The new Houston busways are estimated to cost nearly $7 million per mile and will not have stations or signalling. The Martin Luther King, Jr., busway in Pittsburgh cost $120 million for 7 mi but included nondowntown stations and a railroad relocation that cost approximately $14 million. Conversely, without the railroad, there would have been no available right-of-way. The point is that when busways cost from $7 million to $15 million per mile, a light rail project has the possibility of being less capital intensive for the same alignment and carrying capacity.

If a light rail project relies heavily on subway, the investment will be much higher, but light rail can reduce the amount of subway required as was done in Buffalo where the selection of light rail permitted the elimination of subway in the downtown area and thus reduced cost without the sacrifice of travel time savings or operating efficiency.

Application of the UMTA cost-effectiveness index could result in a negative net cost for a light rail project because rail rapid transit or a busway could be more capital intensive and less economical to operate. It appears that the UMTA criteria might well favor well-designed light rail projects where capital investment is the most significant element in the choice.

Where the baseline alternative to light rail is existing bus service with no right-of-way investment, but constrained by traffic congestion, the operating and travel time savings made possible by a preferred light rail right-of-way can go a long way toward amortizing the required investment.

OPERATING COSTS

In UMTA's Third Annual Section 15 Report on National Urban Mass Transportation Statistics, it was a light rail operation that was recorded with the lowest cost per passenger-mile (8¢) of any transit operation in the United States (8,Table 3.19.4,p.3-252), including small, nonunion bus operations in which the manager might also drive a peak-hour bus.

Light rail can offer the potential for the lowest operating cost per passenger, per passenger-mile, and per capita for a given volume of travel in a properly selected corridor of travel. Light rail may never offer the lowest cost per vehicle-hour or per vehicle so it becomes critical that light rail installations be limited to routes on which the vehicles will be well utilized by passengers. Token services for civic purposes, but lacking in sufficient ridership, will seldom be viable light rail applications.

Light rail costs per vehicle-hour may well average 20 percent higher than similar bus costs because of track and signal maintenance costs. Busways may also experience these costs, but, as yet, no bus statistics are known to include them. In Pittsburgh busway maintenance is, to some degree, performed by light rail employees without differentiation in terms of where the work was done. Even so, with bus costs in major cities averaging $45 per hour under favorable circumstances (9), it is unlikely that light rail costs will ever be less than $54 per car-hour for four-axle cars. With articulated cars, as with articulated buses, the costs will be higher. With 50 percent more trucks and axles, and 100 percent more body sections, it is likely and often the case that articulated light rail vehicles will cost $81 per hour to operate and maintain (10).

The UMTA criteria do not look to cost per vehicle-hour, and, quite rightly, they should not. It is the work output of the vehicle that will determine how many vehicles are needed and how much total operating cost will be incurred.

Light rail cars are often 25 percent larger than are either single or articulated buses. Where clearances permit, they may be much larger. Size is best measured by square feet of passenger-carrying space.

The Buffalo car is more than over 50 percent larger (11,12,p.54). As a result the number of passengers carried per hour can be much higher than it is for bus vehicles. Speed is equally important in this consideration when local service is provided, but, on the basis of size alone, a nonarticulated light rail car is likely to produce more than 90 passengers per hour with the typical route length and loading standards. A standard 40-ft bus, loaded to the same relative standard, will produce 70 passengers per vehicle-hour. The cost per passenger, then, is 59.3¢ on light rail and 64.3¢ by bus. If the base fare is 75¢, with a 15 percent discount for weekly or monthly passes, transfers, and 50 percent off for off-peak senior citizens, the light rail vehicle offers the possibility of an operating profit of 4.4¢ per passenger whereas a bus under the same circumstances would lose 0.6¢. This figure is not as hypothetical as might be assumed. It is quite realistic. A corridor worthy of light rail service will usually enjoy above average bus ridership. The average bus line may not cover half of its cost from fares, but buses on good routes can do much better than average.

Operating speed also affects economic results. The use of reserved or off-street rights-of-way for transit vehicles permits higher schedule speeds. With 18 mph typical of improved, yet modest, schedule speed, the cost per vehicle-mile, based on $54 per hour for light rail, will be $3.00. Bus cost on the street, in traffic, will be $3.75 per bus-mile at the usual average of 12 mph. (If the bus is put on off-street right-of-way, its cost does not decline as does that of light rail because a new cost is encountered: maintenance of right-of-way that is already part of light rail's cost base.) It is mileage, not hours, that passengers wish to buy. They want to get from here to there in miles. They do not wish to amass hours of travel time. It is not unusual for light rail transit to far exceed 18 mph, given ideal rights-of-way, such as in Buffalo or in Shaker Heights where schedule speeds of more than 20 mph are achieved. The San Diego Trolley, with center city street operation and outlying private right-of-way, achieves 21 mph with great reliability. The Pittsburgh East Busway Route EBA averages 17 mph schedule speed under similar conditions (13). In each case recovery time is included.

The purpose of any transit service is to move people over distances as quickly and safely as possible within reasonable cost. The unit of work output is the passenger-mile. Using the previous example concerning the cost per passenger, disregarding speed, it can be determined that, with speed and distance included, the cost per passenger-mile of typical light rail transit operation is 10¢ ($54 per hour ÷ 18 mph x 12 mi per round trip ÷ 91 passengers ÷ 4 mi/passenger).

Again using typical bus data the bus cost on local streets will be 16¢ per passenger-mile. Here, in the real world, the street bus requires 60 percent more cost per passenger-mile (or per passenger). With the bus on exclusive right-of-way, that cost will fall to some degree, but the heavy cost of obtaining and maintaining the right-of-way must be introduced.

Where light rail must use urban streets to reach downtown because no feasible right-of-way is available, it will not enjoy the low cost of 10¢ per passenger-mile. Operating in the center of the street, rather than at the curb, with safety islands for passenger loading, the speed will fall to 12 or 13 mph. In the very heart of the CBD it will fall to 9 mph (13). The cost per vehicle-mile will rise to $4.32 and the resulting cost per passenger-mile will rise to 14.9¢, 50 percent higher than on the preferred right-of-way. It is nevertheless still below the 16¢ per passenger-mile cost of the city bus, by 1.1¢ per passenger-mile and 4.4¢ per passenger.

It must be remembered that these examples will not hold true if the vehicles are not loaded to the standard conditions. Under light vehicle loads, light rail will not demonstrate cost-effectiveness. Total line volume is not an issue. It is almost irrelevant, as long as sufficient volume exists to fill the vehicles. The key is individual car or vehicle loadings. It is the cost per passenger-mile and the time saving that justify light rail investment, not gross volume.

It appears, under proper circumstances, that UMTA's criteria for cost effectiveness will favor light rail transit in likely applications insofar as operating costs are concerned.

TIME SAVINGS

The third element in the numerator of UMTA's cost-effectiveness index is the value of time saved. Most studies and actual experience find that time saving is an essential element of both patronage attraction and cost containment. Many authorities believe that time saving is the most important element in attracting transit riders.

To be employed in a cost-effectiveness index, the time saved must have a realistic dollar value. Many regional transportation studies have found that travel decisions are based on 6¢ per minute (1984) for the average traveler. Other studies have found that travelers value time saved at $4 per hour for work trips and $3 for nonwork trips. With transit catering to work trips for 80 percent of all transit trips, and other trips for but 20 percent, the average value for transit is $3.80 per person-hour, or 6.3¢ per minute saved (6,p.39;14).

Although exclusive or even reserved rights-of-way may be capital intensive, obtaining time savings that attract passengers is valuable because it has the effect of reducing congestion and pollution while increasing transit revenues and reducing operating expense. These positive values, if present, can more than compensate for the capital investment.

Increasing transit speed from 12 mph on the street to 18 mph on a typical light rail alignment, including reserved-lane operation, private right-of-way, and perhaps some railroad alignment, has as a corollary that the average passenger will be saving 6.7 min on the typical 4-mi urban trip. Where urban congestion reduces street bus speed to 4 or 5 mph in the heart of the CBD, the saving will be much greater with light rail, but late at night the saving may be much less. There are few passengers late at night, however.

Although there may be no typical light rail operation, it is not unusual for a light rail route to carry 20,000 passengers per weekday, or 6 million per year. Calgary serves more, but San Diego serves fewer. With 6 million passengers saving 6.7 min each at 6.3¢ per minute, the annual saving to be included in the numerator of the cost-effectiveness index is $2,532,600. This value of time saved may well exceed any reasonable value of operating cost saved and thus become a significant factor in the formula determining the cost-effectiveness index. This has an unfortunate aspect because time savings do not produce cash to amortize the investment or to offset operating cost. Time savings must be included, however, as long as highway studies use the same time savings to justify billions of dollars in new highway projects, some of which might be more economical and useful if developed as urban transit projects. Quite frequently, light rail projects do save transit travel time and will obtain favorable ratings from the criteria for this reason.

PASSENGERS CARRIED

The denominator in the UMTA cost-effectiveness index is the increase in passengers carried. Light rail lines are not usually proposed unless they are expected to increase the number of passengers carried, but it is possible, as in Toronto, that a light rail operation could be justified on its efficiency in dollars even if it attracted few new passengers.

Such a case might arise where radial transit lines are being converted to a grid system and one of the radials in the former arrangement is being converted to a strategic light rail line serving the radial movement as part of the mixed-mode grid system. Any modest time saving on the light rail line would be offset, at least in part, by the time lost transferring to and from the crosstown lines, but the overall system would benefit because nonradial trip makers would obtain vastly improved bus service. UMTA's cost-effectiveness index might assign infinite cost per passenger to such a light rail plan, which would eliminate it from any consideration, yet it might be just as viable as Canada's first subway, which was predicated on a grid system and widespread transfers. Despite the objection to transfers, the Toronto Transit System, with 66 percent of its passengers having to transfer to get where they are going, is the only significant one to attract more passengers in 1984 than it did during the gasoline rationing years of World War II when the manufacture of automobiles and tires was prohibited (15).

This is a fatal flaw in the UMTA cost-effectiveness index. No major transit system has a better cost-effectiveness than does Toronto with two-thirds of its operating cost covered by fare-box receipts (16,p.10).

Despite this fatal flaw, light rail transit may still benefit from the ridership criteria in many cases if actual ridership instead of sketch-planning projections of questionable veracity is used as a base. The increased speed of travel that light rail can make possible with its own right-of-way has already been discussed. There is another, equally important ridership factor that is applicable to light rail: inherent passenger appeal. The wider aisles, smoother movement, absence of odor and engine noise, all-weather reliability on its own right-of-way, and obvious fixed route to which people can relate all work together to improve ridership. In 1966 the Philadelphia Sunday Bulletin (17) published the results of a study that found that then existing light rail services on the North American continent, following the rapid ascendancy of the private automobile after 1948, lost 26 percent of their passengers (including losses in conversion from the 6-day workweek to the 5-day workweek). Fare increases and service reductions were both factors in producing these unfortunate results. Cities with all-bus systems, largely new since World War II, lost 56 percent of their riders. Individual case histories traced much of these losses to specific conversions from rail to bus operation. This market response ought to have meaning for everyone studying transit marketing and seeking passenger attraction and patronage retention.

Such ancient data may no longer seem relevant, but current data suggest that circumstances may not have changed that much (Tables 1 and 2 and Figure 1). In 1981 light rail service replaced bus service on Routes 32 and 100 into Centre City San Diego. These two bus routes carried 12,500 passengers per weekday (18). Route 32 was an all-day trunk line 16 mi long and generally 0.5 mi east of the rail line on a prime arterial but occasionally closer to the rail alignment. New articulated buses were used on a 15-min headway. There was no peak headway augmentation. Route 100 was an express service on Interstate

TABLE 1 Cumulative Annual Ridership Development Data on San Diego Trolley Route 510 (000s)[a]

	Route				
	510 (trolley)	29	32	100	Total
FY 1981		2,392	3,862	215	6,469
FY 1984	5,401	1,703	739	0	7,843
Percentage change	–	−28.8	−80.9	−100	+21.2
Ridership adjusted for 17.9% downtrend in San Diego Transit lines not affected by trolley (33% fare increase and return of gasoline availability)					
Bus in 1984, no rail		1,964	3,171	177	5,311
Actual 1984	5,401	1,703	739	0	7,843
Percentage change	–	−13.3	−76.7	−100	+47.7
Directly Affected Routes Only (adjusted for downtrend on buses)					
Bus in 1984, no rail	0	248[b]	3,171	177	3,596
Actual 1984	5,401	0	739	0	6,140
Percentage change	–	−100	−76.7	−100	+70.7
Maximum Load Point Counts (not in 000s)					
Morning rush hour, 1980			450[c]	80	530
Morning rush hour, 1984	1,100		0	0	1,100
Percentage increase					+107.5
Evening rush hour, 1980			700[c]	80	780
Evening rush hour, 1984	1,300		0	0	1,300
Percentage increase					67

[a]Taken from *San Diego Trolley–The First Three Years*, San Diego Association of Governments, Nov. 1984, pp. 24-27.

[b]Riders taken from Route 29 by local buses serving trolley stations.

[c]Bus schedule did not have this capacity.

TABLE 2 Economic Data on San Diego Trolley Route 510 (000s)[a]

	Route				
	510	29	32	100	Total
1981					
Annual bus-miles		707	900	180	1,787
Cost per mile ($) @ $2.50[b]		1,768	2,993	450	5,211
Revenue (%)		54	72	33	61
Revenue ($)		955	1,620	148	2,723
Subsidy required ($)		813	1,373	302	2,488
Subsidy per passenger-mile (¢)		7	6	18	6½
1984					
Annual miles	1,613	616	255	0	2,484
Cost per mile ($) @ $3[c]	4,963	1,848	765	0	7,576
Revenue (%)	80	47	41	0	68
Revenue ($)	3,956	869	314	0	5,138
Subsidy required ($)	1,007	979	451	0	2,437
Subsidy per passenger-mile (¢)	2	11	17	0	4½

Note: Cost-of-living increase from 1981 to 1984 = 27%; cost increase in South Bay Transit radials = 45%; revenue increase in South Bay Transit radials = 89%; fare increase from 60¢ to 80¢ = 33%; increased cost per passenger = 20%; and reduced subsidy per passenger-mile = 31%.

[a]Taken from *San Diego Trolley—The First Three Years*, San Diego Association of Governments, Nov. 1984, pp. 9-19.

[b]MAN articulated buses used in 1981 on Route 32 cost 33% more to operate and maintain.

[c]Bus rate; rail costs taken directly from p. 9 of *San Diego Trolley*.

11,000 Weekday Route 510 trolley passengers x 54% former bus riders
5,940 Former bus riders
6,060 New trolley riders
2,346 Remaining bus riders on Route 32 (3.175% of annual)
13,346 Total weekday transit riders in 1981 with trolley (61% more transit riders with trolley)

FIGURE 1 Ridership development, 1981 only (taken from *San Diego Trolley—The First Three Years*, San Diego Association of Governments, Nov. 1984, Table 10).

5 parallel to the rail line but operating in peak hours only in the prevailing direction.

Route 100 was discontinued, requiring passengers to use shuttle Route 33 to the trolley station or drive there. Route 32 was cut back from Centre City to National City, with the remaining 11-mi route serving as a local convenience or as a competing bus line with free transfers to Route 29 at a 20¢ lower fare. Route 29 was extended to compete with the trolley at the Iris Avenue station with direct service to Centre City 1 mi east of the rail line. Several local bus lines feed both direct bus and rail with lower fares via bus.

Under these circumstances, during the peak hour, six buses brought 390 passengers into the Centre City of San Diego. After a year of trolley operation with all six bus trips discontinued, there were seven articulated rail cars in the peak hour bringing in 875 passengers at a higher fare. Peak-hour ridership was observed to have increased 124 percent. Former California State Senate President James R. Mills stated at the American Public Transit Association Rail Conference in Baltimore in June 1984 that "over one-third of the trolley riders were diverted from their automobiles."

UMTA has reported a different result. The UMTA report states that the trolley carried 12,000 passengers per day, about the same as the number 32 bus carried before the inauguration of rail service. The UMTA report was made before the full-day service schedule was initiated on the rail line and did not include local passengers still riding on bus Route 32, which has continued to operate over 69 percent of its route. If the UMTA report were to be updated to full trolley service, there would now be more than 17,000 average weekday trolley riders (19,p.11) and even more on Saturdays. Approximately 2,000 weekday riders remain on the Route 32 bus. On this basis, the trolley has brought a ridership increase of 52 percent despite two fare increases. If data from parallel bus Route 29 were available, the increase would be even larger.

In a paper presented at an earlier light rail transit conference (20), it was reported that three light rail systems operating unchanged over nearly 20 years (1952-1971) experienced no secular loss of ridership until the last year when the largest of the three systems suffered interminable delay from subway construction directly beneath its trackage and the smallest of the three was shut down for 6 weeks to facilitate Interstate highway construction. (Both systems have since come back quite strong.) Statistics on these three constant light rail systems were compared with national surface transit statistics, which showed a loss of 46 percent despite thousands of new buses (Figure 2). It appears that light rail attracts and holds riders.

It is difficult to apply before-and-after ridership data to a facility that has not yet been built. The estimating process may be reasonably good, but the pressure on the estimators to produce a "winning" estimate may be unprofessional and irresistible. Because of the added volatility of the high leverage exerted by the estimated change in ridership, this factor must be changed if the cost-effectiveness index is to be realistic and straightforward.

A much better denominator would be the full number of passengers carried on the line or lines under study multiplied by the trip length. The resulting passenger-miles are the proper denominator. This will often show light rail to have a great advantage where its installation is justified.

CONCLUSION

A priority ranking system may be necessary to ensure that limited resources are applied where they will do the most good or provide the most benefit. When properly applied, light rail systems should rank quite well by any such measure if it is equitably and rationally devised. UMTA has the basic requirements included in their cost-effectiveness index, but they have destroyed its practical and equitable application by using a delta-type figure for the denominator, which gives rise to infinite cost-effectiveness index numbers. This is neither rational

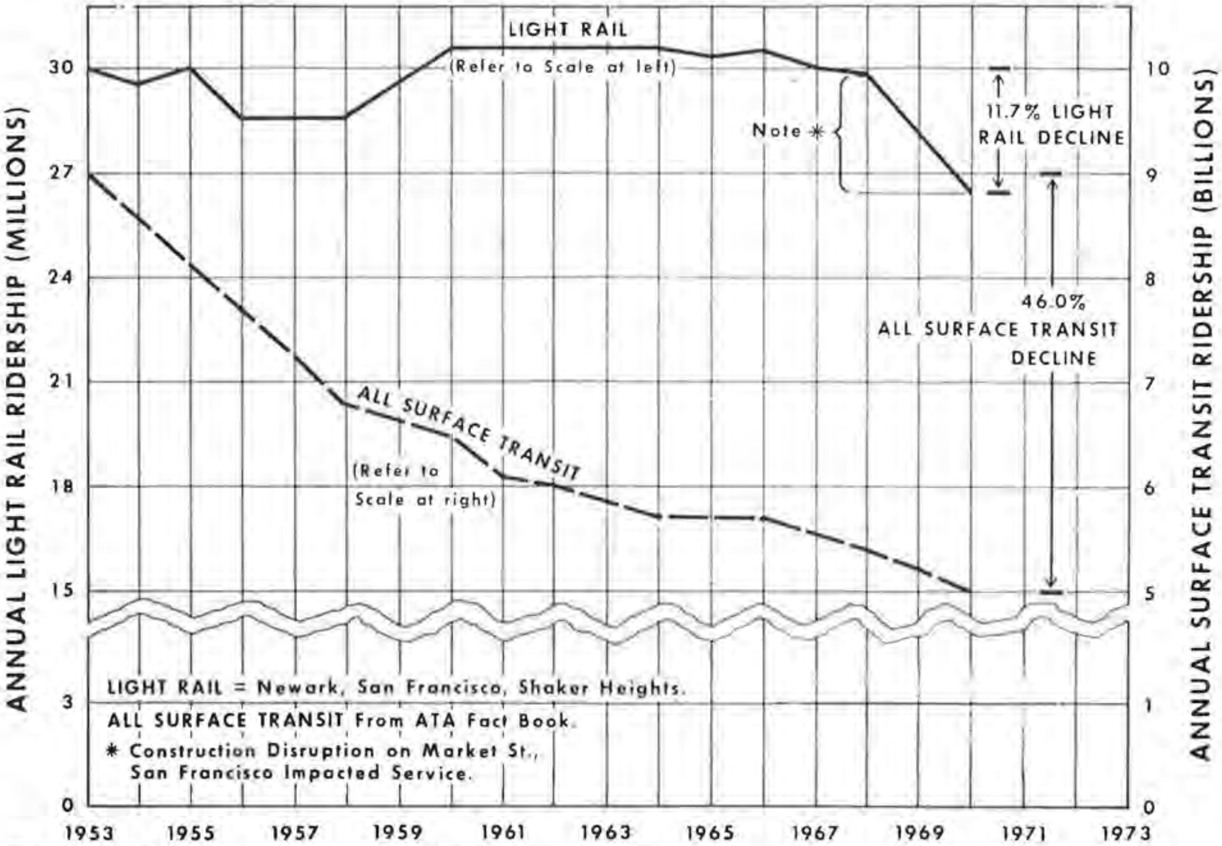

FIGURE 2 Light rail versus other surface transit trends.

nor equitable. If these defects were to be corrected, with passenger-miles applied in the denominator, light rail projects would have a good chance of winning grants because of their potential for relatively low-cost construction, low cost per passenger-mile, and savings in travel time cost. At the same time, light rail projects offer civic values, such as stability; locational advantages; orderly development; assessed value increases for property served; and pollution-free, petroleum-free domestic energy supply.

Light rail projects cannot be justified on civic values alone. The prime justification must be the operational and travel time savings that are made possible by reasonable construction costs.

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