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A whole-system approach to evaluating urban transit investments

JONATHAN RICHMOND*

A. Alfred Taubman Center for State and Local Government, John F. Kennedy School of Government, Harvard University, Cambridge, MA 02138-5801, USA

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New transit capital expenditures are typically evaluated in isolation from the transit/transport systems to which they belong. Problems with reporting performance elements such as ridership and costs are discussed. A focus on evaluating the total transport systems impact of new transit project implementation is called for. On this basis, new US rail transit systems have generally performed poorly. Total transit ridership has generally shown only minimal improvements and, at times, has declined. Financial performance has been disappointing in most cases, particularly when understood in the context of the additional system costs imposed through the reconfiguration of bus networks to serve the new rail systems. Low-cost approaches to improving basic transit services can often be more effective than either rail or bus capital-based projects. An obsession with technology leads to the wrong questions being asked. We should instead start inquiry with the study of needs.

1. Introduction

Rail transit, especially light rail with its claims of lower costs and greater flexibility compared with heavy rail, is becoming increasingly popular in the USA. Metropolitan areas with recently opened systems are almost all building or planning extensions, while proposals are under development for completely new services in cities yet to have developed rail transit. Despite this, there is a lack of up-to-date analysis of how the new rail systems have performed. This paper reports on a study (available in full as Richmond 1998b) to assess how well new rail systems are fulfilling transportation goals. It examines the role of new services in the context of the total transit systems in which they are located with an emphasis on establishing whether systems as a whole have benefited from transit ridership growth and greater financial efficiency.

1.1. *Background — brief project descriptions*

All wholly new US light rail projects in operation as of April 1997 were evaluated, as was the reconstruction to modern light rail standards of an old streetcar system in Pittsburgh. The projects are in Baltimore, Buffalo, Dallas, Denver, Los Angeles, Pittsburgh, Portland, Sacramento, San Diego, San Jose and St. Louis. The light rail systems date from 1981 in the case of San Diego, to 1996, which saw the opening of the Dallas system. The heavy rail developments in Miami

*e-mail: jonathan_richmond@alum.mit.edu

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and Los Angeles, dating from 1984 and 1993 respectively, and Miami's People Mover, opened in 1986, were also reviewed.

It is notable that while rail projects in Baltimore, Buffalo and Pittsburgh are located in traditional East Coast cities, projects in eight other cities attempt to draw passengers to public transport in Western metropolitan areas built on the automobility of the 20th century. The Miami heavy rail and people mover systems represent an effort to bring public transport innovations to a non-traditional city of the South.

To examine alternative approaches, busway/HOV (high occupancy vehicle) lane projects in Houston, Miami, Ottawa and Pittsburgh (starting in 1977 and the earliest project included here), were incorporated as an important element of this study. Table 1 provides introductory data on the systems under review.

The light rail projects, with one exception, show flexibility in their use of rights-of-way. Unlike heavy rail, light rail is not necessarily separated from other traffic flows or pedestrians. Disused rail rights-of-way are often employed. Considerable expense has also at times been needed to create completely new rights-of-way — as for the tunnelling in Buffalo and Dallas, for example.

Light rail is often used in pedestrian environments. It runs the length of Buffalo's 1.4-mile pedestrian mall and is a part of regular street environments for at least some of the route in a majority of cases. Lanes used by light rail are often protected from other flows, but there is generally no grade separation from cross traffic on these sections of route. This type of running contributes to a relatively low average speed of light rail operations, as low as 14.5 mph in the case of Denver and 18.3 mph in Buffalo. San Diego none the less achieves 23.2 mph on its Blue (South) Line, large sections of which permit high-speed protected running. While the Blue Line in Los Angeles averages 22.5 mph, the Los Angeles Green Line averages 35.6 mph. The Green Line is set apart from the other light rail systems in having a completely segregated right of way based on an alignment constructed in conjunction with the new Century Freeway. Wide station spacing also permits the attainment of a good speed. Heavy rail in Los Angeles and Miami runs at 25.0/31.0 mph average speeds respectively.

Direct bus service can be feasibly provided to a variety of relatively low-demand locations. The high cost of rail service means, however, that it must be restricted to corridors of highest demand. The use of available disused rail corridors, often located away from areas of highest residential demand (in Sacramento and Baltimore, for example), has accentuated the need to provide facilities to gain access to rail systems. Most cities with new rail systems have therefore revised bus services to coordinate with rail projects, with a move away from direct bus routes to the city core to an emphasis on feeder buses to take passengers to and from train stations. In such situations, the performance changes of the bus systems are part of the story of the productivity of the rail projects.

Park-and-ride has also been an important strategy in facilitating access to rail. Parking is generally free of charge for rail users. There are as many as 22 free park-and-ride lots in San Diego, but the three lots in Denver also play a significant role in enabling connectivity to light rail in that city.

It is harder to represent the service — and particularly the speed — characteristics of the new bus-based projects reliably because they generally carry routes serving a wide variety of destinations. Where busways are provided, routes often leave the busway at a variety of points, with the same bus providing service on the busway and the ‘feeder’ function on surface streets. Pittsburgh’s management has suggested their ‘local’ busway route as suitable for making a fair comparison with rail. This service runs from the suburban end of the East Busway to downtown Pittsburgh and stops at all five busway stations with an average speed of 27.0 mph. Local service on Miami’s busway, which lacks grade separation from cross-traffic, averages 21.4 mph, by comparison. Park-and-ride lots are heavily emphasized on the Houston busway system, which has 24 of them from which non-stop or one-stop service is operated direct to downtown. Pittsburgh, in contrast, has no park-and-ride facilities adjoining its busways, preferring to encourage bus passengers who start their journeys by car to park at suburban locations at the end of bus lines which extend beyond the end of the busway. Because buses can provide more direct services to a larger number of destinations, proportionately more people generally walk to bus stops than to rail stations.

In contrast to the other bus systems studied, which provide rights-of-way for the exclusive use of buses, Houston’s HOV system — which ran to 67.4 miles in five corridors as of April 1997 — emphasizes the sharing of rights-of-way with other high-occupancy vehicles.

1.2. *Reasons given for developing new projects*

Transit has been in decline in the USA since the 1960s. While the total number of workers increased 78% between 1960 and 1990, workers commuting by private vehicle rose by 136% over this period to reach 101 million automobile commuters in 1990. ‘Transit decreased from 7.8 million in 1960 to 5.9 million in 1990 as more and more people began to drive alone to work’ (Rossetti and Eversole 1993: ES-2).

Private vehicle trips increased from 60% of commuter trips in 1960 to 83% in 1990 and accounted for > 90% of such trips in 14 of the 39 metropolitan areas with populations > 1 million. As Rossetti and Eversole report, transit ridership in these metropolitan areas had by then shrunk to only 9% of commuter trips. Nationally, transit carried 5.3% of workers in 1990.

The decades of increasing car ownership were accompanied by accelerating decentralization, with suburb-to-suburb commuting of increasing significance. Traditionally, public transport services have focused on connecting suburbs to city centres, but new patterns of travel call for greater flexibility in urban transportation.

A number of reasons are none the less commonly given for proceeding with new rail projects. The potential of rail services to achieve high ridership is said to offer relief to congestion as well as enhance environments. In addition to providing access to jobs for the poor, rail is said to appeal to ‘choice-riders’ — higher income commuters who could drive to work if they wished. The standard view is that this group will not use buses but will be drawn by rail’s speed, comfort and middle-class image. Rail is also frequently thought less costly to run than bus systems because higher-capacity trains require fewer drivers. Some advocates believe rail transit will help reverse urban decentralization trends, revitalize city centres and generally make for improved urban environments. My previous research (Richmond 1991, 1998c) has explored in more depth a large range of reasons for preferring rail development over other choices.

The need to find an alternative to the car pervades the political and planning discussions that contributed to the decision to proceed with rail in many of the cities whose systems will be reviewed here. The August 1978 staff recommendation to Portland, Oregon’s Tri-Met Board of Directors (Tri-Met 1978: 5), for example, cites a

Table 1. Basic characteristics of new transit systems under review.

As of April 1997	Urbanized area (UZA) population 1990 (millions)	Year opened	Miles of route	Number of stations	Number of PNR lots	Average speed (mph)	Fare rail ($)	Base fare – bus ($)
Baltimore	1.89	1992	22.5	24	9	20.0	1.35	1.35
Buffalo	0.95	1985	6.4	14	2	18.3	1.25	1.25
Dallas	3.20	1996	20.0	19	5	20.5	1.00	1.00
Denver	1.52	1994	5.3	15	3	14.5	1.00	1.00
Houston	2.90	1979	67.4		24			1.10
Los Angeles – Blue		1990	21.0	22	6	22.5	1.35	1.35
Los Angeles – Green		1995	19.0	14	12	35.6	1.35	1.35
Los Angeles – Red		1993	5.2	8	0	25.0	1.35	1.35
Los Angeles – Total	11.40		45.2	42	17			
Miami – Heavy Rail	1.91	1984	21.1	21	18	30.9	1.25	1.25
Miami – People Mover		1986	4.4	21	0		0.25	1.25
Miami – Busway		1997	8.2	16	2	21.4		1.25
Ottawa	0.64	1983	20.7	24	4			1.85
Pittsburgh – S. Busway	1.68	1977	4.3	9	0			1.25 – 1.60
Pittsburgh – E. Busway		1983	6.8	5	0		1.25 – 1.60	
Pittsburgh – Light Rail		1987	22.5	72	7	15.0	1.25 – 1.60	1.25 – 1.60
Portland	1.17	1986	15.1	30	4	19.7	1.05 – 1.35	1.05 – 1.35
Sacramento	1.10	1987	18.3	29	9	21.5	1.25	1.25
San Diego	2.35	1981	40.5	39	19	23.2	1.00 – 1.75	1.00 – 1.75
San Jose	1.44	1987	20.0	33	13	21.7	1.10	1.10
St. Louis	1.95	1993	17.0	18	7	22.5	1.00	1.00

All data is as of April 1997 unless noted otherwise.
Population data is from the 1990 US Census except for Otawa where it reflects the Ottawa – Carleton service area of OC Transpo.
An additional 7.5 miles opened in Baltimore in September and December 1997; 6.1 miles opened in San Diego in November 1997.
Houston increased its busway miles to 69.6 in September 1997.

Number of stations: Dallas has opened two new stations (total 21 as of May 1998); San Diego has seven new stations (total 46 May 1998) since April 1997.

Park-and-ride: parking is available for the Los Angeles Red Line at Union Station for \$5 per day, but not primarily intended as park-and-ride.

Miami's heavy rail park-and-ride lots cost \$2 a day or, for monthly pass holders only, \$5 a month. Miami busway parking is free of charge.

In addition to the four OC Trasnspo park-and-ride lots, two shopping centers allow transit passengers to park for free.

Paying and parking lots are available at two additional San Diego stations but are not primarily intended for park-and-ride use.

Dallas has opened two new park-and-ride lots (total seven as of May 1998); San Diego three new Park-and-rides (total 22 as of May 1998).

Speed provided for San Diego is for South Line. Busway speeds vary according to service provided.

In Baltimore use of express bus requires a 35¢ extra fare.

In Buffalo there is no fare for using light rail in the downtown mall. Zone bus fares range from \$1.25 to \$1.85. 25¢ transfer bus-to-bus but no fee between bus and rail.

In Dallas, express bus service costs \$2.00.

In Denver an off-peak bus fare of 50¢ applies to both bus and rail services.

HOV lane express but services in Houston are priced in the range of \$1.50 – \$3.50

In Miami there is no transfer fee from busway bus to MetroRail, but 25¢ is charged in the other direction and for all other bus-rail, rail-bus and bus-bus transfers.

Ottawa fare in CA\$. Fare increase May, 1998. Local increased CA\$1.85 to CA\$2.25, express from CA\$2.40 to CA\$3.50, but increased discount for buying tickets.

Portland has a central area ‘fareless square’ with free travel on both light rail and bus

Sacramento had a 25¢ central area midday fare until April, 1998, when it increased to 50¢ but became applicable all-day. Available on light rail and bus.

Most San Diego fares increased by 25¢ in November 1997. \$1 central area trolley fare (compared with \$1.75 on San Diego Transit buses) remained in effect.

St. Louis has midday farefree zone on light rail only.

Metropolitan Planning Organisation (MPO) transportation plan of 1975 based upon findings that the region could not afford the environmental or monetary costs of expanding automobile capacity and that the current system would experience unacceptable congestion unless transit use increased. With the Mt. Hood Freeway withdrawn and its funds made available for transit improvements, light rail was recommended for the Banfield Corridor. Critical to the preference for light rail was the assertion that not only would light rail produce the greatest number of riders — although no more than a busway alternative — but that it would do so at a substantially lower cost than any of the bus alternatives considered. 'Over the useful life of the light rail facility, these operating cost savings will offset the initial capital investment.'

Sacramento's light rail system was also consequent upon freeway abandonment and likewise emerged as an antidote to the 'serious decline in air quality and a loss of personal time and mobility as traffic increases' (RT 1993: 2-1). Light rail was selected as the preferred alternative 'on the basis of being best suited to meet the needs of the growing Sacramento region, to take advantage of potentially available State and Federal funding, and to provide increased transit carrying capacity within the limits of available operating expenses' (UMTA/STDA 1983: S-3).

In San Diego, light rail's cost-effectiveness was stressed. Heavy rail had been the main alternative under review but did not seem financially viable. California Senator Jim Mills authored legislation that provided for a reliance on 'off-the-shelf' technology, development on an incremental basis and the use of existing rights-of-way where possible (Mills and Larwin 1988: 44).

St. Louis also cited efficiency among objectives which included an increase in the 'speed, comfort, and reliability of public transportation', improving air quality, conserving energy and providing a system which maximizes 'operating efficiency and revenue and minimize[s] operating costs and public subsidy' (UMTA/EastWest Gateway Coordinating Council 1987: S12).

Initial environmental work in St. Louis had not found rail the most effective choice, compared with a TSM (transportation systems management) alternative of improving existing bus services, providing traffic signal peremption for buses and other modest improvements. 'The LRT alternatives at a minimum cost of $229 million are substantially more expensive to build than the busway at $112 million or the TSM alternative at $38 million. Therefore, the TSM alternative is more cost-effective in meeting transportation objectives than the other build alternatives' (UMTA/EastWest Gateway Coordinating Council 1984: S-12). Total transit ridership was found to be higher with the TSM alternative (70.7 million annual trips) or a busway alternative (71.4 million) than with the light rail option (69.7 million) (pp. 4–15). 'The total operating costs for each of the build alternatives do not differ significantly. They represent an increase of about 17% over the cost of operating the no-action alternative in 1995' (pp. 2–47).

On the plus side, 'The smoother propulsion provided by electric motors, the use of continuous welded rail, and the greater extent of exclusive right-of-way will give LRT operations better ride quality than comparable bus operations' (pp. 4–13). Of further consideration was that 'Implementing any of the alternative transit improvements will potentially enhance land development opportunities and continued development of downtown St. Louis. The most significant difference among the alternatives is that the LRT options also provide a number of station sites that are attractive for development. More of this development is likely to be refocused rather than net growth' (pp. S-8–S-10).

The *Preferred Alternative Report* (East–West Gateway Coordinating Council 1984), explained the choice of light rail in terms of 'more potential for economic development' and 'Improved image increasing St. Louis' ability to compete for conventions and tourists' (pp. 38–39). Rail would also bring 'greater improvements to transit reliability', 'travel time savings', 'increased accessibility to jobs', 'increased accessibility for the transit dependent' and 'reduced bus congestion in downtown St. Louis' (p. 38). The issue of efficiency is not directly addressed in this decision statement, which states, however, that 'Capital costs and operating costs are financially affordable' (p. 38).

In Dallas there were also mixed signals in decision-making. The light rail project was seen to bring about worthwhile change, with 210 000 daily transit riders in 2010, given the high proportion of employment and population expected to be conveniently served by transit, compared with 130 000 in 1994. Increased use of transit and related changing residential and commercial density patterns would reduce traffic congestion (UMTA/DART 1990: 26). The same report states, however, that financial constraints have meant delays in completion dates for many of the lines. 'The relatively high cost of the light rail system has also meant that *some of the lines may not be cost-effective enough to receive federal funding, which further delays implementation of the full system*' (p. 10; my emphasis).

Pittsburgh decided to reconstruct an existing but deteriorating streetcar system, retaining the light rail approach but, with fixed guideway advocates unable to agree on the best rail technology (Kain *et al.* 1992: 6–12), Pittsburgh's major new exclusive bus right-of-way — the East Busway — was selected as an interim measure which could be later converted to light rail (Crain and Associates 1985).

Ottawa's 'Rapid Transit Appraisal Study', completed in 1976 following a period in which regular bus service had been substantially improved and ridership increased, examined the alternatives of bus and light rail for rapid transit development and found in favour of a bus-based system. The bus alternative was said to be cheaper to both build and operate. Operational advantages of a bus system not only presented the opportunity for cost-saving but permitted the tailoring of services to meet demand not possible with a light rail system.

The Ottawa study, in contrast with most of the US cases, adopted a system-wide perspective, providing a detailed operational evaluation of bus service operation under the rail option as well as the busway choice. While US studies have at times examined the issue of developing complementary bus systems to serve light rail access, they have tended to see bus and rail systems as separate entities and not to regard the cost of feeder bus operations as a part of rail operating costs.

Following prolonged battles over whether to build a rail system — Voorhees and Associates had recommended a $1.5 billion heavy rail system in 1973 (METRO 1997) — Houston decided to develop highway lanes to be used by both buses and other high-occupancy vehicles. The turning point came with the election of Mayor Bob Lanier, who had criticized rail as poor value for tax money and the wrong choice for Houston as a key issue in his election campaign. Section 3 federal rail new start money already appropriated was converted for use on HOV lanes instead.

1.3. *Local view of system performance*

New rail system operators generally claim success. St. Louis Metrolink light rail is a 'nationally recognised success' according to the 1996 Annual Report (Bi-State

1996a: 10). A publicity flyer announces that St. Louis light rail 'ridership continues to exceed expectations', while management points out that light rail brings in 39.2% of its operating costs from fares compared with 20.9% for the buses.

Light rail in Sacramento 'has exceeded all expectations in terms of ridership and community development' (Beach 1995: 15), while 'The success of Portland's light rail system — MAX — has been the subject of a lot of attention' (Arrington 1995: 42). One is told on the back of the MAX pocket timetable that 'every day MAX is helping to protect our quality of life by contributing to less traffic, cleaner air and a healthier economy'.

San Diego is proud of its achievement in building an integrated transit system, while Dallas management stresses recent system ridership growth as a measure of achievement. Some management in a minority of systems are, none the less, voicing concerns about rail performance. In Buffalo there has been talk of the potential benefits from replacing light rail with buses. The recent Chairman of Denver RTD's Board, John Caldara, became a sharp critic of rail development, even if his view was not representative of the board as a whole. 'If we didn't make the mistake, we would now be looking at a better busway system', he said in a telephone interview. 'What is a serious issue is the lack of flexibility, the lack of speed, the force of transfers and the very slow trip time of rail'.

In Los Angeles, a major rethinking of the future role of rail is taking place. This follows cost overruns and criticisms of the degradation of the bus system and loss of its ridership which went along with decisions to target major expenditures to the rail system. The Los Angeles Metropolitan Transportation Authority has suspended expenditures on most planned rail projects in an atmosphere of strained financial resources.

In Pittsburgh, management is satisfied with the decision to build busways and, having seen their success, wishes to continue with busway rather than rail development. Ottawa's management also claims success for their busway, despite recent falls in overall bus ridership in the region.

Houston's management takes pride in their bus/high occupancy vehicle system. They stress the pursuit of mobility — including mobility in private automobiles with more than one passenger — rather than ridership on any specific transport mode, and point to reductions in congestion that have resulted from their efforts. 'Our system is equal to any rail system: 10 000 — 12 000 people per peak direction [in both buses and carpools]. A car with two to three people is a transit vehicle that we don't have to finance, don't have to buy. . . . We encourage carpooling. We don't even mind if they pick up our people at the bus stops' (from interview with management in Houston). With the departure of Mayor Lanier, light rail is none the less back on the political agenda with renewed attempts to have it funded.

1.4. *Previous assessments — the Pickrell report*

Don Pickrell (1990) of the Transportation Systems Center, US Department of Transportation provided the first major assessment of new rail system performance. With $12 billion of federal money spent on new rail transit investments, his report *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Cost* evaluated ridership and cost forecasts that 'led local officials to select ten rail transit projects during the past two decades, by comparing those forecasts to each project's actual costs and ridership' (p. ix). The study also attempted to explain differences between forecast and actual results and made recommendations for improving the accuracy of future forecasts.

Pickrell reported that only in Washington DC was rail patronage:

> More than half of that forecast, and even there ridership remains 28% below that originally anticipated. The number of passengers carried by new rail lines in Baltimore and Portland is somewhat below half of that forecast, while actual ridership on Miami's Metrorail line, as well as on the light rail lines recently completed in Buffalo, Pittsburgh, and Sacramento ranges from 66% to 85% below its forecast levels. Similarly, the two downtown people movers constructed in Miami and Detroit carry 74% and 83% fewer daily passengers than were originally anticipated to use them. The consistent over-estimation of future ridership on recent rail transit projects suggests that, with few exceptions, the levels of travel and related benefits they currently provide are far below those originally anticipated by the local decision-makers who selected these projects. (p. x)

The largest causes of ridership over-estimation, according to Pickrell, were 'overly optimistic assumptions about the frequency and speed of service that new rail lines would provide, as well as about the quality of bus feeder service on which these lines rely to generate much of their ridership' (p. xii).

Pickrell found that 'capital outlays for Pittsburgh's South Hills light rail reconstruction project were actually 11% below their forecast value, while cost overruns on other projects ranged from 13% for Sacramento's recently completed light rail line to 106% for Miami's downtown 'Metromover' project' (p. xii). He says that major design changes played a relatively minor role in cost escalation, which he attributes mainly to the cumulative impact of 'many smaller changes in the physical design of facilities or the standards of their performance' (p. xii).

While Sacramento's light rail operating expenses were 10% below projections for the year 2000, in other cases 'actual expenses range from 12% to more than 200% above their projected levels' (p. xiii). Pickrell adds that not merely were expenses higher for the expected level of rail service but that, except in Atlanta and Portland, 'actual vehicle-miles of service are more typically only one-third to one-half of those originally planned' (p. xiv). He attributes the cost overruns to lower labour productivity, higher compensation and lower operating speeds than had been expected.

Pickrell concludes that 'it is certainly possible that decision-makers acting on more accurate forecasts of costs and future ridership for the projects reviewed here would have selected projects other than those reviewed here, at least in some cases' (p. xvii).

The transit industry responded angrily. In 'Off Track' (APTA 1990), The American Public Transit Association accused Pickrell of 'biased logic, faulty data, and misleading data interpretation'. The APTA was particularly concerned that 'The report used projection data made during the very early project planning stages, rather than the revised and more accurate forecasts submitted with the Final Environmental Impact Statement or the Full Funding Agreements'. Pickrell had made clear, however, that since subsequent (and generally less optimistic) forecasts made after the decision to proceed were by definition irrelevant to the choice of rail, 'this study focuses upon the accuracy of projections that were available to local decision-makers *at the time the choice among alternative transit improvement projects was actually made*' (p. 3; original emphasis).

Pickrell's job was far from easy. In some cases, the comparisons he made when he had no choice — between forecasts for one year and performance in another year, for example — are open to question. In addition, he did not address the wider benefits that might come from rail transit projects — such as reduced congestion or air pollution — which APTA felt significant. This said, the report is a model of clarity in stating each assumption made. The detailed references to every number used, with special data tables produced just to identify source information, are quite unusual and show an attention to detail and to a full disclosure of the relevant facts that one rarely finds in any transit industry report.

There have been further studies in the subject area, including Gómez-Ibáñez (1985), Biehler (1988), Kain *et al.* (1992), Dunphy (1995), Kain and Liu (1995) and Schumann and Tidrick (1995).

1.5. *Methodology*

The emphasis here differs from Pickrell's. While consideration is given to whether forecasts have turned out correct, this seems less important than whether the projects are making contributions to their respective communities. A project might fail to meet its forecasts but still be of value; equally well, a project might surpass its projections but none the less prove to be a poor investment choice.

New transit projects are traditionally assessed in isolation from the total transit systems in which they are set. A basic objective here is to analyse the impact of such projects on total system performance. A project may carry significant ridership, but such a result would not be a public policy achievement if overall transit system ridership overall increased little or even fell. A project may also perform well financially when analysed in isolation, but have quite different consequences for the system as a whole. While it is popularly claimed that trains cost less to run than buses because fewer drivers are needed for a given load of passengers, for example, the real question to be evaluated requires a wider study: not only should this supposition be questioned but, if rail is to save money, the total system — not only the rail system — must be shown to cost less per unit output to operate than before.

The common practice of citing data which compares rail cost and subsidy performance to data for the bus system as a whole may lead to inaccurate conclusions because the implementation of rail may have in itself caused changes to the operating efficiency of the bus system. Any such effect requires identification if the performance of a new project is to be appropriately evaluated. To support this aspect of the study, information was sought on how bus networks had been changed as a consequence of the inauguration of rail service and how this has affected bus ridership and costs.

Visits were made during Spring 1997 to all of the transit systems with projects under review. Requests were made for data on both the full history of ridership and cost forecasts and actual results and, where available, on the larger environmental implications of project implementation. All systems were invited to comment on the final draft report.

Data were more forthcoming in some cities than others. Some transit properties had excellent libraries in which key reports could be identified and read. Others not only lacked libraries but appeared to have little or no trace of even basic historical materials. Some properties devoted considerable energy to helping to locate data; others did not. Some provided answers to basic questions; others did not. While even in the full report (Richmond 1998b) coverage is not entirely even, the examples given here focus on the cases where the most extensive data were available.

A number of specific problems arose in the analysis. A basic issue is the inability to conduct a controlled experiment with which to compare the performance of the system developments studied here. Many environmental variables have changed over the period of project implementation — elements of cost as well as overall inflation, demographic and land-use patterns, car ownership and congestion, to name a few — and it is therefore difficult to say what the system would have been like in the absence of the new service under study. What one can do, however, is to identify structural changes in systems that the new service brought about — changes in the efficiency of existing bus systems due to reconfiguration, for example — while linking changes in total system ridership and financial performance over time to the commencement of new service as reasonably as the evidence allows.

A decision had to be made on how to treat capital costs. APTA (1990: 2) accuses Pickrell of using 'the lowest inflation index, to minimize the effect of inflation on rail construction'. The problem is which inflator do you use? Not only are there a variety of industry specific indices in addition to the broader ones, but also costs have varied at different rates in different cities and regions. There is no easy choice. Possibly there is no correct one. Capital cost data have therefore generally been presented in raw rather than inflation-adjusted form.

Similarly, a choice had to be made on how to depreciate capital. Which discount/interest rates should be used and over which time frames should the projects be amortized? The issue is made more complex because project components may have different life spans. In the end, the decision was made to not attempt to combine capital and operating data for this study to avoid the pitfalls inherent in doing so.

Locally used operating data were found sometimes to differ from federally reported data. Costs were allocated in a number of alternative ways from system to system. In some cases the allocation methods have changed over time, making time series analysis difficult. There have been periods in which federal reporting requirements have allowed the separation of jointly allocated costs (not allocated to any particular mode) from modally reported data. This makes meaningful comparison yet more difficult.

Revenue is not split between modes in National Transit Database (previously known as Section 15) reports, the principal source of federal transit system performance data. Some of the transit properties under study do perform these allocations for internal use, and did supply data, but methods of allocation once more varied. Sometimes allocation algorithms were in use. In other cases, it was a simple matter of seeing how much money was dropped in bus fareboxes, compared with light rail fare collection machines, and using the ratio of these results for assigning income. This will cause problems if the proportion of cash deposited compared with passes used for payment is different on rail than buses.

Not all bus systems had specific line-by-line performance data and there were a variety of methods of allocating costs to lines, generally using a combination of peak buses in use, hours in use and miles travelled. Sometimes performance might vary from one section of route to another: this showed up in San Diego where detailed data are available on each light rail segment; such data were not available in most other instances.

Perhaps the biggest problem has been in handling ridership data. Linked data, which represents the number of complete journeys made irrespective of how many modes or vehicles are used en route, is more valuable than unlinked information, which sums the total boardings on all vehicles. The former is typically developed by Canadian transit organizations, while the latter is generally supplied by their US counterparts. Linked data makes possible the comparison of the total number of transit journeys made before and after a transit innovation, while an unlinked trip increase may disguise an increase in the rate of transferring rather than reflect an actual increase in transit travel. A journey which changes from one bus trip to either two bus trips or a bus and a train remains one linked trip but becomes two unlinked trips although the passenger is still completing only the one journey. Unlinked data for systems that move from a basis of direct bus service to a transfer-based rail system may therefore show an unrealistic increase in patronage. Lacking an alternative, unlinked data is presented here, but should be consumed with caution.

All data on ridership and operating financial performance presented here relates to the fiscal year of the transit property in question, unless specifically indicated otherwise. Since properties end their fiscal years on a variety of dates, data for specific years relates to widely divergent physical time periods (1995 for Buffalo means April 1994 — March 1995 but for Dallas it covers October 1994 — September 1995, for example), creating more problems of comparison. Irregularities in Portland's reporting of ridership and operating cost data caused further difficulties.

The best attempt has been made to represent such data as has been made available in a fair and reliable way. The data is robust enough to support the overall conclusions, which are compelling. It would be surprising, however, if despite the most careful of checking, a few errors do not remain.

The concepts found to be salient under each of the areas of ridership, capital costs and financial operating performance are described in the following and illustrated with examples from the systems reviewed. Richmond (1998b), while focusing on the same three major categories, is organized by cities rather than concepts. Insofar as this paper is intended to explain concepts clearly and perform a summary function, the full report should be consulted for those who wish to examine study results comprehensively.

2. Ridership

Rail ridership is often cited as indicative of rail systems' success. The sight of full trains provides compelling evidence. A realistic assessment is more complicated. The existence of riders on a new project does not necessarily mean that there are more passengers on public transport. To assess ridership effectively one need to understand the effects of the new project on the transit system as a whole.

To look none the less at overall results first, table 2 presents Section 15/National Transit Database data on boardings and passenger-miles for the US cities studied here (except that some San Diego Trolley data is direct from the Metropolitan Transit Development Board [MTDB]) and data provided by OC Transpo relating to Ottawa's bus system. Data is provided at 5-year intervals from fiscal year 1980 (when the only project under review already in operation was Pittsburgh's South Busway) to fiscal year 1995. The Dallas system light rail was not in operation as of fiscal year 1995, but that year is the latest one for which the federally issued data were available at the time of final report production. Note that data is for unlinked trips, not complete journeys: a journey on a bus and a train is represented as two boardings.

Looking at new system ridership in isolation, San Diego has achieved the most impressive results, with 15.6 million boardings in 1995. St. Louis, with 12.5 million boardings in that fiscal year, has the second highest ridership among the light rail systems, with Los Angeles slightly behind. Table 2 does not indicate the 5.2 million passengers who boarded the Dallas light rail system during the first two quarters of its 1998 fiscal year.

Table 2. Boardings by mode, 1980–95.

Boardings	1980				1985				1990				1995			
	Bus	Light rail/PM	Heavy rail	Total	Bus	Light rail/PM	Heavy rail	Total	Bus	Light rail/PM	Heavy rail	Total	Bus	Light rail/PM	Heavy rail	Total
Baltimore	118.8			118.8	98.1		9.6	107.4	99.4		13.6	113.0	87.0	5.8	10.6	103.4
Buffalo	37.1			37.1	35.7			35.7	21.9	8.5		30.4	21.4	7.6		29.0
Dallas	38.1			38.1	45.9			45.9	44.4			44.4	43.9			43.9
Denver	67.4			67.4	57.8			57.8	53.1			53.1	62.8	4.1		66.9
Houston	37.9			37.9	66.1			66.1	88.1			88.1	79.6			79.6
Los Angeles	396.6			396.6	497.2			497.2	401.1			401.1	344.3	12.0	15.9	362.2
Miami	67.4			67.4	61.8		4.9	66.7	59.8	3.2	13.6	76.6	61.6	4.3	14.2	80.1
Ottawa	95.3			95.3	109.9			109.9	113.7			113.7	101.2			101.2
Pittsburgh	100.2	8.0		108.2	83.3	2.5		85.8	75.3	9.9		85.2	64.4	8.0		72.4
Portland	46.8			46.8	54.8			54.8	47.8	6.4		54.2	56.2	7.8		64.0
Sacramento	17.0			17.0	16.1			16.1	14.0	5.7		19.7	16.0	7.1		23.1
San Diego	34.5			34.5	27.7	6.0		33.7	33.2	16.0		49.2	34.8	15.6		50.4
San Jose	31.3			31.3	34.6			34.6	43.3	2.4		45.7	39.4	5.7		45.1
St. Louis	84.2			84.2	51.1			51.1	44.4			44.4	38.7	12.5		51.2

Source: Section 15 Reports/National Transit Database, except San Diego Light Rail [*Source:* MTDB] and Ottawa [*Source:* OC Transpo].
PM = People Mover in Miami.
Values are in millions.

All the other light rail systems carried substantially fewer passengers, although Miami transported greater volumes on its heavy rail. In all but two cases — Sacramento and San Diego where bus boardings were slightly more than double those on rail — rail ridership was significantly less than carried by bus. Taking all systems together, eight times as many passengers boarded buses as trains in 1995. If Los Angeles — where there were 19 times as many bus boardings as rail boardings — is excluded from the calculation, there were six times as many boardings on bus as on rail.

Miami and Sacramento's rail investments have been associated with increases in total transit boardings. Between 1985 and 1995, unlinked trips were up 20% in Miami, 43% in Sacramento. In Sacramento, however, growth in bus boardings exceeded growth in light rail between 1990 and 1995. If one compares 1997 with 1995 data for Dallas, there has been a 17% increase in total boardings. This can be attributed to light rail since bus ridership declined slightly over the period, although it may at least partly reflect an increase in transfers from bus to light rail by passengers previously completing journeys by bus alone.

San Diego has also seen periods of greater bus than light rail ridership growth, but total transit boardings in 1995 were substantially higher than in 1980, with bus boardings virtually the same at the close of the period as at the beginning, indicating a considerable attraction by light rail. St. Louis has seen a sharp decrease in total transit boardings over 1980–95, but the 15% increase over 1990–95 occurred as light rail service began.

Baltimore light rail ridership has recently grown, but remains low compared with total transit system ridership in that city. Denver's transit saw a significant increase in boardings between 1990 and 1995, but light rail boardings only accounted for 30% of the increase. The rest relate to increases in bus ridership.

In Buffalo, Los Angeles, Pittsburgh and San Jose, the arrival of light rail has not stopped total transit boardings falling, despite the fact that a proportion of those boardings after light rail start-up represent transfers between modes not required on previous service, rather than complete trips. The growth of bus boardings in San Jose between 1985 and 1990 was significantly greater than the addition of light rail boardings over the following 5 years. In Los Angeles, rail ridership is tiny compared with the loss of bus ridership triggered by a 1985 fare increase.

Because of discrepancies between National Transit Database data and Tri-Met, Portland's internal data it is difficult to ascertain trends in system ridership related to the arrival of light rail.

Turning to the bus system improvements, Pittsburgh has documented substantial ridership increases in its East Busway corridor, which it sees as a rapid transit service. The East Busway carries the same volume of passengers as the three times longer light rail system. Even so, East Busway ridership is on the decline, as is true for the transit system as a whole. The original South Busway has fared less well than the East Busway, and is also a part of the general pattern of transit decline in Pittsburgh.

Miami's busway is relatively new, but average weekday corridor ridership increased by 52% (3699 daily boardings) and weekend ridership by 72% (4364 daily boardings) between fourth quarter 1996 and fourth quarter 1997 as a result of the service improvements which its inauguration made possible.

The passenger numbers for Ottawa are striking when it is noted that Ottawa has the lowest population of any of the urban areas studied here. Total transit ridership on Ottawa's all-bus system almost equalled Baltimore's 1995 bus and rail transit system ridership, while Ottawa has only one-third the population. Overall bus ridership in Ottawa has, however, recently been in decline.

Houston's bus system ridership fell heavily between 1990 and 1995. The Houston HOV system is unique, however, in not requiring justification in terms of bus ridership alone. Increases in carpool riders, though not reflected in National Transit Database statistics, are seen locally as a gain for Houston and justify a facility also used by buses. Henk *et al.* (1995) reported average vehicle occupancy increases of 20% on three of the four freeways with new transitways they evaluated. The fourth had a gain of 10% (p. xxviii). 'For the entire Houston area, estimates are that HOV lanes presently reduce area-wide congestion by about four percent' (p. xxiii).

The results reported above must be understood in the context of the following themes which can lead to different conclusions than an examination of the raw data considered above.

2.1. *Ridership forecasting has made optimistic assumptions*

In few cases has ridership reached initially forecast levels. St. Louis light rail and the San Diego Blue (South) Line have exceeded forecasts by a healthy margin, while the Los Angeles Blue Line is on track to meeting the ridership projected for the year 2000. The San Diego Orange (East) Line has experienced significantly lower ridership than initially forecast, by comparison, even if its ridership is currently approaching the 2000 forecast made in a subsequent study. In Buffalo, Miami (heavy rail and people mover), Pittsburgh, Portland, Sacramento and San Jose, rail ridership is strikingly less than originally forecast.

The situation is confused by the frequent release of lower forecasts just before opening. According to MTA (1996c), 'Original EIS forecast ridership for the [Los Angeles] Green Line was 100,000 boardings per day. However, shortly before the opening, the forecast was revised downwards to 10,000 boardings per day'. While the initial forecast had been for a mature system — not the first year of operation — and was done without knowledge that reduced federal defence spending would negatively affect employment in the western part of the area served by the line, the very low new forecast enabled Metropolitan Transportation Authority Chairman Larry Zarian to declare exactly 1 year after the East–West Green Line's 12 August 1995 opening that 'The Green Line carries nearly 15,000 passengers each weekday, which is more than we projected for our first anniversary when the line opened last August. This is exciting news for all of us' (MTA 1996a).

Table 3 shows the history of Buffalo light rail forecast and actual ridership (the latter from data supplied by NFTA — Niagara Frontier Transportation Authority). The Niagra Frontier Mass Transit Study of 1971 predicted 160 000 daily weekday riders for the originally planned 11-mile heavy rail system. The forecast assumed high future regional growth. The June 1976 Technical Report, which formed the basis for the project environmental assessment, reflected lower growth expectations than had been assumed in 1971 and recognized declining bus use in Buffalo (Voorhees & Associates 1976: 2). It introduced the 6.4-mile light rail MOS (minimum operable segment) option that was to be eventually built in response to concerns from the federal government over the cost of the 11-mile project originally proposed. Voorhees rated light rail 'favorable or very favorable on most elements' (p. 197). The bus alternatives under examination were rated 'low' on overall service quality.

The light rail evaluation was based on a maximum speed of 65 mph (p. 190), and minimal station dwell times leading to a 17.5 minute planned end-to-end trip time at an average 21.9 mph (p. 189). The consultant's express bus alternatives analysis assumed buses would travel at only 28 mph, even on dedicated facilities, with CBD priority speeds of 12 mph (p. 227). In practice the light rail trip takes 21 minutes, 20% longer than expected in 1976, with an average speed of 18.3 mph. Since travel time plays a critical role in determining the attractiveness of particular means of travel for modelling purposes, an underrepresented trip time can lead to significantly overstated forecasts.

Further forecasts, conducted in 1978, were based on lower demographic projections for Buffalo, but assumed increased parking costs and a faster — 15 minutes, 20 seconds — light rail trip time. Eighty-eight thousand daily passengers — the forecast adopted by the transit system — was at the top of a reported range of 53 000 – 88 000 (NFTA 1987: 3). Sharply lower forecasts were produced in 1981. These reflected the reality of further regional population and employment decline and the need for a higher fare because of proposed cuts in federal operating assistance.

The year 1995 light rail ridership came to only 28.4% of the forecast in the 1976 Voorhees report completed for environmental assessment and only 57.4% of the 1981 forecast produced when the system was under construction. Total 1995 annual ridership on bus and rail together came to 29.0 million, compared with 35.7 million trips by bus alone in 1985, before rail service commenced operations.

Table 3. Forecast and actual boardings, Buffalo Light Rail.

	Average weekday boardings
Forecast for 1995	
1971	160 000
1976	92 000
1978	88 000
1981	45 500
Actual	
1986	17 872
1990	30 010
1995	26 115

Table 4. Forecast and actual boardings, Portland Light Rail.

	Average weekday boardings
Forecast	
1978 for 1990	42 500
1985 for 1987	19 270
Actual	
1987	19 500
1990	20 500
1993	23 700
1996	27 000

Table 4 traces ridership forecasts and results for Portland's light rail. (Source for actuals: data table supplied by Tri-Met (1996b). Note that these numbers reflect results used by Tri-Met for internal purposes. Tri-Met has reported different numbers to the federal government. For the same 1996 fiscal year, for example, Tri-Met reported in its submission to the National Transit Database that 29 857 average weekday passengers were carried by light rail.)

Initial ridership forecasts (based on Tri-Met 1977: 37) used for the staff recommendation of light rail in Portland had been said to be 'probably low due to a number of purposely conservative assumptions used in the simulation process' (Tri-Met 1978: 23). The actual light rail ridership in 1990 was, however, only 48% of the initial estimate for that year.

Tri-Met criticized Pickrell (1990) for comparing this actual ridership with the initial forecast because 1990 was supposed to be the seventh year of operation according to the 1978 forecasts, whereas in practice it was only the fourth year of light rail service (Tri-Met 1990b). The seventh year, 1993, none the less saw ridership still well below the initial forecast. Daily ridership in 1996 still came to only 64% of the original forecast for 1990 (daily ridership numbers from data supplied to author by Tri-Met).

In an internal memorandum, Tri-Met (n.d.) explains why the initial forecasts had been high compared with a subsequent forecast conducted in 1985 which had accurately forecasted 19 270 weekday daily riders for 1987 (a year in which light rail ridership was in fact 19 500). The initial forecast had assumed a 3.3% downtown economic annual growth rate. The growth rate was in fact only 1.4% over 1977–87. Regional growth of 4.6% annually had been assumed; this, however, turned out to be only 2.4% over the same decade. The initial forecast had also assumed a higher level of feeder bus service than was in fact supplied due to a failure to obtain expected tax revenues and had been based on lower fares than were eventually implemented. 'By 1983, reality was clearly different from what had been forecast in 1978. Regional employment was down, the economy was stagnant, payroll tax growth was slow', Tri-Met explains.

Perhaps most significant given the importance of travel time in demand modelling in determining levels of projected ridership, but unmentioned in Tri-Met's memorandum, is that ridership studies had assumed a travel time of 34 minutes for the length of the line (FHWA/ODOT 1978: 165), not the 46 minutes the journey actually takes.

As table 5 shows, initial ridership forecasts for Sacramento light rail were substantially higher than those produced 2 years later. The Draft Environmental Impact Statement (UMTA/SACOG 1981) projected a ridership of 50 000 weekday daily light rail passengers for the year 2000 based on assumptions that journey times would be shorter than by previous buses; that automobile operating costs would be 20% higher; and that there would be an increase in total person trips in the North-East study area of 43.3% between 1979/80 and 2000 and of work trips to the central city of 34.2%.

The report argues that the model used may overstate future highway travel and understate transit travel by as much as 15% and there are: 'indications that public response to the introduction of a new light rail transit system may exceed the levels indicated by system attributes such as travel times and costs alone. Thus, the transit patronage projections presented herein are more likely to understate than overstate future transit demand levels with the improved services specified for this analysis'

Table 5. Forecast and actual boarding, Sacramento Light Rail.

	Average weekday boardings
Forecast	
1981 for 2000	50 000
1983 for 2000	26 000
Actual	
1991	23 148
1996	25 017

(p. 4–23). By the time the Final Environmental statement was produced 2 years later light rail had been selected as the locally preferred alternative and demand estimates were adjusted to project year 2000 ridership of 26 000 weekday daily riders, just over half the original estimate. The new estimates used a 2.5 times transfer penalty factor (i.e. 1 minute of actual time spent transferring was said to feel like 2.5 minutes to the person making the transfer) and adjustments were made for incorrect estimates of total peak travel made in the earlier modelling (UMTA/SDTA 1983: 2–30).

2.2. *Preferential fares policy has artificially increased rail ridership*

Fares policy has been critical in building rail ridership. Low or fare-free zones have been established in many centre-cities. Travel is free in Portland's 'Fareless Square', and the length of Buffalo's pedestrian mall, for example, while it is free at lunchtime in St. Louis. In Sacramento a discount fare of 50¢ applies for downtown trips. Fare structuring has also often helped the competitive position of new rail systems. The frequent use of low flat fares has meant that the cost per mile of travelling by train has often been substantially less than the equivalent unit charge by bus. In Los Angeles, pricing for an express bus trip for the zones covered by the previous Long Beach 456 bus comes to \$2.85, while the equivalent light rail fare is \$1.35. An express bus route that crosses the Green Line provides a faster journey town to downtown Los Angeles than is possible by rail, but costs 50¢ more to use. Before the introduction of light rail in St. Louis, express bus services cost more to use than locals and transfers had to be bought to change buses. A \$1.00 flat fare was introduced for all services at the inception of light rail operations and new multiple-journey tickets eliminated transfer charges except for those continuing to pay for only one trip at a time. With an average 1996 rail trip of 6.1 miles compared with the average 4.2 mile bus trip in pre-rail 1993 and the average 3.8 mile bus trip in 1996 (source: National Transit Database), a substantial discount is being given to rail riders compared with bus-only riders.

2.3. *Many rail riders were already using transit, but lost alternatives*

The start-up of new rail service has generally been accompanied by a restructuring of bus services to feed rail stations and a discontinuation of direct bus services from suburbs to downtown. Former bus riders, who generally form the largest component of rail ridership, thus have little choice but to take the train.

In Baltimore a 1994 survey found that half of light rail riders had previously made the journey by bus. Only 22% had driven solo (an additional 5% had carpooled or been dropped off) (Baltimore Metropolitan Council 1994: S-3). A November 1990 on-board survey (the most recent cited by MTA 1996b) found that only 21% of Los Angeles Blue Line light rail passengers had previously driven, while 63% had taken the bus. In Denver, Howell Research Group (1995b) found that 73% of light rail riders surveyed were previous bus users (p. 23). The single greatest reason given for using light rail (32% of weekday riders) was that 'bus route begins/ends at Light Rail station' (p. 18). In other words, they had no choice.

According to Tri-Met (1991: 3–8), 'Light rail accounted for 5,000 of the 8,000 weekday boarding ride increase in the [Portland total transit] system between Spring 1985 and Spring 1987'. Put another way, only 5000 out of the 19 500 average weekday riders on light rail in 1987 represented trips that would not otherwise have been made by public transport, according to Tri-Met documentation. Tri-Met (1998) estimates that 12 000 out of 27 000 average weekday riders on light rail in 1996 were 'new system rides attributable to light rail'. While my own calculations (Richmond 1998b: 33–34) put the new riders at only 8500, taking either number clearly illustrates the point that light rail in Portland mostly transports people who would otherwise travel by bus.

A survey by SANDAG (1991: 41), reports a higher share of passengers new to transit on board San Diego's light rail. Of those surveyed, 36.9% said they had previously driven alone, while 13.1% had carpooled and only 24.7% had travelled by bus (with other surveyed rail riders making new trips or giving other responses).

2.4. *Need to transfer affects light rail convenience*

A study by OC Transpo, Ottawa (1997) commented that 'we have received a consistent message from customers about their preference for avoiding transfers'. Ottawa's transitway system accommodates a wide variety of express bus services that run on surface streets before entering the exclusive right-of-way. Pittsburgh's East Busway is served by exclusive busway routes with service characteristics similar to light rail, but also carries buses which pick up passengers near their suburban homes before entering the busway. Light rail lacks this flexibility, and in many cases passengers who previously had direct bus service now have to transfer from bus to train, with extended journey times.

In Sacramento, many journeys that now require feeder buses as well as trains take longer than they did on the discontinued bus lines. Management provided illustrations of changed journey characteristics on trips to downtown Sacramento (as shown in table 6), while noting that increased highway travel times since 1987 would have led to increased bus times, assuming the implementation of no new bus priority measures.

When the most recent Los Angeles Red Line extension — to Western Avenue and Wilshire Boulevard — was opened, limited stop Wilshire bus service was cut back to terminate at the Western station rather than provide direct service to downtown. Local buses continued to operate through to downtown, however, because of the need to serve points distant from the rail stations. According to MTA management, most local bus riders travelling between points west of Western Avenue and downtown Los Angeles have chosen to remain on the bus for the entire journey rather than transfer to Metrorail. An estimated half of the 16 000 daily boardings on local service between Western Avenue and downtown 'would be served by the Red Line, but virtually none have diverted'. This was the case even though the charge for transfers between bus and train at Western Avenue was eliminated.

Table 6. Bus and light rail travel times in Sacramento.

	Route time (min)		Route time (min)		Route time (min)	
Previous bus	102	39	106	56/59	78	45
New bus/rail journey						
Feeder bus to light rail		20		35		39
Transfer time		5		5		5
Light rail		24		24		29
Total time via light rail		49		64		64

'There's a lack of any travel time benefit because the access time into the station and at the other end offsets the travel time saving [on the train itself]'.

2.5. *New rail systems focus on automobile access*

In no case has new rail service been shown to have had a noticeable impact upon highway congestion or air quality, although the Denver light rail system has satisfied the objective of removing from centre-city streets buses diverted to terminate at light rail stations. Light rail systems have in fact generally focused on the facilitation of automobile access through the extensive provision of park-and-ride lots, nearly all of which provide parking at no charge.

In Denver, express bus routes, shortened from their former downtown destination to terminate at the I-25 light rail station and park-and-ride lot, lost 17% of their passengers — 1126 out of 6523 daily riders — between September 1994 and May 1995 (source: Denver RTD). With fares on light rail lower than on the express buses, it became cheaper as well as faster to drive to the free park-and-ride lot at the end of the light rail line than to take the shortened bus route and transfer to light rail. As one Rapid Transit District manager explained, 'a lot of people have gone from express bus to driving to the light rail line. We expected people to take feeders more. We had to do two pure expansions of the southern park-and-ride and add a park-and-ride at Alameda'.

A 1995 survey (Howell Research Group 1995a) documented this trend. While most weekend users of the park-and-ride were new to transit, 56% of weekday riders who parked at the I-25 Broadway park-and-ride had previously travelled by RTD bus all the way to their final destination and had been induced by light rail to drive instead. 'Free parking' was the most frequently selected reason (80%) for using the I-25/Broadway park-n-ride on weekdays, followed by 'convenience of Light Rail' (68%) and 'easier to drive to park-n-ride than take the bus' (54%)' (p. 4). 88% of weekday park-and-ride users drove to the lot alone (p. 5).

A similar pattern has been observed in St. Louis. Management there noted that while light rail 'ridership has skyrocketed in East St. Louis', bus ridership in Illinois has gone down 'in large part because of the park-and-ride availability and people felt that if they had to transfer at 5th and Missouri anyway, they might as well drive'.

In both these cases, passengers who would have previously ridden bus transit service directly from their home to their final destination without any automobile mileage have been induced by light rail to drive their cars to a park-and-ride lot instead.

NFTA presented evidence that a fare-free zone in downtown Buffalo has encouraged parking nearby. A number of downtown parking lots provide shuttle vans to a free-fare station. Some employers have even begun subsidising employee parking in these lots. While light rail is used as part of a total journey, it is therefore facilitating these employees drive to downtown rather than inducing them to travel by public transport for the greater part of their trip.

While 54% of Portland weekday rail users had an automobile alternative (Tri-Met 1990a: 28), 43% of suburban radial bus riders had the same option (Tri-Met 1989: 26), showing that ordinary buses can also attract 'choice' riders. A Tri-Met survey found that only 16% of feeder bus riders had the alternative of driving (Tri-Met 1989: 23), showing the greater attraction to motorists of driving to rail stations instead. The rail feeders are primarily used by transit dependants who have lost direct bus service.

There are no park-and-ride facilities adjacent to the Pittsburgh East Busway (although there are two private lots available at commercial rates). Lots are instead provided at the suburban ends of certain bus lines. Automobile-access passengers therefore drive less than if they were to park near the busway.

Ottawa has chosen not to emphasize park-and-ride usage. Four official park-and-ride lots are provided on the transitway and two shopping centres have parking space that may be used by transit passengers. These facilities are geared towards attracting rural area commuters who do not have direct bus access to the transitway.

Houston, however, focuses heavily on car use both to bring passengers to park-and-ride lots that serve express buses and to carry carpools on its HOV lanes. Houston management sees carpools as no-subsidy transit vehicles. By focusing on mobility irrespective of which mode of transport is employed, Houston has documented reductions in highway congestion and improvements in air quality that the new rail system cities have not enjoyed.

2.6. *Relationships between policy alternatives — opportunity costs*

Modest improvements to basic bus services combined with an attractive fares policy have shown they can secure substantially greater ridership increases than capital-intensive projects involving either light rail or busway construction.

Over 1969–80, the service and fare policy of Tri-Met, Portland: 'was primarily directed to increase service on existing routes, to lower fares and, as a result, to increase patronage. This policy was successful: annual patronage grew 150% while service hours grew 110% ... The increase in transit patronage occurred while regional population increased slightly; the result was a doubling of market share (as measured by rides per capita). Tri-Met became a national model of a successful public transportation system' (Tri-Met 1991: 3-3).

Notable bus ridership increases included those over 1975–76 (22 300) and 1979–80 (26 500 increase) (source: table supplied by Tri-Met (1996b) 'Fixed Route Service and Ridership' covering fiscal years 1971–1996). Each of these gains compares favourably to the 12 000 total gain in transit ridership Tri-Met says is attributable to light rail through 1996. Bus services were cut 13% between 1984 and 1986 at a time when resources were being prioritized to light rail. 'A fare change in September 1985, increased adult cash fares, eliminated the youth cash fare and raised the youth pass price. The impact on patronage was significant: a 6% drop, about half of which were youth rides' (Tri-Met 1991: 3–4).

Data presented in a Tri-Met's spreadsheet 'Fixed Route Service and Ridership' are consistent with this finding. It shows that average weekday bus boardings fell by 13 900 (8.3%) between 1984 and 1986. This result unfortunately conflicts with data reported for purposes of the federal Section 15 (National Transit Database) requirement, which shows that unlinked system ridership grew by 1.9% between 1984 and 1986.

In Los Angeles, the same ballot proposition which was to provide funding for light rail supplied a 3-year bus fare reduction which took bus ridership out of a trough of 354.1 million annual passenger bus trips in 1982 to a peak of 497.2 million passengers in 1985, an increase of 143.1 million passengers, or 40.4% over 3 years. With the end of reduced fares and the transferral of subsidy funds to light rail construction, bus patronage fell dramatically: down 46.8 million annual passengers in just 1 year — or more than twice the annual passengers to be expected on the mature Long Beach light rail line under the most optimistic of circumstances. A recent civil rights lawsuit against the MTA in Los Angeles was a representation of anger over the deterioration of basic bus services for those who most need them while so many resources have been committed to the rail programme.

In Ottawa, as in Portland and Los Angeles, improvements to basic bus service made before transitway opening had the most dramatic impacts. Ridership increased two and a half times between 1971 and 1983. Kain and Liu (1995) attribute the largest parts of Houston's increased bus ridership between 1980 and 1990 to 14% real fare reductions and an 80% increase in bus miles.

The evidence points to the need to adopt a wider systems perspective in evaluation — and by deduction in planning — than is offered by raw project ridership data. While preferential fares have inflated rail ridership, most new rail passengers were already transit users before they lost their direct bus alternative. Systemwide gains in ridership have generally been low, while highways have continued to be as congested as before. The overall loss of riders in Los Angeles tells us of the need to examine the opportunity costs of proceeding with high-cost rail construction instead of implementing the types of modest bus service improvements and fare incentives which are likely to produce the greatest improvements in systemwide transit ridership.

3. Development benefits

Urban development issues are not stressed in this study, but merit further scholarly attention. In brief, rail advocates frequently claim that rail but not bus-based projects can have positive impacts on land use patterns (for a critical discussion of this view, see Richmond 1998a), and some systems claim that such advantages have already started to arise. San Diego management points to the attractive integration of light rail into that city's urban fabric, for example. Arrington (1995) states that light rail is desirably shaping Portland's development, although his findings are challenged by local critics (e.g. Buckstein 1996, Cunneen n.d.).

Systems that have adopted bus-based improvements have also claimed land-use advantages related to their transit projects. Wohlwill (1996) finds that 54 new developments have occurred along or near Pittsburgh's East Busway since its 1983 opening, most located near busway stations. Management at OC Transpo, Ottawa, describe Canadian$ 1 billion worth of new development around the stations of their busway system. The issue seems less one of establishing whether or not light rail has succeeded in shaping development than to point out that equivalent benefits have the potential to arise from bus-based systems with similar service characteristics.

4. Capital costs

The significance of capital costs is frequently forgotten in assessing transit project performance. Federal funds have often supplied a large part of investment needs, which then don't seem like real costs from local perspectives. On a subtler level, capital costs are by their nature a one-time expense (even if ultimately the need for system renewal requires further capital expenditures) and the tendency has been to worry more about operating costs that are to continue daily into the future. Capital costs none the less represent the expenditure of real resources, and there is reason for concern that there has been a systematic pattern of failure adequately to gauge capital expenses at the time projects are proposed.

While many of the new transit systems were selected on the basis that they were 'low-cost' alternatives, subsequent cost escalation has seriously affected many of the projects. San Diego's Blue (South) Line — below budget — was an exception. While Sacramento's system came in at $176 million as against an initial forecast of $117 million, its total cost — along with that of the San Diego Blue Line — was none the less lower than for the other rail systems. Pittsburgh's light rail system was constructed close to or even under budget. With its ridership currently higher than the more extensive light rail network reconstruction in the same city, Pittsburgh's East Busway has also proved a relatively low-cost venture. Ottawa's busway system joins the list of light rail ventures that cost substantially more than planned.

Inflation has had a significant role. Beyond inflation, however, there have been many other elements of escalation. There has been a frequent failure to reflect the complexities of construction requirements, and political needs which have emerged in the process of project implementation (putting light rail in tunnel in Buffalo, for example) have added to costs. In some cases the scope of the project has changed considerably between the completion of initial planning and the date of service opening (a route extension to the main airport terminal in St. Louis, for example). In other cases, extra money has been spent after project opening to improve the system (double-tracking in Sacramento, for example).

While circumstances may vary, busway costs come in well below light rail (in Pittsburgh, for example). In the cases of both Ottawa and St. Louis initial studies found that bus options would not only require less in capital costs but also provide greater value overall. Ottawa heeded this advice. St. Louis, pursued light rail despite an unusually strong caution on the uncompetitive cost-effectiveness of light rail.

Cost — like ridership — estimates have frequently become more realistic after the decision to proceed has been made. Further work has often uncovered potential new costs and provided for more accurate projections. While operators such as Portland's Tri-Met have protested at the comparison of their initial estimates with the actual results on the basis that they did in fact keep to their ultimate funding agreement estimate to the federal government, the fact remains that the initial estimates have generally been used to make major decisions, after which alternative options (which might have seemed more attractive in comparison with more realistic projections for the chosen project) are eliminated and the focus shifted to one of achieving a funding structure and project implementation for light rail.

Capital cost profiles in Los Angeles and Portland illustrate many of the processes that have contributed to increased costs. Table 7 provides a history of capital costs for Los Angeles' Blue Line light rail. The Long Beach line was to be modelled on the San Diego Blue (South) Line experience and was heralded as a 'low-cost' answer to the corridor's transport problems. A California Department of Transportation feasibility study (Caltrans 1981) produced the first estimate of $146.6 million. Parsons Brinckerhoff *et al.* (1982), under contract to the Los Angeles County Transportation Commission (LACTC), estimated 'baseline' costs of $194 million in 1982 dollars, which translated into a range of $254–280 million when escalated to account for inflation (p. 10). This higher estimate was said to account for certain cost elements (such as right-of-way acquisition) which the consultants said Caltrans had omitted (p. 18). This was the estimate associated with Los Angeles County Transportation Commission decision making and which enabled County Supervisor Deane Dana to compare the project favourably with the 'highly expensive' Wilshire subway and claim that it would 'make maximum use of limited dollars' (LACTC meeting, 24 March 1982). The 15 April 1982 *Long Beach Press-Telegram* announced that the commission had given the 'go-ahead for the proposed $194 million train last month'.

As Rich Connell reported in the 20 October 1985 *Los Angeles Times*: 'Predictions that the Long Beach line could be built quickly for about $200 million faded soon after the line was selected. Transportation Commission officials said they found that a workable and politically acceptable system required double tracks, a downtown subway, street improvements in downtown Long Beach and other costly additions not initially anticipated'.

As of October 1983, the project was said to cost between $350 million and $400 million (*Los Angeles Times*, 16 October 1983). By the May, 1984 Draft Environmental Impact Report (LACTC 1984: I-80), the capital cost estimate was in the range of $393–561 million for a variety of options. The 11 November 1984 *Los Angeles Times* quoted then LACTC Executive Director Rick Richmond as discounting the possibility that the project would reach $1 billion in capital costs, although he admitted that 'things beyond our control' could drive costs up to somewhere between $500 million and $600 million. The June 1985 issue of LACTC's *The Rail Way* announced that the estimated cost of the project was $595 million in 1985 dollars.

Costs continued to climb as described in an article by LACTC's Edward McSpedon (McSpedon 1989). The relocation of pre-existing Southern Pacific railroad tracks led to 'numerous and substantial' complications. 'As might be well

Table 7. History of capital costs, Los Angeles Blue Line Light Rail.

	$ million
Estimate year	
1981	146.6
1982	254–280
1983	350–400
1984	393–561
1985	595
1990	887
Actual	
1996	890

expected in a case where the owner (SPTC) does not bear the burden of the construction costs, the railroad has been extremely stringent in the application of its construction approval authority, resulting in change orders to contracts and pending contractor claims totalling hundreds of thousands of dollars' (pp. 428 – 430).

LACTC was also required to provide a $50 million railroad protective liability insurance policy. 'The physical configuration of the SPTC trackage has also added to the cost of the LRT project ... At heavy traffic locations it has been necessary to grade-separate the LRT to avoid crossing conflicts with the railroad. Because the alignment of the railroad is being shifted, it has meant physical changes to each of the 37 railroad grade crossings in the midcorridor ... The cost of relocating and replacing freight railroad facilities is estimated to exceed $40 million' (pp. 430 – 431). 'Perhaps the most greatly underestimated difficulty', McSpedon says, 'concerns dealing with other right-of-way users: it was necessary to relocate, replace, remove, or protect 2300 individual utility lines' (p. 432).

Additional extra costs were imposed by demands from municipalities for grade-crossing improvements, upgrades of adjacent streets and sidewalks, installation of new street lighting, computerized traffic signals and signage, addition of landscaping, and construction of new fences and retaining walls. Owing to demands by the City of Compton, 4 miles of Southern Pacific track running through that city was removed and replaced in a corridor to the east at an additional cost of $67 million, $57 million paid by LACTC, $10 million by the City of Compton (largely through a long-term zero-interest loan from LACTC) (pp. 437 – 439).

In a letter to the author dated 3 July 1990, McSpedon declared that 'Forecast total cost is $887 million'. Following opening, a succession of change orders caused further cost escalation. For safety reasons, for example, fencing replacement at intersections was deemed necessary at $40 000 per intersection. As of February 1996, the MTA reported total construction cost of the Long Beach Blue Line at $890 million (MTA 1996a).

As McSpedon concludes, while the use of existing rail corridors 'will always be high on the list of least-undesirable alternatives' for 'the construction of a new rail transit facility in a mature, densely developed urban area with the objective of minimizing construction costs through maximum use of at-grade construction', the use of such corridors 'will probably be much more costly, time-consuming, and complex than might be presumed initially' (McSpedon 1989: 441).

Tri-Met, Portland, unhappy with the treatment of their MAX light rail line in Pickrell's (1990) report, declared in their response (Tri-Met 1990b): 'FACT: MAX

Table 8. History of capital costs, Portland Light Rail.

	$ million
Estimate year	
1978 – I	161.0
1978 – II	191.2
1980	188.0
1982	328.5
1978 – I in 1986 $s	259.2
Actual	
1986	321.0

was built on time and under budget'. Construction costs 'were $7.5 million under the budget, established in the 1982 Full Funding Agreement, *agreed to and signed by UMTA officials*' (original emphasis). According to Tri-Met staff member Bob Post (1988), furthermore, 'The 1978 estimates used in the project DEIS were not presented as the estimated construction costs. They were estimates in 1978 dollars for purposes of comparing alternatives' (p. 1).

If one goes back to the staff recommendation to the Board (Tri-Met 1978), however, one sees a heading 'Capital Costs Are Based on Firm Estimates'. Tri-Met states there that 'contingencies of 20 to 40% were added to each estimate based upon the type of work to be performed. (These contingencies provide for both final design and engineering costs.)' (p. 18). The total 1990 system capital cost is given as $191.2 million including contingencies, as against an initial $161 million estimate (Tri-Met 1990b). Pickrell uses a further estimate of $188 million, including allowances for inflation (Tri-Met 1980: 9a), as his forecast basis.

The staff recommendation did acknowledge that 'several modifications currently under consideration could affect the project costs, though not to such an extent as to change the conclusions of this report'. Several of the changes that were to in fact happen — and increase costs — are then listed.

The 1982 Full Funding Agreement with the federal government was for $328.5 million, and Tri-Met (1990) reports the actual cost as $321 million as of 'experience: 1986'. Tri-Met escalates the original $161 million estimate to $259.2 million in 1986 dollars. In Tri-Met's normalized dollars, that would make for a 24% real cost increase. Pickrell also normalizes dollars, based on 1988, and he estimates that there was a 55% increase compared with the higher 1980 projection (p. 33). As in Los Angeles, the estimates used as the basis for decision-making proved low.

The tendency to underestimate capital costs does not merely lead to the selection of less viable construction projects. It creates a bias towards capital against operating expenditures as well as contributing to a potential shortfall needed for other expenditures when more resources than expected get consumed during construction. This has been most apparent in Los Angeles, where the bus system has suffered severe decline while resources have been prioritized to light rail. Increasing bus services and holding back the level of fares can be important tools in encouraging transit ridership. The value of such measures may not be properly understood in the light of unrealistic capital estimates for major projects which make the latter seem unduly attractive compared with providing enhanced services based on existing infrastructure. This is especially the case given the frequent claim that modest capital expenditures now will be rewarded by reduced operating costs and subsidies once the new project is in operation.

5. Operating financial performance

Tri-Met's staff recommendation to proceed with light rail in Portland declared that: 'In the context of Tri-Met's entire system, light rail transit will reduce annual operating costs several million dollars compared with the other alternatives' (Tri-Met 1978: 12). This view has provided a common justification for the capital costs of rail construction. As the *Los Angeles Times*, reporting on the Blue Line light rail, wrote on 20 October 1985, 'One of the arguments made most often for the rail line is that it will be cheaper to operate because a single driver on a train can carry up to five times as many passengers as a bus'. The Tri-Met document echoed this view: 'Light rail costs less to operate largely because fewer drivers are necessary. A light rail vehicle can carry four times as many passengers as a bus'. There was even greater optimism in Sacramento: 'Light rail is a bargain. It will allow RT to operate more cost-effective transit service. With a train, an RT employee can move 10 times more passengers than with a bus' (RT 1987).

Driver costs do make up a substantially lower share of total rail costs than for bus systems, but maintenance costs tend to be substantially greater for the rail system. While irregularities in Portland's accounting procedures make the exact extent of the difference (while substantial) unclear, 1995 facilities maintenance costs accounted for 22.8% of costs for the Los Angeles Blue Line, as against only 4% of bus operating costs. While bus facilities maintenance cost was three times the cost of rail facilities maintenance, MTA buses carried 29 times as many passengers as light rail and 13 times the passenger-miles. While this may not be unacceptable *per se*, it is none the less inappropriate to make simple comparisons based on obvious characteristics such as the number of drivers required to provide a service.

In six cities — Baltimore, Buffalo, Dallas, Miami, Los Angeles, Pittsburgh — the financial performance of rail transit is clearly inferior to the average of bus system performance in the respective cities. Table 9 shows the history of operating financial performance in Los Angeles.

The first estimate, from the Blue Line Final Environmental Impact Statement (LACTC 1985: III-86), is based on attainment of forecast ridership of 54 702 weekday daily passengers in the year 2000. While the Los Angeles County Transportation Commission (LACTC) reduced ridership estimates close to opening date, in June 1990 it also increased its cost estimate for first year Blue Line operations (Padron and Associates 1990). The Southern California Rapid Transit District Budget (SCRTD 1990), set the Fiscal Year 1991 costs yet higher. For the first fiscal year of operation, 1991, operating costs came to $5 million more than this high estimate, while fare revenues only covered 10.1% of operating costs. By 1995 the farebox recovery had increased to 13.1%. In the same year, bus operations covered 33% of operating costs with fares (MTA 1996c, adjusted per MTA 1996d).

In Baltimore, rail was projected to have a farebox ratio of 69% (Mass Transit Administration 1988: 2–11) 'after the first or second year of operation'. In 1995, which followed 2 years of light rail operation, rail's farebox recovery was 26.6% according to local data (for buses the same source, which does not include all overhead elements reported in federal data for all modes together, reports a farebox recovery of 57.2%). In Buffalo, project consultants Voorhees (1976) had estimated an 84% system-wide operating and maintenance costs farebox recovery ratio (rail and bus) for 1995, given construction of the light rail system now in place. The actual

Table 9. History of financial performance, Los Angeles Blue Line Light Rail.

	Cost ($ million)	Revenue ($ million)	Farebox recovery (%)
Forecast			
1985 for 2000	12.5	8.4	67.0
1990a for 1991	27.7		
1990b for 1991	33.6		
Actual			
1991	38.6	3.9	10.1
1995	41.9	5.5	13.1

Table 10. History of farebox recovery ratios in San Diego.

	Farebox recovery (%)				
	South (Blue) Line	East (Orange) Line	Light rail system	San Diego Transit	Amarillo/ MTDB Contract 932
1982	80.7		80.7	42.1	
1985	86.2		86.2	38.9	
1990	131.0	52.7	92.9	42.1	98.6
1993	90.5	38.6	65.6	43.7	83.6
1996	91.7	38.4	65.7	47.3	81.4

system-wide farebox recovery ratio in that fiscal year was 32.6% (National Transit Database). Except for a few months, the farebox recovery ratio has been consistently worse for rail than bus service (source: data supplied to author by NFTA).

Denver's overall transit system reports a slightly (<1% increment) improved farebox recovery ratio since the recent start of light rail, but San Diego has by far the greatest achievement in the financial performance arena, with a 92% farebox recovery for its Blue (South) Line light rail in the system's 1996 fiscal year. Financial results have been disappointing on San Diego's Orange (East) Line, however, which has shown inferior financial results to the average for San Diego Transit's bus system.

In addition to San Diego's and Denver's systems, Portland, St. Louis, Sacramento and San Jose's light rail operations can be seen to have lower costs or higher farebox recovery ratios than the average of existing bus systems. Such comparisons of average performance can be misleading, however, both because they fail to pit rail performance against equivalent bus lines and since they mask the effects of structural changes to the bus system made to coordinate with rail.

The example of St. Louis illustrates the issue. Bi-State management are proud of the fact that light rail has achieved a farebox recovery ratio significantly higher than for the bus system. For the 1996 fiscal year, light rail covered 39.2% of costs from fares, compared with 20.9% for the bus system (Bi-State 1996b). The farebox ratio for the system as a whole, however, declined from 24.4% in 1993 to 23.0% in 1996 — and as can be seen, the bus farebox ratio fell further. According to an interviewed manager, it had been estimated that truncating bus routes and eliminating expresses would save $3 million per annum. However, the savings were 'reinvested back into bus service to add more feeder service and to add service evenings and weekends on buses tied into Metrolink [light rail]'.

Fares were also restructured for the inauguration of light rail, reducing fares for longer journeys. While a former bus passenger who now uses two modes (bus and rail) to complete a journey is counted twice for purposes of unlinked ridership data, they only pay their fare once. That fare would have previously been credited to the bus system. It must now be shared between bus and light rail and therefore contributes a lower share of total system costs. As one Bi-State manager put it, 'when you truncate a bus into the train they have to ride the train. Before they only had to go on one bus and go downtown. The fare is now only 10¢ more to ride two modes of transportation'.

5.1. *Bus lines with comparable markets to rail have above average performance*

The operating performance of new rail systems is invariably reported in comparison with data representing the average of bus system performance. Light rail generally runs in high-demand corridors, however, where trunk line buses typically perform better than in the system as a whole.

Gómez-Ibáñez (1985) was critical of making direct comparisons between light rail and overall bus performance in San Diego, suggesting 'the possibility that the new LRT lines 'skimmed the cream' off the older bus systems by taking over one or two of the most heavily travelled and profitable trunk bus routes and leaving the buses to operate the less profitable, but necessary, feeder services'. MTDB Director of Planning and Operations William Lieberman (1986) replied, however, that 'The operating cost per revenue passenger is actually about 12% less for LRT than for the former South Bay bus lines'. Cost per passenger-mile, he said, was 25 – 30% lower on light rail than on the former bus lines. This comparison does not, however, charge the cost of feeder bus services associated with light rail to rail.

The financial experience of Transportes Amarillo y Rosa, a private enterprise line started to replace the original line 32 (running the length of the light rail route) is an important example of the possibilities for bus services to attain high standards of financial productivity compared with light rail service. Mundle & Associates (1986) reports that:

> The Amarillo y Rosa route, in less than a year of operation, has been operating at a breakeven point [in terms of avoidable, not fully allocated, costs according to MTDB]. The first eight months of service required an investment by Southwest Coaches, Inc., totalling approximately $100,000. To the extent the route begins to turn a profit, this investment will be recouped gradually.
> At the same time, San Diego Transit and the San Diego Trolley are operating services in the corridor which receive public subsidies. Route 32, for example, required approximately $335,000 in subsidies for the first half of FY 1986. Of this amount, approximately $190,000 were avoidable costs.

A lower fare was offered than on light rail, and by 1990 the line was carrying an estimated 1.37 million annual passengers (MTDB 1990: A-2). When the private enterprise route became subject to a contract agreement with MTDB, its performance dropped. Ridership fell when fares for the bus route increased sharply to meet regional standards, removing the competitive price advantage the bus had previously enjoyed. By 1996 farebox recovery was 81.4%, still much higher than the 47.3% for San Diego Transit bus services and above the 65.7% attained by the light rail system as a whole, if below the 91.7% farebox recovery for the Blue (South) Line light rail service in that fiscal year (all measured on the same cost basis). Since light rail is located in the financially better performing corridors, it makes more sense to compare its results with high-achieving trunk bus services such as this one, rather than with the average for all buses, which includes a variety of peripheral routes with a necessarily lower financial performance.

5.2. *While trunk bus lines have above average financial performance, rail feeders are below average*

While bus lines with comparable markets to rail have above average performance, bus services established to support new rail systems exhibit very poor financial performance, although transit managements do not allocate their costs to rail. Mundle (1986: 10) notes that while the 32 line referenced above 'was one of the top performing routes in the system' while it operated all the way from downtown San Diego to the Mexican Border, 'It is now [following truncation to a light rail station] slightly below system averages for key performance indicators'. It took the restoration of the route to full corridor length to bring a return to high financial performance.

The experiences of Portland and Sacramento provide further illustrations of light rail's negative impacts on bus system financial performance. Currently, total costs and subsidies per passenger and per passenger-mile in Portland are lower for light rail than for the bus system as a whole. The results for 1996 are presented in table 11 (based on Tri-Met 1996a).

As can be seen, there is little difference in the cost of transporting a passenger by bus or rail, although rail is 24% cheaper per passenger-mile than overall bus service because the average rail passenger travels further than the average bus passenger. Rail costs less to subsidize than the bus system as a whole, in terms of both passengers and passenger-miles.

Table 12 (based on calculations from data supplied to the author by Tri-Met for 1996) shows, however, that this average includes low-performance rail feeder bus lines whose costs are attributable to rail rather than a valid element of costs to be used for comparison with those of rail. There are currently 10 routes designed to serve light rail stations. The average cost per passenger on these low-volume routes is 67% more than the cost of an average bus trip and 71% more than the cost of an average light rail trip.

There is a considerable range in the costs of radial and crosstown buses in Portland. Route 4 makes an interesting comparison with light rail because, unlike lines closer to the rail line which have been truncated, this route still operates from the same Gresham terminal as light rail and runs into downtown with local service on a route that is 23 miles south of the light rail line for most of its distance. The cost per passenger for the 4 in 1996 was 23.5% less than the average cost for all bus passengers and 21.9% less than the cost per rail passenger. Average trip length on individual routes is not currently available, although for this line it is likely to be above the average for buses as a whole given the longer route length and focus on downtown. Using the average trip length for all buses, however, the cost per passenger-mile comes to 38.5¢, essentially the same as the 38.4¢ for rail.

The 72 route is also of interest because its high volume makes it more nearly comparable with the volume of passengers carried by rail. With 12 304 average weekday riders, this one line carried 46% the number of passengers on light rail in 1996. Its cost per passenger for the 1996 fiscal year was 36.8% less than the average

Table 11. Operating financial performance, Portland Light Rail and Bus, 1996.

	Light rail	Bus
Cost per passenger ($)	1.83	1.87
Cost per passenger-mile ($)	0.38	0.50
Subsidy per passenger ($)	1.32	1.43
Subsidy per passenger-mile ($)	0.27	0.38
Farebox recovery (%)	27.8	23.8

Table 12. Costs for different types of bus service in Portland, 1996.

	Average operating cost	
	Per passenger	Per passenger-mile
Average radial/crosstown bus	1.77	0.47
4	1.43	0.39
72	1.18	0.32
Feeder bus lines	3.12	

cost for all bus passengers and 35.5% less than the cost per rail passenger. Using average bus ride length once more yields a cost per passenger-mile 17.2% less than for rail.

One sees a similar picture in Sacramento. As in Portland, the financial performance of buses taken as a whole is inferior to rail, but radial routes perform better than average while feeder buses are strikingly below average. The subsidy per passenger and per passenger-mile on these services is not only high; it must be added to the subsidy for a light rail ride to compute the true total subsidy cost of a passenger using a feeder to connect with light rail. It is this scale of subsidy that should be compared with the subsidy cost of transporting a passenger by bus alone.

From 1985 to 1996, covering the period from before Sacramento rail's start-up to recent experience, bus costs per passenger increased by a factor of 1.42 while bus costs per passenger-mile increased by a factor of 2.19 — 1.5 times as much, reflecting the shorter average trip length of buses used in light rail feeder service. These statistics show that the bus reconfiguration to complement light rail produced reduced productivity on the bus system in terms of cost per passenger-mile transported. If one removes from 1996 bus costs that part of the cost increase associated with the decrease in passenger-miles per unit cost since 1985 (1.42/2.19 times 0.59), then the adjusted bus cost per passenger-mile system-wide comes to 38¢ instead of the unadjusted 59¢, less than the 41¢ cost of light rail.

5.3. *An unfair comparison in Pittsburgh*

Light rail's lower projected operating subsidy requirements were critical to making it the preferred option for the Pittsburgh South Hills Corridor according to the evaluation conducted by DeLeuw Cather (1976). While the estimated capital costs of a busway system were lower than for light rail, operating costs for a busway system were estimated at $39.05 million, compared with only $22.61 million for light rail, both for the year 2000 (II-3, II-5). Annualized 1985 total (capital and operating) cost requirements showed a clear advantage to the light rail alternative with rail coming in at less than two-thirds of the subsidy and debt service requirements of the busway, half the subsidy per passenger-mile and less than half the subsidy per passenger (II-26).

The Port Authority of Allegheny County (PAT 1996) has produced some unusual and provocative statistics on the costs of their East Busway operation, and these are presented in table 13 (passenger-mile data based on an average trip length reported for both Busway and light rail systems of 7 miles).

As can be seen, busway buses performs substantially better than rail. The analysis is controversial because costs allocated in calculating busway journey costs are based

Table 13. Light rail and bus operating costs, Pittsburgh, 1995.

Cost per ($)	Light rail	Busway bus	Non-busway bus
Passenger	3.22	0.95	2.55
Passenger-mile	0.46	0.14	0.64

only on the time buses are on the busway and in downtown, not on the time many routes require to complete journeys from suburban origins beyond the end of the busway. By removing the feeder portion of journeys, busway performance is shown in an unduly positive light, although no differently than the way light rail is seen when the costs of (bus) feeder systems are excluded. Challenged on the reasonableness of this procedure, one Pittsburgh manager replied, ‘they don’t include the feeders for rail, so why do it for bus?’

For the Pittsburgh bus system as a whole, farebox recovery was 40.6% in 1995, so it would be reasonable to assume that for busway trips the result was somewhat better. By comparison, the farebox ratio for light rail in that fiscal year was 28.2%, making it fair to conclude that the assumed lower cost operation of light rail relative to express bus made by the consultants conducting environmental impact work was wrong.

Ottawa earns a higher farebox recovery than is typical in United States systems (farebox recoveries are generally higher in Canada than in the US), but, at 53% for 1995, it is lower than the 70% predicted to result from development of the busway system.

METRO, Houston, takes the novel step of calculating the cost per passenger-mile of car and vanpool use of HOV lanes — it was 4.0¢ in 1995 — inclusive of depreciation. The comparative depreciation-inclusive cost per passenger-mile for bus passengers was 55.3¢ (compared with the National Transit Database operating/maintenance cost which is reported at only 40¢), illustrating the relatively low cost of improving the efficiency of the use of private vehicles and leaving some disturbing questions about how one should evaluate the performance of transit projects. If improved mobility is the goal, then Houston is one of the few cities to be measuring the effectiveness with which it is being attained. The investment in the HOV lanes may not have had a significant effect on improving the financial performance of the bus system, but their overall impact on enhancing the productivity of the transport system as a whole — private and public — is notable.

6. Conclusion

Optimistic claims that new urban rail systems would increase transit ridership, reduce congestion and improve the environment while at the same time improving the financial performance of transit systems have proved incorrect in most instances evaluated here. The evidence shows that the capital funds spent have generated few benefits. While rail’s contribution to increasing transit ridership on the systems under review has been mostly minimal, changes in bus operating practices designed to accommodate rail have generally had a negative effect on the financial productivity of the transit systems concerned.

With notable exceptions in Los Angeles (Blue Line), St. Louis and San Diego (Blue South Line), ridership has in many cases fallen far short of the forecasts available to decision-makers at the time choices were made, even if in some instances it has exceeded the pre-opening estimates prepared well after decisions were made. In no case, furthermore, has new rail service been shown to have a noticeable impact upon highway congestion or air quality, although the Denver light rail system has satisfied the objective of removing from centre-city streets buses diverted to terminate at light rail stations.

Houston is the only case with documented major improvements in traffic flows and pollution. Houston presents a special case for evaluation because of heavy carpool and vanpool use of its HOV lanes alongside its bus services and management's focus on all forms of high-occupancy ridership, whether private of public, as a way of promoting mobility.

Policies such as the provision of low flat rail fares and fare-free zones have been critical in building light rail ridership. Lowering bus fares would have also induced bus ridership. The park-and-ride lots emphasized on many systems in a bid to attract 'choice' riders have encouraged driving to rail stations. Bus systems have a better chance of encouraging users to leave their cars at home because broader route structures permit the completion of a greater proportion of journeys in a single vehicle.

The issue of 'who is served' is critical, furthermore, and should not be sidestepped. With the emphasis on attracting 'choice' riders to rail, the lot of those without a choice has frequently worsened as alternative through bus services have been discontinued to encourage rail ridership. Journey times compared with those by direct bus have often increased for passengers who must now make a transfer from bus to rail. A high proportion of existing transit passengers, however, have no alternative but to continue using transit.

Despite impressive-looking gross rail ridership figures, the number of passengers attracted to rail who are 'new' to transit has in most cases been insubstantial because of the predominant presence of a captive market. Whole systems perspectives are needed to make us realise that rail impact on total public transit ridership has not only been slight, but that equal or better results could generally be obtained from relatively minor adjustments of fare levels and low cost improvements to existing bus services.

Urban development benefits are frequently claimed for light rail, but systems which have adopted bus-based capital improvements have also cited land-use-related advantages for their projects. While these issues have not been stressed here and merit further study, the important point is that equivalent benefits are likely to result if rail and bus have similar service characteristics.

In most cases capital costs have been higher than forecast, in some cases by a large margin. Inflation has played an important role in increasing capital costs, and in many cases inflation has proven higher than might reasonably have been expected when forecasts were made. A frequent failure to represent the complexities of construction requirements has often led to unanticipated cost escalation, however, as have changes to project design required for political reasons and other changes in the scale or design of the project.

While the new systems have by and large generated little new transit ridership, high capital costs were often also justified at decision-making on the basis that they would lead to reduced operating expenses. A common misunderstanding is that because trains require fewer drivers to transport a given number of passengers they cost less to operate. This fails to account for the fact that other rail system costs tend to be more expensive than for buses. Except for San Diego's South Line, rail farebox recovery has been low.

Comparing rail with the average for buses is not helpful because it doesn't evaluate the performance of equivalent types of service and does not demonstrate the impact of implementing new rail service on total system financial performance. It is more appropriate to compare rail performance to that of equivalent density bus lines and also to assess the productivity of new feeder bus lines — routes whose costs are caused by light rail but which managements never aggregate with light rail costs in assessing the rail systems' financial results.

Bus lines of the type rail service has replaced typically have much higher productivity than the bus system in general, whereas the new feeder bus routes implemented in support of rail systems invariably run at substantially lower productivity than the bus system as a whole. Reconfiguring bus systems to serve light rail therefore increases average bus-operating costs. Claims to improved efficiency made for light rail in isolation can thereby translate into negative impacts on total system financial performance when 'before and after' total system results are evaluated.

So far capital costs have not been mixed into the equation, other than to state what they were. A recent analysis by Kain and Liu (1995) does just this, however, and their findings merit noting:

> Using total cost per boarding to compare the four systems produces different rankings than when operating costs per boarding are used. This is an important finding. Both policymakers and publicly owned transit operators tend to focus on operating costs in assessing system performance, to the virtual exclusion of any consideration of capital costs or of the total cost of providing transit services. When operating costs per boarding are [alone] used as the index of system performance the San Diego Trolley's per trip costs are substantially lower than any of the bus operators. In contrast, San Diego Transit [bus system] has the lowest [fully allocated capital and operating] total cost per boarding by a significant amount. (pp. 7–14)

The sharp loss in bus ridership when fare subsidies ended and the money went to build light rail in Los Angeles instead especially demonstrates the alternative potential that has been lost by the diversion of resources to both build and operate rail. The tendency to forget about capital money that has been expended, whether from local or federal sources, is therefore inappropriate.

The major bus improvements included in this review show the ability to offer more flexible service at lower cost than rail. Ottawa's all-bus system contradicts any notion that buses cannot provide the capacity of light rail. The Pittsburgh busway runs against the notion that Americans will not ride buses to work. Miami's new busway has stimulated large increases in transit ridership in the corridor it serves. The Houston case represents a unique example of moving beyond unimodalism to promote mobility in general.

Of the light rail systems, San Diego's Blue (South) Line has shown the best performance. There is no doubt that light rail provided the rallying point for transit development in that city. The fact that political or public support for rail may not be rational from an economist's viewpoint does not detract from the fact that this support exists and that, in the end, the outcome for San Diego has been improved transit service all round — including both rail and bus service improvements. These improvements, accompanied by substantial increases in ridership, might not have materialized in the absence of rail.

One only has to switch to Pittsburgh, however, to see the counter argument to the claim that light rail is needed to catalyse changes in travel patterns.

Pittsburgh's busway system was built with the original idea that it would be convertible to rail at a later date. The success of bus operations has led management to lose interest in converting to light rail. Further busway development is being promoted instead. The moral is that higher-performance but less glamorous projects can gain local acceptability once success has been demonstrated.

Two further points need to be made concerning bus service. While the capital investments in Ottawa and Houston have been important, the most significant increases in ridership in both these instances were achieved by adding and improving ordinary bus services at relatively low cost, with the capital facilities coming later as the icing on the cake and adding relatively little extra ridership. We should not become lost in a debate over whether special rights-of-way for buses rather than trains are better, but instead consider the way resources are expended on the system as a whole. Often quite simple solutions — adding more buses, keeping fares down — can go a lot further than high-cost capital projects. To put this another way, capital expenditures on new rail systems have often removed opportunities for far more significant transit improvements by draining resources from lower-cost but more effective alternative options. Nowhere has this been more clear than in Los Angeles, where the damage to bus ridership from the diversion of resources to rail far exceeds any ultimate benefit expected to be derived from rail system development.

Second, US transit properties are behind in optimising their bus networks. There has been a failure to examine innovative new ways to provide services in an industry that is tradition-bound. A focused effort is needed to design bus systems that provide better service and operate more efficiently.

Innovation is also needed in moving beyond conventional ways of defining transit and, in particular, breaking down the barrier between private and public transport. The HOV system in Houston cannot be justified solely in terms of express bus ridership. The carpools and vanpools using the lanes make them viable, however, and while overall improvements in traffic flow occur, a facility is put in place which can speed buses without the need for improvements in bus service to justify the entire cost. It can seem a bit disquieting at first to see Houston compiling statistics combining bus and carpool passengers to measure both system throughput and cost per person served, but this practice brings home the point that what we are after is mobility, and whether it is achieved by private or public means is less important than having it achieved speedily, efficiently, and at least negative impact on the environment — all goals which the Houston approach serves.

Perhaps most importantly, we have to remove ourselves from an obsession with technology and move instead to an art that appears to have been lost in public transport: the study of needs as the starting point of inquiry. Instead of asking if a light rail project is feasible when we discover an abandoned right-of-way, we must ask who our clients are and from there proceed to study how they may best be served.

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Note

Where indicated in the text, data were provided to the author by transit agencies in tabular/spreadsheet format and are not further referenced.

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