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REFERENCE

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Potential and Cost of Commuter or Regional Rail Service

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For approximately 100 years, railroads have carried commuting passengers between home and work in nine major metropolitan areas in the United States and Canada. These operations, with one exception, have demonstrated a stability of patronage not usually present in public transit by highway. In more recent years, Toronto has instituted a new, successful, and growing commuter or regional railway system, which indicates that the potential for such service is contemporary as well as traditional. Currently, fuel consumption and currency inflation are two of the most serious national problems. Highway traffic problems are closely related. At least in theory, commuter or regional rail service can mitigate all three of the adverse effects to the mutual benefit of all concerned. The potential usefulness of such commuter or regional rail service is analyzed to determine the demographic characteristics that contribute to its effectiveness. The results are reviewed to test the viability of commuter or regional rail service in other possible areas—either additional corridors in the 10 metropolitan areas currently served or new services to cities served only by highway transit. The possible reduction in federal transit operating assistance and the ever-present need for cost-effectiveness in urban public transit require rigorous cost analysis and economic advantage to justify any commitment to new or expanded service. Labor, energy, and other cost factors are analyzed to determine the potential economic viability of such rail service vis-à-vis other transit alternatives.

Urban transportation of passengers can be provided by highway or railway. Air travel is much too energy intensive and expensive for short trips and would be physically impractical in central business districts (CBDs) without ground transportation to support it. Water transportation is not possible for most urban areas and, although still useful in unique circumstances, this mode has been abandoned as impractical in most of those cities that used it in the past.

In most cases, the primary alternatives for effective urban transportation are highway and rail. All highways function together as a single ubiquitous system, but rail transit is divided into three physically similar but institutionally different types of service and operation:

1. Heavy rail rapid transit, which is incapable of street operations;
2. Light rail, or street railway, which is best used off-street; and
3. Regional or commuter rail, which uses freight railroad track.

Regional or commuter rail passenger service is superficially the easiest to implement because it can, where feasible, use existing rights-of-way coincident with other rail activity.

The efficiency of rail rapid transit would usually commend it for all urban rail passenger service, except for the high installation cost and the requirement for high volumes of travel. Regional or commuter rail is used to avoid the high capital cost of rail rapid transit and attendant requirements for high-volume travel. Light rail can be used in place of commuter rail where freight and intercity passenger movements can be relegated to off-peak or middle-of-the-night hours. Regional or commuter rail service is most appropriate for existing suburban trackage with modest travel volumes, at least at the outer extremities.

Commuter or regional rail service is well worth consideration where it can offer faster travel than city transit service (approaching automobile competitive speeds), where it costs less to provide than automobile travel plus parking, and where it removes more than 600 passengers/peak hour (one-way) from congested streets, thus creating the equivalent of an additional traffic lane without the cost.

INVENTORY OF SERVICES

To study and evaluate the usefulness and viability of regional rail service, existing services are reviewed herein to develop their characteristics. Table 1 (1-3) delineates the regional rail routes in the United States and Canada, grouped by operator in their respective metropolitan areas. Some of the data are a bit arbitrary, as some passengers and mileage are common to more than one line or route, but the representation is generally valid.

MODES

Regional rail service is operated in four different modes, which can be combined practically into eight alternatives:

1. Conventional train operation with locomotives,
2. Locomotive-powered trains in push-pull operation,
3. Diesel self-propelled cars or trains operated without locomotives, and
4. Electric multiple-unit train operation (without locomotives).

All four modes serve passengers quite similarly, except that electric multiple-unit trains offer much faster service. It is also a more economical service for frequent operation. Otherwise, the difference among modes is largely technical, but with economic variations.

The push-pull mode is most efficient in simple point-to-point operation, particularly if two cab-control cars are employed per train to permit dropping unneeded cars during the off peak. The cab-control car enables the engineman to operate from the lead car, with the locomotive pushing the train from the rear. This avoids the necessity for turning the train at terminals. The disadvantages of push-pull operation are its loss of acceleration in peak hours with heavier trains and its loss of flexibility in shifting cars between trains to maximize peak car utilization.

The locomotive-drawn train without the push-pull feature requires inconvenient and costly yard switching operations at each end of each trip throughout the day in order to keep the locomotive on the front of the train. It is not recommended for large or frequent service operation because of these problems.

Diesel self-propelled cars are flexible in their operating pattern and offer better acceleration than a longer locomotive-powered train, without the cost of a locomotive. However, the many engines that require service and maintenance make them uneconomical for longer trains. The high cost and lower

Table 1. Commuter rail routes in the United States and Canada.

Commuter Rail Route	Line Length (miles)	Cars	Weekday Passengers
Boston: Boston and Maine Railroad			
Attleboro	32		2 470
Ayer	36		4 515
Framingham	21		1 560
Franklin	28		1 560
Hamilton-Wenham	23		3 270
Haverhill	33		7 380
Lowell	26		8 925
Rockport	35		3 265
Stoughton	19		990
Total	253	232	33 935
Chicago			
National Railroad Passenger Corp. (Amtrak): Valparaiso	44	10	900
Burlington Northern: Aurora	38	141	47 000
Chicago and Northwestern			
Geneva	36		25 560
Harvard	63		36 125
Kenosha	52		27 315
Total	151	307	89 000
Chicago, Milwaukee, St. Paul and Pacific			
Elgin	37		11 500
Walworth	74		12 500
Total	111	128	24 000
Illinois Central Gulf			
Blue Island	18		13 000
Joliet	38		800
Park Forest	30		39 000
South Chicago	12		26 000
Total	98	173	78 800
Norfolk and Western: Orland Park	23	15	1 850
Northeastern Illinois Regional Commuter Railroad Corp.			
Blue Island	16		18 120
Joliet	39		7 880
Total	55	89	26 000
Chicago South Shore and South Bend: South Bend	74	46	9 000
Chicago area total	594	909	276 550
Detroit Grand Trunk Western: Pontiac	26	30	1 500
Montreal			
Canadian National (CN)			
Cartierville	8		4 000
Duex Montagnes	29		4 035
Ste. Hilaire	21		400
Total	58	64	8 435
Canadian Pacific (CP)			
Farnham	43		300
Rigaud	40		6 000
Ste. Therese	26		250
Total	109	49	6 550
Montreal area total	167	113	14 985
New York			
Metropolitan Transit Authority			
Dover Plains	77		65 165
New Caanan[a]	41		6 000
New Haven[a]	73		55 170
Poughkeepsie	72		57 165
Total	263	766	183 500
Long Island Railroad			
Babylon	38		40 290
Brooklyn	9		61 265
Far Rockaway	23		23 305
Greenport	96		11 155
Hempstead	22		27 935
Long Beach	25		23 070
Long Island City	9		9 490
Montauk	117		6 625
Oyster Bay	35		10 720
Port Jefferson	59		32 460
Port Washington	20		32 795
West Hempstead	22		9 490
Total	275	1011	288 600
New Jersey: New Jersey Transit			
Bergen County	23		12 000
Boonton-Netcong	48		12 000
Gladstone	42		10 000
Montclair	12		1 500
Morris and Essex	35		30 000
North Jersey Coast	67		15 000
Pascack Valley	31		9 000
Port Jervis via Paterson	87		12 000
Princeton	2.5		1 000
Raritan Valley	67		10 000
Trenton (Amtrak line)	58		27 500
Total	472.5	973	140 000
New York area total	1010.5	2750	612 100
Pittsburgh			
Pittsburgh and Lake Erie: Beaver Falls	30	5	420
Baltimore and Ohio: Versailles	18	10	1 780
Pittsburgh area total	48	15	2 200
Philadelphia: Southeastern Pennsylvania Transportation Authority			
Chestnut Hill East	11		6 100
Chestnut Hill West	12		9 000
Doylestown	35		11 500
Fox Chase	11		6 300
Ivy Ridge-Manayunk	9		1 300
Norristown	18		3 600
Paoli-Downingtown	31		22 000
Trenton (Amtrak)	33		7 200
Warminster	20		5 000
West Chester-Media	28		15 000
West Trenton	33		6 750
Wilmington (Amtrak)	27		10 000
Total	68	402	103 750
San Francisco: Southern Pacific: San Jose	47	83	22 150
Toronto: Government of Ontario Transit			
Georgetown (CN)	29		4 000
Hamilton (CN)	39		17 435
Milton (CP)	33		3 500
Pickering (CN)	22		17 435
Richmond Hill (CN)	21		2 900
Toronto area total	144	221	45 270
Washington, D.C.			
Amtrak: Baltimore	40	10	1 200
Baltimore and Ohio			
Baltimore	37	10	1 350
Martinsburg	73	22	3 500
Total	110	32	4 850
Washington area total	150	42	6 050
Total U.S. and Canada	2707.5	4797	1 118 490

[a]Connecticut Transit Authority.

acceleration (than electric cars) should be considered in detail before any attempt is made to avoid electrification. Speed is a necessity as well as a two-way advantage. Speed attracts ridership more than any other single factor (other than the service itself) and augments revenue that helps to sustain the service. Speed also offers the opportunity on busy lines to reduce fleet investment and crew cost, as a single train can make more productive trips per day.

ALTERNATIVES

The following eight alternatives are derived from the list of modes given above:

1. Conventional trains (1);
2. Push-pull trains (2);
3. Self-propelled diesel trains (3);
4. Electric multiple-unit trains (4);
5. Self-propelled diesel trains, supplemented in peak hours with conventional trains (3 and 1);
6. Self-propelled diesel trains, supplemented in peak hours with push-pull trains (3 and 2);
7. Electric multiple-unit trains, supplemented in peak hours with express diesel locomotive trains (4 and 1); and
8. Electric multiple-unit trains, supplemented in peak hours with electric locomotive-powered trains (4 and 1 or 4 and 2).

Electric operation offers faster service than diesel and is free of any dependence on foreign relations for fuel supply. It also provides a more efficient alternative for short-train operation if multiple-unit cars are used. Electric operation is subject to high power demand charges, however, which suggests the use of diesel locomotives on the longest trains in peak hours that operate express over a portion of the route to minimize acceleration losses. If demand charges for power are reasonable, electric locomotives should be used to speed up service and reduce maintenance costs. The best rail horsepower attainable from a standard diesel locomotive is 2400 (1800 kW), but a straight electric can produce more than twice that, thereby greatly reducing locomotive maintanance costs. Electric locomotives, however, lack the necessary adhesion to equal multiple-unit car performance with long trains.

RESULTS

As highways have been improved and freeways constructed into CBDs, automobile travel has increased markedly in urban areas. At the same time, local street transit has languished at its 1895 schedule speed of approximately 10 mph (4, Codes 2004, 3019, 5031, 6032, 9015, p. 2-196). Suburban express lines may exceed 15 mph, but this is hardly competitive with automobile operation, even on congested freeways. Regional rail service is an exception to this limitation. Speeds range upward from 20 mph to in excess of 40 mph.

Population growth in metropolitan areas between 1927 and 1972 did not increase urban transit travel. Except for the period of gasoline and tire rationing between 1942 and 1946, urban transit travel fell sharply from 70 million passengers per weekday to a mere 20 million--a loss of 72 percent in the absolute and 85 percent per capita. Suburban transit losses were even greater on a per capita basis (5, Table 9, p. 52; Table 11, p. 55; 6).

As the result of this precipitous decline, small cities no longer have the traffic base to support viable urban transit in any form. Larger cities need higher transit speeds to win back lost riders; reduce congestion, energy, and inflationary problems; and improve center-city accessibility.

Federal aid to highways began in 1914 and reached a high level with the passage of the Interstate Highway Act in 1955. The resultant free highway system was far too strong a factor against which private capital in public transit could not effectively compete. Only with federal aid to urban transit in 1964 did transit begin to modernize effectively by building new facilities capable of scheduled speeds of 20-30 mph.

Because regional commuter railroads were not usually a corporate part of urban transit systems, they were often ignored in transit planning and funding, much to the disadvantage of all concerned. Philadelphia recognized this mistake in 1955 and tried to correct it. The state of New York bought the Long Island Railroad for the same reason. The government of Ontario undertook to provide a new commuter rail service in 1967, and now Chicago's Regional Transportation Authority has actually undertaken commuter train operation. California has contracted for San Francisco Peninsula commuter train service and for a new service from Los Angeles to Oxnard. The Southeastern Michigan Transportation Authority has assumed responsibility for commuter rail service in the Detroit area. The Massachusetts Bay Transportation Authority (MBTA) has followed the same course, and now (1983) New Jersey and Pennsylvania are undertaking actual operation of regional rail service in the Northeast Corridor, Hoboken, and Philadelphia areas.

The reasons Philadelphia began this trend, and other areas have followed, are threefold:

1. Regional rail travel did not decline as highway transit declined. The superior speed, comfort, and reliability of rail travel held most of its patronage despite increased automobile competition on new freeways. Only in cases of total rail abandonment did rail travel decline markedly. Growth in train travel was evident on other lines, although highway transit continued to decline (5,6).

2. Highway congestion was becoming intolerable in certain urban areas, with attendant undesirable side effects. A previous street railway line may have carried 8000 one-way passengers per peak hour on a major artery in 1944, but the return to unrationed motor fuel for automobiles in 1947 hampered the free movement of streetcars (and buses) and accentuated the switch from transit to automobile. The problem was that where street cars carried 8000 passengers/h in a single lane, albeit slowly, the switch of 4000 of these riders to faster automobiles required another seven highway lanes, which were simply not available in the highly concentrated center city. The switch also required costly parking facilities. These two factors drove businesses to the suburbs, where open land was available with sewer subsidies along new freeways, which facilitated automobile access, but not transit. Then the open land filled up with low-density urban sprawl, and congestion moved to the suburbs.

3. CBDs depend on accessibility for viability. Highways alone cannot provide the necessary accessibility for lack of capacity, whereas regional rail service can, as can rapid transit.

These considerations have necessitated the continuance of regional rail service. Where properly applied, it is by far the most efficient and cost-effective mode of public transportation when ridership generation and capital cost, as well as operating costs, are considered. The usual three-person multiple-unit train crew on four cars (peak) will typically produce 15 000 passenger miles of travel

Table 2. Metropolitan areas with regional (commuter) rail potential.

Area	Population[a]	Activity Factor[b]	General Riding Habit[c]	Percentage of Population Riding[d]	Weekday Passengers[e]	Cars Required[f]	No. of Possible Lines[g]
Los Angeles[h]	8 351 266	708	7.3	2.66	221 726	696[i]	6
Detroit[h]	3 970 584	412	4.3	1.55	61 508	194	5
Cleveland	1 959 880	309	3.2	1.16	22 710	71	3
St. Louis	1 882 944	293	3.0	1.10	20 743	65	3
Pittsburgh[h]	1 846 042	256	2.7	0.96	17 769	56	3
Minneapolis-St. Paul	1 704 423	235	2.4	0.88	15 060	47	2
Houston	1 677 863	344	3.6	1.29	21 701	69	3
Baltimore[h]	1 579 781	243	2.5	0.91	14 434	45	3
Dallas	1 338 684	342	3.6	1.29	17 214	55	3
Milwaukee	1 252 457	224	2.3	0.84	10 548[j]	33	3[j]
Seattle	1 238 107	202	2.1	0.76	9 403	30	2
Miami	1 219 661	149	1.5	0.56	6 833	21	1
Cincinnati	1 110 514	182	1.9	0.68	7 600	24	2
Kansas City	1 101 787	180	1.9	0.68	7 457	23	2
New Orleans	961 728	160	1.7	0.60	5 770	18	2
Phoenix	863 357	104	1.1	0.39	3 376	12	1
Indianapolis	820 259	188	2.0	0.71	5 798	18	2

Notes: Atlanta and Washington are omitted because rail rapid transit will serve the suburbs; Buffalo, Denver, Portland, and San Diego are omitted because light rail lines are planned.
Totals for some columns are as follows: weekday passengers = 469 650, cars required = 1477, and number of possible lines = 46.

[a] Populations are from UMTA (10).
[b] The activity factor is composed of twice the number of million square feet of nonresidential building space in the CBD, plus the number of CBD employees (in thousands), plus 0.000 05 times the population.
[c] The general riding habit for regional rail service in those cities that have daily service is 8.44 (annual rides per capita) in Table 1. To avoid use of New York's unique density, Chicago and Philadelphia were used to calibrate the riding habit relative to the activity factor; Chicago is 1.03 percent and Philadelphia is 1.06 percent. The weighted average is 1.04 percent.
[d] The percentage of population riding is 3.05 in the cities in Table 1 that have daily service. To avoid New York's unique density, Chicago and Philadelphia were used to calibrate the estimates for this table by weighing the two cities in proportion to their urbanized area population. The rate is 3.32 percent, reduced for each city in proportion to their respective activity factors.
[e] The weekday passengers are 1/275.7 of the annual ridership to reflect lower weekend travel.
[f] The number of cars required is based on 318 passengers/car/weekday, including spares. If bilevel cars were used, the number of passengers per car would be 483/weekday. This is based on 104 passengers (158 for bilevel cars) in each peak, plus 110 passengers on all other midday and evening trips.
[g] The possible number of lines is based on approximately 7500 passengers/line/weekday, with higher volumes in the largest cities, with fewer lines per capita, and lower volumes in the smallest cities.
[h] Existing commuter rail service may not represent the realistic potential.
[i] In 1944, Los Angeles had 8557 population/suburban rail car. This estimate equals 12 000 population/regional rail car.
[j] My site-specific calculations in 1980 found a potential of 13 500 weekday passengers on five lines, which indicates the conservative nature of these estimates.

(PMT) during a full work shift. By way of comparison, three express bus drivers will typically produce but 6200 PMT at best; i.e.,

140 crew miles move 47 four-car train miles and 93 two-car train miles = 374 car miles at 40 PMT per car mile = 15 000; all day load factor = 38.5 percent.

Three bus drivers each make two round trips, one in each peak, carrying 47x3x2 = 282 passengers; off-peak, three round trips will average 54 passengers = 162 off peak = 444 total x 14 miles = 6216; all day load factor = 48 percent (smaller vehicles facilitate higher load factors).

Regional rail service has higher infrastructure cost than suburban bus service, but the resulting amenities (stations, weather protection, wider seats and aisles, and exclusive rights-of-way) attract more passengers and revenue to pay the cost.

A complete regional rail service requires 3.8 employees of all necessary disciplines to support each car in the fleet, whereas a bus requires only 2.25 employees for peak-hour express service with little midday, evening, and weekend service [data from meeting of New Jersey Transit Corporation on October 27, 1981, in which 2880 rail employees reported, and from other sources (4, Codes 2068, 3022, 5027, 5031, and 7006, p. 2-220; 7; 8; 9, which reports on 969 rail cars, less 160 leased out to others or in dead storage)]. Even so, the rail car will serve 4000 PMT/day (100 miles x 40 PMT/car mile), while the bus can serve only 1730 (100 miles x 17.3 PMT/bus mile).

The commuter rail employee is 37 percent more efficient or productive than the suburban bus employee in the typical case. Of course, all cases are not typical.

Employee efficiency is irrelevant, however, if service quality is not equal. Where there is no adequate railway, there can be no regional railway train. Similarly, without a well-located freeway, no express bus can compete effectively for suburban commuters.

POTENTIAL

Table 1 identifies 10 metropolitan areas with regional commuter rail service. Table 2 identifies 14 additional areas with a sufficient population density and traffic congestion problems to raise the question of the usefulness, practicality, and economy of regional rail service to reduce total travel costs, energy consumption, and air pollution while increasing mobility and central city values. In several metropolitan areas, regional rail service is being considered, but its implementation can be delayed by institutional barriers and resulting misunderstandings. It is, however, much easier to remove institutional problems than it is to change the inherent laws of physics, economics, and travel behavior.

A regional railway is less likely to be successful if it is too short. Few lines of less than 10 miles appear viable. Few commuters will ride much more than 45 min in large numbers. Express service can cover 30 miles in this time span. Lines longer than 30 miles are possible, but may be more interurban than commuter in character. New York City is an exception. Because of its huge size, many lines exceed 30 miles in length.

In many suburban metropolitan areas, densities average 1500 population/mile^2, but this declines with distance in typical, but not all, cases. A population of 6000/route mile is typical. A 20-mile line would serve a population of 120 000, with a riding habit (annual rides per capita) of 18 (11), which suggests a typical weekday ridership of 7000 passengers (3500 in each direction). More heavily populated areas would experience a much heavier volume of patronage, and thinly settled areas would be less. The riding habit tends to vary inversely with the square of the distance, which also impacts on actual ridership. The 7000/weekday figure is offered as a typical example to describe the order of magnitude from which to develop cost attributes and feasibility.

APPLICABLE AREAS

Given the criterion for a suburban population of 120 000/line, but with tolerance for a wide variation, there are perhaps 14 metropolitan areas in addition to the 10 areas that now have regional rail service that might well have the potential for successful implementation, as suggested in Table 2. A concentrated center city is essential to commuter rail viability, thus making success in Tampa or Tucson unlikely [data from letter from author to J.R. Gilstrap, American Public Transit Association, Washington, D.C., June 19, 1982, and from other sources (3, Chapter 2, p. 101, and Exhibits 2.14 and 2.15; 5, p. 35)].

Areas now served by regional commuter trains generate one million passengers per weekday, which is equal to approximately 3 percent of the metropolitan area population. This percentage will vary up or down in proportion to the number of lines operated, but for a metropolitan area with two million population and eight lines (the four compass points and four lines in between), 7500 average weekday riders per line may be typical--certainly similar to the abstract example developed above (5,6). (It may be significant to note that one million weekday regional rail passengers in 10 metropolitan areas is equal to all of the nation's total commercial airline travel in approximately 140 metropolitan areas.)

Regional commuter rail service should not be expected to solve all urban problems with a single installation. Each line must have its own justification in its own area. If it is justified, it should be provided regardless of its inability to solve problems outside its limited service area. Just as all motorists do not use all freeways, everyone should not be expected to use a single rail line before it is judged to be justified.

JUSTIFICATION

What is the justification for a rail line if it does not serve a majority of the population and solve most urban problems? There are several reasons why a regional rail service might be justified:

1. It may reduce the cost of travel,
2. It may reduce the transit system deficit,
3. It may relieve unacceptable highway congestion,
4. It may save energy by reducing foreign oil imports (3,5),
5. It will probably provide a safer means of travel, and
6. It may aid in the restoration of center-city values to strengthen the city's financial support.

It is not axiomatic that the provision of regional rail service will accomplish all, or any, of these advantages, but a well-designed service in a corridor of good potential should achieve most, if not all, of them.

It was determined previously that a typical service would attract 7000 average weekday riders on a radial route. To analyze the value and viability of such a regional commuter rail passenger service, a pro-forma income statement has been constructed (Table 3). At fares found optimum by existing experience (i.e., as high as possible without deterring significant ridership), it has been found that regional rail service should serve the public at a considerably reduced deficit when compared with automobile or suburban bus operation. Foreign petroleum importation could be reduced by 8 million gal/year/line if city development is affected, and by almost 700 000 gal of oil/year on the basis of travel efficiency only. (The higher saving is due to less driving, more walking, and more concentrated development with less urban sprawl.) In addition, 867 automobile trips will be eliminated from the major urban arteries in each peak hour that would not have been eliminated with suburban bus service. This traffic reduction is equivalent to adding a lane of movement to the street in each direction and it saves many millions of dollars in construction cost, as well as adds commercial activity.

SERVICE

The above calculations are heavily dependent on the service pattern established for the convenience of the potential rider. It is usually true that 95 percent of the patronage will be center-city oriented, and that more than 20 percent of these will seek to travel in a single hour in one direction: between 7:30 and 8:30 a.m. inbound and between 4:30 and 5:30 p.m. outbound.

This demand curve requires three peak trains arriving in the city at 7:45, 8:15, and 8:45 a.m. for a typical city with typical business hours. In some cities, arrival might be one-half hour earlier. The first two trains will probably require seven and eight cars, respectively, with five cars for the last arrival. In the evening, the process will be reversed at 4:45, 5:15, and 5:45 p.m.

The balance of the demand will be spread throughout the day and evening, with inbound patronage declining as time moves on. Outbound patronage will grow throughout the day until the evening peak, after which it will decline sharply. There will be minor peaks in the opposite direction, but these will not be large enough to require or justify additional resources.

Four train crews will be required to efficiently produce attractive service for 7000 average weekday riders. Three crews will be required for the morning peak. One of these will finish in 8 h, and will be replaced by the evening crew, which also works 8 h. The other two crews will work both peaks, on duty almost 10 h, with 1 h off duty at midday. Each crew will consist of an engineman, a conductor, and an assistant. Additional (extra) assistant conductors will be required for the trains in excess of four cars to ensure full revenue collection. Automated fare collection is not cost effective for this volume of travel over these distances.

To better use paid crew time and to maximize revenue, additional train service may be prudent during the off peak to fully achieve the 7000 passenger potential explained earlier. For efficiency, outbound trains would be scheduled off peak at 8:00, 9:00, and 10:00 a.m.; 12 noon; and 1:45, 2:45, 3:45, 6:45, and 9:15 p.m. These would return inbound at 9:45, 10:45, and 11:45 a.m., and 1:45, 3:30, 4:30, 5:30, 6:30, and 8:30 p.m. In total, there would be 3 round trips by each crew, or 12 in all, on weekdays.

Table 3. Pro-forma income statement of regional (commuter) rail line operation of 22 miles that serves 7000 passengers.

Item	Cost
Annual revenue	
1 929 900 passengers at $0.25	482 475
27 018 600 passenger miles at $0.095	2 566 767
Incidental revenue	45 758
Total	3 095 000
Annual operating expenses	
Maintenance of way and structures	
50 170 560 ton-miles at $0.003	150 511
15 stations	135 000
Total	285 511
Maintenance of equipment	
4 locomotives at $30 000 plus $0.67/mile	224 359
22 cars at $10 000 plus $0.40/mile	456 368
Total	680 727
Fuel: 590 920 miles at $0.50	295 460
Train and engine crews	
6 x $90 x 1.35 fringe benefits x 313 days	228 177
11 x $90 x 1.35 fringe benefits x 254 days	339 471
3 x $90 x 1.35 fringe benefits x 59 days	21 506
Total	589 154
Station agents and janitor (4)	94 000
Train supplies and expenses at $0.46/car mile	271 823
Direct supervision (3)	135 000
Promotion and advertising	36 000
Insurance and liability	50 673
General and administrative at 19.26 percent of revenue	596 252
Incentive payments, if earned	30 400
Total	3 065 000
Net annual railway operating income	30 000

Note: The following statistics can be computed from the income statement: cost per train mile = $19.68; cost per passenger mile = $0.1134; cost per car mile = $5.19; number of employees = 68; and labor-cost ratio = 64 percent.

Saturday regional rail service usually attracts 30 percent of the weekday volume. Most contracts guarantee train crews 26 days pay per month (without premium), so weekend train service does not add to crew cost. Personal business, shopping, sporting events, plus a few downtown workers account for most of the Saturday travel market. Two of the four regular crews can be assigned to work Saturday trains, which offer six round trips during the day. No evening service is likely to be justified.

Sunday and major holidays generate little more than 10 percent of average weekday travel. One crew, not worked on Saturday, can provide three Sunday noon through afternoon round trips for recreational, personal, and sporting-event travel. No early morning or evening service can be justified.

COST

Service and cost are mutually interdependent variables. Peak-hour travel physically determines the number of rail cars and locomotives needed. Peak-hour service, to achieve the potential, must provide service every half hour (or more often, if needed) to provide the necessary capacity. Off-peak service would not be justified on a fully allocated cost basis, but such costing has no basis in practical reality or in economic theory. Off-peak labor requires little if any added payroll cost. Off-peak service increases revenue and reduces unit costs of operations as well as the cost per passenger carried. Accordingly, it is cost effective to schedule sufficient service to fully use guaranteed crew time together with the minimum amount of necessary rolling stock (otherwise idle after the morning peak). Minimal evening service permits the reduction or elimination of overtime for three (in this case) midday crews; thus, it is valuable in capturing additional revenue from passengers who could not use the trains regularly because of their hours if evening service were not offered. Electric operation usually obtains off-peak power at half price, as there is no demand charge during the off peak.

Maintenance of Way and Structures

Maintenance of way and structures has been found to cost 3 mills (1982) per gross ton mile. If a single track rail line carries 10 million gross ton miles of traffic per year, the cost per track mile for maintenance will be $30 000, a generously high figure (12). Additional cost will be incurred for regional passenger stations on a site-specific basis, as identified in Table 3. Seven employees will be required in this case.

Maintenance of Equipment

Maintenance of equipment costs consist of servicing and repairing locomotives and cars plus supporting equipment. These costs include a fixed (time variable) cost and a mileage (use variable) cost. Each locomotive is estimated to cost $30 000/year, independent of use, plus $0.67/mile for each mile operated. Electric locomotives will cost 50 percent more but will produce 100 percent more output, thereby reducing the total number of locomotives where more than one per train is required.

The fixed annual cost of passenger car maintenance is estimated at $10 000, plus $0.40/car mile for each mile operated. Self-propelled coaches will cost 33 percent more if electric and 50 percent more if diesel powered, but they will avoid locomotive costs.

These cost estimates will maintain the equipment in good condition over its full life span. Fifteen employees will be required to perform the work estimated in Table 3.

Fuel

Fuel consumption in regional railway service averages 0.5 gal/car mile, including the locomotive's share. Diesel fuel was $1/gal in 1982. If electricity is used, a rate must be negotiated with a power supplier. Any price per kilowatt hour below $0.07 will be less costly than diesel fuel.

Crew Cost

Train crews usually work a 150-mile basic day, six days/week, with proportional reimbursement for additional miles or hours beyond eight (or nine if released from duty for an hour). There is no premium paid for overtime or work beyond 40 h/week. In regional railway service, it is difficult to schedule more than 150 miles/day. Actual crew costs are tabulated in Table 3. For a weekday, 17 train employees and enginemen will be required (a dozen in four crews) for a typical schedule, and five additional assistant conductors will be required in peak hours to collect tickets in the longer trains, with one additional employee for each additional pair of coaches. It may be noted that only 25 percent of the total employees necessary to provide the service are involved in on-board train operation. With bus operation, approximately 50 percent of the employees are drivers.

Station Agents and Janitors

The on-board train employees are insufficient to make change and sell tickets to all peak-hour passengers. Exact fares would discourage too much patronage and have no value on regional railway trains. Ticket sales off the train are necessary

Table 4. Alternatives analysis of annual regional rail service costs.

	Costs ($)			
Item	Rail	Bus	Bus plus Automobile	All Automobile
Operating costs (000s)	3065	4960	5037	5115[a]
Capital amortization and interest (000s)	2750	1575	2641	3675
Total annual cost (000s)	5815	6475	7678	8790
User charges (000s)	3049	3049	5920	8790
Incidental revenues (000s)	46	15	8	0
Net public cost (000s)	2720	3411	-[b]	-[b]
Cost per passenger	3.01	3.36	3.98	4.55
Cost per passenger mile	0.215	0.240	0.284	0.325

[a] From Cupper (13). Note, these are fully allocated costs. Avoidable costs are one-half the full cost based on fuel consumption, tire wear, mileage-related servicing and repairs, added accident exposure, and accelerated depreciation.

[b] As explained in the text, a minimum highway investment of $140 million was cited as necessary for the necessary capacity to move the travel volume predicted herein. The annual cost of this investment over 40 years at 12 percent will be $14.7 million—almost twice the user charges involved. The motor fuel taxes generated for such use will approximate $177 750/year. Obviously, there can be no economic justification for highway commuting by automobile into central cities in peak hours. The highway construction cost is not included in the costs per mile cited above. Such highway construction costs equal $7.62/passenger and $0.544/passenger-mile.

for as many passengers as possible. This will require a station ticket agent in the CBD station from 7:30 a.m. to 9:30 p.m., with both shifts on duty simultaneously in the late afternoon to handle the afternoon peak. No agent is necessary on weekends. A third agent is necessary to serve passengers at the busiest suburban station and to handle monthly ticket sales by mail.

A janitor is required to serve the central station from 11:00 a.m. to 7:00 p.m., with some released time to attend to the busiest suburban station at the beginning two days of the week.

Train Supplies and Expenses

Train supplies and expenses cover the sundry costs of operating the trains, other than fuel and repairs. Seven employees, equipped with the necessary skills to make on-the-spot adjustments, will be required to furnish train supplies and to inspect the trains for safe operation. The cost of labor and supplies will be $271 823 (averaging $0.46/car mile) for the service to be provided, as shown in Table 3.

General and Administrative Expenses

Three top-level supervisors will be required to oversee the enginemen, train crews, and maintenance employees, in addition to the staff necessary to administer these functions. Accounting, claims, dispatching, payroll, promotion, and general office duties will require 15 employees and cost $500 000/year. All employee costs are based on payroll data published by the Association of American Railroads, with specific data for each classification.

Incentive

The railroad that operates a contract commuter or regional railway service must be fully reimbursed for its prudent costs, such as have been set forth in Table 3. Simple, outright full-cost reimbursement, however, is not a viable or businesslike arrangement without some incentive or penalty (for inferior performance). Accordingly, some cost for an incentive must be budgeted. A 1.5 percent additional incentive reimbursement is reasonable, based on experience, coupled with penalties for late or missed trains, cost increases above indexed levels, and losses of passenger volume in excess of peer group performance. On the likelihood that some penalty will be incurred, a 1 percent net allowance is provided in Table 3.

Total Costs of Operation

Total annual operating costs for a 22-mile, 7000 weekday passenger regional railway operation in 1982 will be approximately $3 065 000, as shown in Table 3. This will serve 1 929 900 passengers and carry them more than 27 018 600 PMT. To carry the same work load by bus (although substitute bus service is most unlikely to carry the same volume), a fleet of 49 buses would be required (at 47 seats each). These buses will average $100 000/year each in operating costs (4, Codes 1003, 3022, 3019, 5015, 5066, and 9021, p. 2-211) and will cost $0.18/passenger mile, which is 50 percent more than rail service. This difference in cost will permit operation of attractive regional rail service without the need for federal Section 5 (Urban Mass Transportation Act of 1964, as amended) operating assistance, which may be phased out. The bus service alternative is prohibitively costly.

The knowledge that other regional and commuter rail lines operate with multi-million dollar annual losses will raise the question of the accuracy of this paper, which predicts no losses at all from operations. There are at least five reasons for this difference:

1. No firemen are employed;
2. No yard crews are necessary;
3. Simple, largely unattended stations are used;
4. Rolling stock use is optimized; and
5. The proposed route is selected for its viability.

As evidence that regional rail service need not be a loss leader, for a decade the Chicago and Northwestern Railway operated its passenger service on a profitable basis, including the purchase of hundreds of new coaches. It now operates at a loss because state policy dictated subsidies to avoid fare increases that would have overcrowded highways during the past inflationary spiral.

CAPITAL INVESTMENT

Capital investment must also be considered. A fleet of four locomotives and 22 coaches, as used in this example, will require an investment of $25 million, plus servicing facilities and modest station and parking facilities equal to $2 750 000/year for capital recovery at 12 percent interest over 33 years.

The alternative capital investment for a fleet of 49 buses and a garage for them will cost $10 million--equal to $1 575 000/year. It was shown previously that bus service would cost almost $2 million more per year to operate than rail service. The added capital cost for rail is much less than the added operating cost for bus service of equivalent capacity. The same is true for automobile service. A fleet of 2917 automobiles would be required to transport the 7000 average weekday passengers likely to use train service. The annual capital cost of these automobiles would be $3 675 420, plus $2 701 860 avoidable annual cost of automobile operation and $2 412 650 for parking. There is also the automobile-associated cost of providing adequate roadway capacity, but this is so huge in a congested area that it cannot be estimated here with any accuracy. It is sufficient to point out that just one more lane of freeway for 14 miles in a radial direction in a large metropolitan area would cost

$140 million as a rough but minimal approximation.

A summary of these costs is provided in Table 4. Clearly, there appears to be a justifiable need for additional regional rail commuter service.

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Assessment of Rail Automatic Fare-Collection Equipment Performance at Two European Transit Properties

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The findings of an assessment of the performance of automatic fare-collection (AFC) equipment at two European transit properties—Tyne and Wear Transport Executive and Stuttgarter Strassenbahnen—are summarized. The properties operate in Newcastle, England, and Stuttgart, West Germany, respectively. Each has recently installed self-service ticket vendors and/or automatic gates that incorporate such new technologies as microprocessors, failure diagnostics, coin recycling, and needle printers. The analysis of the AFC equipment at each foreign property was based on a property evaluation plan (PEP) developed by Input Output Computer Services, Inc. The specific objectives of the assessment were to (a) apply the PEP to the two properties in order to assess AFC equipment performance; (b) assess any major performance differences between similar types of equipment, including equipment in use at U.S. rail transit properties; and (c) investigate innovative equipment techniques for possible use by U.S. transit properties. Analysis of performance results indicated that reliabilities for the European equipment were significantly greater than those for AFC equipment in service at Port Authority Transit Corporation, Illinois Central Gulf, Washington Metropolitan Area Transit Authority, and Metropolitan Atlanta Rapid Transit Authority. It is suggested that such state-of-the-art equipment could be used at some American transit properties. The net result could be increased maintenance productivity, enhanced unmanned station operation, and improved control of accounting data.

An assessment of automatic fare-collection (AFC) equipment performance was conducted at two European properties in accordance with procedures defined in the property evaluation plan (PEP) developed by Input Output Computer Services, Inc. (IOCS) (1). The properties examined were Tyne and Wear Transport Executive of Newcastle, England, and Stuttgarter Strassenbahnen of Stuttgart, West Germany. The assessments were conducted as part of the UMTA Rail Transit Fare Collection (RTFC) project. The UMTA RTFC project has identified a critical need for U.S. transit systems to develop improved AFC systems in order to improve operating efficiency, enhance control of receipts, and reduce labor and maintenance costs.

The two properties were selected because each has recently installed equipment that incorporates microprocessor technology, needlepoint printers, and coin recycling. Each assessment was based on data collected during an on-site survey and, where available, on transaction and failure data provided by each property.

OBJECTIVES

The objectives of the current study were threefold:

1. To apply the PEP to the two properties in order to assess AFC equipment performance;
2. To assess any major performance differences between similar types of equipment, including equipment in use at U.S. rail transit properties; and
3. To investigate innovative equipment techniques for possible use by U.S. transit properties.

DATA COLLECTION AND ANALYSIS

A data-collection plan was developed for each property in accordance with procedures described in the PEP. Each plan was designed to observe a sample of AFC equipment in service. Each plan called for data collection during peak hours for a 5-day period in July 1981.

Statistical analysis of performance measures consisted of chi-square and t-tests of proportions. The tests were used to determine whether a machine, or group of machines, exhibited a performance measure significantly different from that of another machine or group. Where significant differences did exist, failure distributions were examined in an effort to explain the differences.