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Current Paratransit and Ride-Sharing Activities

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Jitney Paratransit Services: An Appraisal of Present and Future Operations

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Jitney, one of the oldest paratransit modes and one of the few that are privately owned, is examined to ascertain its present and future viability. Land use, population, travel patterns, and transportation system characteristics are drawn from field observations and census sources for jitney corridors in Atlantic City, Chicago, and San Francisco. These corridors are prototypes of two different types of jitney operations: (a) taxicabs operating as jitneys and (b) specially licensed jitney vans. Jitney and bus operations are compared to differentiate the relative start-up and operating cost advantages of each mode. An advantage of the jitney is its low start-up cost. Corridors appraised to be suitable for jitneys are those that have a mix of intense land uses that generates a consistent demand for intracorridor travel, low rates of automobile ownership, and travel demand that is evenly dispersed spatially and temporally to reduce deadheading. However, the future viability of jitney could be endangered if fare increases instituted to provide adequate wages for drivers threaten jitney's competitiveness with publicly subsidized transit services.

Since the growth of American cities has been shaped largely by the automobile, the development of transportation modes other than the private automobile that could provide an acceptable level of service is a challenge. This is especially true in suburban areas where gross densities are far too low to permit broad geographic coverage or frequent service by conventional transit. Recently, innovative solutions have been proposed to address public transit needs in contemporary suburban America. Many of these solutions rely principally on paratransit modes, and the jitney has been increasingly proposed as a mode that might provide or augment transit services.

Jitney is a fixed-route, route-deviation service with unscheduled, variable, but frequent headways. The service is provided in a 6- to 18-passenger vehicle by a self-employed professional driver. Jitneys offer an intermediate level of service between conventional bus and demand-responsive dial-a-ride or taxi. The jitney driver is a private businessman who either owns the vehicle or leases it by the day. So there must be a sufficient level of demand if each driver is to make a profit.

It is the purpose of this paper to note the characteristics of land use and population, trips and trip makers, and competing modes and mode choices in three U.S. corridors in which jitneys have operated successfully. The costs, revenues, and profits of existing jitney services in Atlantic City, Chicago, and San Francisco are presented. This cost information will help to identify those areas in which jitney service would be feasible. A comparison is made between the cost components of jitney and bus service. These cost components are then projected into the future for the purpose of assessing the relative advantages and disadvantages of the modes in the next 20 years.

The evidence in this study suggests that jitneys can be economically viable and beneficial to the community in a limited range of corridor types. Jitneys have a potential for increasing average vehicle occupancy in corridors, especially when they are provided as a component of a family of shared-ride services, since they can divert trip makers from the automobile, increase the mobility of service-area residents, reduce travel time and dollar costs for the user (and for the nonuser through reduced congestion), increase the vehicle occupancy of local taxis, supplement regular transit in peak hours, and provide a higher, though slightly more costly, level of service than bus during off-peak hours. Jitney can, however, be disadvantageous if many riders are diverted from bus in a corridor in which bus services must be maintained to serve high travel demand. The implementation of jitney could also result in roadway congestion if jitney diverts riders primarily from conventional public transportation rather than from the automobile, if it induces a significant degree of new trips, or if roadway capacity along the route is already low. Moreover, inflationary trends, particularly in labor and fuel prices, are shrinking the profits of jitney operators. Jitney operators will be forced to raise fares while the fares of their primary competitor, the municipal transit company, can be kept low through public subsidy.

CORRIDOR LAND-USE AND POPULATION CHARACTERISTICS

Jitneys operate in highly developed corridors in which there is sufficient demand and automobile use is constrained either because of the lack of physical space to work or operate an automobile or the lack of sufficient family incomes to own and maintain an automobile.

Atlantic City

Atlantic City is a narrow development built on the Atlantic coast whose primary industry is tourism. The jitney route runs the length of the city, and the jitney corridor, which is realistically defined as a band 0.8 km (0.5 mile) on either side of the jitney's route, approximately half the width of the city. The indigenous population numbers 477 889; density is 1485 persons/km^2 (3862 persons/mile^2) but swells to about 1 million during the summer (1). In the jitney corridor, the 1970 median family income of permanent residents was approximately $10 500, and 52.3 percent of the households were without automobiles. Nearly 32 percent of the population were elderly and 21 percent were under 18 years of age, which suggests that a large proportion of the population does not drive (2).

Three major thoroughfares run the length of the city and serve distinctly different trip purposes and populations. Jitneys operate 6.7 km (4.2 miles) on Pacific Avenue to serve hotels, restaurants, churches, and small, less gaudy shops. This is located between Atlantic Avenue with its department stores and government and private offices, and the boardwalk, with its eateries, novelty shops, and amusements for tourists.

Pacific Avenue has two narrow lanes in either direction and numerous traffic signals. Parking is prohibited at all times, and illegally parked automobiles are towed away within minutes. (Overall parking is scarce in the jitney corridor except in off-street lots, where a fee of

$1.00-$1.50/day was charged in 1977.) Jitneys are better suited to this thoroughfare than conventional buses since the vehicles are shorter, narrower, more maneuverable, and able to accelerate and decelerate more rapidly.

Chicago

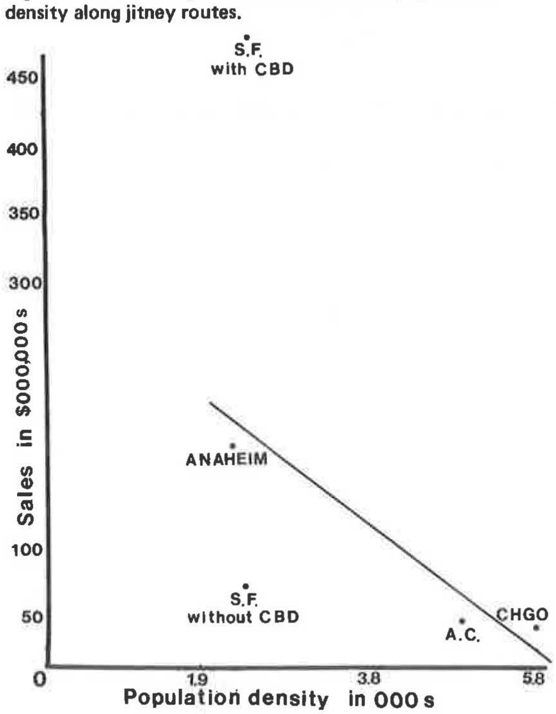
The Chicago jitney runs to within 2.4 km (1.5 miles) of the central business district (CBD). The total population, within a band 0.8 km (0.5 mile) on either side of the 7.2-km (4.5-mile) route, is 137 245 persons. The 1970 median family income in that band was $6309, and 63.7 percent of the households were without automobiles. A total of 40 percent of the corridor population was under the age of 18 or over the age of 65, and many in this group are likely to be nondrivers (2).

There is a substantial contrast in the characteristics of housing and population within the corridor. In the south end, the housing stock is significantly older: About 66 percent of the housing is older than 30 years as opposed to less than 2 percent in most northern tracts, closer to the CBD. In the past, new housing was built at greater distances from the CBD. Recently, however, urban redevelopment has brought middle-income families to the fringe of the CBD. There are moderately dense residential areas that contain three- to nine-flat apartment houses at the corridor's south end. Strip commercial development is clustered at major cross streets, approximately 0.8 km apart. Much of this residential and commercial property is deteriorating, and about 5 percent is abandoned. The vitality of this area is more critical to the viability of jitney than to its legalization since the lower capacity of this mode requires short trips to maintain high passenger turnover and sufficient revenues. Consequently, income extremes vary from $4563 in a southern tract to $11 580 in a northern CBD fringe tract (2).

Finally, there is a noticeable difference in the percentage of households that have no automobile: 45 percent and 69 percent, respectively, in the northern and southern sections. The relatively low automobile ownership in the higher-income areas to the north can be attributed to the limited parking that is available in that region, which is characterized by high-rise and townhouse development. Population density is roughly 20 000 persons/km^2 (52 000 persons/mile^2) in the north and 3378 persons/km^2 (8750 persons/mile^2) in the south. In the north, retail stores are concentrated at a modern plaza, whereas to the south, retail stores are located along (and especially at) the intersection of primary and secondary arterials (2).

For 5.6 of the 7.2 km (3.5 of the 4.5 miles) of the Chicago jitney route, King Drive is a broad parkway with four lanes in either direction. No parking is permitted on this section, so jitneys and buses need not maneuver around parked vehicles. Along the southernmost 0.62 km (1 mile) of the route (farthest from the CBD), King Drive is a four-lane street on which parallel parking is permitted.

Figure 1. Sales at major retail centers versus population density along jitney routes.



San Francisco

San Francisco jitneys operate along a 16-km (10-mile) route through the CBD, offering service from the Civic Center through the tourist, retail, and residential areas and running southeast from the CBD to the city limits. The population within the 0.8-km (0.5-mile) band of the route is 63 000, and there is considerable retail business in the corridor. The 1970 median family income in the corridor was approximately $10 500, and 66.6 percent of the jitney-corridor households had no automobiles [the latter statistic is 34 percent in the San Francisco central city and 19 percent in the San Francisco standard metropolitan statistical area (SMSA)]. Senior citizens and juveniles constitute 41 percent of the corridor population (2).

Comparison of Jitney-Corridor Land-Use Intensities

Two rough indicators are used to quantify the intensity of residential and commercial land use along the jitney corridor. For both measures, corridor width was set at 0.8 km (0.5 mile) since a frequently used rule of thumb specifies that fixed-route, nonexpress bus service draws most heavily from the residences and businesses within two to three blocks of its route. In addition, in areas of moderate- to high-intensity land use, transit routes are frequently spaced within 0.8 km of each other. Finally, the use of jitney in conjunction with some other mode—bus, for example—is discouraged by the lack of transfer privileges between jitney and other modes; potential riders must therefore walk to the route.

The first measure examined is the density of corridor population. As Figure 1 shows, the density of jitney routes varies from 2431 persons/km^2 (6300 persons/mile^2) along Mission Street in San Francisco to 4898 persons/km^2 (12 690 persons/mile^2) in Atlantic City. These densities are at least two to three times the density of most suburbs and, since trip demand is a function of population density, this suggests that jitney services may not operate successfully in the suburbs (2).

Another key factor in the suitability of jitney service for any corridor is the intensity of its commercial development. To easily quantify this, a second measure was developed from the 1967 U.S. Census of Business (3), which is a count of major retail centers along the route, the total sales, and the number of stores in each center.

As Figure 1 shows, residential and commercial development compensate for or counterbalance one another, and as population density diminishes sales at major retail centers increase. It is essential that residential and commercial users be intermixed so that trips for various purposes can originate and be completed within the corridor.

As in most market situations, jitney supply responds to demand. This can be both an asset and a liability. Jitney operators conserve their resources by not operating when demand is light; it is more difficult, however, to maintain a policy-stipulated minimum level of service. In an attempt to maintain a minimum level of service, San Francisco stipulates that drivers must not fail to work for more than 10 consecutive days without a reasonable excuse (4).

COMPETING MODES AND MODE CHOICE

Since jitney offers a significantly different level of service, it coexists and competes with a broad range of other modes. Jitney offers an intermediate level of service between conventional bus and the demand-responsive modes of dial-a-ride and taxi. Unlike conventional buses, jitneys (a) provide a seat for every passenger, (b) deviate two to three blocks from their route during periods of low demand to drop off passengers, (c) run more frequently than buses (which often results in shorter wait times for passengers), and (d) have vehicle speeds that are more comparable to automobile speeds (although speeds are slow since jitneys generally travel on congested arterials). In contrast to demand-responsive service, jitney fares are low, often comparable to bus fares, probably because of lower labor costs and the minimization of deadheading.

Atlantic City

Atlantic Avenue, the retail and office strip in Atlantic City, is serviced by conventional buses. But, since street parking is permitted, automobiles are still the predominant vehicle mode. Motels, restaurants, and other businesses that serve tourists are located along Pacific Avenue. Automobiles share the street with jitneys, but street parking is prohibited and off-street parking is available at the maximum cost of $1 for a full day or any portion of a day. Travel times for automobile users do not seem to be any shorter than those for jitney users because of the numerous and closely spaced traffic signals.

The only other mode that might operate on Pacific Avenue is taxi. In a two-day period in 1977, however, we observed only a single taxi, and even that was without passengers. Because of the linear layout of the city, most fixed-route modes deliver passengers to within 0.4 km (0.25 mile) of their destinations without a transfer. In addition, taxi rates are quite exorbitant at $0.95 for the first 0.22 km (0.14 mile) and $0.10 for each additional 0.8 km (0.5 mile), plus $0.20 for each additional passenger.

The Atlantic City boardwalk is unsuitable for the traffic of heavyweight vehicles. Lighter-weight, motorized trams shuttle tourists along the approximately 7.2-km (4.5-mile) boardwalk for a $0.60 fare. One can also engage a rolling chair—a wheeled chair pulled by a motor bike—at $3.50/half-hour.

No mode-split estimates are available for this corridor. An origin-destination (O-D) survey of Atlantic City should include tourists as well as residents to fully represent trip-making patterns since the population doubles during tourist seasons (1).

Chicago

The King Drive corridor in Chicago is serviced by four public modes: conventional bus, rail rapid transit, metered taxi, and jitney. The standard bus fee is $0.50 plus $0.10 for transfer privileges. Transfer privileges for transit users are crucial to the mode-choice decision for the trip maker who is leaving the corridor.

Metered taxis also operate in the corridor, charging $0.85 cents for the first 0.3 km (0.2 mile), plus $0.10 for each additional 0.3 km. In September 1977, when an ordinance fixed these higher fares, the previous $0.20 charge for each additional passenger was dropped as an incentive to group riding. However, taxi drivers are still legally prohibited from picking up additional passengers except at the request of the first passenger and usually refuse to carry more than four passengers.

Bus is the predominant work-trip mode in the corridor: Bus is used for 39 percent of the work trips, automobile for 31 percent, and taxi for 1 percent. In comparison with all but the most affluent and densely populated areas of the city, this is an extremely high share for taxi (5). It is our feeling that the overwhelming majority of those who reported taxi actually used jitney service.

San Francisco

San Francisco jitneys compete with automobiles, trolleys, municipal buses, and Bay Area Rapid Transit (BART). Belknap (4) has compared jitney and BART travel time and fares and concluded that, although fares are nearly the same for both modes, BART in-vehicle times are less, especially for longer trips. Jitney in-vehicle times are usually 2-2.3 times longer than those of BART. Three factors that probably result in shorter walk and wait times for jitney users are that (a) jitney stops are spaced at every block instead of every 0.8-3.2 km (0.5-2 miles), (b) jitney average headways are usually less than 4 min whereas BART headways are 12 min throughout the day, and (c) jitney stops are closer to businesses and residences, which cuts access time.

CHARACTERISTICS OF TRIPS AND TRIP MAKERS

Available information on characteristics of jitney users and the length and purpose of passenger trips is sometimes sparse. In an attempt to round out the picture, other factors are discussed here, including spacing and major traffic generators in relation to passenger-trip lengths and the types of activity centers in relation to user characteristics and trip purpose.

Chicago

Chicago's King Drive jitneys serve an area of closely spaced trip generators and varied land uses: high-rise and three-flat residences, shopping strips and malls, numerous hospitals, and park and school facilities. Trip makers were observed to use the jitney for the following trip purposes: (a) medical, (b) school, (c) shopping, (d) social, and (e) commuting to work (if both their residence and employment were in the corridor and also if the final leg of their trip was faster by jitney than by bus). Passengers were of all ages and both sexes. The average passenger-trip length on Chicago jitney is approximately 1.9 km (1.2 miles), little more than one-fourth of the total route length.

Demands per square kilometer per hour for the Chicago jitney service are given in Table 1. These estimates, and those for the Atlantic City jitney service,

Table 1. Average passenger-trip length, demand density, and productivity of Chicago and Atlantic City jitney systems.

System	Number of Jitneys in Operation	Avg Vehicle Occupancy	Passengers per Vehicle Run	Passengers per Vehicle Kilometer	Avg Passengers per Vehicle Hour	Avg Headway (min)	Passengers per Hour (all vehicles)	Demand Density (demands/km^2/h)
Atlantic City								
Morning peak	65[a]	4.0[a]	12.8[a]	1.9	23.0	1.3[a]	1498	137.8
Midday off-peak	30[a]	6.3[a]	16.3[a]	2.4	37.5	2.2[a]	1125	103.4
Evening peak	70[a]	3.9[a]	11.5[a]	1.7	20.7	0.7[a]	1449	133.2
Chicago								
Morning peak	40[b]	7.0	18	2.5	46.8	1.1[b]	1872	160.6
Morning off-peak	10[b]	4.0	10	3.5	24	5[b]	240	20.6

Notes: 1 km = 0.62 mile; 1 km^2 = 0.386 mile^2.

[a] From Urbanek and Guenther (6). [b] From observation by the authors (1976).

Table 2. Costs for Chicago King Drive jitney.

Item	Costs or Revenues ($) Per Day	Per Vehicle Kilometer	Percentage of Operating Cost	Percentage of Gross Revenues
Variable cost, fuel and oil	8-9	0.043-0.049	29	11.8
Fixed costs				
Lease of vehicle[a]	20-22	0.011-0.119	71	28.9
Chauffeur's license	0.027	0.0006	1	-
Total daily cost	28-31	0.158-0.168	100	40.7
Profit	44-47	0.25	-	60.6
Gross revenue	75	0.41	-	100

Note: 1 km = 0.62 mile.

[a] Includes vehicle licensing, capital costs, maintenance, and garaging.

are derived by using statistics observed and reported for both peak and nonpeak periods on average passenger transactions per jitney run, the average number of jitney runs per hour, and the number of jitneys in operation.

Demand peaks are strong in Chicago: 720 demands/km^2/h (1872 demands/mile^2/h) in the morning rush hours versus 92 (240) in the morning off-peak hours. Although jitney operation is most profitable when demand is steady and evenly spaced, Chicago jitney drivers have the flexibility to operate their vehicles as jitneys or taxis, and many choose to resume legal taxi operation in the off-peak periods.

Atlantic City and San Francisco

Atlantic City and San Francisco jitneys operate around the clock, shuttling tourists between hotels, restaurants, shops, and nightclubs. In addition, it has been reported that, along Pacific Avenue in Atlantic City and Mission Street in San Francisco, jitneys serve students, teachers, office workers, and local shoppers (4, 6).

Average passenger-trip lengths are not reported in the literature on Atlantic City jitneys. Based on our observations of approximately 30 passengers, most jitney passenger-trip lengths range from 1.6 to 3.2 km (1 to 2 miles) on the 3.6-km (2.25-mile) midportion of the route. Few, if any, passengers were observed to ride jitneys at the end section of the route. On the midportion, trip generators are very closely spaced so that trip purposes can be satisfied close to the trip origin.

Demand does not peak as strongly along Pacific Avenue or Mission Street as it does along King Drive in Chicago (Table 1). By using data of Urbanek and Guenther (6), demand for the Atlantic City jitney service was estimated at 576, 557, and 433 trips/km (1498, 1449, and 1125 trips/mile) during the morning peak, afternoon peak, and midday off-peak periods, respectively. Average demand for the San Francisco jitney was reported as 274 and 198 demands/km^2/h (714 and 514 demands/mile^2/h) for the morning and afternoon peak hours, respectively (4). These demand figures were derived by multiplying the number of jitneys observed in service by the average vehicle occupancy at a peak load point. This is a conservative estimate of demand since it assumes no passenger turnover.

ECONOMIC ANALYSIS

Jitney, in contrast to many other paratransit services, is still an unsubsidized, profit-making enterprise. Jitney drivers are in business for themselves as owner-operators or leasers of their vehicles.

Chicago

The fixed and variable operating costs given in Table 2 for Chicago jitney drivers were reported by the drivers in the fall of 1976. (Attempts to question owners of jitney cabs about their operations failed. Owners denied that their cabs operated jitney service.)

Jitney drivers lease their vehicles and operating permits for $20-22/day. They must also obtain a chauffeur's license at a cost of $10/year. These are their only fixed costs and make up 71 percent of their total expenditures. The driver purchases a full tank of gasoline from the cab owner before taking the cab on the road. When the cab is returned, the driver is reimbursed for the unused gasoline. In 1976, drivers estimated that they spent approximately $8-$9/day for gasoline. If they are accruing 185 km/shift (115 miles/shift), the cost of gasoline is 4-5 cents/km (7-8 cents/mile) and represents 29 percent of total costs.

Our observations revealed about 4 h of peak demand with an average of 47 jitney passengers/h and about 5 h of off-peak demand with an average of 24 passengers/h. If drivers transported about 300 passengers/day for a $0.25 fare, they would gross $75.00/day. If they worked 200 days/year, they would gross $15 000/year. (Note that all observations of King Drive jitney operations were made on clear, mild days.)

The Chicago jitney driver's net earnings are approximately $45.00/shift or, assuming 200 shifts/year,

Table 3. Costs for Atlantic City jitney.

Item	1969 Cost per Vehicle Kilometer ($)	Growth (%) Actual Annual Rate	Total Six-Year Rate	1975 Cost per Vehicle Kilometer ($)
Fuel[a]	0.022	8.5	67	0.036
Maintenance[a]	0.029	8.1	60	0.047
Insurance[a]	0.024	4.6	31	0.032
Administration[a]	0.005	6.6	47	0.008
Fees and licensing[a]	0.005	2.1	13	0.005
Medallion[a,b]	0.004	6.6	47	0.005
Capital[a,b]	0.036	6.6	47	0.053
Total without labor	0.125	-	47[c]	0.188
Gross income	0.375	-	20[d]	0.592
Profit or labor	0.249	-	8[c]	0.404

Notes: 1 km = 0.62 mile.
Costs are based on 20 000 km/year, 100 shifts/year, and 200 km/10-h shift.
[a]From Urbanek and Guenther (6).
[b]Cost per kilometer based on methods explained in text.
[c]Growth rate calculated from ratio of 1975 to 1969 costs (or profits).
[d]Growth rate is ratio of 1975 to 1969 fares.

$9000/year. In contrast to Atlantic City jitney drivers, who net 74.6 percent of their revenues, Chicago jitney drivers net slightly less—60.6 percent (Table 2). This 14 percent difference is attributable, at least in part, to the fact that Chicago jitney fares had not increased in 20 years until 1977, when fares were raised to $0.35. Atlantic City jitney fares have doubled since 1956, in correspondence with increases in the consumer price index, which has also doubled (7).

Atlantic City

In Atlantic City, jitney operators are individual entrepreneurs. They own their vehicles and their operating permits (referred to as franchises) or medallions. The limited number of operating permits are bought and sold as a jitney operator would buy and sell his or her vehicle.

From calculations based on the frequency of service and the number of jitneys known to operate on the route at a given time, an overall route speed of 16 km/h (10 mph) is estimated. Speeds are relatively slow because of the short blocks, closely spaced traffic signals, and many turning vehicles.

It is assumed that the jitney operator drives an average of 200 km (125 miles) each day and 20 000 km (12 500 miles) each year. The jitney vehicle accumulates about 161 km/day (100 miles/day) in service but is also used off the route as the driver's transportation to and from work, for lunch, and for other incidental trips. The use of the jitney vehicle off the route is one of the few operator benefits. It is a form of indirect income, like the gratis use by employees of a company automobile or transit.

Fixed and variable costs per vehicle kilometer are given in Table 3. The 1969 costs were inflated to 1975 prices by using commodity-specific consumer price indices (8). In that same period, fares increased 40 percent, from $0.25 to $0.35. Fixed costs make up 34 percent of total driver expenditures and have increased 38 percent in 6 years. The vehicle has been amortized over 10 years. Since the value of an operating permit is assumed to keep pace with inflation, its annual cost is equal to the interest that money could have earned if it had been invested.

Variable costs, which compose 66 percent of all expenditures, have increased 61 percent in the six-year period. Both vehicle maintenance and fuel costs have increased at rates greater than the general inflation rate. If this trend were to continue, it would become increasingly difficult to economically operate so many kilometers while serving so few passengers.

The total costs of operating jitney have increased 47 percent in six years (Table 2). Despite a 40 percent increase in fares (and in revenue, assuming demand has remained constant), jitney drivers' real earnings have not kept pace. If jitney is to remain viable, drivers' earnings must be comparable to wages in other occupations that require similar levels of effort and skill.

Urbanek and Guenther (6) observed an average of 11.5 transactions/jitney run during the peak period and 16.3 during the off-peak period. Overall speed is estimated at 12.5 km/h (7.8 mph) during peak periods and 16 km/h (10 mph) during off-peak periods so that 1.8 and 2.3 runs/h are made during these respective periods. Assuming 2.5 h of peak demand and 7.5 h of off-peak demand shifts, an average number of transactions per 10-h shift is 340, or 34 transactions/h. At $0.35/passenger, average daily revenue is $119.00 for the daily 200 km (125 miles) driven.

If a driver works one hundred 10-h shifts/year, as Urbanek and Guenther (6) suggest, the annual gross is $11 900. Each driver is permitted to work 273 shifts/year by jitney association rules, but demand is sharply curtailed when tourism falls off in the winter. It is not possible to accurately estimate a jitney driver's annual salary from these data. Assuming that 450 passengers/10-h shift are carried, Lea's Compendium of Paratransit (1) estimates a driver's annual net revenue at $10 500. This implies that the driver works more than 100 shifts/year.

COST COMPARISON: JITNEY VERSUS CONVENTIONAL BUS

To illustrate more clearly the different organizational structure and labor requirements of jitney and bus operations, their component costs are compared. The average bus costs used in this comparison were developed from a sample of 32 transit companies that reported their component costs to the American Public Transit Association (8). The accuracy of the comparison would be improved if costs from more jitney services could be used, but very little information is available on the economics of jitney operations, primarily because most such American operations are illegal. Even in cities where jitneys are legal, the jitney operators' associations do not keep detailed records since each operator is self-employed and works a flexible schedule. However, even though adequate data are available only for the Atlantic City jitney, the costs of van-type operations are expected to be similar elsewhere.

A comparison of cost components illustrates the relative simplicity of jitney operation, its lower start-up costs, and the lack of income security for the driver. Jitney costs per vehicle kilometer are lower than those for bus. The differences in the cost-component breakdowns are not insignificant [see Table 4 (6, 8)]; rather, they dramatically reflect the different types of organizational structure and labor used by each mode.

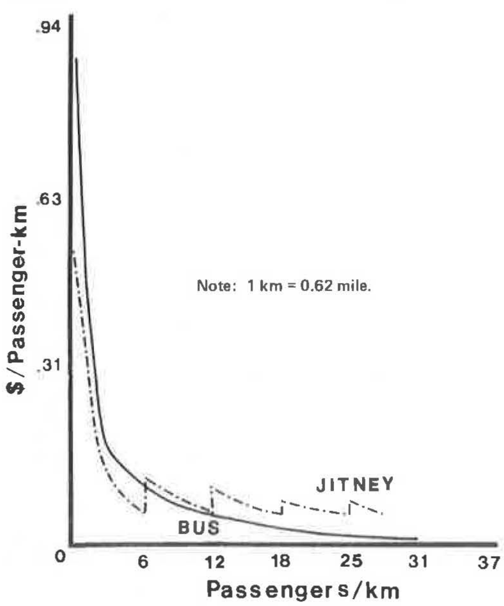
Because of the seasonal and demand-responsive nature of the jitney business, an owner-operator's vehicle accumulates approximately 20 000 km/year (12 500 miles/year). Typically, a conventional bus, which is likely to have many drivers, accumulates about 48 200 km/year (30 000 miles/year). The difference in kilometers traveled by each vehicle type will affect vehicle costs per kilometer and per year. For example, fixed costs such as annual fees, administrative expenses, and, in part, insurance decrease on a per-kilometer basis as vehicle kilometers of travel increase. On the other hand, if a vehicle is driven more kilometers, annual fuel and maintenance costs increase.

Table 4. Comparison of bus and jitney costs in 1975 dollars.

Category	Cost ($) Per Vehicle Kilometer Bus	Jitney	Per Vehicle Bus	Jitney
Fixed costs				
Insurance	0.035	0.032	1 710	637
Administration	0.148	0.008	7 140	162
Fees and licensing	0.03	0.005	1 440	113
Operating permit	-	-	-	138
Capital	0.102	0.053	4 905	1062
Subtotal	0.315	0.105	15 195	2112
Variable costs				
Fuel	0.045	0.037		
Maintenance	0.148	0.047		
Labor*	0.357	0.404		
Subtotal	0.550	0.488		
Total	0.865	0.593		

Note: 1 km = 0.62 mile.
*Costs per vehicle hour for bus and jitney are $7.19 and $7.18, respectively.

Figure 2. Costs versus vehicle load factors for bus and jitney.



Probably as a result of reduced vehicle size and capacity, annual jitney insurance, licensing, fees, and capital costs are lower than they are for bus. These fixed annualized costs are $1975 for each jitney and $17 026 for each bus in operation. Figure 2 shows that, at low passenger loads, fixed costs for jitney are lower per passenger kilometer. The savings in labor costs in a jitney operation result from the lack of guaranteed wages to operators during periods of low demand. The hourly earnings of a jitney operator are competitive with those of most bus drivers. If part-time or seasonal labor supplies were to dry up or if a jitney-type service were to be provided by union drivers, much of the cost efficiency of jitney would disappear.

It is difficult to determine a standard for comparing the labor costs of bus with the profits of jitney. Bus drivers are assured a set hourly wage for a minimum number of hours each year, whereas the jitney operator's profits depend on factors such as corridor activity, the weather, and the season. In sum, the jitney operator has no guaranteed income. In the peak season, the bus driver and the jitney operator have similar hourly earnings, but the jitney driver's annual earnings are 50 percent less (Table 4).

Comparison of gasoline and maintenance costs per kilometer is complicated by the fact that local bus costs were computed by assuming an average 19.7-km/h (12.1-mph) speed. Jitneys operate at 16 km/h (10 mph) since they characteristically operate on congested arterials in high-density corridors where traffic signals are closely spaced. Fuel and maintenance costs for local buses that travel on these same congested arterials might be expected to be slightly higher than the costs given in Table 4. Nevertheless, it seems most appropriate to compare fuel and maintenance costs on a per-vehicle-kilometer basis, fixed costs on an annual basis, and jitney operator profits and bus labor costs on a vehicle-hour basis.

Administrative costs constitute 17.1 percent of the budget of a conventional bus operation compared with only 1.2 percent of the budget of a jitney operation. This stems from the intricate scheduling of bus routes and train lines, the management of a large labor force, the planning of new services, and the acquisition of the capital equipment and maintenance facilities that are needed to guarantee a high level of transit coordination and reliability. Moreover, some of the administrative costs incurred by a bus operation are assumed by the municipal and state agencies that regulate jitneys.

It is evident in Figure 3 that variable costs per passenger kilometer are a larger cost component for jitney than for bus. In general, variable costs, which are already 66 percent of operator expenditures, can be expected to increase at a faster rate than fixed costs. This does not bode well for jitney since jitney operators may have to raise fares more rapidly than the subsidized municipal bus company, perhaps eventually pricing themselves out of the market.

SUITABLE CONDITIONS FOR JITNEY

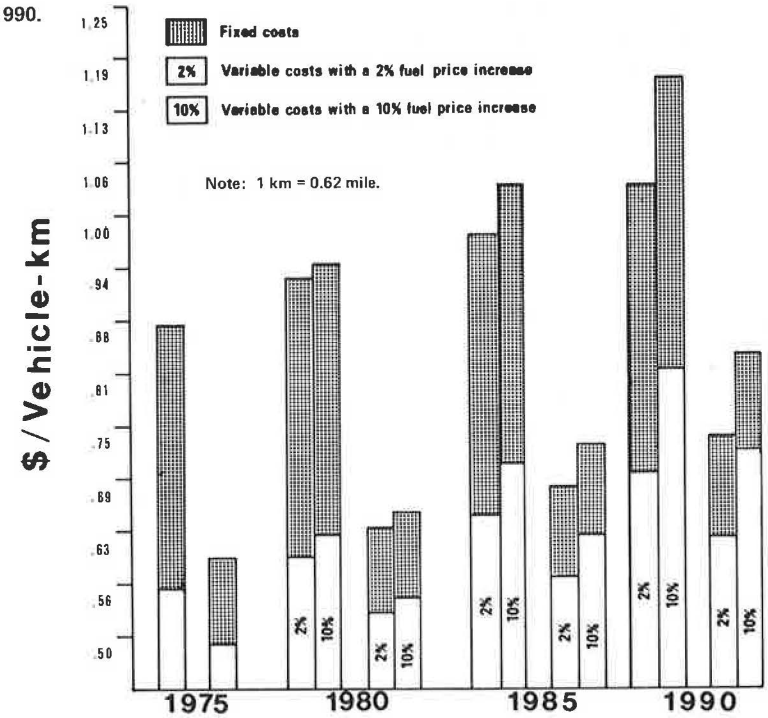
Land Use

Jitney serves a broad range of land uses: motels, tourist attractions, businesses, schools, hospitals, residences, and shopping centers. In each of these categories, the intensity of land use is high. Generally, however, it can be said that a mix of land uses increases the likelihood that trips for various purposes can be generated and satisfied within the corridor and will be distributed throughout the day. Since this land-use pattern would tend to generate travel demands that are evenly dispersed in time and space and result in fewer deadhead vehicle kilometers traveled, it is advantageous that traffic generation be evenly dispersed along the corridor. Closely spaced generators could translate into shorter passenger trips and, consequently, higher passenger turnover and more revenue per kilometer. For these reasons, jitneys are frequently successful in these types of corridors rather than in the low-density, low-trip-frequency suburban areas occasionally proposed as areas for jitney service.

User Characteristics

Jitney operations appear to be successful in corridors in which automobile ownership is low. Automobile ownership is often lower among the elderly, high-rise dwellers, visitors or tourists, and the poor. In Chicago, those too young to drive regularly use the King Drive jitney for trips to schools, parks, and shopping areas. Jitney is

Figure 3. Projected bus and jitney costs to 1990.



also advantageous for the moderately handicapped since each rider is guaranteed a seat and the first step is lower than that of a bus.

Types of Trips Served

To assume jitney profitability, passenger trips must be short—less than 3.2 km (2 miles). Though further investigations need to be made, it appears that jitney is better suited to routes of 6.4-8 km (4-5 miles) and operate most profitably in the intensely used portion of a ribbon development.

Roadway Conditions

The most heavily traveled routes are good candidates for jitneys that operate alone or in conjunction with transit during peak periods. A word of caution, however: Jitney can increase road congestion. If jitney is to be implemented, a careful investigation should be made of probable mode shifts, current and projected corridor congestion, and the feasibility of altering the operational characteristics of the roadway to facilitate jitney operation.

Most contraints on automobile use in a corridor would be to the advantage of jitney. Automobile use is often constrained in heavily used corridors. In these situations, street parking is usually restricted, off-street parking is insufficient and high priced, and various types of vehicles congest the roadway. In some intensely used corridors, a community may desire to restrict private automobiles. Fringe parking can be provided at the borders while jitneys shuttle within-corridor trip makers. If a suitable environment for jitney does not already exist, it can be created.

Economic Conditions

Because jitney offers an intermediate level of service between automobile and bus, it would be an amenity in any corridor in which user time (especially wait time) and comfort are highly valued. However, as in any operation in the private sector, the service must provide an adequate profit.

One of the advantages of jitney is low start-up costs. An owner-operator can purchase a vehicle, a license, and insurance for less than $10 000. If current prohibitions were relaxed, taxicabs could begin jitney operation almost at once. The jitney owner-operator does take risks: When demand is low, so are profits. Although the jitney operator's hourly profits are comparable to a bus driver's salary, work is occasionally seasonal or clustered in a few hours of the day. An adequate reserve force of part-time or seasonal workers (e.g., students or the semiretired) would contribute to the economic feasibility of jitney.

Jitney is not the most cost-effective choice if demand is high and buses can be filled at frequent headways. In this case, jitneys might supplement the bus service in order to reduce bus-company expenditures for labor and capital to meet the peak-hour demand.

Variable cost components, which make up approximately 13 percent of the costs of jitney operation, are all increasing at a rate greater than the general rate of inflation. If this trend continues, and especially if fuel costs increase at a rate that exceeds the inflation rate, jitney operators will be forced to increase their fares accordingly. They will then run the risk of increasing prices more rapidly than subsidized municipal bus service and eventually pricing themselves out of the market. Current jitney users may choose to give up the added comfort and convenience of the jitney and ride the bus; at the same time, some automobile users may choose to use jitney because of increased automobile operating costs.

SUMMARY

Jitney has frequently been grouped with other paratransit modes as suitable for low-density communities. Actual jitney operating experience, however, has been in high- to moderate-density areas. A major conclusion of this study is that, unlike most other forms of paratransit, jitney is best suited to corridors of high travel-demand densities—in the range of 77-154 trips/km^2/h (200-400 trips/mile^2/h). This is because jitneys by definition are low-capacity vehicles that operate on frequent, but variable, schedules. To obtain significant benefits from these low-capacity vehicles, passenger trips must be short and passenger turnover high.

Conditions that are conducive to the economic health of jitney include the high premium the user places on wait time and comfort, an adequate supply of part-time or seasonal labor, and a relaxation of the municipal codes that prohibit jitney. In the long run, a moderation of inflationary trends in fuel, maintenance, and labor would favor jitney, but serious competition from subsidized municipal transportation services can be anticipated and may be jitney's greatest challenge.

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Dial-A-Ride in Rochester: Search for a Viable Suburban Transit Alternative

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The evolution of the federally assisted demand-responsive transportation demonstration in Rochester, New York, is examined. The history of dial-a-ride in Rochester is divided into four phases: (a) the growth period, from 1973 to late 1975; (b) 1976, the transition period, during which growth of dial-a-ride service ended and reassessment began; (c) 1977, the period of drastic cutbacks; and (d) the new demonstration, which began in November 1977. The problems and achievements of the program in each of these phases are evaluated, and the implications of the Rochester experience for suburban transit services in other cities are cited.

Since August 1973, the Rochester-Genesee Regional Transportation Authority (RGRTA) has experimented with various demand-responsive transportation operating strategies in order to develop an attractive and affordable transit service in suburban areas of Rochester, New York. As in other cities, the population of metropolitan Rochester has become increasingly suburban over the past three decades and, because of the low population density and diffused trip patterns that characterize these suburban areas, conventional fixed-route bus services can generally not be efficiently provided. In the early 1970s, RGRTA viewed dial-a-ride (DAR) as a more effective means of providing transit service in low-density areas and subsequently developed plans to implement DAR services in several suburban areas of Rochester where little or no fixed-route transit service existed. Rochester is thus a prime example of a metropolitan area in which DAR was intended to play a major role in an areawide transit system. Ann Arbor, Michigan, and Santa Clara, California, are the other two major American examples thus far.

The Rochester DAR service began on August 6, 1973, in a 25-km^2 (9.6-mile^2) area within the suburban town of Greece. Service was provided between 8:15 a.m. and 5:30 p.m. on weekdays only. Approximately 51 000 people were served. The regular one-way fare was $1.00, considerably higher than fares on most other DAR operations. Additional passengers making the same trip, however, paid only 25 cents. Customers could request immediate service or make an advance reservation. In addition to DAR, a work subscription service was implemented to Kodak Park in the southeast corner of the service area, for which the weekly fare was $7.00. One month later, a subscription service to four schools began, for which weekly tickets cost $5.00. Seven small Twin Coach buses were acquired to provide the service, which was called PERT (PERsonal Transit).

Even before service in Greece began, plans were being made to expand PERT services into other suburban areas. In January 1974, only five months after PERT service started, plans were made to expand Greece services and implement DAR systems in five other suburban areas within two years. A total PERT vehicle fleet of 70 vehicles was envisioned by February 1977. Computerized dispatching was to begin in early 1975 (1).

PERT expansion plans culminated in an October 1974 application to the Urban Mass Transportation Administration (UMTA) for a $2.6 million grant to establish a 2.5-year demonstration project in which demand-responsive services would be expanded and integrated with existing fixed-route services. The application called for the implementation of computerized dispatching in early 1975, the expansion of the Greece system and the initiation of a PERT system in Irondequoit in

Figure 1. Average daily DAR ridership in Greece: 1973-1978.

September 1975, and the establishment of a PERT system in Henrietta in July 1976. Twenty small buses would be acquired to support these expansions. Details of this first demonstration are available elsewhere (2).

By 1976 several major problems were recognized, and a local transit funding crisis threatened the ability of RGRTA to assume the cost of PERT after federal demonstration funds expired the following year. To reduce PERT costs, the Henrietta expansion was postponed, service cutbacks in Greece and Irondequoit were made, and RGRTA invited competitive bidding for the operation of DAR services. RGRTA also developed a funding strategy in which the suburban towns, rather than the authority, would eventually be required to cover the local share of DAR operating deficits. A new $1.7 million UMTA demonstration grant was obtained in 1977 to test this new operating and financing strategy in two new service areas and to support the transition of Greece and Irondequoit services. The second demonstration is currently under way, and an evaluation plan (3) and an implementation report (4) have been prepared.

The operating history of the Rochester DAR system can thus be divided into four periods:

1. From initiation of service in August 1973 until late 1975 was a growth period, during which the Greece service area expanded several times and DAR ridership grew steadily for about a year and a half.
2. The year 1976 was the second, the transition, period, during which growth ceased and retrenchment began.
3. The year 1977, during which PERT services were cut back drastically to reduce their total cost and maximize their effectiveness, was the third period.
4. The new demonstration, which began in November 1977, constitutes the fourth period.

THE GROWTH YEARS

Results of DAR Operations

Many-to-many DAR service was the main feature of the PERT program during the 1973-1975 period; it accounted for about three-fourths of the vehicle hours supplied and carried about two-thirds of total PERT ridership. The Greece DAR service area and operating hours were expanded during this 2.5-year period, off-peak service was eliminated on two of the three fixed-route bus lines within the service area, and many former fixed-route passengers responded by switching to DAR. DAR was also actively promoted during this period. In addition to a general household mailing, there were two half-fare weeks and two widespread distributions of half-fare coupons.

All of these events had a positive effect on ridership, which grew from about 170 passengers/day during the first three months of service to about 490 passengers/day during 1975 (see Figure 1). During this period, the vehicle fleet was increased to 16 vehicles as 9 vehicles made by five different manufacturers were acquired. This diversity of vehicle types was purposely sought by RGRTA so that several types of minibuses could be evaluated before the planned regionwide expansion of PERT.

Passenger surveys disclosed that DAR served a diverse market. About 20 percent of its users came from households that had no automobile, whereas about 30 percent were from households that had two or more automobiles (about 5 percent of the service-area households were without an automobile, and 35 percent had two or more automobiles). Likewise, a broad cross section of age groups and occupational categories was represented.

Service quality during the 1973-1975 period was considered satisfactory but not exceptional. A customer who called for immediate service waited an average of 25 min for pickup (a parameter defined as mean system response time). The most negative DAR characteristic was uncertainty about pickup times. Pickups were an average of 6 min late, and about 40 percent of all pickups were made more than 10 min before or after the predicted pickup time. The average in-vehicle ride time was 16 min, and the average trip length (direct driving distance) was 4.5 km (2.8 miles).

DAR vehicle productivity remained relatively constant during this period despite the steadily rising demand. During 1975, when ridership leveled off at its highest point, vehicle productivity averaged about 5.2 passengers/vehicle-h. An average of 5.8 passengers/vehicle-h was achieved during the summer of 1974, but the service area was smaller than in 1975 and service quality was lower because of increased demand.

The low vehicle productivity resulted in a relatively high cost per passenger. Operating costs per vehicle hour during 1975 were about $18, about the same as costs for the regular fixed-route system. At a vehicle productivity of 5.2, an average cost per passenger of about $3.50 was generated. The average passenger fare, however, was only about $0.70 because of various discounts. The net operating deficit was thus about $2.80/passenger.

Results of Work and School Subscription Service

Unlike DAR, the two PERT subscription services changed little during the first two years, and there was little overall growth in demand for either service over time. The work subscription service underwent distinct seasonal ridership cycles, reaching about 175 passengers/day in the winter and about 125 passengers/day in the summer. School subscription service, which also had seasonal cycles, carried a modest 60-80 passengers/day.

Unlike DAR users, users of the work subscription service were generally an affluent group; 75 percent had 1975 household incomes of more than $15 000, and almost all (96 percent) came from households that had an automobile. Eighty-four percent had a driver's license, and most (72 percent) never used other transit services. They used PERT subscription service because there were more workers than automobiles in their families; 84 percent reported more household workers than automobiles and, in 66 percent of the cases, there were two or more workers per available automobile. Although work subscription users were as affluent as the general population of the service area, they were distinguished by the unusually large number of workers per automobile in their households.

The average work subscription tour carried eight passengers and took slightly less than 1 h to complete, including deadheading. Consequently, vehicle productivity averaged 6.7 passengers/vehicle-h. Revenue recovery was about 30 percent—higher than that for DAR but low by peak-period operating standards. The average direct-distance passenger trip was 5.5 km (3.4 miles) long but, because of diversions to accommodate other passengers, it required 23 min of on-board ride time. This resulted in a relatively slow average travel speed of 14.5 km/h (9 mph).

School subscription service was characterized by short, circuitous tours and high load factors. The average passenger-trip distance was only 1.7 km (1.1 miles), but the average on-board trip time was 18 min because the bus picked up or dropped off 10-15 passengers along a circular path in the area of each school served. Vehicle productivity averaged 15 passengers/vehicle-h, and the 40 percent rate of revenue recovery was slightly higher than that for the work subscription service and much higher than that for DAR.

Services for the Elderly and the Handicapped

In addition to the services described above, PERT offered several special services for the elderly and the handicapped. In January 1974, PERT began to operate weekly "shoppers' special" bus trips from housing developments for the elderly to a major shopping mall. Service to another mall began shortly afterward. Together, these services carried 175 passengers/week. In one case, a grocery store paid the entire cost of the service and no fare was charged; a 25-cent fare was charged for the other service. These two services were well patronized, and vehicle productivity averaged about 21 passengers/vehicle-h.

PERT service for the handicapped began in June 1975, after the introduction of three new vehicles equipped with wheelchair lifts. This service transported handicapped persons from the Greece service area and any part of the adjacent town of Irondequoit to a dozen locations, principally health and social service facilities in and near the Rochester central business district (CBD). A $2.00 fare was charged, and a one-day advance reservation was required.

PERT service for the handicapped was used little during its first year of operation, averaging only about three passengers a day. A few individuals accounted for most of this demand, and buses rarely served more than one trip at a time. In addition, buses almost always had to deadhead between the service area and downtown destinations, and thus vehicle productivity averaged only about 1 trip/vehicle-h. The cost per trip was about $18.

Problems

Although PERT was generally perceived favorably during its first two years, several serious problems emerged during this time that resulted in a redirection of PERT in 1976. These problems strengthened the position taken by local officials who opposed the large regionwide role envisioned for DAR.

Operating Efficiency

PERT's most serious problem was high costs. Contrary to what was predicted before the initiation of service, fares were covering only a fraction of operating costs. These unfulfilled expectations resulted from erroneous estimates of demand, vehicle operating speeds, and hourly operating costs. DAR demand density was estimated at 3-4.6 demands/km^2/h (8-12 demands/mile^2/h); average vehicle operating speed was predicted to be around 24 km/h (15 mph). Based on these assumptions, DAR vehicle productivity was projected as 10 passengers/vehicle-h or more (1). In addition, in the fiscal year that preceded the implementation of DAR service, Regional Transit Service (RTS) operating costs per year were $13.00/vehicle-h. Coupled with the projected DAR vehicle productivity, this would have resulted in a cost of $1.00-$1.25/passenger, which would have been covered largely by passenger fares.

Actual DAR demand density rose to only about 0.7 demand/km^2/h (2 demands/mile^2/h), average vehicle operating speed was about 16 km/h (11 mph), and RTS operating costs escalated rapidly, increasing by about 50 percent between 1972 and 1975. The net result was an average DAR cost of $3.00-$3.50/passenger rather than the $1.00-$1.25 expected in 1972.

These conditions created a situation in which the cost of carrying DAR passengers slightly exceeded what a regular taxi would charge for comparable trips. Although the typical exclusive-ride taxi had a lower vehicle productivity than DAR, since there was no shared riding, its hourly operating costs were about half of PERT's and resulted in slightly lower costs per passenger.

Likewise, the work subscription service attracted less demand than anticipated and consequently had higher costs per passenger than expected. This service carried about 1 percent of Kodak Park workers who lived in the PERT service area, and RTS fixed-route buses carried about 6 percent. Thus, each PERT bus had to serve a large area, which decreased vehicle productivity and increased passenger travel time.

Route Rationalization

A second major problem was the elimination of off-peak fixed-route transit services within the PERT service area in favor of DAR, which now served the former fixed-route demand. This policy was known as route rationalization. The two routes eliminated had off-peak headways of 40 and 45 min and carried about 260 passengers during the time that service was eliminated. Route rationalization was based on the assumption that DAR could carry ridership more efficiently than the fixed routes could and would provide high service quality. Almost all of the fixed-route passengers, however, traveled to destinations outside the PERT service area and were thus required to use DAR and then transfer to a fixed-route bus at the edge of the service area.

Route rationalization was unsuccessful for three reasons:

1. Only about a third of the former fixed-route passengers switched to DAR. The remainder either stopped making their trip, switched to fixed-route buses during the peak period when service continued to operate, or switched to nontransit modes. All of these alternatives were undesirable from the transit operator's perspective.
2. The increase in DAR operating costs attributable to route rationalization slightly exceeded the savings by RTS in eliminating off-peak service on the two route segments, which resulted in a net increase in total operating costs.
3. The fixed transit routes had been in place for years, and transit-riding habits had formed around them. A survey of passengers who transferred between DAR and fixed-route buses disclosed a strong preference for traveling by fixed-route bus alone rather than using DAR. This preference was expressed even by passengers who had previously had to transfer between fixed routes. Users felt that the fixed-route buses were both faster and more reliable; the long and unpredictable wait times encountered in transferring from fixed-route buses to DAR supported this perception.

TRANSITION PERIOD

Planned Changes in PERT System

In an effort to correct the problems discussed above, several major changes were planned for 1976. These included modifications to the Greece PERT system, as well as the implementation in Irondequoit of a new set of PERT services that would be designed to avoid the mistakes made in Greece.

Computerized Scheduling and Dispatching

From the time the PERT system was first conceived, computerized scheduling and dispatching of DAR were seen as an integral part of the system. Computerization was viewed as a way to optimize vehicle tours and thereby improve vehicle productivity and service quality. In addition, for DAR systems with more than about 10 vehicles, computerization could improve the overall manageability of the system and lower control-room costs by reducing labor requirements. In 1975, approximately 8 vehicles were being used to provide daytime DAR service in Greece, and the single manual dispatcher would have been unable to dispatch effectively if the operating fleet increased further. Testing of the computerized dispatching system began in Greece in September 1975, and the system was fully operational in June 1976.

PERT Services in Irondequoit

PERT services in Irondequoit were first envisioned as consisting of a large DAR service area and subsidiary subscription services to major suburban work sites, as in Greece. But when detailed planning began in 1975, the original plans were radically altered in response to the results of the Greece experience.

Unlike Greece, Irondequoit was served by a relatively extensive fixed-route bus network; eight bus routes traversed the area for which DAR service was originally contemplated. However, the fixed-route system inadequately served travel patterns within Irondequoit; most transit passengers traveled to points outside Irondequoit, such as the Rochester CBD. As in Greece, PERT was intended to serve these local trips, but RGRTA wanted to avoid the problems associated with replacing fixed-route services with DAR as well as the high DAR costs experienced in Greece.

Consequently, the Irondequoit PERT service package implemented in April 1976 focused on adjusting and supplementing the existing fixed-route system rather than substituting a new set of services for it. DAR was established in an 18-km^2 (6.9-$mile^2$) service area that had a population of 33 000—less than half the size of the Greece DAR service area or the originally planned Irondequoit service area [the Irondequoit DAR service area was expanded in September 1976 to 22 km^2 (8.6 $mile^2$)]. Furthermore, service was eliminated on only one segment of a fixed-route line, and this route segment paralleled another fixed-route line 0.4 km (0.25 mile) away (on two other segments, RTS fixed-route service was eliminated but a PERT fixed route was implemented on the same streets). Thus, only minimal coverage by fixed-route transit service was lost.

The other PERT service innovations in Irondequoit were two route-deviation services, a loop shuttle, checkpoint subscription services, and minor scheduling changes on fixed-route services. During the midday and early evening periods, two local fixed-route services were combined into the Summerville Shuttle, and three route-deviation locations were added that were served on request for an additional 10 cents. A second route-deviation service, Urban PERT, operated after 9:00 p.m. in a wedge-shaped area extending from the Rochester CBD into Irondequoit. Within this area, buses that operated on established fixed-route lines would deviate to any location for an additional 75 cents. The loop shuttle was a one-way, fixed-route loop that operated at midday in central Irondequoit, connecting Irondequoit's major activity centers. Work subscription service served nearby Kodak Park and the Xerox Corporation in the more distant town of Webster. In contrast to what was done in Greece, however, pickups and drop-offs were made only at selected checkpoints to increase vehicle productivity and decrease travel time. A subscription service to the Association of Retarded Children also operated with checkpoints. Finally, PERT took over the operation of two peak-period fixed-route services and changed their schedules slightly for better coordination with the Kodak Park work-shift times served by the two routes.

Dew-Ridge Shuttle and DAR Zonal Fare System

In September 1976, two major service changes were made to improve PERT reliability and vehicle productivity. In Greece, RGRTA established the Dew-Ridge Shuttle, which operated along streets where fixed-route service had been eliminated. Although passengers traveling outside the service area still had to transfer between the Dew-Ridge Shuttle and RTS fixed-route buses, schedules were coordinated. In addition, unlike the previous fixed-route alignment, the shuttle provided a direct fixed-route link between the service area's major population center and largest shopping malls.

In addition to its fixed-route component, the Dew-Ridge Shuttle operated in a point-deviation mode in the northern quarter of the former DAR service area. Pickups and drop-offs were made anywhere within this area for a 75-cent fare (a 30-cent fare was charged along the shuttle's fixed-route component as well as to one of the four checkpoints within the point-deviation area). The Greece DAR service area was reduced during the midday period when the Dew-Ridge Shuttle operated, and this resulted in shorter trips that could be more efficiently served by DAR. The Dew-Ridge Shuttle was to serve longer trips along the two former fixed-route corridors.

The second innovation implemented in September 1976 was a DAR zonal fare system. Before this time, the regular DAR fare was \$1.00 and there was a \$0.05 transfer charge between service areas. In September 1976, the Greece and Irondequoit DAR service areas were integrated and divided into six zones. The base fare was \$0.75 and increased by \$0.50 with each zone boundary crossed, up to a maximum of \$2.75. This fare policy was intended to increase overall DAR revenue recovery, encourage longer trips on the Dew-Ridge Shuttle or RTS fixed-route buses, and make DAR fares correspond more closely to the actual cost of different types of trips.

Restructured Service for the Handicapped

During its first year of operation, PERT service for the handicapped carried few passengers and was very expensive to operate. As a result, in October 1976 it was modified in four ways:

1. The service began to follow a general schedule in which buses would only leave the Greece and Irondequoit areas around 9:00 a.m., 11:00 a.m., and 2:00 p.m., and return from the CBD at 10:00 a.m., 12:00 noon, and

3:00 p.m. Load factors and productivity increased as passengers were grouped together.

2. The fare was lowered from $2.00 to $0.50 to broaden the appeal of the service.

3. The service began to serve customers who resided in the wedge between the Greece and Irondequoit suburbs and the Rochester CBD since the buses had to pass through that area anyway.

4. Probably most important, PERT staff started to work with social service agencies in defining the transportation needs of the local handicapped by identifying individuals who could most benefit from the service and resolving operational problems.

New Problems

Vehicle Breakdowns

Unfortunately, several unforeseen problems minimized the effects of the planned 1976 service improvements. Foremost was the high incidence of vehicle breakdowns in the winter of 1975-1976. Between November 1975 and February 1977, the average PERT vehicle was out of service 33 percent of the time. Since the PERT spare factor (total vehicles ÷ peak vehicle requirement) was between 1.23 and 1.29 during most of that period, there was a continual shortage of vehicles. In fact, promotion of the modified service for the handicapped had to be postponed until 1977 because there was no assurance that any of the four vehicles that had wheelchair lifts would be functioning.

There were several reasons for the poor vehicle performance during this period. Several types of vehicles were used. Except for one converted van, all were new models developed in response to the anticipated growth in the demand for small transit buses during the 1970s. Several of the models used in Rochester are no longer even manufactured. The diversity of vehicle types aggravated the problems. RTS, which was responsible for PERT maintenance, found it prohibitively expensive to stock a complete spare-parts inventory for each type of vehicle. In addition, RTS mechanics had to become familiar with a variety of mostly gasoline-powered small buses after having been accustomed to large diesel buses.

Computer-Related Disruptions

The implementation of computerized dispatching, which began in September 1975, was a slow process marked by many setbacks. Computerized dispatching was not functioning on a full-time basis until June 1976 and, during the eight-month transition period, DAR service was often disrupted by computer-related problems. These disruptions compounded the operational difficulties caused by vehicle breakdowns during the same period. The major computer problems encountered included a delay in the delivery of the required communications equipment, failures of computer hardware and telephone lines, excessive computer-system response times, errors in street-network and software coding, and deficiencies in the scheduling algorithm.

Management Disputes

The effectiveness of PERT was hindered not only by operational problems but also by organizational troubles. These problems began when RGRTA conceived the PERT system and were magnified during 1976.

When the PERT system was planned in 1972 and 1973, RGRTA perceived DAR as a means of expanding transit into an untapped suburban market and boosting transit ridership. In addition, DAR would substitute for unprofitable off-peak fixed-route services, thereby improving RTS operating efficiency. RTS upper management, seeing DAR as an unaffordable expansion technique that would deprive the existing fixed-route system of necessary capital improvement funds, disputed these claims. Thus, although RTS officially operated the PERT system, its upper management gave the service no active support. They did not want to be blamed for failing to achieve the goals set by RGRTA, which they felt were unrealistic. RTS viewed PERT as an autonomous organization under RGRTA to which RTS supplied drivers and vehicles.

Operating Results in 1976

DAR Services

Vehicle breakdowns had the most pronounced effect on DAR services. The subscription and fixed-route services were given first priority, and DAR service operated with a reduced fleet. Computerization problems further worsened the DAR situation. In Greece, during the summer of 1976, about 45 percent of pickups were made within 10 min of the predicted pickup time in comparison with 60 percent in 1975. Average ride time also increased by 25 percent. The quality of service in Irondequoit was somewhat better, but this resulted from lower overall demand and a smaller service area.

The decrease in service levels caused DAR ridership in Greece to decline by 21 percent, to about 390 passengers/day. However, the number of persons requesting service dropped by only 11 percent, and the additional 10 percent decrease resulted from a dramatic increase in no-shows and cancellations. In other words, about half of the lost riders totally rejected DAR, whereas the other half tried to use the service but, out of frustration, canceled or did not show. In September 1976, the Dew-Ridge Shuttle captured about a third of total DAR ridership, and daily DAR ridership dropped to 260 passengers.

The decrease in DAR ridership also caused DAR vehicle productivity to drop, and it hovered around 4 passengers/vehicle-h during most of 1976. Although the Dew-Ridge Shuttle had a vehicle productivity of about 9 passengers/vehicle-h, overall PERT vehicle productivity and revenue recovery stayed about the same as in 1975. Operating costs continued to rise, however, which caused the net deficit to grow.

Irondequoit Operations

Most of the Irondequoit services attracted little new transit demand. DAR demand density reached 0.4 passenger/km^2/h (1.1 passengers/$mile^2$/h), half of that achieved in Greece during 1975. This difference occurred because more residents of Irondequoit had access to fixed-route buses whereas DAR was the only off-peak transit available to most residents of Greece. The low demand density in Irondequoit resulted in a vehicle productivity of about 3.5 passengers/vehicle-h. As costs rose to about $25/vehicle-h in late 1976, the cost per trip exceeded $7.00.

The other off-peak Irondequoit services were even less successful in attracting new patrons. The loop bus averaged only 37 passengers/day for a vehicle productivity of 4.7 passengers/vehicle-h. The Summerville Shuttle carried about 135 passengers/day, but this represented only about 45 percent of former ridership on the two RTS fixed routes the shuttle replaced. According to a telephone survey of these former users, about 35 percent switched to RTS buses during the peak period or walked to another RTS bus, about 15 percent switched to automobile travel, and 5 percent switched to DAR.

The Summerville Shuttle's route-deviation option was rarely used; only two deviation requests a day were made. Urban PERT had even fewer route-deviation requests.

The Irondequoit subscription services attracted an average of 10 passengers/vehicle tour. This was higher than in Greece but resulted in lower revenue recovery because of the lower fares for checkpoint subscription service.

CUTBACK PERIOD

Transit Funding Crisis

In both 1976 and 1977, RGRTA struggled continually to obtain sufficient funding to maintain public transit services in Rochester. Fixed-route fares were increased in May 1976, and service cutbacks were necessary. During this crisis period, the DAR system was openly criticized because of its low ridership and high operating costs relative to the basic fixed-route system. The local press gave considerable attention to the criticism and, by the fall of 1976, even the acting RGRTA director was openly pessimistic about the future of DAR.

Service Cutbacks and Fare Increases

In October 1976, the newly appointed RGRTA executive director began to thoroughly reassess PERT services. The first steps taken were to eliminate the least effective services, decrease operating hours for the remaining services, and raise fares to reduce costs. Urban PERT, the loop bus, and the Summerville Shuttle were cut because they attracted little new transit demand, and the work subscription services were eliminated because of what was judged to be poor revenue recovery by peak-period standards. DAR service hours were reduced to 8:00 a.m. to 3:00 p.m. on weekdays only, and the zonal fare system was replaced by a flat fare of $1.25. This not only raised revenue recovery but also greatly simplified the complex fare structure, which had confused both customers and DAR personnel.

These changes, which were mostly made in January 1977, lowered annual PERT operating costs from $1.1 million/year (in late 1976) to $300 000. The remaining PERT services could then be supported by demonstration funding through October 1977, which gave RGRTA another four months to develop a long-range solution to PERT's funding problems.

Dial-a-Ride and Service for the Handicapped

The problem of vehicle breakdowns was solved by the decreased vehicle requirements and by replacing seven of the least reliable vehicles with new vans in 1977. Three of these vans were equipped with wheelchair lifts, which allowed the revamped PERT service for the handicapped to begin. Ridership increased quickly during February and March 1977. About 40 passengers/day have been carried since April of that year; 25 percent of these have been confined to wheelchairs. Vehicle productivity has increased to about 2.5 passenger trips/vehicle-h, which is rather high considering the long trip distances and low vehicle density involved.

DAR ridership decreased to about 150 passengers/day in Greece and 55 passengers/day in Irondequoit, which roughly corresponds to the ridership that rode before 3:00 p.m. prior to January. Ridership remained steady until early 1978, when it rose suddenly to about 180 passengers/day in Greece and 80 passengers/day in Irondequoit. The quality of service rose in 1977 to a higher level than in any previous time period, including the 1975 period in Greece before excessive vehicle breakdowns began. The average length of time between a request for service and pickup was 17 min, and about 65 percent of the pickups were made within 10 min of the predicted pickup time. But, since demand and vehicle densities were substantially lower than in 1975, it is unclear to what extent the improvement in service quality is attributable to these factors or to computerized dispatching.

Although the total cost of PERT dropped sharply in 1977, DAR unit costs remained high. DAR vehicle productivity in 1977 was about 4 passengers/vehicle-h in Greece and 3 passengers/vehicle-h in Irondequoit, which resulted in costs per passenger of $6-$8. The increase in DAR ridership in 1978 reduced costs per passenger to about $5 in Greece and $6 in Irondequoit.

NEW DEMONSTRATION

Strategies

As the initial demonstration approached its October 1977 termination, RGRTA considered alternative strategies for retaining DAR services in Greece and Irondequoit and continuing the expansion of transit service into suburban areas. RGRTA was financially constrained, however, and its first priority was to expand the service for the handicapped to a regionwide operation. RGRTA allocated $150 000 for the 1977/78 fiscal year to operate this expanded service; when matched with funds provided by Section 5 of the National Mass Transportation Assistance Act of 1974, these funds would pay for about eight buses in weekday daytime service. No additional funds were appropriated for DAR.

RGRTA also recognized that current DAR costs were unacceptable and would have to decrease considerably if DAR was to be a viable transit alternative. RGRTA developed a new strategy for both lowering total DAR costs and limiting the RGRTA share of the operating deficit. To achieve the lowest possible cost, DAR services would be provided by an operator selected through competitive bidding. In addition, the suburban towns in which services were provided would be responsible for funding the local share of the operating deficit.

In August 1977, RGRTA applied for a $1.7 million UMTA demonstration grant to begin DAR service in two new service areas under these new conditions and to change the Greece and Irondequoit services to follow the new plan.

Description of the Demonstration

The new demonstration began on November 1, 1977, immediately after the expiration of the first demonstration. RTS has continued to operate PERT services in Greece and Irondequoit and was to continue to operate them until the scheduled end of the demonstration in July 1979. In addition, new DAR services in the suburban towns of Brighton and Henrietta and the extensions of service to the handicapped have been operated since July 1978 by Paratransit Enterprises, Inc., a private transportation operator selected by RGRTA through competitive bidding. At the conclusion of the new demonstration, a new bidding procedure was to be held to select operators for all DAR services and services for the handicapped.

RGRTA provides vehicles (Checker cabs for DAR service and minibuses for service to the handicapped) and pays Paratransit Enterprises between $11.70 and $14.20/vehicle-h of operation, the exact amount depending on the type of service, the number of vehicles operated in service, the level of vehicle productivity achieved, and driver accident records. This is approximately 40 percent less than RTS operating costs in Greece and Irondequoit. RGRTA also keeps all fare revenues that are collected. Service quality is comparable to that in Greece and Irondequoit, but the net operating deficit in January 1979 was about $3.00/passenger.

Before applying for the new demonstration grant, RGRTA invited suburban towns to participate in the demonstration as locations for new DAR services. To participate, however, the towns had to be willing to pay half of the services' operating deficit after the demonstration (UMTA Section 5 funds would be used to pay the other half). Thus, the decision to participate in the demonstration meant that a town would be fully responsible for the continuation of service after the demonstration ended. The towns did not have to make specific fiscal commitments two years in advance, but they did have to develop, with RGRTA, criteria on which the demonstration services would be evaluated. If these goals were achieved during the demonstration, the town would then be expected to financially support the service after the end of the demonstration.

Future Uncertainties

The new demonstration is another chapter in the search for a viable suburban transit alternative in Rochester, but whether it will be the final chapter is unknown. Two major uncertainties cannot be resolved until the end of the demonstration. The first is whether the towns will continue to support DAR. Brighton and Henrietta have not made contractual commitments, and Greece and Irondequoit have thus far not made any commitments to assume transit costs. The second major uncertainty concerns RTS management-union relations. Knowing that the new demonstration services were likely to be provided by nonunion labor working for lower wages, the local chapter of the Amalgamated Transit Union (ATU) refused to give a 13c certificate of clearance (clause 13c of the Urban Mass Transportation Act of 1964) for the project. The U.S. Department of Labor refused to intervene, feeling that the 13c agreement for the first demonstration, which guaranteed all demonstration work to ATU, should be followed. The new demonstration appeared to be doomed and, as the end of the first demonstration approached, RGRTA formally announced that PERT services would terminate on October 28, 1977. On that day, ATU international overruled the local chapter, and PERT services resumed a week later under the new demonstration funding.

RTS later proposed a lower wage structure for PERT drivers in order to submit a competitive bid for the new service operations, but the local union rejected this proposal and RTS consequently did not submit a bid. The union rank and file viewed the proposal as an insidious attempt to divide the union and feared that management would soon select new areas for wage cutting, such as park-and-ride routes and straight shifts.

If there is competitive bidding for Greece and Irondequoit services in 1979, there could be a direct substitution of nonunion services for current union services. It is not known how the ATU will react to this nor how that reaction will affect DAR operations.

CONCLUSIONS AND IMPLICATIONS

The history of DAR in Rochester has been long and complicated and marked by many disappointments as well as achievements. Many lessons have been learned during the six years of experimentation that other cities can apply to improve their own plans for suburban transit service.

Level of Service

The more flexible a transit service is, the less it adheres to a schedule and the greater is its potential for unreliability in predicting pickup and drop-off times. A many-to-many DAR service that responds to immediate requests has a high degree of such flexibility and is thus viewed by most users as less reliable than regular fixed-route service. Yet users of fixed-route transit, in Rochester and other cities, rate unreliability as the major problem with transit service. DAR, then, is not likely to be viewed as a major service improvement over fixed-route transit except by users for whom the door-step service is particularly important, such as the elderly and the handicapped.

Coordination of transfers between DAR and fixed routes was a critical problem in Rochester and is likely to be a problem in any DAR system in which only a few passengers transfer. If most DAR passengers transfer at the same location, a many-to-one situation is approached and an approximate schedule coordinated with fixed-route service can be followed. This service strategy was used in Ann Arbor, Michigan, and in various Canadian cities. The many-to-one situation can be approximated by locating the transfer point at the major trip attractor of the service area, something that was not done in Greece and Irondequoit.

Level of Demand

Substantial overestimation of the demand for DAR service in both Greece and Irondequoit led to much lower vehicle productivity than was anticipated. In both service areas, moreover, DAR demand density was lower than that which already existed in the local fixed-route corridors, even when headways were 30 min or more. Suburban DAR services are likely to have low mode shares and should not be expected to significantly increase total transit use in an urban area. They can be used, however, to fill special travel needs that are not satisfied by the regular fixed-route network and, if a large ridership is generated, it is often possible to implement a fixed-route service to serve the identified demand pattern more efficiently.

Economics

The Rochester experience suggests that several difficulties arise when an established transit operator provides DAR services. The hourly operating costs of large unionized systems are usually higher than local taxi costs by 50 percent or more, and this difference often outweighs the increased efficiency that results from shared riding. As a result, local taxi costs per passenger may be less than those of DAR.

When DAR is provided by a local transit operator, costs per passenger are usually higher than those of fixed-route transit, and these costs will invariably be compared. At a time when most transit systems face rapidly increasing deficits and uncertain funding futures, DAR is likely to be among the first to lose in the competition for scarce resources.

In short, the viability of DAR in large urban areas may depend on its having lower operating costs than conventional fixed-route services in the area. This can be accomplished by having a separate job classification with lower wage rates for DAR drivers and workers, as was done in Cleveland and attempted by RTS in Rochester, or by having a separate DAR operator, as is being done in Rochester.

Service and Operations Strategies

Several additional lessons have been learned from the five years of DAR operating experience in Rochester. The most significant are discussed below.

Replacing Fixed-Route Services

Where transit habits have already formed around an established fixed-route network, DAR should be used to supplement these services rather than replace them unless the DAR service offers indisputably higher service levels or is much less costly than the existing fixed-route service. When the superiority of DAR is less certain, it may be better for DAR and fixed-route services to coexist temporarily until habits change and to encourage the transition by means of an active marketing campaign that stresses the benefits of one mode over the other.

Striving for Simplicity and Stability

PERT management, in trying to fine-tune the system and respond quickly to its perceived shortcomings, instituted a rapid succession of service and fare changes, especially between 1974 and 1976. Some innovations, such as zonal fare systems, were quite complicated, and users were often confused by the constant shuffling of service alternatives. Fine-tuning the system can thus be counterproductive if it is done too frequently or if it complicates the overall operation. A service should be easy to understand and simple to use. Frequent service changes should be avoided, and any changes should be well publicized.

Selecting the Type of Vehicle

There are a multitude of small transit vehicles on the market, many with poor or unknown track records. An operator would be wise to select one vehicle with which other operators have been satisfied and prepare the system's maintenance shop to deal with that one type of vehicle.

Opting for Computerized Scheduling and Dispatching

Computerized scheduling and dispatching are expensive but have worked well in the two service areas operated by RTS. In a large, regionwide DAR system characterized by many service areas, computerization may reduce control-room operating costs; there is no consensus, however, that service quality or vehicle productivity can be improved by computerized dispatching or even that existing scheduling algorithms are effective under conditions of high demand and high vehicle density. Additional research is needed to define the proper role for computerized scheduling and dispatching.

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Many persons provided information for this paper, including staff members from the Rochester-Genesee Regional Transportation Authority; Regional Transit Service, Inc.; the Massachusetts Institute of Technology; and Paratransit Enterprises, Inc.

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Hybrid Paratransit Service

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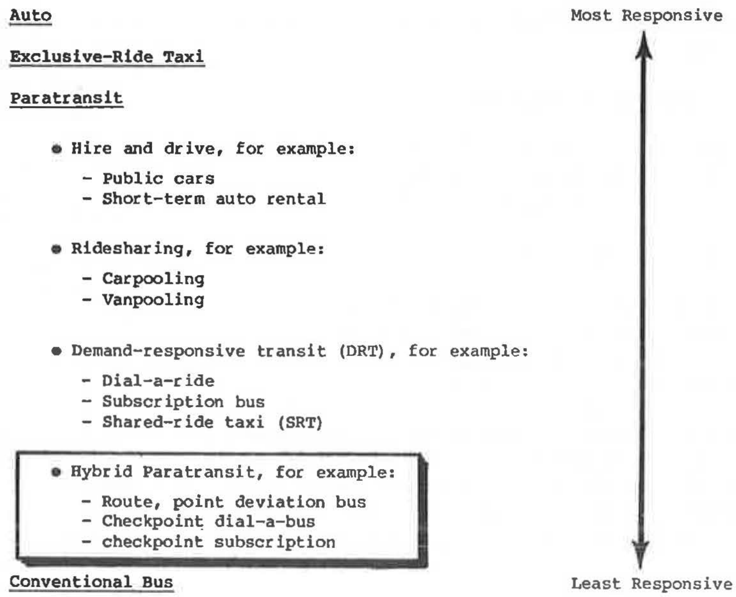
Hybrid paratransit, which combines features of conventional bus service and demand-responsive transportation, is examined. Hybrid paratransit sacrifices some of the flexibility of demand-responsive transportation to attain improved productivity and cost savings but retains some of that flexibility to achieve the levels of service necessary for adequate market penetration. One example of hybrid paratransit is checkpoint subscription service, a prearranged operation in which groups of passengers gather at common locations for collection and passengers are distributed only to those locations. Checkpoint and doorstep subscription service were analyzed and compared by applying models that predict cost and performance. The results show not only that the expected productivity increases accrue to the hybrid operation but also that, under many circumstances, the level of service of hybrid paratransit is superior. In addition, for any level of ridership, there may be a vehicle size that minimizes the operating costs of both subscription services. It is concluded that hybrid paratransit may offer service and cost characteristics that dominate demand-responsive transportation under a variety of conditions and may be the most appropriate option for service areas of moderate population density.

In most urban areas, transit alternatives that do not rely on fixed-guideway facilities are clearly the most appropriate service options. Until recently, as indicated by the appearance of such reports as that by Kirby and others (1), planners designing nonguideway public transportation systems typically restricted their attention to

Figure 1. Role of hybrid paratransit in spectrum of nonguideway transportation.



conventional fixed-route and fixed-schedule transit. In the current climate of increased awareness of paratransit modes, the range of alternatives now available for consideration is much broader than it was just a few years ago.

Paratransit has often been defined as the spectrum of transportation options that fall between exclusive-ride taxicab service and conventional fixed-route, fixed-schedule bus service. Various forms of demand-responsive transportation (DRT) rapidly emerged as among the most prevalent types of paratransit. Perhaps the most important DRT modes include (a) immediate-request, many-to-many dial-a-ride and (b) advance-request, many-to-one subscription bus. In sharp contrast to conventional bus service, which requires its patrons to tailor their travel needs to predetermined routes and schedules, these two DRT modes tailor both routes and schedules to the travel needs of their riders.

Recently, a new class of paratransit modes has earned an important place in the spectrum of nonguideway transportation options. Figure 1 shows the role of what is here defined as "hybrid paratransit". This term has been coined because the modes that fit into this category combine features of both DRT and conventional bus operations. For example, route- and point-deviation bus services are based on a predefined route but also make door-to-door passenger pickups and drop-offs. Checkpoint dial-a-ride and subscription bus combine the route and schedule flexibility of their DRT counterparts but, much like conventional service, require passengers to walk to a "bus stop".

The key distinguishing characteristic of a hybrid mode is that it offers demand responsiveness in relation to either space or time but not both or it discourages full responsiveness by charging its users additional fare for the option of purchasing additional responsiveness. Route- and point-deviation bus services do not offer temporal responsiveness since predetermined schedules are used, but they do provide spatial responsiveness since the buses will deviate to accommodate door-to-door travel requests (though at a higher fare in some operations). Checkpoint dial-a-ride and subscription bus make temporal responsiveness available to users since schedules are tailored to demand, but spatial responsiveness is limited in that door-to-door pickups and drop-offs are not made and, instead, passengers are required to use a predetermined set of dispersed checkpoints within walking distance of their doors.

Examples of past and current hybrid paratransit services include the route-deviation bus system operated in Mansfield, Ohio (2, 3), and the point-deviation systems of Columbus, Ohio (4, 5), and Merrill, Wisconsin (6-10). Another version of hybrid paratransit—checkpoint many-to-many service—was suggested by the Transport Canada Research and Development Centre for operation in Ottawa (11).

PROMISE OF HYBRID PARATRANSIT

Hybrid paratransit systems, with their compromised characteristics of both DRT and conventional transit, have the potential of operating at significantly higher productivities (measured in passengers per vehicle hour) than DRT, a situation equivalent to lower-cost operations. Although by definition hybrid paratransit is not as responsive to the travel needs of passengers as DRT, the degree of responsiveness that it does retain is likely to make it significantly more attractive to users than a conventional bus system.

Productivity can be improved by shifting a DRT operation into a hybrid service because, by requiring travelers to partially accommodate the service, more efficient vehicle tours (in terms of the degree of ride sharing) can be designed and dispatched. This does not mean that all hybrid systems will exhibit productivities that are superior to those of all DRT systems. The density of demand also has a strong impact on the level of productivity that is actually achieved. Putting aside for the moment the question of what productivity will be achieved, the potential productivity of hybrid paratransit systems that share some of the characteristics of conventional transit far exceeds that of DRT. To illustrate this point, it is useful to consider the two ends of the responsiveness spectrum: conventional bus and exclusive-ride taxi. When demand densities are low, the productivities of conventional bus systems are similarly low; in corridors of high demand, conventional buses may exhibit productivities of 40-50 passengers/vehicle-h. In contrast, the productivity of a taxicab rarely exceeds 4 passengers/vehicle-h regardless of the density of demand.

Because the potential increase of productivity of a hybrid operation over a DRT system could be attained at little or no marginal (operating or capital) cost, the implication is the ability to significantly reduce cost per passenger trip by operating hybrid instead of DRT service. Thus, for a given subsidy level, hybrid fares can be considerably lower than DRT fares. In addition to lower costs and fares, hybrid systems are also likely to provide more reliable service—an often-cited area of weakness in many DRT systems—because restricting the responsiveness of service eliminates a degree of the randomness of passenger travel requests or at least allows the system operator to plan better for the randomness. Ewing and Wilson (12) present empirical evidence that confirms the superior reliability (and productivity) of a few hybrid services in comparison with comparable DRT systems.

Of course, it is not realistic to expect to increase productivity, lower costs, and improve reliability without giving up something in return. Level of passenger service can be expected to decline as a result of any shift from DRT to hybrid paratransit service because of the deliberate restrictions placed on responsiveness to passengers. Riders of route- or point-deviation bus systems would have to time their trips to match the fixed schedules of those services, and riders of checkpoint dial-a-ride or subscription bus systems would have to walk to the closest checkpoint to use the service. Both types of systems represent a reduced level of service in comparison with DRT, which picks up passengers at the their door as quickly as possible after their request for service. Nevertheless, the promise of hybrid paratransit depends on the hypothesis that improved reliability and potentially lower cost more than compensate for the resulting reduction in level of service. Although a full test of this hypothesis must await considerably more operating experience with hybrid paratransit, important inferences can be drawn from a comparison of the results of mathematical models of DRT and hybrid paratransit systems. The following sections of this paper describe such an experiment.

COMPARISON OF DRT AND HYBRID PARATRANSIT MODELS

Description of Services

As an example comparison of DRT and hybrid paratransit services, models of doorstep and checkpoint subscription-bus systems were developed and applied. Both types of operations require passengers to request service either well in advance or on a "standing-order" basis—e.g., monthly. Both services are usually oriented to a many-to-one trip pattern. Both services rarely schedule standees and may use vehicles that range in size from 5-passenger (taxi) sedans or 8-passenger vans to 50-passenger buses, depending on the expected density of demand. Finally, for both types of service, the afternoon distribution tours are usually the "mirror images" of the morning collection tours.

Doorstep and checkpoint subscription services differ in that a doorstep subscription bus will pick up passengers at home whereas a checkpoint subscription bus requires users to walk (or otherwise travel) to the closest of a set of checkpoints to be picked up. The locations of the checkpoints can be specified after passenger requests are known so that the lengths of passenger walking trips and vehicle tours can be minimized. Alternatively, the locations of the checkpoints can be predetermined so that all potential users of the checkpoint subscription service know in advance the location of their checkpoint if they request service. In that case, of course, only the checkpoints that are closest to passengers would be included in the vehicle tours; it is quite possible that a number of predetermined checkpoints would not be used by any subscription rider.

Figure 2 shows the type of collection tours that would be developed for both doorstep and checkpoint subscription-bus operations for the same set of passengers. The models that were developed and applied to compare these examples of DRT and hybrid paratransit are designed to yield the following output: required fleet size, productivity, cost per passenger, and passenger travel time (including walk time for checkpoint service). As input, they require a description of the service area, the type of service to be offered (including vehicle size), and the passenger demand density to be tested. Because demand is an input, these models are properly considered supply or performance models.

Analysis and Results

The development of the models of doorstep and checkpoint subscription services can be traced back a number of years through an evolutionary process that involved a number of researchers. A key, and common, element of the current models is the calculation of the length of tour a vehicle would traverse in order to visit a given number of points in an area of given size with a given aspect ratio (ratio of the area length to width). This part of the models was first developed by Mason and Mumford (13) in an effort to model dial-a-ride service. Ward (14) borrowed the Mason and Mumford tour-length model and used it in a fairly restrictive model of doorstep subscription service. Working from the Ward model, Batchelder and others (15) and Englisher and Sobel (16) relaxed many of the restrictions of the formulation and added the capability of representing checkpoint subscription service. In a parallel effort, Billheimer and others (17) also used the work of Ward to develop models of both doorstep dial-a-ride and doorstep subscription service. Finally, Menhard and others (18) further modified the work of Englisher and Sobel to improve the models' realism and accuracy.

The models presented here fall midway between the models of Englisher and Sobel (16) and Menhard and others (18). A vehicle round trip is disaggregated into three or four main components and analyzed piecemeal. Figure 3 shows these components, which include an external line-haul segment, a zonal line-haul trip segment, either of two types of collection-distribution tours (called simultaneous and sequential tours), and a sector line-haul segment for use with simultaneous collection-distribution tours.

A sequential collection-distribution tour is one in which all distribution passengers are dropped off before the collection passengers are picked up. This type of tour helps to avoid possible problems with vehicle capacity constraints but can potentially pass close to collection passengers who are waiting for service and not pick them up. The doorstep subscription service is modeled with sequential collection-distribution tours. A simultaneous collection-distribution tour entails the picking up and discharging of passengers in a single "sweep" without regard to the order of passengers entering or leaving the vehicle. This type of tour was selected for checkpoint subscription service to avoid the necessity of visiting the same checkpoint twice in a single tour when distribution and collection passengers both live near the same checkpoint.

The zone in Figure 3 corresponds to the service area being analyzed, and the sectors represent the area served by a single vehicle. Clearly, sector size depends, in part, on the density of demand.

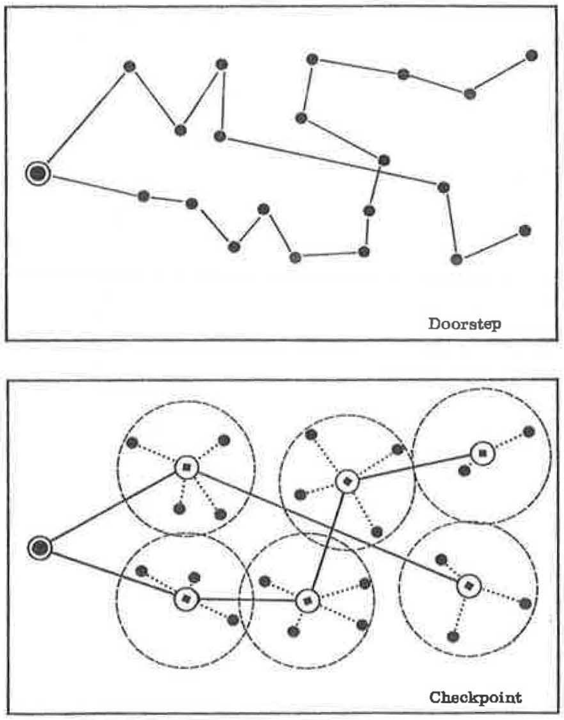
The fundamental equations for the models are the following:

$$d = V/A \quad (1)$$

$$a = 60n/dT \quad (2)$$

$$D_L = \pi(\sqrt{A}/4)[1 - (\sqrt{a}/\sqrt{A})] \quad (3)$$

Figure 2. Configuration of doorstep and checkpoint collection-distribution tours.



$$D_{CD\text{-}SEQ} = f_a \sqrt{a/2}(2.96 + 0.16\ NS_c + 0.2\ NS_d) \quad (4)$$

$$D_{CD\text{-}SIM} = f_a \sqrt{a/2}\ \{2 + [NS/(NS + 1)] + (1.2 + 0.2\ NS)\} \quad (5)$$

$$T = f(D_{EX}, D_L, D_{CD}, LYOV, TPD, NS, V_{EL}) \quad (6)$$

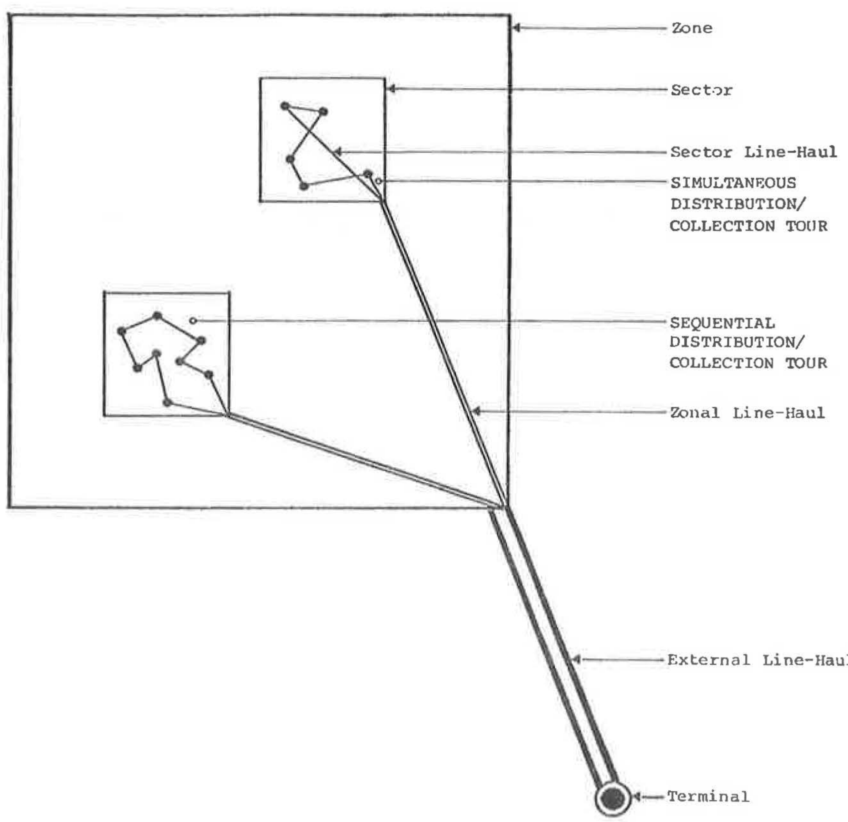
$$FLT = A/a \quad (7)$$

where

- d = demand density (trips/km²/h);
- V = design volume (passengers/h);
- A = service or zone area (km²);
- a = sector area (km²);
- n = vehicle size (number of seats);
- T = vehicle round-trip travel time (min);
- D_L = zonal line-haul distance (km);
- $D_{CD\text{-}SEQ}$ = distance of sequential collection-distribution tour (km);
- f_a = street adjustment factor, relating rectangular distance to straight-line distance, usually equal to $4/\pi$ (19);
- NS_c = number of collection stops in a tour;
- NS_d = number of distribution stops in a tour;
- $D_{CD\text{-}SIM}$ = distance of simultaneous collection-distribution tour, including sector line-haul (km);
- NS = total number of stops in a tour;
- D_{EX} = extensional line-haul distance (km);
- $LYOV$ = layover time between tours (min);
- TPD = time to pick up or drop off a passenger (min);
- V_{EL} = "cruising" velocity of subscription vehicles (km/h); and
- FLT = fleet size (number of vehicles).

Equations 2-6 are applied iteratively until the value of T in Equations 2 and 6 is tolerably equivalent. Note that any reasonable estimate of T will suffice for the

Figure 3. Structure of subscription-service model.



initial application of Equation 2. Computational experience indicates that convergence is quite rapid—usually in fewer than 10 iterations—for tolerances in the range of 90 s in 30 min. The converged value of T is then used

Figure 4. Cost per passenger versus travel time for volume of 120 passengers/h.

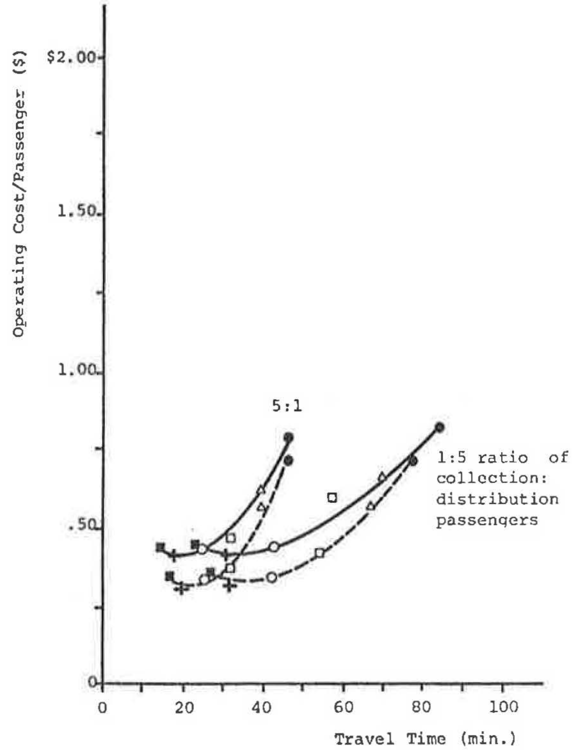
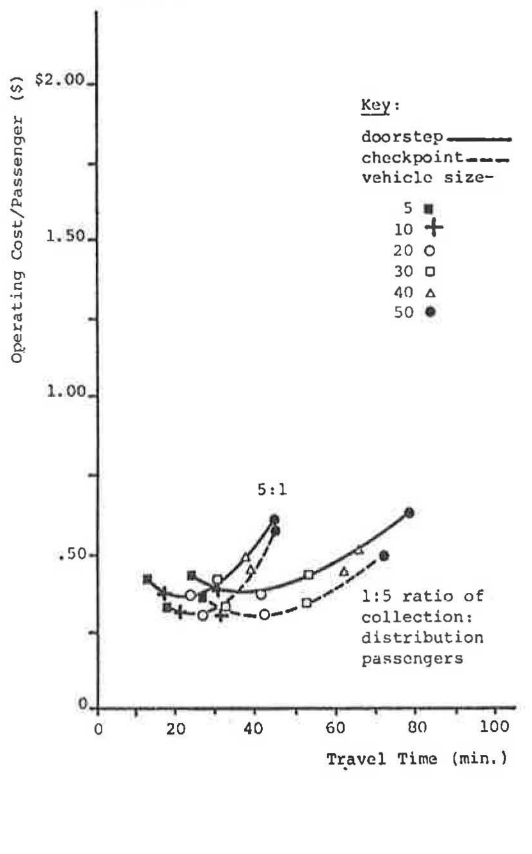


Figure 5. Cost per passenger versus travel time for volume of 240 passengers/h.



to calculate average passenger travel times. Other outputs of interest include the productivity of the services (passengers per vehicle hour), cost per passenger and per passenger kilometer, and vehicle kilometers and vehicle hours traveled.

The models were applied to test and compare doorstep and checkpoint subscription services in a hypothetical area of 15.5 km^2 (6 $mile^2$), the closest point of which is 2.4 km (1.5 miles) from the subscription terminal. Layover time was assumed to be 5 min, and vehicle cruising speed was taken as 48.3 km/h (30 mph). Time to pick up and drop off passengers at a stop was set at 1 min, maximum walk distance was set at 0.4 km (0.25 mile), and walk speed was assumed to be 4.8 km/h (3 mph). A cost per vehicle hour of $5.50 was specified (primarily to cover labor costs); cost per unit of distance traveled ranged from $0.16/km ($0.25/mile) for a taxi-like sedan to $0.40/km ($0.64/mile) for a 50-passenger bus. Volumes of 30-300 passengers/h were tested in travel patterns representative of a morning peak period, an afternoon peak period, and a midday (balanced) period. Vehicle sizes of 5, 10, 20, 30, 40, and 50 passenger seats/vehicle were tested for each ridership level and travel-pattern run.

Results of the tests are shown in Figures 4-9. Figures 4 and 5 compare average cost per passenger versus average passenger travel time for doorstep and checkpoint subscription service for volumes of 120 and 240 passengers/h, respectively [these volumes correspond to demand densities of 7.7 and 15.5 passengers/km^2/h (20 and 40 passengers/$mile^2$/h)]. Results are shown for all six vehicle sizes tested. In addition, the pattern of passenger demands is varied so that the ratio of collection passengers to distribution passengers is tested at 5:1 and 1:5.

Figure 6 compares doorstep and checkpoint cost per passenger as a function of ridership for two vehicle sizes and a 5:1 ratio of collection to distribution passengers. Figure 7 plots doorstep and checkpoint vehicle kilometers of travel for two different demand levels, at a 1:1 ratio of collection to distribution passengers, versus the size of vehicle used to provide the service. Figure 8 shows doorstep and checkpoint passenger travel time versus ridership for two vehicle sizes and a 5:1 ratio of collection to distribution passengers. Finally, Figure 9 compares doorstep and checkpoint passenger travel time at one level of demand versus the size of the vehicle used for a 5:1 ratio of collection to distribution passengers.

A number of interesting results can be inferred from the graphs. For example, Figures 4 and 5 show that, when checkpoint service operates with larger vehicles, it provides not only lower-cost service, as expected (because of higher potential productivities), but also shorter travel times than doorstep subscription service. This can be seen by comparing the data points that form the doorstep and checkpoint curves: The checkpoint-service points that denote large vehicles (30, 40, and 50 passengers, for example) are not only below the corresponding doorstep data points (less expensive) but also fall to the left of the doorstep points (lower travel time). This apparently counterintuitive result is actually quite reasonable. Although passengers of checkpoint subscription bus must walk to gain access to the service, this travel-time degradation is more than compensated for by the reduction in the length of the collection-distribution tour that results from the multiple pickups at each visited checkpoint. This impact is not apparent for small vehicles because the maximum potential reduction in the number of stops on a collection-distribution tour is small (perhaps 2 or 3 stops for a five-passenger vehicle); in contrast, large vehicles that operate in the checkpoint hybrid mode might reduce the number of stops on their collection-distribution tours by as many as 20 or 30. Of course, the increase in travel time attributable to the walk requirement is the same for checkpoint subscription passengers regardless of the size of the vehicle that will carry them.

Figures 4 and 5 also show that, for any vehicle size, checkpoint subscription service will always be less expensive to operate than doorstep service as a direct result of its superior productivity (the dashed lines con-

Figure 6. Cost per passenger versus ridership.

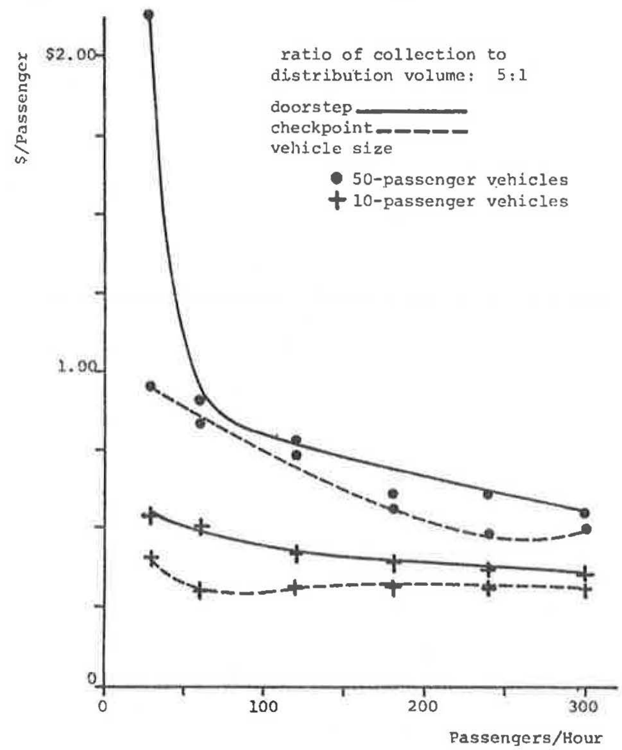


Figure 7. Vehicle kilometers of travel versus seating capacity.

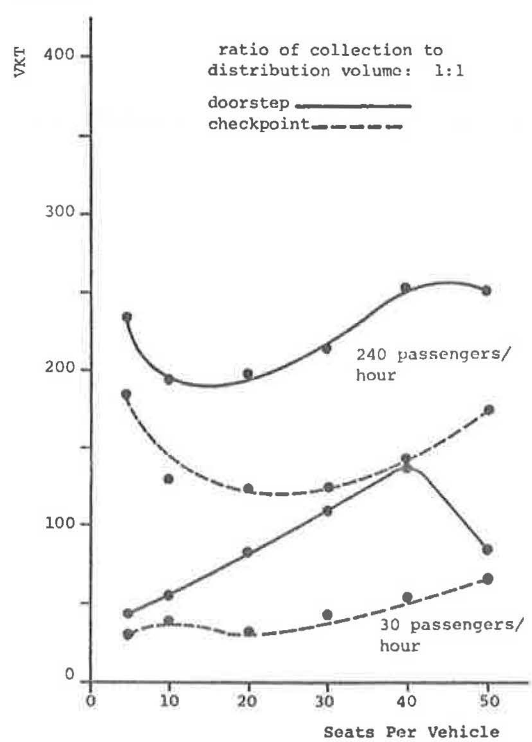


Figure 8. Travel time versus ridership.

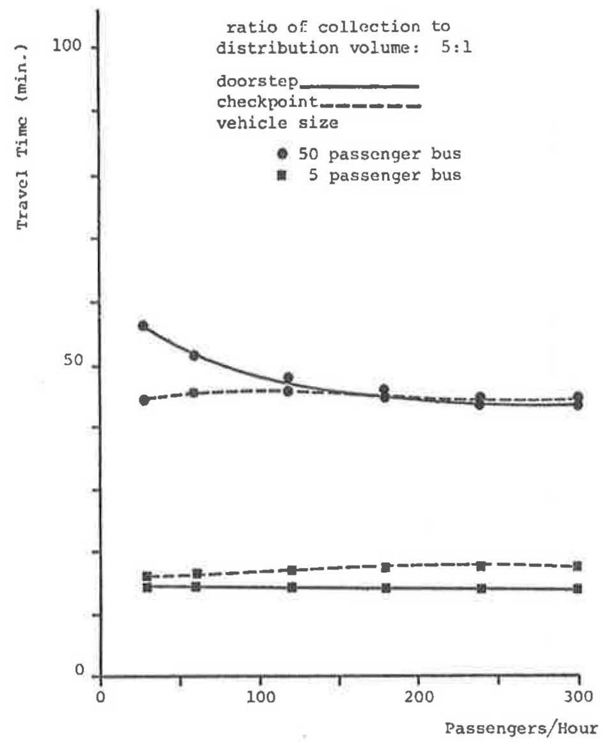
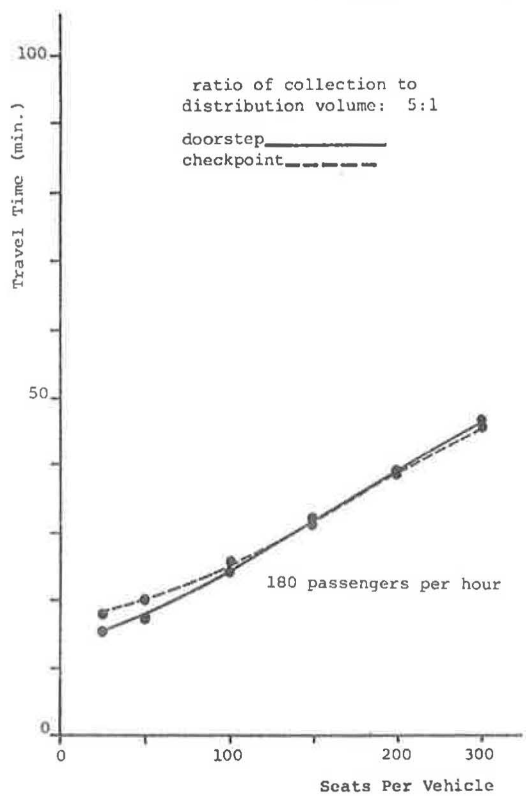


Figure 9. Travel time versus seating capacity.



sistently fall below the solid lines). In correspondence with its improved productivity, checkpoint service typically requires a smaller fleet of vehicles to carry a given passenger load and consequently also uses fewer vehicle kilometers and vehicle hours of service. These reductions translate into savings in total operating costs, which compounds the impact of improved productivity for reducing costs on a per-passenger basis.

An interesting corollary to the examination of costs is that, for each of the DRT and hybrid operations, there is a particular vehicle size (different for the two modes) that, if selected, will minimize the cost of providing service. This minimal-cost vehicle size is a function of passenger volume and its distribution and generally appears to be about 15-18 seats/vehicle (results for the "balanced" services of 1:1 ratio of collection to distribution passengers, which are not shown, are closer to 10 or 12 seats/vehicle). Of course, a more detailed cost model, including capital acquisition costs, would have to be developed and tested before confidence could be placed in the values of "design decision" results of this type. It should be noted here that the minimal-cost solution for a checkpoint operation usually results in slightly greater travel time than that for doorstep service. This indicates that the minimal-cost vehicle size for checkpoint service is below the size required to significantly reduce the collection-distribution tour and thereby compensate for the added walk time of checkpoint service versus doorstep subscription bus.

Figures 6-9 provide some different types of insights that are not directly available from the cost versus travel time format of Figures 4 and 5. For example, it is apparent in Figure 6 that, with the exception of 50-passenger vehicles operated in the doorstep mode, only very modest economies of scale are inherent in subscription service. However, although cost per passenger is not very sensitive to passenger volume, it is quite sensitive to the vehicle size used. Figure 7 shows the discontinuities in vehicle kilometers of travel as different vehicle sizes are tested in response to changing fleet requirements (a factor strongly influenced by selected vehicle size). Checkpoint service often requires fewer vehicles than doorstep subscription service, especially when large vehicles are used, because the lower travel times for checkpoint operation allow each vehicle to make additional round trips for a given period of time. Finally, Figures 8 and 9 show that, although travel time is reasonably insensitive to passenger volume, it is strongly affected by the selected vehicle size.

CONCLUSIONS

As a result of the above discussion of hybrid paratransit, two basic types of conclusions can be reached: One concerns operational lessons that can be learned from the study comparison of doorstep and checkpoint subscription bus service, and the other deals with the policy implications for the planning and provision of paratransit.

For subscription service, if vehicle sizes have not been predetermined, it appears that significant savings in operating costs can be achieved simply by making a judicious selection of vehicle size after a reasonable analysis. Even if vehicle size is a given constraint, important cost savings will accrue if the service operates in a checkpoint instead of a doorstep mode. Under some circumstances (e.g., with large vehicles), such cost savings would also be accompanied by superior levels of service offered to subscription bus users. Better service at lower cost is a possibility too attractive to ignore.

From the perspective of paratransit service policy, hybrid paratransit should clearly be given at least as much emphasis as DRT. Compromises between two extremes often combine the "worst of both worlds", but this is not the case for hybrid paratransit. This paper has shown that under some circumstances hybrid paratransit displays the best features of DRT and conventional fixed-route, fixed-schedule bus: low cost and high level of service. Hybrid paratransit options may make the most sense in areas of moderate population density, where population is too sparse to economically support conventional bus service but where requests for DRT service would overload system capacity. Of course, for a number of reasons, it may be preferable to retain in the system design the ability to "sell" DRT-like responsiveness to users for additional fare—e.g., a checkpoint subscription that will pick up riders at their homes for an extra 25 cents/trip. Such a premium service-fare combination is likely to be attractive or necessary to users such as shoppers and the elderly and the handicapped and can be equitably provided with flexible (e.g., user-side) subsidy schemes.

In summary, hybrid paratransit should be given full and serious attention as an alternative in a broad range of service options available for implementation.

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The opinions and information contained in this paper are my responsibility and do not necessarily reflect the position of the U.S. Department of Transportation.

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**K. L. Sobel was with Multisystems, Inc., when this research was performed.*

Integrated Paratransit: Myths and Realities

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A study that involved a systematic attempt to estimate all of the potential impacts of a range of integrated transit-paratransit options in a variety of settings is reported. The study concluded that, in some but not all instances, the benefits of integrated paratransit—in terms of improved service levels and mobility, reduced automobile expenditures, and other impacts—may justify system deficits. Necessary conditions for this include (a) high paratransit productivity, which could possibly be achieved by implementing hybrid fixed-route and demand-responsive service (such as checkpoint many-to-many), and (b) low operating costs, which might be achieved by contracting with private operators. Integrated paratransit was found to have a positive but insignificant impact on automobile use and ownership and no measurable impact on vehicle kilometers of travel, fuel consumption, or emissions. Areas that have population densities of 1160-2300 persons/km^2 (3000-6000 persons/mile^2) and limited existing transit service are promising locations for implementation of integrated paratransit service.

Paratransit, the family of transportation services that falls between exclusive-ride automobile and conventional fixed-route transit, has been the center of considerable analysis and discussion in recent years. A number of national conferences have been held on the general subject of paratransit, and other conferences have been held to discuss individual paratransit services such as vanpool, dial-a-ride, taxi, and services for the elderly and the handicapped. Many research and demonstration projects on paratransit have been initiated at the federal, state, and local levels.

Despite these analyses, or perhaps as a result of the level of analysis, there has been a fair amount of confusion and disagreement about paratransit. The ways in which it can or should be integrated with fixed-route service and the potential impacts of such "integrated paratransit" service have been the subjects of a debate in which the overall concept has gained both proponents and opponents. For example, some researchers point to integrated paratransit as the future of metropolitan area transportation (1), whereas other researchers cite the failures of paratransit or claim that such services are too costly (2-4). Some studies advocate paratransit as a means for energy conservation (5), whereas others cite paratransit as among the most energy-consuming transportation modes (6, 7).

To help settle some of these controversies and to begin to sort through and integrate the wealth of paratransit experience that already exists, the Urban Mass

Transportation Administration (UMTA) has initiated an integrated paratransit (IP) program. The program was designed to evaluate the costs and benefits of IP, develop methodologies for estimating demand and supply characteristics, design improved vehicle control systems, explore the potential for and implications of major shifts of demand to IP, assess various deployment concepts, and determine research needs.

The first project initiated under this program was a benefit-cost analysis of IP systems. This study represents the first systematic attempt to estimate all of the significant potential impacts of a wide range of IP options in a variety of settings. This large-scale analysis has provided at least partial answers to many of the questions about paratransit.

STUDY METHODOLOGY

Analysis Framework

The basic approach used in estimating the benefits and costs associated with implementation of IP involved the analysis of a range of scenarios for IP and conventional transportation service in a variety of settings. The settings selected were actual urban areas, each representative of a larger group of urban areas. To identify representative settings, all 271 U.S. standard metropolitan statistical areas (SMSAs) were classified by using a cluster analysis procedure that develops groups (of urban areas) that are similar across a set of prespecified factors. In this application, demographic factors that were felt to be relevant to transportation service—such as population, population density in the central city and urban area, and transit mode split for work trips—were used. Cluster analysis served as a computer-based aid for organizing data and systematizing judgment as to what would constitute a representative range of cities for analysis. This ensured that different types of cities were considered in the scenario analysis and allowed the use of real, rather than hypothetical, data in the analysis.

One city, which in some but not all cases was the most representative city, was selected from each of the identified seven groups. The seven settings were intended to be representative of all SMSAs in the United States except New York City. In keeping with the concept of using prototypical cities, each city was provided with a pseudonym intended to convey information about a characteristic common to the cities in the group. The general characteristics (which tended to be geographically based) and selected pseudonyms of the groups are given in Table 1.

The IP scenarios developed for each setting were based on local setting characteristics. However, the motivating force that guided the development of the scenarios was the necessity to test different IP service concepts and configurations. No attempt was made to design optimum scenarios for each setting, but different alternatives—for example, service configurations, fare structures, and operating entities—were analyzed within each setting. Some basic characteristics of the settings and scenarios are given in Table 2. Data on the market characteristics of existing paratransit and IP systems as well as on the relations between system and setting types were used in the generation of scenarios. A classification scheme that distinguished IP systems on the basis of a number of key factors was used to ensure that as wide a range of IP options as possible were analyzed.

In addition to the IP scenarios, conventional fixed-route bus and exclusive-ride taxi scenarios were designed and analyzed for each setting. The fixed-route alternatives were designed to result in either coverage, cost, or patronage comparable to that of the IP alternative in order to determine the circumstances under which fixed-route service is superior to IP and vice versa. The taxi alternatives were designed to determine the extent to which expansion of, or improvement to, taxi service can obviate the need for expanded IP services

Table 1. Pseudonyms and characteristics of urban-area groups.

Pseudonym	General Characteristics	Representative City
Southern Belle	Moderately small, largely southern cities with low central-city density, high concentration of single-family housing in urban area, and low income	Augusta, Georgia
College Town	Small cities with moderately low central-city density but also a low percentage of single-family dwellings, very small population of elderly, high automobile ownership, and low transit use; many college towns	Reno, Nevada
Sun City	Small to medium-sized cities, predominantly southern and southwestern, with low central-city density, high percentage of single-family dwellings and central-city population and employment, high automobile ownership, and low transit use	Albuquerque, New Mexico
Mid-American City	Medium-sized cities, with low to medium central-city population and a high percentage of single-family dwellings, high automobile ownership, and low transit use; very "average" characteristics in general	Grand Rapids, Michigan
Mill Town	Moderately small, largely northeastern manufacturing cities with a low percentage of single-family dwellings, very large population of elderly, low automobile ownership, relatively low income, and relatively high transit use	Portland, Maine
Large City	Fairly large, primarily midwestern and northeastern older cities with high central-city family density, low central-city population (as percentage of total), fairly large population of elderly, fairly low central-city employment, and relatively high transit use	Cincinnati, Ohio
Metropolis	Major metropolitan areas with large population, high density, moderately low percentage of single-family dwellings, low automobile ownership, and high transit use	San Francisco, California

Table 2. Comparison of 1980 characteristics of IP settings and scenarios.

Pseudonym and Scenarios	1980 Urban-Area Population	1980 Paratransit Service Area: Eligible Population	Size (km^2)	Population Density (persons/km^2)	Number of Paratransit Vehicles
Southern Belle; A, B	177 000	100 700	81.8[a]	1231	46[a]
College Town; A, B, C	142 000	78 000	42.7[b]	1826[b]	42[b]
Sun City	460 800				
A		100 000	69.2	1446	16
B		100 000	69.2	1446	19
Mid-American City	339 000				
A, B, C, D peak		54 000	67.6	799	38
A, B, C off-peak		151 000	143.0	1056	43
D off-peak		304 000	218.3	1392	55
Mill Town	118 730				
A		18 400	36.5	504	6
B		12 500	25.4	492	4
Large City; A, B	1 577 300	1 577 300	1126.1	1400	229
Metropolis	2 408 000				
A		85 926	134.7	2033	38
B		156 044	279.7	1897	70

Note: 1 km^2 = 0.386 $mile^2$.
[a] Vanpool excluded. [b] Special areawide service for the handicapped excluded.

or mass transportation services in general. The benefits and costs that resulted from these nonparatransit alternatives were compared with those of the paratransit alternatives in the evaluation of system designs.

To understand further the factors that influence the implementation of IP services on a local level and to provide a better basis for projecting the penetration of IP services, in-depth case studies of the implementation of seven IP systems that now operate in the United States were carried out. These analyses led to the identification of a set of recurring themes that seem to influence IP implementation.

Benefit-Cost (Impact) Estimation

A key element of the methodology that differentiates this study from previous ones is the benefit-cost analysis used to reach the conclusions presented. This was not a traditional benefit-cost analysis; no single net-benefits estimate or benefit-cost ratio was produced. In other words, no attempt was made to impute a net value or economic impact to IP service.

The decision to implement an IP system or any transit system cannot be made solely on the basis of such a single measurement, which would have questionable meaning in any event. Instead, a decision maker must weigh the impacts of IP on different segments of society in both the public and private sectors. Consequently, the results were reported in an "impact incidence matrix" format. The impact groups and impacts considered are given in Table 3. This list of impacts was selected from a more lengthy original list. Some impacts were eliminated from the study based on their computability, on a priori judgment of their significance, and on a preliminary analysis that indicated that the impacts were extremely small. Thus, this list represents only the potential major impacts of integrated paratransit and other services and not all possible impacts.

A number of modeling tools, combined with a base of empirical data, were used to project costs, ridership, and other impacts of these scenarios. The primary modeling tool was a demand-supply-equilibrium model called FORCAST, which incorporates a disaggregate demand model for projecting paratransit patronage. This model, which was developed and extensively validated in a previous research effort (8), was refined during this study and proved to be extremely flexible. The outputs of the models were combined with the appropriate data to develop the types of benefits and costs given in Table 3. A detailed description of the analysis approach is available elsewhere (9).

RESULTS

Some of the key results of the study are probably best presented in terms of answers to questions that might be asked about paratransit or integrated paratransit systems.

Positive Versus Negative System Impacts

Can the deficit of an IP system be justified by the positive impacts generated?

In some instances, the answer is yes. In a number of the settings considered, but not all, the net positive impacts of IP—such as a reduction in automobile expenditures, an increase in consumer surplus, and an increase in employment—appeared to be able to offset the deficit. (In the context of this study, consumer surplus provides a measure of the decrease in overall transportation cost, reflecting both travel time and fare changes as perceived by the users of the service.) Table 4 gives some of the results of the analyses of several scenarios. The benefits of the first scenario could potentially justify its cost, whereas the benefits of the second scenario do not seem to come close to justifying costs. For the remaining three scenarios, it is uncertain whether the service costs are justifiable. These determinations could vary depending on the priorities of the decision maker.

In cases in which the IP systems appeared most justifiable, there appeared to be no significant negative impacts other than cost and, in some cases, a reduction in revenue and profit for the taxi industry. The negative impact on taxis could be alleviated or reversed by contracting with private operators for IP service.

It should also be noted that, in the cases in which IP appeared to be possibly justifiable, the total net cost per marginal transit passenger was relatively low (less than 90 cents) and, correspondingly, the revenue-to-cost ratio relatively high. This was the result of either, or both, of two factors: relatively low hourly operating costs (<$11.00/vehicle-h) and relatively high productivities (≥9 passengers/vehicle-h) (throughout this paper, passengers per vehicle hour is referred to as productivity). Low operating costs can be achieved in urban areas where prevailing transit wage rates are low and in all urban areas through contracts with the private sector. Note that the costs of both publicly and privately

Table 3. Matrix of IP service impacts by group affected.

Impact Group	Impact
Users	Mobility (by market segment) New transit trips Induced transit trips Change in consumer surplus (by market segment)
Community	Coverage (by market segment) Spatial Temporal Vehicle kilometers of travel Fuel consumption Emissions Employment opportunities (by employment sector) Jobs Payroll Automobile expenditures Elimination of chauffeur trips
IP operators	Cost (by operator) Gross operating Net operating Gross capital Net total (subsidy) Management fee (for private operators only)
Competing transportation providers, including taxi industry, parking lot operators, and social service agencies	Passengers (where appropriate) Revenue (where appropriate) Profit (where appropriate) Opportunity cost (where appropriate)
Major employees	Parking requirements Cost Opportunity cost
Local government	Operating subsidy Capital subsidy Loss of parking revenue
Federal government	Subsidy Operating Capital Total

Table 4. Sample of results of IP scenarios.

Pseudonym	Scenario	Total Net Transit Cost ($000)	Total Cost per Passenger ($)	Consumer Surplus ($000)	Automobile Expenditures ($000)	Total Number of Jobs	Taxi Profits (%)
Southern Belle	Checkpoint many-to-many service	+559	0.44	+735	-332	+70	-40.2
College Town	Public operation of many-to-many service	+2486	2.83	+186	-693	+85	-44.7
	Private operation of many-to-many service	+604	0.88	+149	-591	+86	+156.2
Sun City	Feeder service and route deviation	+145	0.77	+114	-182	+8	-27.8
Mid-American City	Complete coverage	+1566	1.79	+268	-738	+91	-32.8

operated transit services have been increasing rapidly in recent years. If the private sector becomes increasingly involved in contract services for the public sector, there is a chance that labor will begin to bring pressure to bear to close the gap between private and public wage levels. It may thus become increasingly difficult to keep operating costs at levels below $11.00/h.

High productivities can be achieved in two ways:

1. "Hybrid" fixed-route/paratransit services, such as checkpoint or route deviation, yield higher productivities than doorstep services.
2. Vehicle density significantly affects achievable productivity for most paratransit service. Our analysis suggested that, although demand sufficient to justify additional vehicles may not always be generated, systems that can support relatively high vehicle densities are those that are likely to be most cost effective. For very flexible systems such as dial-a-ride, vehicle densities on the order of 0.6 vehicles/km^2 (1.5 vehicles/$mile^2$) are needed to yield high productivities.

Reduction of Automobile Use

Can IP service achieve significant modal shifts from the automobile?

On an absolute level, the answer to this question is no. In none of the cases analyzed did IP reduce automobile use by more than 1-2 percent. The capacities (i.e., achievable productivities) of paratransit systems are too low to result in significant diversion from automobiles at any reasonable vehicle fleet size, given present population densities and automobile operating costs. On a relative level, however, IP service could substantially increase total transit ridership. In areas that had very limited fixed-route service, transit ridership was shown to increase by as much as 70 percent with the initiation of IP service.

Integrated paratransit was also projected to result in a slight reduction in automobile ownership (based on existing models of automobile ownership). Again, however, in no case was the reduction projected to be greater than 3 percent. The ability of IP to reduce automobile ownership was highly dependent on coverage;

Table 5. Impact of IP service on automobile use.

Pseudonym	Scenario	Annual Vehicle Kilometers of Travel: Number (000s)	Annual Vehicle Kilometers of Travel: Percent	Automobiles Owned: Number	Automobiles Owned: Percent
Southern Belle	Checkpoint many-to-many service	-7930	-0.8	-62	-0.8
College Town	Public operation of many-to-many service	+354	+0.2	-133	-2.8
	Private operation of many-to-many service	+563	+0.4	-114	-2.3
Sun City	Feeder service and route deviation	-347	0.0	-35	-0.1
Mid-American City	Complete coverage	+183	0.0	-142	-0.9

Note: 1 km = 0.62 mile.

areas that had service coverage that facilitated off-peak areawide trips realized the greatest percentage decrease in automobile ownership. Apparently, the ability to travel anywhere in the area by transit, particularly for nonwork trips, provided an inducement for families to eliminate a second or third automobile.

Table 5 gives these results for the five sample scenarios discussed earlier.

Vehicle Travel, Fuel Consumption, and Air Pollution

Does IP have a significant impact on vehicle kilometers of travel, fuel consumption, and air pollution?

The answer to this question appears to be no. Previous studies have suggested that paratransit has a negative impact on vehicle kilometers of travel and fuel consumption (6, 7). This study, which was the first to consider large-scale systems and the impact on automobile ownership, does not lead to the same conclusion. In most but not all cases, IP was projected to decrease vehicle kilometers of travel and fuel consumption. In no case, however, was the impact more than 0.7 percent of area vehicle kilometers of travel and fuel consumption. Emissions of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x) increased in some cases and decreased in others; again, however, the percentage changes were less than 1 percent. Thus, for all practical purposes, one must conclude that IP will have no noticeable effect on vehicle kilometers of travel, fuel consumption, or air pollution, and such impacts should not be a stated major purpose of IP implementation. Note that the fixed-route alternatives generally increased vehicle kilometers of travel and fuel consumption—although by less than 1 percent—and decreased some emissions. The exclusive-ride taxi alternatives resulted in the highest increase in all three categories.

Potential of Various Service Configurations

Which paratransit configurations show promise?

The results of the analysis suggest that hybrid services that combine characteristics of fixed-route service and paratransit, and thus have relatively high capacities, may be among the most promising. For example, checkpoint many-to-many service, in which pickups and drop-offs are made on demand only at designated checkpoints scattered throughout the service area, appeared to offer higher service quality and productivity (and therefore to generate greater demand) than comparable doorstep service. This concept should now be demonstrated to determine whether passengers are actually willing to walk short distances to checkpoints. The results of the analysis suggest that a good location for a demonstration of checkpoint many-to-many service would be a moderately dense inner suburban area (1350-1930 persons/km^2) that has limited transit service and a number of dispersed activity centers.

Route-deviation service seems to be much more cost effective than service that uses tightly spaced, parallel fixed routes in areas of moderate population density. In the one scenario tested that used route-deviation service, the ends of six routes spaced 1.2 km (0.7 mile) apart were replaced by three route-deviation services. In the 1980 scenario in which population density was 1550 persons/km^2 (4000 persons/$mile^2$) and the base ridership was 258 passengers/weekday, total daily ridership increased to 346 as a result of increased headways and doorstep service. At the same time, total vehicle hours were increased by only 15 percent. This resulted in a net annual savings to the transit authority of approximately $2500. In another scenario in which population density and average daily ridership were greater in the area served by a similar route-deviation service, the fixed-route alternative proved to be more expensive and to provide lower-quality service. This concept has been tested but only on a limited basis.

Doorstep many-to-many service may have greater impacts than demonstrations thus far would suggest if high vehicle densities [>0.6 vehicle/km^2 (>1.5 vehicles/$mile^2$)] and greater reliability (perhaps through computer dispatching) can be achieved. These systems will probably make economic sense, however, only if they are privately operated.

Ride-sharing services, such as vanpools, received less consideration in the analysis, partly because they do not represent public service in the same sense as demand-responsive modes and partly because of the lack of validated techniques for projecting demand. The analysis that was performed suggested that vanpools have the potential for attracting a significant portion (10 percent or more) of work trips to major employment centers. Vanpools appear to offer the greatest potential for attracting large market shares when they serve a single large firm and the firm is active in vanpool administration and promotion.

Paratransit as Feeder Service

Can paratransit and transit service be integrated in such a way that paratransit service is used extensively as a feeder mode?

The study results suggest that, depending on system design, paratransit can function as a feeder mode to a greater extent than it has thus far in most systems. The key factors in determining the extent of feeder service are the service configuration and the extent of transfer coordination.

For example, in one scenario that used a cycled many-to-one feeder-service option (i.e., regularly scheduled), more than 60 percent of the paratransit passengers were feeder-distributor passengers. In that alternative, passengers had to use the feeder option to make all but very short trips on the paratransit service. This parallels the results of the Ann Arbor Teltran system.

In another setting, operating many-to-one cycled service with coordinated transfers resulted in 32 percent of paratransit passengers transferring to or from line-haul service, whereas using many-to-many service without coordinated transfers resulted in only 11 percent of passengers traveling as feeder passengers. Note, however, that a large number of transfers are not required for a successful operation. In smaller urban areas, systems that do not require transfers may be feasible, attract higher overall ridership, and use only slightly more resources than those that do require transfers. Coordinated transfers make the most sense in larger areas where short feeder trips that connect with much longer line-haul trips can be made.

Implementation Strategies

How do different implementation strategies determine the impacts of IP service?

A variety of IP implementation strategies were considered in the study. The results suggest that implementation of service in areas previously unserved by transit tends to maximize the change in mobility and consumer surplus. If the density in a new service area is high enough, an IP system can be extremely cost-effective. Furthermore, the lack of any existing transit service can facilitate the implementation of IP service, since there are not likely to be vested interests in maintaining an existing transportation system and the local residents are likely to desire service. It is unclear, however, how many areas there are in the country that are still unserved by public transportation and also have sufficiently high densities to support IP service.

A second strategy involves replacing ineffective fixed-route service with paratransit. This approach may lead to only small net cost increases if the paratransit system offers better service than the fixed-route system. The results of the analysis indicate that this may be feasible, particularly in low-density areas. But eliminating existing services may be extremely difficult. Transit labor may object if it views the change as a possible threat to jobs, especially if a private operator is to be involved in the service. In addition, residents of the area who were able to use the fixed-route service may protest if they perceive the new system as decreasing their levels of service. Such protests were instrumental in stopping IP service in Santa Clara County, California, and in reinstating fixed-route service in Rochester, New York.

A third approach, which involves augmentation of fixed-route service with "overlay" paratransit service, tends to maximize coverage, level of service, and reduction in automobile ownership. This approach, however, is likely to have relatively small impacts on mobility and change in consumer surplus, and would also generally result in the greatest diversion of fixed-route passengers. Although the results suggest that many new transit trips would be generated, the cost per passenger could be very high because of competition between transit modes.

The use of paratransit service as a pilot project to serve as a generator of transit demand and to identify travel corridors that can be more effectively served by fixed routes has been discussed in the literature (1) but has been subjected to little experimentation. This strategy may make the most sense in growing areas where paratransit service can be used until population and demand densities are great enough to support fixed-route service.

One consideration in the implementation of paratransit service involves the size of the service area. The study examined both the use of paratransit in a limited area and the provision of areawide service. The first approach allows for the selection of service areas in which paratransit service can be used most effectively; the second approach allows no such distinctions and can result in very high costs per passenger. In some cases, the areawide approach may be dictated by political concerns. If equitable provision of service is an issue in a region where the suburbs are taxed to support regional transit, some form of transit may have to be implemented in all areas even though population density is not great enough to support any type of service. Implementing 100 percent coverage paratransit service may be the simplest way of achieving, or offering, equitable service. In attempts to implement areawide service, it has been determined that a staged implementation approach is preferable in order to develop operating experience, perfect system design, and gain community acceptance.

The implications of the implementation analysis suggest that IP service may be more feasible in smaller urban areas (areas of <50 000 population) than in larger ones. Among the reasons for this are (a) the existence in smaller areas of poorer transit service and more extensive unserved areas and (b) the lower prevailing wage rates and less restrictive provisions of transit labor unions in smaller urban areas. In addition, in smaller communities IP service is more likely to be seen as a service for the transit dependent, who represent a major market group for such service, whereas in larger areas issues such as congestion and air pollution are likely to be primary and, as noted earlier, IP service has no significant impact on vehicle kilometers of travel or pollution. This need not imply that paratransit services will not be implemented in larger metropolitan areas. On the contrary, as noted above, integrated paratransit can be viewed as the best way to provide equitable service to suburban areas in larger metropolitan regions. But, unless arrangements can be made with private operators to keep costs down and unless route rationalization can be avoided to the fullest extent possible to minimize citizen protests, IP service may not be readily accepted in some large urban areas.

Population-Density Requirements

Are there certain population densities at which IP service makes the most sense?

Although the differences between scenarios reflected differences in type and scale of service as well as size of setting, some patterns that relate service type to population density seem to emerge from the analysis. At very low population densities—for example, <580 persons/km^2 (<1500 persons/mile^2)—IP service appeared to be feasible and more cost effective than fixed-route service. At a population density of 1930-2300 persons/km^2 (5000-6000 persons/mile^2), there were trade-offs between fixed-route and IP service and neither option dominated. Finally, at population densities greater than 2300 persons/km^2 (6000 persons/mile^2), fixed-route service became more cost effective than paratransit service.

These results tend to confirm the conventional wisdom about the population densities at which paratransit service is most cost effective (this analysis represents one of the first attempts to systematically identify the actual numerical ranges). Note, however, that population density is not the sole determinant of the preferable type of system. The location of major activity centers, the existence of travel corridors, and the demographic characteristics of the population are also key factors in determining what type of system makes the most sense.

In the context of this discussion, it is important to understand how paratransit service can be less expensive than fixed-route service. It is commonly believed that demand-responsive and other paratransit services are more expensive than fixed-route transit. In fact, on an hourly basis, paratransit is only slightly more expensive than fixed-route service, perhaps by as much as 15-20 percent (which reflects the cost of dispatching). The differences between the two modes may be most significant on a per-passenger basis. At higher densities, when sufficient demand is generated, fixed-route service is significantly lower in cost per passenger because of higher productivities. At lower densities, either the fixed routes are spaced so as to serve only a portion of all persons in the area or a large number of routes are needed. Vehicles must travel along the routes whether there is demand or not. In either of these cases, demand-responsive service may be less expensive on a per-passenger basis. In addition, greater possible paratransit coverage may yield greater changes in automobile ownership and consumer surplus.

Effect on the Taxi Industry

Would the introduction of IP service have a significant impact on the taxi industry?

The answer to this question is yes, if paratransit were entirely publicly operated. Most of the scenarios that featured publicly operated IP service resulted in a decrease in taxi revenues of about 10 percent and, because of economies of scale, a decrease in taxi profits of 30-40 percent (these percentages were derived under the assumption that all drivers in each setting were commission drivers). Clearly, this is a significant impact on an industry that is currently only marginally viable. The extent of the impact would vary from company to company within a given setting, and the overall impact would depend on the local condition of the industry. For example, in one setting in which the taxi industry was very weak, the profit from the exclusive-ride taxi service was projected to decrease by more than 70 percent.

One obvious way to deal with this problem is to contract with the taxi industry to operate all or portions of the paratransit system. Our analyses suggest that in most cases this would more than offset the loss of exclusive-ride taxi revenue and at the same time reduce the cost of the IP service. But it may not always be possible to contract with a private operator. For example, a taxi operator may not be the appropriate provider of route-deviation service or other hybrid systems that combine fixed-route and demand-responsive service. In cases in which some fixed-route service is curtailed, labor provisions such as Section 13c of the Urban Mass Transportation Act of 1964 may make it impossible to provide paratransit service without using unionized transit labor. These are only some of the potential institutional problems.

If contracts with the private taxi industry are to be instituted, a number of factors must be considered, including the following:

1. Drivers may not be of the same quality or reliability as those in the public sector because of the lower prevailing wage rates in the private sector. This could be viewed as a problem particularly in providing services for the elderly and the handicapped. If a concerted attempt is made to hire more reliable drivers, wage rates may be forced up.
2. In cases of integrated services, it may be more difficult to achieve coordinated transfers between fixed-route and paratransit service if different groups of employees are involved.

The terms of the contracts are important to both parties. The private sector must be ensured of a return that is sufficient to make participation worthwhile, and the public sector should be given a share of any benefits from system economies. Some mechanism is required by which these advantages to both sectors can be provided.

SUMMARY

In summary, this study has concluded that, in some but not all instances, the benefits of IP options in terms of improved service levels and mobility, reduced automobile expenditures, and other impacts may justify system deficits. This is based on several factors, including (a) high paratransit productivities, possibly achieved by implementing combined (hybrid) fixed-route and demand-responsive services (such as checkpoint many-to-many), and (b) low operating costs, possibly achieved by contracting with private operators. IP service was found to have a positive but insignificant impact on reducing automobile use and ownership and no measurable impact on vehicle kilometers of travel, fuel consumption, or emissions. Promising locations for paratransit implementation are areas in which population density is 1150-2300 persons/km^2 (3000-6000 persons/$mile^2$) and existing transit service is limited.

The results presented here are in no way startling or novel. They represent the moderate view: Paratransit is neither a panacea nor a failure. A properly designed paratransit system can be a cost-effective transportation system that yields a variety of benefits to different groups. In some cases, however, paratransit systems do not yield sufficient benefits to justify expenditures. Furthermore, paratransit is not the solution to problems of congestion, energy consumption, or air pollution although it may play a small role in alleviating those problems.

The study results will undoubtedly be the source of further confusion and disagreement. They are not the final word. They are based on a more extensive study of the subject than any undertaken previously, but even this study has addressed only some of the many variations of IP service and the types of settings in which it can potentially be applied.

ACKNOWLEDGMENT

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Review and Assessment of Paratransit Models

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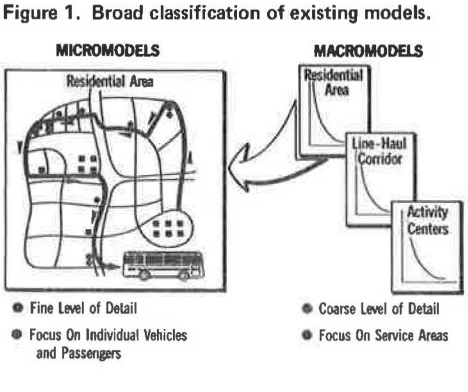
The development of integrated paratransit systems has been accompanied by the development of a wide range of modeling and analytic activities designed to shed light on the delicate balance between supply, demand, and cost in a paratransit network. Modeling and analytic approaches have ranged from complex situations to simple rules of thumb. Of the wide range of theoretical models developed so far by academics, researchers, and consultants, relatively few have been applied in a practical planning context, and the results of these limited applications have been mixed. A comprehensive survey of the analytic procedures and tools developed to address paratransit planning and evaluation problems is presented. Modeling procedures are described and classified, the historical development of the models is traced in the context of the parallel development of paratransit systems, the performance of existing models is compared, and the attributes and application potential of several general classes of models are summarized.

The development of integrated paratransit systems has been accompanied by the development of a wide range of modeling and analytic activities designed to shed light on the delicate balance among supply, demand, and cost in a paratransit network. Modeling and analytic approaches have ranged from complex simulations to simple rules of thumb. Of the wide range of theoretical models developed to date, relatively few have been applied in a practical planning context, and the results of these limited applications have been mixed.

Figure 1. Broad classification of existing models.



A comprehensive literature search, accompanied by extensive discussions with members of the paratransit community, has resulted in the identification of more than 70 references that deal with the modeling of flexibly routed transportation systems. This paper summarizes the development, classification, and application potential of the models represented in the literature. A more detailed examination of model attributes, as well as a comparison of the relative capability and ease of use of similar models, can be found elsewhere (1).

SURVEY OF EXISTING MODELS

General Classifications

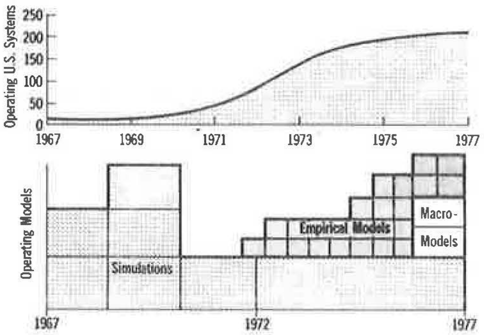
A coarse system of classification for existing models that is based on the level of model complexity and the focus of the modeling effort is shown in Figure 1. This classification system divides paratransit models into two distinct groups:

1. Micromodels, which deal with a fine level of detail and focus on the relations between individual vehicles and passengers, and
2. Macromodels, which deal with a coarser level of detail and focus on individual service areas and region-wide performance rather than on individual vehicles and passengers.

Micromodels

Micromodels are primarily used to address analytic questions and explore detailed vehicle-passenger relations in a single service area. Detailed simulations and disaggregate supply-demand models serve as two examples of the general classification of micromodels. Current and past micromodels of paratransit systems

Figure 2. Historical development of paratransit systems and models.



include the computer simulations developed by Northwestern University (2, 3), Westinghouse, (4), General Motors (5), and Ford Motor Company (6); Princeton's generalized feeder simulation model (7); the computer-aided routing systems (CARS) simulation developed by the Massachusetts Institute of Technology (8-10) and updated in the advanced dial-a-ride (ADAR) project (11); and, on a somewhat less detailed level, the supply-demand models developed by Cambridge Systematics, Inc., and Multisystems, Inc. (12).

Macromodels

Macromodels can range in complexity from sophisticated stochastic models to simple rules of thumb. Four levels of complexity were identified in classifying macromodels for this state-of-the-art review. These four levels are, in order of decreasing complexity, (a) stochastic models, (b) deterministic models, (c) empirical models, and (d) rules of thumb.

There are no clear lines of demarcation that separate these classifications, and the distinctions between adjacent categories tend to blur at the edges. A similar classification scheme was used by Wilson and Hendrickson (13) in reviewing paratransit supply models. The criteria to be included in each category are described in a general way below:

1. Stochastic models—Stochastic models approach micromodels in level of complexity, depth of detail, and data requirements. Relatively few stochastic models of paratransit systems have been developed thus far. Stochastic queueing models have been formulated to represent exclusive-ride taxi systems (14, 15), and Markov models of many-to-one and many-to-many paratransit services have been developed (16, 17).

2. Deterministic models—Most recent theoretical efforts to model the performance of paratransit systems can be classified as deterministic models. These models typically treat the stochastic aspects of system performance by using deterministic approximations grounded in geometric probability relations. Examples of this approach can be found in the work of Ward (18-21), the Systan SMART model (22-24), the Multisystems macromodel (25), and the descriptive supply model developed by Flusberg and Wilson (26).

3. Empirical models—Empirical models "attempt to develop simple relationships between the key attributes of system performance and design" (13), generally through regression analysis. Early empirical models (27) used simulations as a basis for generating regression relations; more recent models have reflected actual operating experience in developing relations between factors such as fleet size and demand density or ridership and population (28, 29).

4. Rules of thumb—Rules of thumb represent a distillation of conventional wisdom, operating experience, modeling results, and "quick-and-dirty" calculations reduced to single sentences that have the ring, although not necessarily the reliability, of axioms. Examples of rules of thumb are the following: "It is considered necessary to maintain the level of service such that the ratio of waiting plus travel time for a demand-responsive trip to the time required to make the same trip by automobile does not exceed 3.0" (30) or "an average of one seat per 1040 population" represents a rough cut at the total number of seats needed to start a dial-a-ride service (31).

Model Genealogy

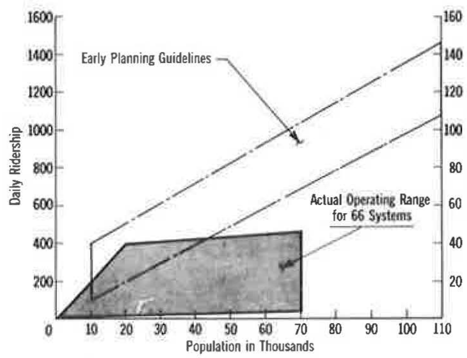
Figure 2 traces the development of paratransit models over time and relates that development to the historical introduction of paratransit systems in U.S. cities. The graph at the top of the figure charts the approximate number of operating paratransit systems in U.S. cities between 1967 and 1977. The flow diagrams beneath the graph trace the chronological development of major paratransit macromodels and micromodels over the same period and show the genealogical relations between successive modeling efforts.

Between 1967 and 1970, when there were relatively few paratransit systems operating in the United States, most efforts to model the paratransit concept took the form of complex simulations. At least four different simulations were developed during this period by Northwestern (2), Westinghouse (4), General Motors (5), and the Massachusetts Institute of Technology (M.I.T.) (9, 10, 32). As more and more paratransit systems were introduced in U.S. cities between 1972 and 1977, more and more system models were developed. But the relative complexity of the theoretical models diminished as operating experience with real systems was gained. When this paper was written, only one of the original simulations—the M.I.T. model—was known to be still in use. The most recent modeling efforts reflect regression analysis of operating systems (29, 31).

It is not surprising that elaborate simulation models should give way to simpler, empirical models as operating experience with actual systems increases. The simpler models are more accessible to planners than the simulation models, require fewer data to apply, are more easily understood, and offer results that are no less trustworthy than those of complex models for several basic planning tasks. Simulations contributed to the early understanding of demand-responsive systems by illuminating the nature of basic supply-demand relations and contributing to the education of the simulation developers, several of whom went on to help plan operating systems and develop less complex models. Although certain basic research questions remain that can best be answered through the use of detailed simulations, many practical operating decisions that relate to fleet size, service area, and operating policies can be guided just as readily by empirical models.

Early modelers of paratransit systems tended not only to develop more complex models than later analysts but also to be more optimistic. Early paratransit models were supply models that treated demand exogenously and had no internal capability for reconciling supply and demand levels. Nor was there much operating experience to provide an external reference for such a reconciliation. Modeling results were thus heavily dependent on the level of demand selected by the modeler. Early modelers typically overstated system demand and, as

Figure 3. Early planning guidelines and subsequent operating experience.



a result, overspecified system service levels. As Wilson (13) has observed, "Early studies of the economic feasibility of dial-a-ride suffered particularly from this problem, overestimating demand by between one and two orders of magnitude, leading to an overoptimistic economic assessment of the system."

The discrepancy between overly optimistic early expectations for demand-responsive systems and actual experience is reflected in Figure 3, which compares early planning guidelines developed by the Mitre Corporation (28) with later guidelines that reflect a wider range of operating experience (33). As Figure 3 shows, although the later guidelines based on operating experience with 66 systems overlap a portion of the area covered by the earlier guidelines, the ridership levels and demand density reflected by actual operating systems are but a fraction of the range anticipated in earlier theoretical work.

MODEL PERFORMANCE

The findings of a series of comparisons made among models of a specific type and function are summarized here. In the case of microsimulations, inputs, outputs, and assumptions of different models were compared; past and potential uses of simulations in paratransit planning and analysis were reviewed; and the advantages and disadvantages of the simulation approach were itemized. In the case of macromodels, the performance of the simpler demand, supply, and cost models was compared by using sample data from a range of existing services. The details of the comparison process are discussed by Billheimer and others (1).

Simulation Models

A simulation model is an attempt to create artificial events related to artificial objects in a manner that parallels what occurs in a real system. The interrelation of the modeled events is often complex even though the specification of the individual events and objectives may be simple. Simulation is an effective tool in developing an understanding of system behavior when the relations between model events and objects are easily understood and specified but the cumulative effect on the whole system is uncertain. The chief advantage of the simulation approach to paratransit modeling is that it enables the analyst to model those details of the interaction between passengers and vehicles that cannot be treated effectively in purely analytic models and permits the investigation of different algorithms of vehicle control.

Although the simulation approach supports the exploration of detailed system dynamics, it has several serious disadvantages. Simulation models are cumbersome, inflexible, subject to statistical sampling errors, and limited in the scope of their application. They are cumbersome because they usually have extensive data requirements, and some familiarity with computers is needed if they are to be used effectively. Since existing demand-responsive simulations usually model only one type of service, they are somewhat inflexible for analyzing alternative service types. Furthermore, extensive data requirements may make it difficult to model more than one setting. The cost of using simulation models can be high and, because of the detailed, specific nature of the input requirements, the results typically are not readily transferable to other systems and settings.

Existing simulations are incapable of addressing one of the most important problems in the analysis of demand-responsive systems, the problem of demand prediction. The analyst must use some other approach to estimate demand and then use the simulation to explore the relation between demand and such supply-related questions as fleet size or response time. In the past, this process has not led to notably accurate estimates of either supply or demand (1, 13).

Since the cited disadvantages can be severely limiting in certain applications, extreme caution should be exercised if simulations are to be used in such activities as feasibility analyses, systems design, or model calibration. Nonetheless, simulation remains the most effective tool for evaluating paratransit control algorithms and is one of the few methods currently available for obtaining disaggregate measures of system performance.

Disaggregate Models of Supply and Demand

Few existing models treat paratransit supply and demand interactively at the disaggregate level—that is, focus on individual trip makers or socioeconomic groups rather than on entire service areas and treat the relation between supply and demand interactively. The most significant one is a model developed by Cambridge Systematics and Multisystems (12) that places a sophisticated analytic tool in the hands of the user without burdening him or her with excessive input requirements and appears to be a potentially valuable tool for analyzing systems that have reached a steady state.

Macromodels

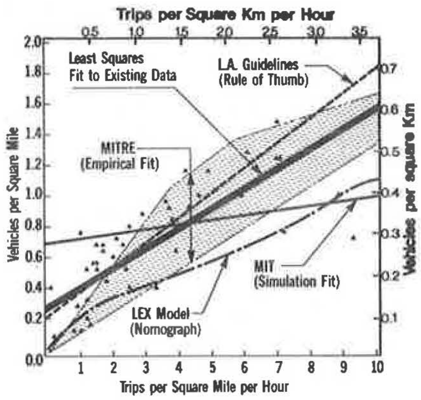
Existing macromodels of paratransit systems have addressed questions of system demand (ridership and fare elasticity), supply (fleet size), performance (level of service and response time), and cost. A hybrid class of models, designated as supply and demand models, has attempted to balance the interlocking relation between supply and demand. This relation is typically more complex in demand-responsive systems than in conventional fixed-route systems. In both types of systems, ridership is heavily dependent on service quality. In conventional systems, however, service quality is relatively independent of ridership except when the capacity of the system is approached. By way of contrast, in demand-responsive systems, service quality may suffer as ridership increases over all ranges of demand. In an attempt to reflect this interactive relation, certain supply and demand models iterate between ridership estimates and service measurements until an equilibrium point is approached. This iteration can be accomplished by computer, as in the case of the model recently developed by Cambridge Systematics and Multisystems (12), or by the successive application of nomographs, as in an

Table 1. Analytical estimation of demand density in five test cities.

	Demand Density (trips/km²/h)						
		Predicted					
City	Observed	Empirical Fit to Population	Empirical Fit to Population Density	Lea Systems	LEX/TRAN Calculator	Los Angeles Guidelines	Mitre Nomographs
Naugatuck, Connecticut	0.3	0.4	0.77	0.9	1.16	1.12	0.33
Merrill, Wisconsin	1.3	0.8	1	0.4	7.7	1.1	0.7
Danville, Illinois	1.2	0.15	0.31	0.12	1.54	0.58	1.5
Syracuse, New York	0.06	0.31	0.8	0.85	2.7	0.9	0.2
Orange, California	2	1.16	1.7	5.2	9.65	1.12	1.8

Note: $1\ km^2 = 0.386\ mile^2$.

Figure 4. Comparison of four approaches to estimating fleet size.



earlier macromodel developed by the Mitre Corporation (34).

Comparisons of Demand Models

In an effort to assess the utility of existing demand models, six of the simpler models were tested by using data from five sample dial-a-ride cities (see Table 1). The cities were chosen because, collectively, they span a spectrum of city types: small urban areas, large low-density areas, and thickly populated inner cities. None of the cities chosen was used in calibrating the six demand models tested, which are identified below:

1. Empirical fit of demand to service-area population in 43 cities that have dial-a-bus transit systems (29);
2. Empirical fit of demand density to population for the same 43 cities (29);
3. Empirical fit of demand to both population and population density on several Canadian dial-a-bus operations (35);
4. Use of nomographs that reflect both the fare and the population density of the service area (36);
5. The rule of thumb, e.g., 13.5 passenger trips/day/km² (35 passenger trips/day/mile²) (31); and
6. Simultaneous estimates of demand and vehicle supply by the use of nomographs obtained by an empirical fit to dial-a-bus data for 16 cities (34).

The actual demand densities observed in each of the five test cities (in trips per square kilometer per hour) as well as values estimated by using methods 1 through 6 above are given in Table 1. Although more extensive tests should be made as additional data become available from operating systems, certain observations appear to be justified on the basis of the current analysis. It is evident in Table 1 that method 6, the Mitre nomograph technique, performed more consistently than the other methods. It seldom produced widely inaccurate estimates and sometimes gave excellent ones. The superior performance of this model can be traced jointly to the broad spectrum of city types used in its calibration and to the theoretical soundness that arises from considerations of supply-demand equilibrium. Most empirical approaches to demand prediction performed poorly in this test and, except in the case of the Mitre model, there seemed to be little overall connection between the sophistication of a model and the quality of its results.

Models of Fleet Size

Models for estimating fleet size attempt to predict the number of vehicles needed to serve a given area. Most fleet-size models require demand as an input and show approximately linear relations to demand. If demand is known, many methods of fleet-size estimation perform well in test cases; without demand estimates, most such methods fail miserably. Only the Mitre nomograph technique, because of its equilibrium structure, produced useful estimations of fleet size without accurate demand input. Figure 4 compares the fleet size (in vehicles per square kilometer) predicted by four simple models based on demand densities with a least-squares fit to data from 66 existing systems.

Performance and Cost Models

Cost models usually attempt to predict the operating costs of a new system. Because demand-responsive systems are characteristically labor intensive, labor costs typically account for between 50 and 80 percent of total system costs. In practice, system costs vary widely as a function of wage rates, work rules, and union practices. Existing models range from very simple rules of thumb to more complex, computer-based methods. The simple models are generally based on fits to one key variable, such as fleet size or labor wages. Their performance in test cases is generally adequate for purposes of preliminary planning, but they leave many variables unaccounted for and hence give the user no meaningful information on controlling costs.

Performance models attempt to estimate some variable in order to predict system performance. A variety of analytic techniques are devoted to the estimation of average wait and ride times. They perform adequately for test cases but require information on demand and fleet size. Some models attempt to analyze performance by considering system productivity. Test cases reveal, however, that these approaches have tended toward overestimation. As more and more operating data that reflect relatively low levels of productivity have become available, models have become increasingly conservative in estimating this factor. Figure 5 shows the gradual decrease of productivity estimates over time as they approach the median figure of six passengers per vehicle hour reported by a sampling of 60 general-

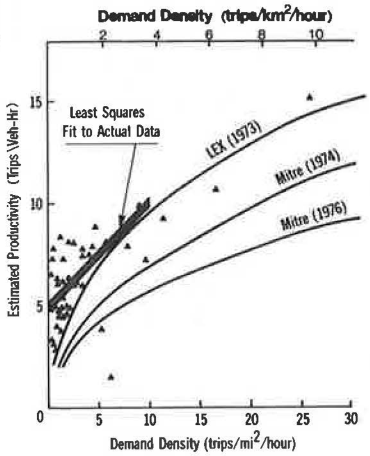
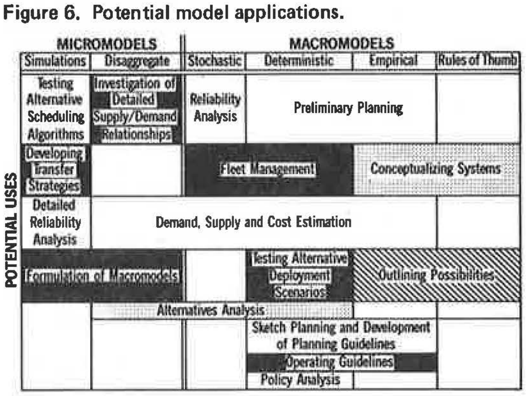


Figure 5. Productivity as a function of average demand density.

Figure 6. Potential model applications.



market dial-a-bus systems (33).

General Observations

The failure of many models to produce accurate results in test cases can be traced to a number of factors. Chief among these are unrealistic optimism, a narrow range of calibration sites, and insufficient screening of sample data. Early demand-responsive transportation models tended to reflect an optimism about demand potential that was not borne out by operating experience. As a result, many early models produce grossly inaccurate estimates of demand, and they are usually unable to deal effectively with realistic demand levels.

Thus far, approaches that involve the use of surveys have not been effective predictors of demand. The main difficulty lies in the tendency of respondents to overestimate their potential use of a system that is still in the planning stages. In practice, advance surveys have yielded results that would promise ridership levels more than 10 times those actually experienced. Extrapolation from these very large values of "noncommitment" demand to relatively small values of real demand rarely produces accurate predictions of real demand.

The user of any model of demand-responsive transportation systems must ensure that the assumptions used in developing the model accurately reflect the situation in the area of interest. Several empirical models have been calibrated for cities that have a narrow range of demographic traits and perform poorly when applied to areas outside that range (1). Nonetheless, the relative success of certain models in predicting demand in areas similar to the calibration regions suggests that future empirical models should attempt to segregate data from different types of systems. Currently, many empirical models mix data from many-to-many services in attempting to develop relations between demand or fleet size and demographic characteristics. This practice reduces the likelihood of obtaining an acceptable fit to existing data. As more data from operating systems become available, it may be possible to stratify the samples used in calibrating empirical models by demographic characteristics and type of service so that more accuracy can be obtained.

POTENTIAL USES

Figure 6 associates potential model applications with various levels of complexity identified in the model review process. In many cases, an application may span several levels of model complexity. In general, of course, the more complex micromodels are theoretically capable of undertaking any of the tasks designated for less complex models. However, the cost, the inflexibility, and the undependable record of these models dictate that they be considered only for tasks that cannot be handled by the simpler models. By virtue of their position in the midrange of system complexity, deterministic macromodels appear to have the widest range of potential uses. Simple enough to be used and understood by a wide range of users, they remain sufficiently detailed to provide insights into the complex relations that link supply, demand, and cost parameters.

SUMMARY

As the first of the micromodels developed to represent paratransit systems, computer simulations have been tested in many of the applications listed for all model levels in Figure 6. These micromodels have shown themselves to be well suited for the detailed analysis necessary in the design and evaluation of scheduling and dispatching algorithms. However, Wilson, one of the early developers of the simulation approach to paratransit modeling, notes in his review of supply models (13) that "experience suggests a good deal of caution in the use of simulation models for planning new systems." Simulation models have not fared well in past planning tasks for a variety of reasons, including their dependence on exogenous demand estimates, their failure to reflect important stochastic elements, their inflexibility, the significant investment of time and cost required for their application, and their relative inaccessibility to the planning community. The planner who is designing a small demand-responsive system typically does not need the level of detail provided by a simulation model, lacks the time and sophistication necessary to adapt and apply the model, and could probably not justify the relatively high cost of analysis in light of the relatively low cost of the system itself.

Nonetheless, the simulation approach "remains the most effective tool in algorithm design and the only way to obtain disaggregate measures of system performance" (13). Existing simulations have been limited even in these applications by an inability to represent more than one control algorithm and the failure to replicate aggregate performance measures within acceptable limits of accuracy. These deficiencies in existing simulation models have led the Urban Mass Transportation Administration to fund the design and development of a more flexible microsimulation model that is capable of replicating and evaluating a wider range of service and control alternatives (37).

Although simulations have generally not served successfully as direct system-design tools, they have played an important role in contributing to the modeler's understanding of paratransit systems and have supported the development of macromodels that are appropriate for design work.

Deterministic models appear to be able to reflect many of the important aspects of system operation. If expanded to include such stochastic measures as system reliability, the most complex of these models—the Multisystems macromodel (25) and the Systan SMART model (23)—should prove useful in testing alternative deployment scenarios, evaluating trade-offs between different service combinations, and developing general guidelines that relate system design to area characteristics.

Empirical regression models are currently the most accessible tool for the system planner and offer the best means for developing rough, rapid estimates of supply, demand, and cost. As more and more operating data from different systems become available, these models should be refined to reflect the impact on supply-demand relations of such site-specific factors as climate, historical transit ridership, and automobile ownership.

ACKNOWLEDGMENT

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Evaluation of Interpersonal Influences in the Formation and Promotion of Carpools

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A three-phase analysis of the role of interpersonal factors in carpooling performed at the University of Iowa is described. Phase 1 used laboratory simulation methods in which respondents rated the relative desirability of alternative carpool descriptions. The desirability of carpooling was found to decrease as the number of nonacquaintances in the pool increased, and particularly low ratings were given to carpools that consisted wholly of nonacquaintances. In phase 2, attitudinal and behavioral data from an existing industry-based carpool promotional program were analyzed by using Federal Highway Administration matching techniques. The data confirmed the importance of acquaintanceship as a factor in carpooling. Phase 3 used the findings from phases 1 and 2 to design and implement promising strategies for promoting carpooling. Strategies that stressed person-to-person contact between potential carpoolers and used existing networks of acquaintanceship to increase the number of carpools were emphasized. It is concluded that evaluation of such strategies should be useful in formulating future carpool promotional programs.

Over the years, transportation researchers have increasingly come to realize the importance of social factors in travel decisions. In particular, the choice of a multioccupant mode, such as carpooling, for the journey to work involves interpersonal as well as economic factors. Programs designed to increase carpooling must take this into account. The goals of this paper are to advance some ideas about the role of interpersonal factors in ride sharing and to show how these ideas can be used to promote carpooling.

Hartgen (1), Horowitz and Sheth (2), Kurth and Hood (3), Levin and others (4), and Margolin and others (5) all view ride sharing as a psychosocial process. Hartgen's review of recent findings leads to four hypotheses for why ride sharing is not very common: (a) Carpoolers have unique trip and travel needs, (b) solo drivers lack the information needed to form carpools, (c) attitudes of carpoolers are different from those of solo drivers, and (d) the social processes involved in carpooling are difficult for solo drivers to overcome. Hartgen (1) reports that Margolin and Misch used decision analysis panels in the Washington, D.C., area to develop hypotheses about ride-sharing motivation and found that the factors that deter people from carpooling include a desire to maintain independence, concern over waiting for others, and personal incompatibilities with other members of the pool. Among the more interesting data in the study by Margolin and Misch on interpersonal factors were that 87 percent of their commuters wanted to meet prospective members before making any ride-sharing arrangements and 39 percent felt that they would have to know the people first. Since traditional carpool matching programs ultimately leave it to the individual participant to contact other potential ride sharers on a list, a reluctance to contact strangers can be a major problem in forming carpools.

The carpooling research program at the University of Iowa (4, 6, 7) is based on the premise that a thorough understanding of the individual decision processes and attitudes that underlie ride-sharing behavior is a prerequisite for designing and implementing effective carpooling programs. Thus, the analysis consists of three phases: (a) laboratory simulation studies of the in-influence of interpersonal factors on attitudes toward carpooling, (b) analysis of attitudinal and behavioral data from existing carpooling programs, and (c) design, implementation, and evaluation of potentially effective strategies for promoting carpooling.

Table 1. Study response on likelihood of carpooling in carpools of certain characteristics.

Characteristic	Likelihood of Carpooling (mean rating)	
	Males	Females
Daily savings[a] (cents)		
20	7.1	7.0
50	8.9	8.6
Additional travel time[a] (min)		
10	10.9	10.2
30	5.1	5.4
Acquaintanceship among riders		
No acquaintances		
Two males	6.2	5.6
One male, one female	7.0	7.0
Two females	7.2	7.5
One acquaintance		
One male nonacquaintance, one male acquaintance	7.8	7.5
One male nonacquaintance, one female acquaintance	8.1	8.2
One female nonacquaintance, one male acquaintance	8.2	8.1
One female nonacquaintance, one female acquaintance	8.4	8.3
Two acquaintances		
Two males	9.1	8.2
One male, one female	8.9	8.5
Two females	9.0	9.2

[a]Specified as difference between driving alone and carpooling to work with two other people.

LABORATORY SIMULATION STUDIES

Hypothetical carpool formations were described by varying the number of riders in the pool, the gender of each rider, and whether or not each rider was a prior acquaintance of the respondent (4). Respondents then rated the desirability of each alternative carpool formation. These ratings can be summarized as follows:

1. Ratings increased as the number of acquaintances in the pool increased. The lowest ratings were given to carpools in which there were no acquaintances. Even one acquaintance in the pool raised the ratings to above neutral.
2. Both male and female respondents rated carpools with female riders higher than carpools with male riders.
3. The gender of riders did not affect carpool desirability ratings as much when the riders were acquaintances as when they were nonacquaintances. When the rider was an acquaintance, gender did not matter; when the rider was a nonacquaintance, both male and female respondents preferred female riders.

A second study (4) extended these results by showing that they hold when cost and time factors as well as interpersonal factors are considered. In the second study, hypothetical carpool formations were described by varying rider characteristics, cost savings for carpooling versus driving alone, and additional travel time for carpooling. These results are given in Table 1.

The data show that, on a 15-point scale of rated likelihood of joining a carpool, ratings were about 1.7 points higher when the daily savings were 50 cents than when they were 20 cents and about 5 points higher when the additional daily travel time was 10 min than when it was 30 min. In addition, ratings varied by about 3 points as a function of rider characteristics. Rider characteristics thus had effects comparable to those of cost and time factors. As shown by Levin and others (4), the most parsimonious model of the effects of rider characteristics on the desirability of a given carpool is as follows: The desirability of a carpool is an average of the desirability levels of the individual riders, the desirability of a given rider being a joint (multiplicative) function of gender and acquaintanceship. The main implication of this averaging model is that a desirable carpool mate (i.e., an acquaintance) can compensate for an undesirable carpool mate (i.e., a nonacquaintance) and lead to a carpool formation of at least moderate desirability. We will return to this point later when we discuss methods of increasing the desirability of carpools.

Results of the laboratory simulation studies thus led us to believe that interpersonal factors are comparable in importance to more traditionally studied cost and time factors in carpooling and, in particular, that acquaintanceship is a potent factor that should be incorporated into strategies for promoting carpooling. To be sure, other interpersonal factors, such as commonality of interests, occupation, and age, can be shown to play a role in the desirability of joining a carpool. However, many of these factors can be subsumed under acquaintanceship; for example, people with contrary interests will not likely become good acquaintances. In fact, this easy-to-operationalize factor may be a good surrogate for a cluster of other interpersonal factors. Thus, the next step in the study of interpersonal factors in carpooling was an investigation of the role of acquaintanceship in an existing program of carpool promotion.

EVALUATION OF AN EXISTING CARPOOLING PROGRAM

In phase 2 of the research, an industrial firm that was in the process of initiating a carpooling promotional program was surveyed. The firm was interested in promoting carpooling because it wanted to expand its facilities and increase the number of its employees without having to set aside valuable space for additional parking. The company strongly encouraged ride sharing through frequent newsletters and memorandums, newspaper and television advertisements, and a widely publicized press conference at which the start of a ride-sharing program was announced. [Additional information about this program is provided in reports by Dueker and others (8) and Levin (9).] A Federal Highway Administration origin-destination matching program was used to provide lists of names and addresses to 91 employees matched according to work schedule, work location, and home address within a 2.5-km^2 (1-$mile^2$) area. From these, only two new carpools were formed and one existing carpool was enlarged, but 10 of the people on the lists joined carpools with people who were not on the lists.

Six months after the promotional program was initiated, a questionnaire was administered to all 1900 employees, of which 1325 (70 percent) were returned. Separate sets of questions were designed for carpoolers and noncarpoolers. The crucial items for noncarpoolers were (a) a checklist of reasons for not carpooling and (b) an indication of whether or not the respondent was interested in carpooling. The crucial items for carpoolers were (a) ratings of the importance of various reasons for carpooling and (b) a description of the current carpool, including names of riders, how well acquainted each rider was with the respondent before formation of the carpool, distance from riders' homes to the respondent's home, and an indication of who contacted whom to initiate formation of the carpool.

An initial hypothesis based on the laboratory studies [and on other research, including that done by Margolin and others (5)] was that employees would be reluctant

Table 2. Study response (percentage of respondents) on importance of reasons for carpooling based on distance between riders.

Reason for Carpooling	Degree of Importance	Distance Between Riders 1.6 km	3.2-8 km	≥9.6 km
Save money	Very important	60	74	83
	Important	32	10	17
Conserve energy	Very important	52	42	61
	Important	41	47	39
Share driving	Very important	31	26	50
	Important	32	37	9
Enjoy company	Very important	26	26	35
	Important	40	32	35
Family needs the automobile	Very important	15	16	13
	Important	14	5	9

Note: 1 km = 0.62 mile.

to initiate contact—the first crucial step in forming a carpool—with strangers. Two aspects of the data supported this hypothesis. Although 35 percent of the respondents indicated that they were carpooling, only 1 percent indicated that they had begun carpooling as a result of the program. The most important result in relation to the carpoolers was that more than two-thirds of them were at least fairly well acquainted with their fellow carpoolers before pooling began. Only 15 percent did not know one another at all before carpooling. The data on acquaintanceship are summarized in the table below:

Degree of Acquaintanceship	Number of Males	Number of Females	Total Number	Total Percent
Very well acquainted	278	12	290	39
Fairly well acquainted	206	9	215	28
Slightly acquainted	127	5	132	18
Not at all acquainted	102	7	109	15

We also attempted to trace the sequence of contacts involved in setting up a carpool by asking respondents to list their fellow carpoolers and indicate who contacted whom. Among acquaintances the process was apparently rather casual; quite often person A would indicate that he or she contacted person B but person B would say the opposite.

Whereas half of the riders in a given carpool lived within 3.2 km (2 miles) of each other, 16 percent lived more than 16 km (10 miles) apart. Table 2 summarizes the importance of various reasons for carpooling as a function of distance between riders. The farther riders lived from each other, the more important they rated cost savings and energy conservation as reasons for carpooling. In addition, a large percentage of carpoolers rated enjoying the company of others and sharing the driving as important reasons for carpooling. Thus, there appear to be some perceived social as well as economic and energy-conserving advantages to carpooling.

The table below summarizes the data for noncarpoolers by comparing the reasons for not carpooling indicated by those interested and those not interested in carpooling:

Reason	Number Not Interested	Number Interested
Carpooling would be too time consuming	111	7
No one has contacted me	36	84
Wouldn't save enough money	146	10
Don't like to contact strangers	33	14
Need the automobile	282	21

Most noncarpoolers (74 percent) indicated that they were not interested in carpooling. The primary reason seems to be a need for the automobile during or after working hours. Of those who did not enter carpools but indicated that they were still interested in carpooling, the primary reason for not having joined a carpool was lack of contact with other potential carpoolers. In other words, the crucial initial contact had not been made.

In summary, analysis of this promotional program reinforced earlier views of attitudinal differences between carpoolers and noncarpoolers and the role of interpersonal factors in ride sharing. Much of whatever success the program had could be attributed to promotion aimed at increasing employee awareness of the desirability of ride sharing. This presumably encouraged people to talk with their friends about the feasibility of sharing rides. But very few people took the initiative to call strangers whose names were supplied on a computer-generated matching list.

Most noncarpoolers had strongly felt reasons for not carpooling; this group is therefore probably not a good target for promotional programs. A sizeable number of employees, however, appear to be interested in carpooling but do not contact strangers to initiate formation of a carpool. These people would constitute the ideal group for the application of promotional strategies that use the "personal touch" to overcome problems with traditional matching techniques. Several such strategies are described in the following section.

PROMOTIONAL STRATEGIES

A 1976 evaluation of existing carpool incentives and disincentives by the Federal Energy Administration (FEA) (10) distinguishes successful from unsuccessful strategies. On the whole, incentives are recommended over disincentives. These include carpool matching and promotion, vanpools and buspools, preferential parking, and parking subsidies. The current view is that carpooling promotional programs should include such incentives wherever possible but go beyond those recommended by FEA by making carpooling socially desirable as well as economically advantageous.

The three strategies described below are the result of consideration of our laboratory findings that carpools that consist of all nonacquaintances are of low desirability and our study of actual carpool formation, which showed that very few people initiated contact with nonacquaintances on their matching list.

Chaining

In the laboratory study, the desirability of carpooling decreased as the number of nonacquaintances in the pool increased, but even one acquaintance in the pool raised the level of desirability to above neutral. Thus, attempts should be made to ensure that each potential carpooler knows at least one person in the pool. Lists of potential carpoolers would be drawn from, for example, employees of large firms who have the same work schedules and destinations. Since the study of carpool formation showed that carpoolers often live far apart, home addresses would be matched only roughly in terms of possible routes to be taken to work. Each member of the list would be asked to identify acquaintances on the list with whom he or she would be willing to carpool. Acquaintanceship networks would be examined to form "chains". A chain of the form A-B-C-D would be optimal where person A knows person B, B knows C, and C knows D. In such a chain, each person would have at least one acquaintance in the carpool. B and C could serve as the contact persons to organize the pool because they would never have to contact a stranger. Even a pool of the type A-B, C-D would have the desirable property that each person would know one other person in the pool; however, identifying a "contact person" would be more difficult in this case (see the discussion of this point below).

The main practical problem that we discovered with the chaining strategy is that there must be a large number of people on the original lists before new chains can be formed, especially since most carpools are already based on acquaintanceship networks. However, people who do not know each other quite well enough to have initiated carpools on their own or who did not realize that they lived along the same corridor might well be influenced by the chaining strategy.

Face-to-Face Contact

A major reason for the limited success of existing matching and promotional programs is that individuals are ultimately left with the responsibility of contacting others—usually strangers—to initiate the formation of a carpool. A work setting would be the ideal place to bring together interested people who have been identified as potential carpoolers on the basis of origin-destination matching (broadly defined). This might require no more than a 20-min coffee break during which potential poolers could meet each other, "break the ice", and then discuss subjects such as cost sharing, driving rotation, and optimal routes as well as groundrules on smoking, playing the radio, conversation (e.g., no "shop talk"), and whether the carpool would make stops along the way for shopping or other purposes. In other words, more could be accomplished in one personal meeting than might be accomplished in several long and inconclusive dyadic telephone conversations. And, of course, those telephone calls might never be made because of reluctance to contact strangers.

One side benefit of this procedure could be that people who work in the same organization would recognize each other in person even if they did not recognize each other's names on a printed list. A major step in this procedure would be to obtain a coordinator who would arrange for the meeting, isolate different potential carpool groupings, and so on. In an industrial setting, someone like the personnel manager would be ideal for this purpose. This person would have to be convinced that the program's benefits to the company and its personnel would outweigh the time and effort involved. The researcher would have to provide detailed guidelines for ease of operation. Other suggestions regarding management's role in increasing ride sharing are provided in a report to the U.S. Department of Transportation by a team of researchers from the University of Tennessee (11).

Identification of Contact Person

As indicated, a major hurdle in forming a carpool is ensuring that the initial contact between potential carpoolers is made. The chaining procedure accomplishes this by eliminating the need to contact strangers, and the face-to-face procedure brings people into direct personal contact rather than supplying lists and requiring telephone contacts between strangers. A less satisfactory, but much simpler, method is to identify a single contact person in each potential carpool. All carpooling programs require some sort of questionnaire or survey of potential participants. A simple expedient would be to include the following item: Would you be willing to telephone other people (on your list) to form a carpool? Although one could not assume 100 percent validity in positive responses to such a question, it is fairly certain that a grouping without any "yes" respondents is doomed to failure. Having identified one or more contact persons in a potential carpool grouping, the researcher or coordinator could then maintain contact with that person in order to monitor or encourage the carpool formation process.

Some of these strategies are currently being tried out in Cedar Rapids, Iowa. We are working with the personnel directors of the two largest hospitals in the city, who are interested in promoting carpooling to help their employees save money (many employees commute from long distances and do not make large salaries). The main problem in working with hospital personnel is that there are many different work shifts and a considerable amount of changing from one shift to another.

A one-page questionnaire was sent to each employee in his or her pay envelope. This questionnaire was an abbreviated version of the one described earlier for phase 2 of the research program; the major results concerning the reasons for carpooling and not carpooling were replicated. Individuals who were interested in carpooling on the basis of work schedule and route to work were then matched and provided with the opportunity for face-to-face meetings.

It is too early to assess the success of this effort, but one anecdote will serve to illustrate the various phases of the program and the inevitable frustrations encountered in promoting carpooling. One of our meetings was attended by three female employees who were friends and were already carpooling together but who wanted to find a male employee who would do the driving in bad weather. According to our laboratory study, the fact that there would be three female acquaintances in the pool would make it desirable for them, and the one male nonacquaintance would find it desirable to carpool with female riders. Despite this idyllic situation, we have not yet been able to find that one male who matches the women on work shift and driving route.

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Technology Transfer in Paratransit: Five Case Studies

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The evolution and adaptation of paratransit from the perspective of technology transfer are examined. Three key factors in successful technology transfer and local adoption are the presence of necessary prerequisites (local paratransit-program mandates, a service patron, and entrepreneurial staff skills), the resolution of barriers (recognized as including local transportation planners, government agency staff, and federal programs and policies), and the transferability of the situation (unique local program or community characteristics that militate against the successful duplication of case study experiences). Five case studies are used to represent the major paratransit modes and mandates and substantial operating experience: the Seattle-King County Commuter Pool; the Knoxville Commuter Pool; Colonial Paratransit and Taxi Company of Bethel Park, Pennsylvania; Dial-a-Bat of Brockton, Massachusetts; and the Choanoke Area Development Association, Inc., of Murfreesboro, North Carolina. All five programs have evolved toward successful examples of technology adaptation and are characterized by broadly conceived mandates and multiple service activities. The case studies underscore the significance of the noted local prerequisites, particularly the role of the patron.

The principal objective of this paper is to examine the evolution and adaptation of five leading paratransit programs from the perspective of technology transfer. Examination of paratransit from this perspective provides new insights into the success and failure of local programs.

Successful local technology transfer and adaptation have occurred when the technology has been accepted in all its ramifications and has secured a stable role in the broader institutional milieu. For paratransit, this means operational transportation services that (a) serve a significant purpose that was previously not well served by other modes of transportation or institutions and (b) are accepted and supported by stable institutional structures.

Our interest in paratransit from the perspective of technology transfer arose from an Urban Mass Transportation Administration (UMTA) university research and training grant for the development of curriculum materials to support paratransit instruction in colleges and universities. A major element of these materials was five case studies of mature local paratransit organizations that had successfully implemented paratransit services. All facets of service development were investigated so that they could be related to instructional concepts being developed. They thus represent prototypes of successful local technology transfer and adaptation in the paratransit field.

CONCEPTS OF TECHNOLOGY TRANSFER

Technology transfer commonly includes two dimensions. The first is technology transfer in the sense of the evolution of a technology from conceptualization to broad practical application. In this process, a technology is perceived as "transferring" from one stage of development to another, and its overall evolution—generally described in terms of the number of units in operation (e.g., the number of carpools formed)—is presented by the familiar cumulative growth-decay, or S-shaped, curve (1).

In all cases, the model suggests an initial slow-growth phase; a rapid-growth, or adolescent, period; and a slow-growth, mature phase that leads to a no-growth point of equilibrium. The fundamental assertion of the model is that there are recognizable and predictable phases in the life of a technology that culminate at a point of eventual saturation or cessation of use. At that point the technology is generally succeeded by a technology that has greater utility or potential.

The second dimension of technology transfer is concerned with the interinstitutional diffusion of a technology and the process of its institutional adaptation. In this dimension of technology transfer, it is commonly held that there are three sets of factors that affect the local adoption of a new technology such as paratransit: the existence of key prerequisites for local adoption, the effective resolution of barriers to adoption, and transferability factors (unique local situations) that may preclude duplication or adaptation of a successful program elsewhere.

Prerequisites

Three key prerequisites to local adoption of paratransit surfaced during the case study investigations. The first is the presence of a local mandate or interest to effect a technology "pull" as opposed to a technology "push" (a push would be federal programs that require paratransit elements, often as a prerequisite to overall program funding). The presence of a viable local mandate is seen as fundamental to a soundly conceived and broadly implemented paratransit service.

The second prerequisite is an enthusiastic and effective patron, generally an individual or individuals who are willing to take the initiative and who have control over the necessary local resources to implement a program. It should not be forgotten that the patron is assuming some risk in seeking the adoption of any innovative concept.

The third prerequisite is the staff that has the entrepreneurial skills and motivation to directly manage and operate the services. This type of staff is more commonly found in the small-business sector than in local transportation planning departments.

Barriers

Paratransit, like any innovation, must overcome a number of barriers. In a sense, the absence of one or more of the prerequisites mentioned above represents a significant barrier; in fact, it is difficult at times to conceptually separate prerequisites and barriers. The discussion of barriers to paratransit has centered around institutional, regulatory, insurance, and labor issues. Barriers such as those described below have received little attention:

1. Traditionally trained transportation planners are coming to be recognized as barriers to paratransit development. For example, Gakenheimer and Meyer (2) note conflicts between long-range planners and the transportation system management (TSM) perspective of short-range operational planning. Paratransit service planning and implementation are a principal issue in this disaffection among planners. Rather than a grand, long-term process of facility conceptualization that is aloof from the general public, paratransit planning involves "nitty-gritty", short-term service planning, implementation, and management in intimate contact with the public—a messy business! Paratransit development is not what transportation planning was advertised to be, and it is not the transportation planning that our facilities-oriented transportation training programs emphasize.
2. In typical fashion, the crosscurrent of federal funding programs is undercutting existing mechanisms for the provision of paratransit service, principally the private taxi industry. Current government programs inherently lack cost consciousness and a mandate for cost-competitive provision of service. At the same time, year-to-year ad hoc federal support of paratransit undercuts program resources (much of the year is spent fighting for next year's budget), program status, and serious integration of paratransit programs in long-term regional transportation plans.
3. Government bureaucrats have an aversion to dealing with the private sector, and vice versa. This is particularly evident among the planners and managers of social service agencies, who are chary about contracting for client transportation services with profit-making taxi or bus companies. Underlying this there appears to be a fundamental mutual distaste in both sectors for the perspective from which the other sector operates.

Transferability

Transferability refers to the specific characteristics of a case study situation that can affect the degree to which the situation can be duplicated elsewhere and the generality of the observations that can be made about it. What works in one city may not work in another and for reasons that cannot be explained by prerequisites and barriers alone.

FIVE CASE STUDIES

The five case studies used in this research are the Seattle-King County Commuter Pool; the Knoxville Commuter Pool; the Colonial Paratransit and Taxi Company of Bethel Park, Pennsylvania; Dial-a-Bat of Brockton, Massachusetts; and Choanoke Area Development Association, Inc. (CADA), of Murfreesboro, North Carolina. - The characteristics of the five case studies are summarized in Table 1. They were originally selected to represent the major market applications (commuter work trips, service to the elderly and the handicapped, rural service, and social service agency coordination), the major paratransit modes, and—as prominent and mature organizations—the likely evolution of the scope of programs and services over time. It was found that none of the programs can be simply characterized as just a carpool matching service or a provider of specialized services. All are multifaceted, and this, it is asserted, is partly responsible for their vitality and survival.

Seattle-King County Commuter Pool

Significance

The significance of the Seattle-King County Commuter Pool program is that it is a broadly conceived, multimodal paratransit development program primarily undertaken within the context of TSM.

Chronology

The Seattle-King County Commuter Pool was organized in 1974 as a regional carpool program sponsored by the U.S. Department of Transportation. The broad public interest in carpool matching that was anticipated did not materialize, however, and early in 1975 the commuter pool initiated a broader, multimodal paratransit program focused on the commuting needs of employees at major employment centers in the Seattle area. The approach was based on a comprehensive survey of employees to determine, in detail, their daily commuting arrangements and their personal interest in mass transit and paratransit alternatives (3).

The survey program was initially conceived to include the direct planning and implementation of a variety of paratransit services for individual employment centers. In practice, however, the Seattle program encountered the regulatory and insurance barriers common to most paratransit programs, and these problems had to be resolved first. When this paper was written, most of the principal barriers had been overcome and prototype buspool and vanpool programs had been implemented. By 1978, the commuter pool estimated that, through their carpool, vanpool, and buspool programs, peak-hour traffic had been reduced by 3733 automobiles

Table 1. Characteristics of five case studies.

Case Study Characteristic	Seattle	Knoxville	Colonial Taxi	Dial-a-Bat	CADA
Location					
Large urban area	X		X		
Medium-sized urban area		X		X	
Rural					X
Market					
Commuter work trips	X	X	X		X[a]
Elderly and handicapped			X	X	X
Social service agency clients		Some	X	X	X
Operational service					
Carpool matching	X	X			
Vanpooling	Some	X	X		X[a]
Express bus	X				X
Taxi			X	Some	
Subscription van or bus			X	X	X
Dial-a-ride			X	X	X[a]
Other functions					
Resolution of operational barriers	X	X		X	X
Development of incentives	X			X	X
Service consulting	X	X	X	X	X
Public-awareness programs	X	X			
Institutional base					
Add-on to existing government agency	X			X	X
Independently conceived	X	X			
Private enterprise			X		

[a]Planned service expansion for late 1978.

and there were attendant reductions in air pollution and energy consumption (4).

More significantly, the Seattle program now encompasses a still broader range of developmental activities, including the development of preferential parking and other ride-sharing incentives, survey and consulting services to aid local employers who are implementing paratransit and parking management programs, general publicity about issues of regional transportation congestion and alternative solutions, and, most recently, promotion of flexible work hours among employers to reduce peak-hour commuting demand.

Prerequisites

Three prerequisites have both made possible the success of the Seattle program and greatly affected its evolution. The first prerequisite has been a strong local mandate for the alleviation of peak-hour congestion where the alternatives of further freeway development and expanded bus service were not available. Federal mandates for abatement of air pollution and conservation of energy precipitated the program, but TSM—getting more use out of existing facilities—has been the primary sustaining local interest in the program.

The second prerequisite has been the effective patronage of the Seattle traffic engineer, who initiated the Seattle commuter pool and provides an administrative base for it within his department. This patronage has worked to encourage the TSM-oriented approach to paratransit; the commuter pool has not gotten involved in coordinating or providing services to social service agencies or the elderly and the handicapped.

The third prerequisite has been the availability of a program-development staff that has entrepreneurial and, to some extent, service-management inclinations and skills. The principal staff members have backgrounds in planning and personnel and are not formally trained in transportation.

Barriers

There have been several significant barriers to the Seattle program. In the early development of the commuter pool, local transportation professionals were competing for the federal support that was expected for the program while simultaneously resisting acceptance of the TSM short-range planning perspective. This competition has since been resolved; the TSM activities of the program have become accepted, and the Seattle-King County Commuter Pool is now reasonably secure as a special-purpose regional agency.

Now that the Seattle program is relatively mature, its future hinges on the prospective turnover in key staff, the prospects that it will adopt still broader development mandates (particularly in the area of social services), and its long-term institutional affiliation or incorporation.

Knoxville Commuter Pool

Significance

The significance of the Knoxville Commuter Pool program lies in its broad-scale implementation of a third-party commuter vanpool program and its subsequent development of the transportation brokerage concept.

Chronology

The Knoxville Commuter Pool was organized in 1975 under the supervision of the Transportation Center of the University of Tennessee as the operating element of a $1 million demonstration grant from UMTA for the demonstration of third-party vanpool brokering as a means of fostering commuter ride sharing as an adjunct to existing bus commuter service. In 1977, the Knoxville Commuter Pool was transferred as one program into the newly created Knoxville Department of Public Transportation Services, which was intended to be the comprehensive public transportation management arm of the city government. Basing the Knoxville Commuter Pool in the city government proved politically infeasible, and in 1978 the program was returned to the university and was recast as a regional ride-sharing program, principally under Federal Energy Administration sponsorship.

The principal thrust of Knoxville Commuter Pool activities has been vanpooling. By the end of 1977, 51 vans had been purchased and put into operation. The agency has now had considerable experience in vanpool promotion and management and in overcoming barriers, notably in the area of vanpool insurance. In late 1977, the commuter pool began divesting itself of the vans by selling them to driver-operators and turned its attention to multimodal transportation service consulting and brokering. The agency has started to investigate services for social service agencies and is currently developing an interactive, micro-computer-based ride-information system to provide support for handling inquiries about the transit schedule, inquiries about buspooling, vanpooling, and carpooling, and referral services for social service agency transportation.

Prerequisites

The federal demonstration grant was the primary impetus for the Knoxville Commuter Pool, but there was strong local interest in the alleviation of downtown congestion and improved public transit service. These mandates, however, did not become the preserve of the commuter pool, for the Knoxville Transit Authority vigorously developed express bus services and the Tennessee Valley Authority independently developed extensive express bus and vanpool services for employees at its headquarters building in downtown Knoxville and elsewhere in Tennessee (5).

Frank Davis of the University of Tennessee is the initiator and patron of the Knoxville Commuter Pool through the university's Transportation Center. The Knoxville Commuter Pool has been under the management of John Beeson, a former businessman and an effective entrepreneur for vanpooling.

Barriers

It is an irony that the Knoxville Commuter Pool, which has gained national recognition for dealing successfully with barriers to paratransit, should itself be confronted with potentially significant political barriers to its continued existence. In 1977 and 1978, a major preoccupation of the agency staff was establishing a role for the agency in the local governmental structure. Final institutionalization of the Knoxville Commuter Pool is unresolved.

Colonial Paratransit and Taxi Company

Significance

The Colonial Paratransit and Taxi Company of Bethel Park, Pennsylvania—an aggressive, multiservice, private paratransit organization—illustrates the potential services that can be cost-competitively provided by for-profit taxi companies. Colonial Taxi also underscores the continuing turf conflict between the private and public sectors.

Chronology

Colonial Taxi is a family-owned small business that, through aggressive, discerning management, has developed over the past 25 years from an exclusive-ride taxi company into a multiservice provider of paratransit. The company principally serves the south side and southern suburbs of Pittsburgh. In the mid-1950s, the company began providing contract services to private charities and school districts, principally to transport handicapped children. At about the same time, the company began offering shared-ride commuter services that feed suburban transit routes.

Today, Colonial Taxi has more than 170 vehicles, including 100 Checker passenger sedans and sixty-five 12-passenger vans (many equipped with wheelchair lifts). Income is derived from a variety of service programs; only 21 percent comes from traditional exclusive-ride taxi service. The distribution of income from the various services provided is given below:

Service	Percentage of Income
Demand-responsive shared-ride taxi	9
Subscription van and bus service to social service agencies and local communities	27
Agency-sponsored and private van service for the handicapped	28
Taxi service for the elderly	11
School busing	5
Exclusive-ride taxi	21

Colonial Taxi grossed about $1 900 000 in 1977.

Prerequisites

The key prerequisite of Colonial Taxi's success has been the qualifications and personality of its president, William Knaus, who was recognized as "1978 Operator of the Year" by the International Taxicab Association (6). Knaus is an aggressive entrepreneur who has a good instinct for national trends in the paratransit field, knows local transportation institutions, and possesses the necessary management skills to operate a small-scale service enterprise. These traits, unfortunately, are not always found in the taxi industry today.

Barriers

Two types of barriers have plagued Colonial Taxi as it has expanded its services; both have arisen from government programs and regulatory policies. In recent years, the organization has been involved in lawsuits as it has attempted to defend its service market from government encroachment.

The first type of barrier has been government regulation and policy on the way Colonial Taxi does business. Restrictive regulatory provisions for paratransit were developed by the state of Pennsylvania in response to the services being initiated by Colonial Taxi and other taxi organizations in the state. A more significant threat, however, has come from federal programs. This includes federally funded efforts by the regional planning agency to coordinate and control local social service agency transportation through a transportation brokerage similar to the one in Knoxville. This, in effect, would challenge the de facto transportation brokerage that Knaus and the Pittsburgh taxi companies have created and the working relations Colonial Taxi has established with public agencies over the years.

A second threat comes from federal capital grant programs, notably Section 16b2 of the Urban Mass Transportation Act of 1964 (as amended), for the purchase of van-type vehicles by nonprofit social service agencies. Social service agencies entering the transportation market compete with Colonial Taxi, often to unfair advantage, in that total capital and operating expenses or economic liabilities are not necessarily computed in the operating costs of these federally assisted agencies

Dial-a-Bat

Significance

Brockton Area Transit (BAT) of Brockton, Massachusetts, was one of the first public transit properties in the United States to tackle the problem of coordinating the transportation services of local social service agencies. Dial-a-Bat, the paratransit element of Brockton Area Transit, is a demand-responsive service for agency clients and the elderly and the handicapped.

Chronology

Dial-a-Bat was developed without federal demonstration or other specific funding, through the initiative of the administrator of Brockton Area Transit, Michael Padnos. Operations began in February 1977 after a year of planning and negotiation with local social service agencies. By early 1978, Dial-a-Bat was transporting more than 10 000 patrons/month, 90 percent of whom were clients of about 20 local social service agencies. At that time, Dial-a-Bat had eight 12-passenger vans and two minibuses equipped with wheelchair lifts.

During the first 13 months of operation, approximately 83 percent of Dial-a-Bat patronage was subscription service and 17 percent was demand-responsive dial-a-ride (reservations must be made one day in advance). Dial-a-Bat has subcontracted a small percentage of its dial-a-ride trips, generally those originating in outlying residential areas, to a local taxi company. Since approximately 90 percent of the subscription patronage—and 75 percent of the total patronage—is children, there is a significant decline in activity in the summer.

The cost of the combined Dial-a-Bat operation in fiscal year 1977 was $1.57/passenger, and 45 percent of this was recovered from fares and agency charges. The deficit represents less than 10 percent of the total BAT operating deficit. Costs include administrative and operating costs but not vehicle capital costs. The subscription service in the first 13 months of operation recorded a mean productivity of 12.50 passengers/vehicle-h; the dial-a-ride service averaged 2.21 passengers/vehicle-h but was increasing consistently over time and exceeded 3.00 passengers/vehicle-h by early 1978. Social service agencies are charged $7.00/vehicle-h for subscription service and $2.50/vehicle-h for each one-way dial-a-ride trip by clients. Elderly and handicapped patrons are charged $1.00/dial-a-ride trip and $0.50/subscription trip.

Prerequisites

A strong local mandate for improved public transit service was established through the efforts of the mayor of Brockton and was facilitated in 1973 by Massachusetts legislation that included provision for state assumption of half the operating deficit of local transit that was not assumed by the federal government. BAT was established in 1974. Since taking over the previous bus patronage on the greatly expanded fixed-route service, it has increased fivefold to 10 000 patrons/day in 1978.

BAT administrator Padnos was the patron for Dial-a-Bat; he conceived the idea and hired a Harvard government major to plan and implement the service. An experienced supervisor employed by one of the local taxi companies was hired as the "manager of mobility" (MOM) to operate the service, interface with social service agencies, and deal directly with the general public.

Barriers

One barrier that had to be overcome was acceptance of Dial-a-Bat by local agencies. Negotiations with the agencies were described as involved but cordial. A significant prerequisite in agency acceptance was the early participation of a major private, nonprofit social service agency that was already providing transportation—Self-Help, Inc. BAT entered into a contract with Self-Help in which BAT replaced aging Self-Help vehicles and Self-Help, in name, manages and operates Dial-a-Bat. This gave Dial-a-Bat a strong social service identity and initially enabled the service to use nonunion drivers (as employees of Self-Help) at lower wages. BAT absorbed the start-up expenses and provided the vehicle insurance under the same policy as the fixed-route transit buses.

Federal funding programs have been both a boon and a bane for Dial-a-Bat. Padnos noted that none of the current federal statutes related to social service transportation require that agencies take affirmative action to ensure coordination. Consequently, not all agencies in Brockton make use of Dial-a-Bat. Agencies also find that working within Title 19 (Medicaid) and Title 20 guidelines of the Social Security Act presents many problems, some of which are unresolved.

It should also be noted that in February 1978 Padnos was successful in hammering out a Section 13c supplemental labor agreement that placed no restrictions on the use of nonunion drivers in current or expanded Dial-a-Bat services.

Choanoke Area Development Association

Significance

The Choanoke Area Development Association operates one of the premier rural paratransit systems in the United States and has long been engaged in the coordination of social service agency transportation. It represents both the problems and the potential of public transportation in rural areas.

Chronology

The Choanoke Area Development Association (CADA), a private, nonprofit corporate entity headquartered in Murfreesboro, North Carolina, has operated rural paratransit services for the clients of local social service agencies since 1966. Having started with one leased station wagon, the CADA transportation service has expanded to a fleet of 15 vans and minibuses. In mid-1978 it provided subscription service to more than 7000 patrons/month. In late 1978 CADA embarked on an expansion of service that involved the development of scheduled rural bus routes supplemented by demand-responsive feeder vans.

CADA serves a four-county region that had a total 1970 population of 121 950; 40 percent of the households have incomes below federal poverty guidelines. CADA subscription bus services developed in response to local social service agency needs and the availability of federal funds. The recently expanded services have enabled CADA to achieve the broader objectives of providing public transit for all citizens in the region and generally increasing rural mobility and access to jobs in local towns. In mid-1978 the subscription services were operated at a total cost (including capital expenses) of about $1.00/vehicle-km ($0.60/vehicle mile) and an average productivity of 3.60 passengers/vehicle-h. Charges to social service agencies cover about 70 percent of the costs.

Prerequisites

CADA, as a major social service agency, established an internal mandate and was in the transportation business before the advent of substantial federal funding for social service transportation in the 1970s. CADA has been careful not to overextend itself in transportation; all vehicles have been purchased outright rather than leased, and all costs associated with delivering transportation have been accounted for in practice. Federal demonstration funds for transportation have been used twice for system expansion. A 1972 grant from the Office of Economic Opportunity enabled CADA to centralize operations and formally pursue contracts with local social service agencies. Demonstration funds provided under section 147 of the Federal-Aid Highway Act of 1973 were used in 1978 to develop fixed-route public transit services.

The executive director of CADA, James T. Barnett, has taken a personal interest in the transportation service and is its patron. A former businessman, Barnett has developed an experienced operating and maintenance staff that provides what is probably one of the most cost-effective rural transportation services in the United States.

Barriers

CADA is well-established in the Choanoke region. The transportation service is one of three principal divisions in the organization. The experienced staff should ensure continuity of service in the event of Barnett's departure. In 1973 and 1977, changes in North Carolina Public Utility Commission regulations concerning the operation of public transit systems enabled CADA to become a public transit operator legally able, in 1978, to charge fares and establish routes. There were few other barriers to service implementation. Insurance costs have been minimized by allowing the insurance provider to approve new drivers.

CADA is, however, quite dependent on federal funds for achieving its goals. The demonstration grants have been used as opportunities to meet previously established goals. Unfortunately, CADA has not always been successful in gaining access to available federal funds. In 1976 Barnett gave up attempts to obtain funding under Title 20 of the Social Security Act because the paperwork requirements were too burdensome for cost-effective operation of transportation service for Title 20 clients.

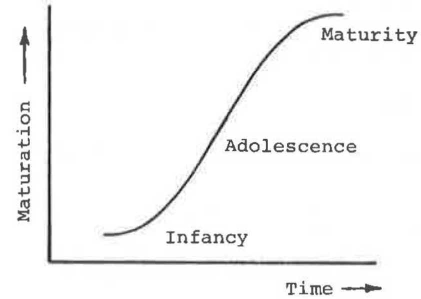
SUMMARY OF RESULTS

Examination of the case studies reported in this paper suggests the following summary observations on technology transfer and on broader implications for public transportation.

The three growth phases of technology—infancy, adolescence, and maturity—are related to local institutionalization of paratransit in general. Figure 1 shows a graphical representation of the three growth phases of technology: infancy, adolescence, and maturity. In relation to the local institutionalization of paratransit, these three phases of growth can be characterized as follows:

Phase	Characteristic
Infancy	Single-mode orientation, generally prompted by federal program or requirement
	Cursory or limited planning
Adolescence	Rationalization and broadening of mandate
	Innovative development of new markets and services
Maturity	Complete development of multidimensional service
	Emphasis on refining service and minimizing cost
	Secure local mandate and integration into local institutional structures
	Mechanisms for regenerating staff and adapting to changing conditions

Figure 1. Evolution of paratransit programs.



In paratransit the initial stages of development are characterized by limited modal development—e.g., carpool matching services—generally in response to a federal mandate or funding opportunity and accompanied by, at best, cursory planning. Many paratransit programs, particularly those that limit themselves to a single federal program, will probably evolve no further.

All five of the case studies reported here have advanced to the adolescent or expansion stage, and some are approaching maturity. Successful technology transfer occurs in the mature phase, when programs have secure mandates, a broad range of operational services, and mechanisms for staff training and adaptation to changing markets and opportunities. Table 1 gives some aspects of this development for each case study.

With regard to prerequisites, strong local mandates exist in all five case studies although they generally do not correspond to such federal mandates as energy conservation, abatement of air pollution, and equity of access to transportation. More relevant local concerns are easing traffic congestion and saving money.

Patrons were easy to identify in all case studies except the Knoxville Commuter Pool. In Knoxville, the paratransit program suffers from being a university-based technology push (i.e., a sizeable federal vanpool demonstration) rather than a locally initiated technology pull. An effective local patron or patron institution is a key factor, if not the key factor, in successful institutionalization.

Finally, entrepreneurial skills were evident in all case studies except, perhaps, Seattle, where operational services were least developed. Colonial Taxi is exceptionally well managed, but CADA demonstrates that management skills are not the exclusive preserve of the private sector.

The existence of barriers underscores the need for patrons. In all five case studies, there were many barriers to implementation of service that could only be resolved or circumvented by the vigorous effort of agency staff.

There is some evidence that transportation planning professionals have been barriers to paratransit technology transfer. But, more significantly, they have not been a factor or presence in these case studies. Virtually all of the principal staff people involved in the agencies studied had non-transportation-planning backgrounds.

Without federal funding programs, none of these case studies would have existed; if they did exist, their role would have been greatly diminished. However, some federal programs (e.g., energy conservation) appear to represent little long-term local impetus for local paratransit development, and others, particularly in human services (e.g., the Social Security Act), have presented difficulties for agencies. Federal policies may unintentionally threaten services that are already provided by the private sector, such as Colonial Taxi.

Colonial Taxi is a successful example of a situation in which government agencies are working with the taxi industry and the taxi owner is the patron in technology transfer. All of the case studies involved in coordinating social service agency transportation have been successful, but in all of these cases effort and education were required to overcome initial reluctance by the agencies.

No compelling evidence was found in any of the case studies of unique circumstances that would preclude technology transfer. Key factors in transfer are the previously identified prerequisites and barriers. It should be emphasized, however, that all of the programs studied are to a great extent the personal accomplishments of individuals; effective transfer of local paratransit technology is not yet at the "cookie-cutter" stage.

It can be concluded that the evolution of paratransit fits the typical characteristics of the technology transfer model. As a new transportation technology, paratransit has experienced innovative leadership (typically from persons outside of the traditional professional community), the implementation of new concepts, and a growth-decay curve of staff development and interest. In most locales, the public transportation community is just in the process of getting used to these innovations.

Finally, there is evidence in these case studies that the successful paratransit organizations are those that are broadly conceived and operated. The paratransit concept has been criticized by some for implying a broad focus in transportation that is not relevant in practice. However, at least two of these case studies—Colonial Taxi and CADA—have evolved into organizations that encompass virtually the entire spectrum of paratransit service planning.

ACKNOWLEDGMENT

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Estimating the Costs of a Subscription Van Service

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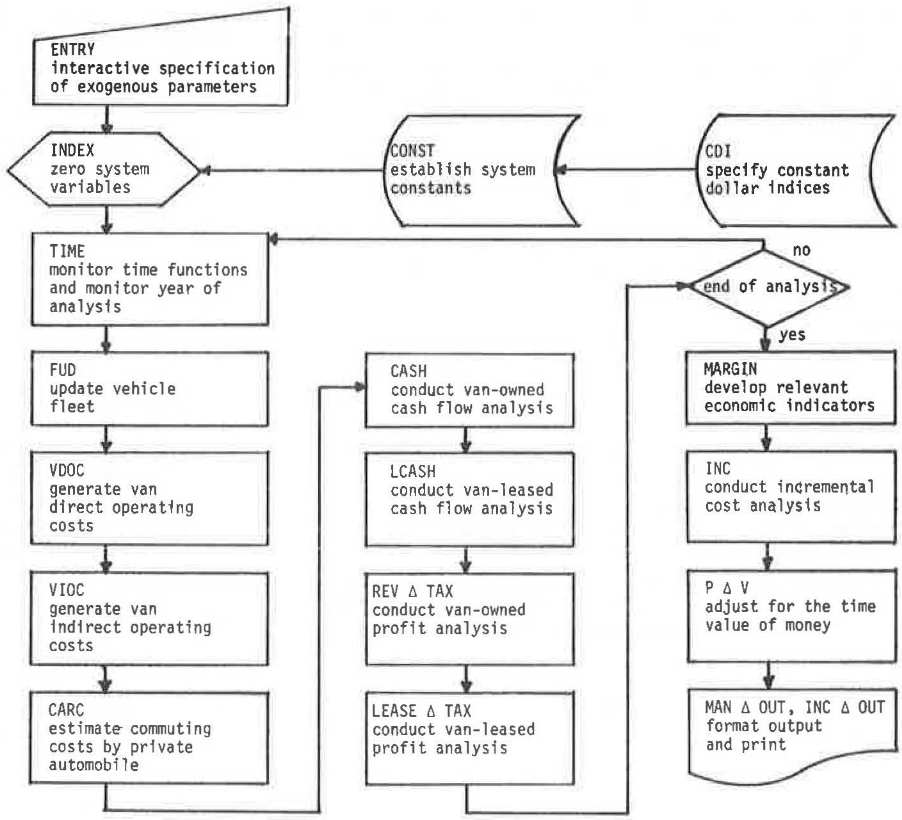
The development and results of a model that examines in detail the costs associated with supplying subscription van service in a small urban community are discussed. The service is assumed to consist of a number of vehicles that travel fixed routes for an extended period of time. Start-up costs, equipment replacement, system growth, and other variables are incorporated in the analysis. The effects of depreciation, taxes, purchasing and leasing of equipment, and other parameters are monitored. Possible savings to participating commuters under service cost-recovery criteria are also investigated. The procedure developed was implemented by a series of interactive computer routines coded in APL and simulated in a hypothetical demand situation for the Fredericton, New Brunswick, area, and a sensitivity analysis of the major variables and assumptions was performed. The analysis indicated that the model produced reasonable estimates of the results of introducing subscription van service in the Fredericton area. The development of the model is described, and a representative module is provided to show the level of detail undertaken in the analysis. Results of the simulation runs are presented, and variables in the sensitivity analysis that were found to have major impacts on the economic viability of subscription van service are discussed.

Many innovative transportation schemes have been suggested to alleviate existing urban commuting and parking problems. Most of these programs, however, tend to be long-term solutions for a very current problem. The technology required for some proposed solutions is not yet available. Other proposals have associated implementation costs that are prohibitive under current economic conditions. These problems of application are especially prominent in smaller urban areas such as those typical of the Atlantic Region of Canada and many areas of the United States.

Increasing the efficiency of existing transportation facilities is one way of alleviating many of the current transportation problems in these urban centers. Although this may be only an interim solution, such increases in efficiency can be realized in any urban center, regardless of size, and show almost immediate results.

Figure 1. Methodology for economic analysis of subscription van service.



Thus, every effort should be made to implement any economically sound scheme that will increase the efficiency of transportation systems.

Pooling the daily work trip is one proven way of increasing the efficiency of transportation systems, and one of the more innovative applications of pooling in the journey to work is vanpooling. Several vanpooling programs have been established in North America in the past decade. Many have been very successful; each, however, has had its merits and demerits.

Before the implementation of a vanpooling program, the proposed service should be thoroughly assessed on an economic basis. In making such an assessment, the analyst is faced with two major questions: Should the service be implemented? If so, in what format and how extensive should the system be? To answer these questions, one must analyze the proposed service for various levels of implementation.

The research reported in this paper was an attempt to simplify this analysis for a subscription van service by developing a workable simulation package to assess the effect of various supply strategies on several economic parameters. The parameters investigated concern both the operation of the service on a managerial basis and incremental costs encountered by commuters who participate in the program. To test the model, a hypothetical demand situation for the Fredericton, New Brunswick, area was used and a sensitivity analysis was conducted on the major exogenous parameters.

DESCRIPTION OF THE MODEL

A flow diagram of the simulation package developed is shown in Figure 1. The model provides for a parallel analysis of both van-owned and van-leased operation. No provision was made in the model for the analysis of a combination of the two even though a fleet composed of both owned and leased vehicles might well be an appropriate strategy.

Each type of operation is considered to be a corporation, and the capital required is assumed to be borrowed for a length of time and at an interest rate that are designated at each particular application of the model. Direct and indirect operating costs, interest, revenue, leasing-related costs, and tax or subsidy computations are performed as required. Van-owned and van-leased cost figures are used to calculate net profits on an annual as well as a periodic basis, and return on investment is determined on an annual basis. In addition, incremental costs to commuters who use the service are estimated for services that are found to operate on a cost-recovery basis.

Economic comparison of van-owned and van-leased operations on an annual basis is clearly not valid because of the relatively uneven cash-flow situation of a van-owned operation and the constant cash-flow situation of a van-leased operation. Thus, provision was made in the model to analyze the subscription van service over an extended period of time. This required that all costs be set to constant (1975) dollars to allow for relative inflation rates for different cost items. It was also necessary to consider the time value of money and to incorporate this value into the analysis.

Data used in the model were extracted from various published sources. For situations in which no data were available, assumptions were made. The major assumptions concerning the operation of the service were as follows:

1. The system analyzed is a typical subscription van service (or vanpool operation) that uses conventional vehicles to transport commuters who travel to the same or immediately adjacent jobsites.
2. There is an adequate supply of vans.

3. No deadheading is associated with the commuting trips.
4. The residence of the average patron of the service is located seven-eighths the length of the van's journey from the jobsite.
5. All users of the service live on the normal route the van would follow to the place of work.
6. All capital assistance to the project is borrowed.
7. Costs for planning, design, and monitoring of the system are extraneous and are not included in the analysis.
8. All financial negotiations occur on an annual basis at the beginning of the year.
9. An 8 percent provincial sales tax is included in the leasing costs and purchase price of the vehicles.

The major assumptions concerning incremental costs encountered by commuters who use the service were as follows:

1. The introduction of a subscription van service will not produce any savings in the fixed costs of owning a vehicle for individual participating commuters.
2. The cost of time to the commuter is subjective and irrelevant to an incremental monetary analysis.
3. Ridership for the service is drawn equally from all sectors of the community population.
4. The personal vehicles of individuals who use the service are not used to a greater extent during working hours than they were before the switch to the vanpool service.

Several other minor assumptions were also incorporated into the analysis.

MODEL DEVELOPMENT

The model was implemented by a series of subroutines, or modules, coded in APL. Each element in Figure 1 represents one of these modules. All cost items were estimated in a disaggregate manner. A detailed description of the VDOC module will serve to illustrate the level of detail at which the analysis was undertaken.

The following computations were necessary to develop direct operating costs within the VDOC module. Assuming that the work year consists of 250 days and 5 percent additional van usage is encountered from miscellaneous travel, the average annual distance traveled by each van, in kilometers (KPY), is

$$KPY_y = 500 \times DIST \times 1.05 \times STUPF_y \quad (1)$$

where DIST is the average one-way trip distance for all vans (km) and STUPF is a start-up delay factor to allow for delays in pool formation during initial installation of the service.

DIST is an exogenous variable that is specified on each application of the model. STUPF, which is specified within the TIME module, was developed from documentation of the delays experienced during implementation of a subscription service (1).

Having determined van utilization, one estimates annual costs for the following items (in dollars per van). For fuel,

$$GASV = KPY_y \times PPL \times CDI_{z;6}/CONSV \quad (2)$$

where

PPL = cost of fuel (\$/L),
$CDI_{z;6}$ = constant dollar index for oil products for year z, and
CONSV = average expected fuel consumption (L/van).

Values for constant dollar indices were taken from a recent study on intercity highway passenger transportation (2) and adjusted where necessary to fit the current situation.

Routine oil changes are necessary for vehicle servicing. The cost of these is

$$OILV = KPY_y \times (NLPCV \times PPLO \times CDI_{z;6}) + (PPOF \times CDI_{z;5})/CI \quad (3)$$

where

NLPCV = oil required for an oil change (L/vehicle),
PPLO = cost of oil (\$/L),
PPOF = cost of an oil filter (\$), and
CI = distance between oil changes (km).

Assuming that the life of a tire is 32 000 km, annual tire costs per van are

$$TIREV = KPY_y \times 4 \times PPTV \times CDI_{z;2}/32\,000 \quad (4)$$

where PPTV is the cost of a van tire and $CDI_{z;z}$ is the constant dollar index for tires for year z.

Vehicle maintenance other than routine servicing was estimated as follows:

$$MAINV = KPY_y \times MCPVKV \times CDI_{z;5} \quad (5)$$

where MCPVKV is the average van nonroutine maintenance costs (\$/vehicle-km) (2) and $CDI_{z;5}$ is the constant dollar index for vehicle maintenance costs for year z.

Tolls and parking fees that would be encountered by the vehicles were determined by using

$$FEES = 250 \times (PARK + 2 \times TOLLS) \quad (6)$$

where PARK is the cost of parking (\$/vehicle/day) and TOLLS is the one-way tolls encountered by vans en route (\$/vehicle/day). PARK and TOLLS are both exogenous variables that are specified interactively. Therefore, from the above, total direct operating costs (in dollars per van per year) can be generated by using

$$DOCV_y = GASV + OILV + TIREV + MAINV + FEES \quad (7)$$

MODEL APPLICATION

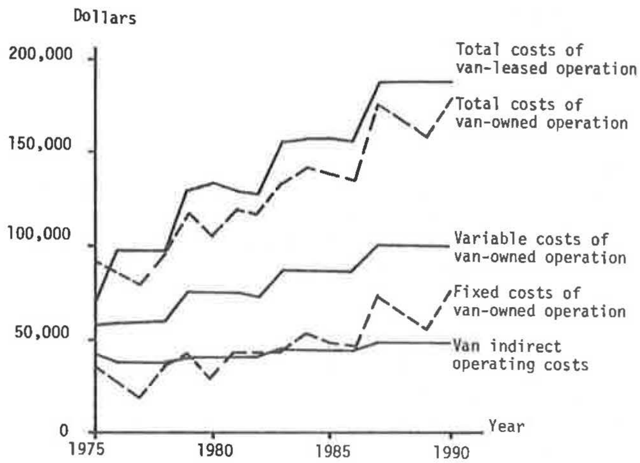
The model was used to assess the economic viability of implementing a subscription van service in the Fredericton area. Fredericton, a city of approximately 40 000, is the seat of the provincial government and the location of the University of New Brunswick. It is also a commercial center that has six shopping malls as well as a central business district. Several small industries are located in the city, but they play a minor role in the employment scheme. The variety of employment opportunities that the city provides makes it an employment center for several smaller "satellite" communities that are situated as far away as 70 km. Some people thus make very long daily commuting journeys. In fact, the situation is such that some individuals are currently operating private one-person, one-van services.

The demand for a subscription van service has been intuitively identified from a cursory examination of the work force and commuting patterns in the area. Since the demand figures in the simulation are only an engineering guess, the results of this analysis should not be interpreted as the necessary outcome of establishing a service in the area. Nevertheless, the model should give a good indication of what could happen if subscrip-

Table 1. Variables entered in simulation run.

Variable	Specification
Initial year of project	1975
Final year of project	1990
Number of vans to be operated each year	10, 10, 10, 10, 15, 15, 15, 15, 20, 20, 20, 20, 25, 25, 25, 25
Number of passengers per van per year	10
Replacement interval of vans in the van-owned operation	3 years
Proposed fare	$0.07/km
Average one-way trip distance for all vans	40 km
Type of van to be operated	Conventional 12-passenger, six-cylinder vehicle with standard transmission
One-way tolls en route	Zero
Parking costs per vehicle per day	$2.40/day
Interest rate on working and borrowed capital	0.115
Interest rate on invested capital	0.095
Length of debt payback period	Five years
Method of paying van driver	Indirect payment (free ride)
Average weighted speed limit en route	50 km/h
Commuter-traffic vehicle-occupancy rates for each year	1.65, 1.65, 1.66, 1.66, 1.67, 1.67, 1.68, 1.68, 1.69, 1.69, 1.70, 1.70, 1.71, 1.71, 1.72, 1.72

Figure 2. Operating costs (in constant 1975 dollars).



tion van service were introduced in the Fredericton area or a similar region.

The variables interactively entered to simulate the operation of a service in the Fredericton region are given in Table 1. The service was analyzed for the 1975-1990 period and was assumed to grow in a stepwise manner. Preliminary testing of the model indicated that interest costs dominate in loss situations. The fare to be charged for using the service was therefore specified at a level at which the service could operate at a modest profit.

On initial inspection, this fare appears to be high. An investigation of vanpooling in northern New Brunswick (3) found that the average fare charged was $0.025/km. However, the vanpools in that area were generally providing a minimum of service. Many of the vans were carrying 15 people (besides the operator), and some were even being operated without heaters during the winter months. A fare of $0.07/km may therefore not be as high as it initially appears.

The average one-way trip distance is only an estimate of what might be experienced. This variable would be a function of a detailed demand analysis, which was not undertaken. A conventional 12-passenger, six-cylinder van with standard transmission is specified as the type of vehicle used. Parking fees of $2.40/day and payment of van drivers by way of a free ride are also noted.

Finally, the average weighted speed limit en route and vehicle occupancy rates (VOR) for commuter traffic for each year of the analysis are required to complete the exogenous, interactively specified parameters. Although the average commuter-oriented VOR in North America is approximately 1.4, an investigation of commuter traffic in the Fredericton area found the VOR to be 1.65. Whereas the VOR for commuter traffic in the Fredericton area is greater than normal, changes in factors that would tend to increase the VOR would probably have less overall effect in this area than in other areas. Nevertheless, current energy and economic situations indicate that some additional pooling in the journey to work is likely to occur in the next few years. Thus, a modest increase in the VOR over the analysis period was specified.

SIMULATION RESULTS

The detailed approach to costing illustrated by the description of VDOC above produced encouraging results. Many models developed in the past appear to merely restate the average unit costs on which they are based. To avoid this, all costs were treated in as detailed a manner as possible. As a result, the cost figures generated by the model appear to be dynamic in nature. Several cost fluctuations over the period analyzed are evident in the managerial analysis, particularly in the van-owned operation.

Figure 2 is a summary of the service costs generated by the model. As expected, the costs of the van-leased operation are quite stable. The only major changes are in the first year, because of start-up delays, and at four-year intervals, because of fleet increases. On the other hand, the costs of the van-owned operation are quite varied. Fluctuations in the variable costs of the van-owned service are similar to those for the van-leased operation. But changes in fixed costs are quite prominent. The variables that cause this include vehicle replacement, debt payments, interest costs on invested capital, and interest accrued on excess working capital. Indirect operating costs, which are assumed to be the same for both operations, amount to approximately 30 percent of all costs.

Except for the initial year, the estimated costs of a van-leased operation are consistently higher than the estimated costs of a van-owned operation. However,

Figure 3. Net profits (discounted to 1975 dollars by interest rate on borrowed capital).

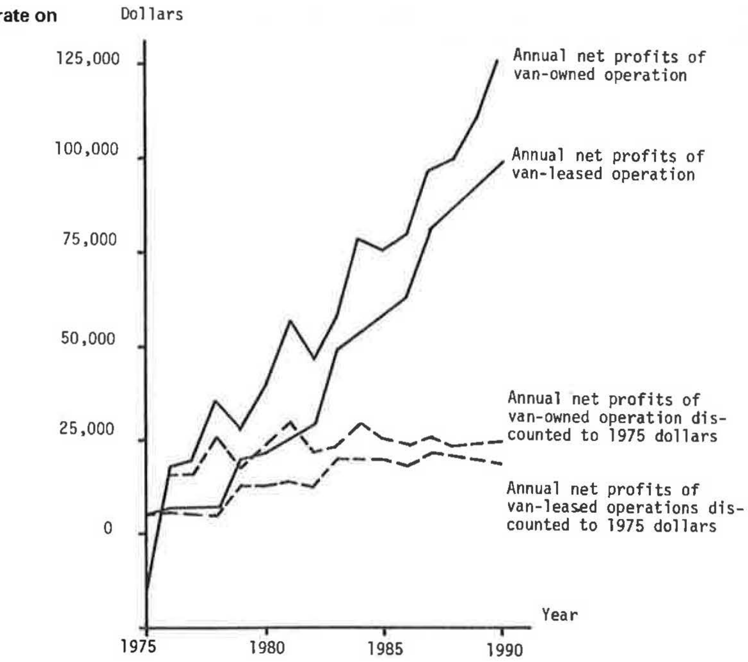
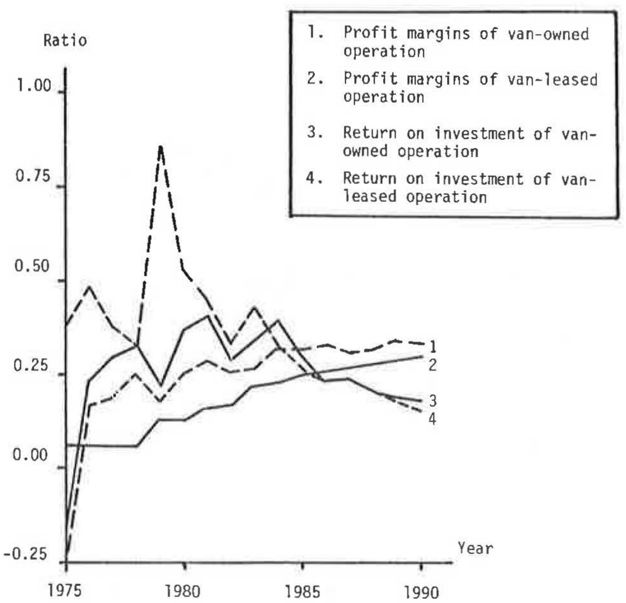


Figure 4. Investment criteria.



because of the nature of leasing agreements and the assumptions in the model concerning such agreements, these results could be misleading.

There are two basic types of leasing contracts: the net lease and the finance lease. In the net-lease contract, an extra mileage charge is levied on the lessee, and the responsibility of the used vehicle at the termination of the contract is on the lessor. On the other hand, a finance-lease agreement has no extra mileage charges, and, on termination of the agreement, provides definite advantages in situations in which the lessee may want to purchase the vehicle after leasing it for a period and prices of used vehicles are relatively high and stable. However, although finance-lease costs are probably lower, they are not easily predictable. Therefore, net-lease contractual costs were incorporated in the analysis. As a result, cost estimates in the van-leased analysis may be higher than those that would actually be encountered. A van-leased service may thus be more appropriate than Figure 2 would suggest, particularly in view of other factors such as cash flow and investment risk.

Net profits and net profits set to present value over the period analyzed are shown in Figure 3. As in the case of costs, van-leased net profits are quite stable and van-owned net profits fluctuate. However, as a result of the smoothing effect of setting figures to present worth, the net profits of both operations set to present worth are relatively consistent over the period.

Although net profits are greater in the van-owned operation, the annual return on investment realized in the van-leased operation is greater until the last few years of the analysis, as shown in Figure 4. This indicates the greater initial risk involved in a van-owned operation. In addition, the effects of additional costs encountered during service start-up are visible in both van-owned and van-leased return on investment. Profit margins, on the other hand, are consistently higher in the van-owned operation because of the higher net profits realized.

Costs to the commuter in the simulation run were found to be approximately 3.5 cents/km for commuting by automobile and were relatively constant over the analysis period. Thus, the incremental cost of using the service was found to be about 3.5 cents/km (in constant 1975 dollars). When one considers the assumptions noted earlier concerning incremental costs to the commuter, it appears that a major impetus for participating in a vanpool program would be the opportunity savings encountered from the disposition of a vehicle. In fact, one survey of vanpool participants found that 25 percent of the participants had either disposed of a vehicle, were planning on disposing of a vehicle, or had avoided buying a vehicle because of their participation in the vanpool program (4).

SENSITIVITY ANALYSIS

Two levels of sensitivity analysis were undertaken in this research. In a model of this nature, a sensitivity analysis of the exogenously specified variables can be useful.

Figure 5. Variations in net profits set to present value for van-owned operation (cumulative over study period).

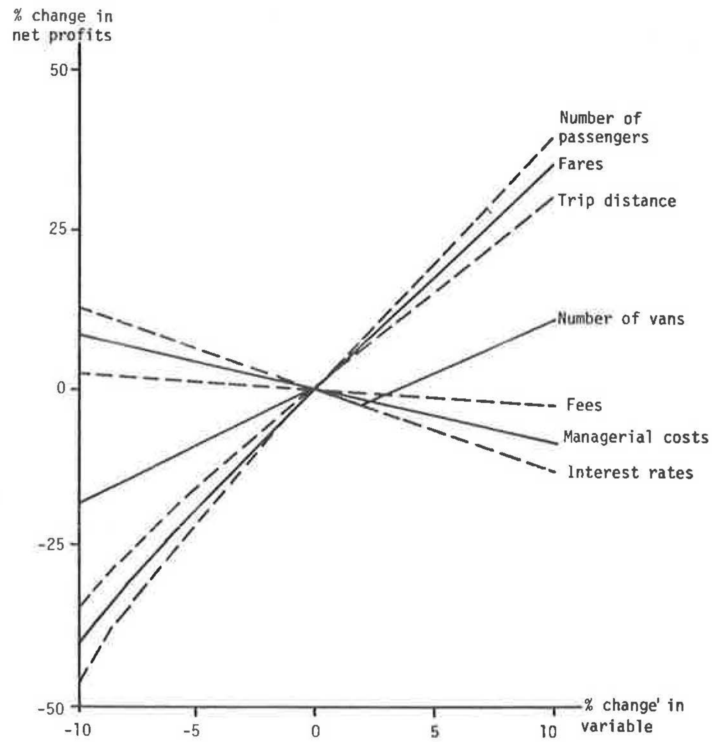
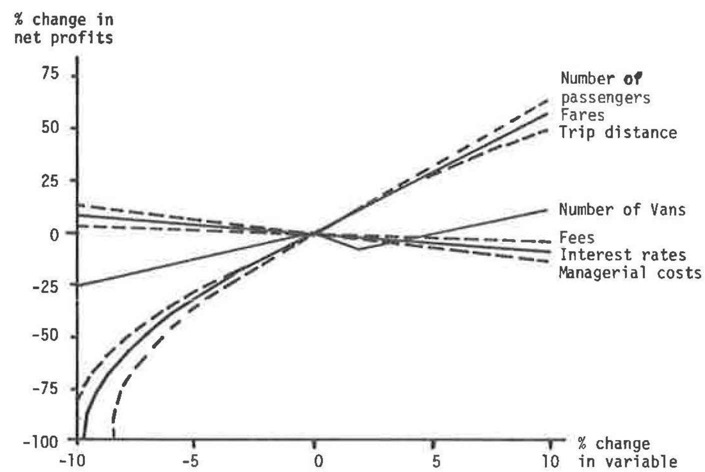


Figure 6. Variations in net profits set to present value for van-leased operation (cumulative over study period).



It provides an indication of how changes in the variables may influence the economic status of the operation and thus provides insight into what could happen when the service is implemented. In addition, since there is no way of actually testing the model, a sensitivity analysis of deviations in the basic assumptions is useful in delineating the possible scope of error. The hypothetical simulation run discussed above was used as a base run for the sensitivity analyses.

Effects of Alterations in the Exogenous Variables

Estimates of changes in net profits set to present worth for van-owned and van-leased operations on a ±10 percent variation in several of the major exogenous variables are shown in Figures 5 and 6. Of these parameters, the major factors that influence net profits are number of passengers, fares charged, and average distance traveled by the vans. A 10 percent variation in these factors was found to alter net profits set to present worth in the van-owned operation by 30-35 percent over the analysis period. Even greater differences were realized in the van-leased operation.

The effect of number of passengers is greater in this example than that of fares charged because the van operators are paid indirectly by way of a free ride. Direct payment of van drivers would make the effect of these variables consistent. The importance of interest rates in marginal and loss situations is clearly evident in Figure 6. Note that the slopes of the curves that represent number of passengers, fares, and trip distance increase drastically as net profits set to present worth approach a loss situation (-100 percent change in net profits).

Variations in number of vans produced a net profit curve similar in magnitude to that developed from altering the interest rate. However, the effects of these changes are diametric. In addition, the relative importance of interest rates and managerial costs differs in the two types of operations. A ±10 percent variation

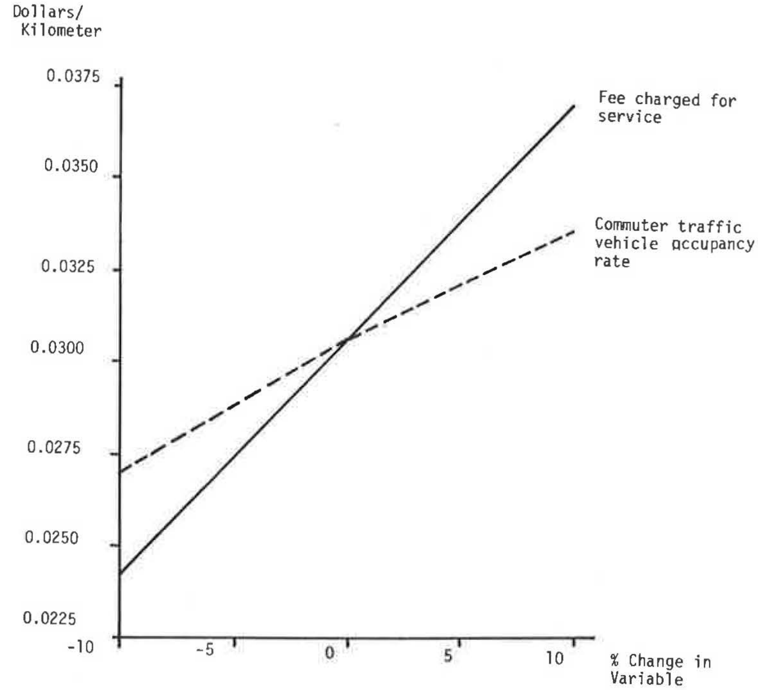


Figure 7. Incremental costs to the commuter in 1990.

of the interest rate in the van-owned operation has more effect than a ±10 percent difference in managerial costs. But, since the van-lease operation exhibits a lower financial risk, variations in managerial costs are more influential than equivalent variations in interest rates. Fees were found to produce very little alteration in net profits set to present worth.

Because several of the exogenous variables were not amenable to alterations of ±10 percent, their sensitivity was assessed differently. In these analyses, changes in the vehicle power train, the loan pay-back period, and the method of driver payment were the only factors found to alter net profits considerably.

The vehicle power train was changed from a six-cylinder standard to an eight-cylinder automatic transmission. This reduced net profits set to present worth for the van-owned operation by 9.4 percent and for the van-leased operation by 13.8 percent. But, since differences in fuel consumption were not considered in this analysis, the actual variations in net profits realized could be greater.

The loan pay-back period was analyzed at annual intervals from 2 to 5 years. A reduction in the loan pay-back period was found to reduce net profits set to present worth in all cases; a net loss was encountered in the van-owned operation in the case of a loan pay-back period of 2 years. These results indicate that short-term loans should be avoided if possible. All loans undertaken were assumed to be paid over a fixed period of time. For this reason, loan prepayment—something that could be encountered in reality—was not considered in the model.

The method of paying van drivers was altered to direct payment. This reduced van-owned net profits set to present worth by 56.6 percent and caused a loss in the van-leased operation. The method of driver payment thus appears to be a critical factor in determining the economic feasibility of a service.

Estimates of changes in incremental cost to the commuter as a result of a ±10 percent variation in several of the major variables were developed. The factors found to significantly influence incremental cost to the commuter were the fee charged for the service and the commuter-traffic VOR. The effect of these variables is shown in Figure 7.

Effects of Alterations in Basic Assumptions

The only assumption that, when it was altered, markedly changed the results of the managerial analysis was the residential distribution of vanpool participants. Since the revenue generated by the service was the only cost item that would be altered by a different residential distribution and fares are specified as a function of distance, the impact of a ±10 percent variation in the residential distribution of vanpool participants was found to be identical to that of the same variations in the fare charged. Thus, the scope of possible model error in the managerial analysis can be delineated. But the possible scope of error on incremental costs to the commuter is not as clear.

In one operation, 25 percent of participating commuters were able to realize savings on an extra vehicle. When the effect of this savings was investigated, it was found to reduce incremental costs to the commuter by 87.6 percent (4). Another study (3) found that extra use of the family vehicle amounted on the average to 64 km/week, which would increase incremental costs to the commuter by 60.7 percent. Finally, at least one study (4) found that individuals who participated in a similar operation came from a commuting population that had an average VOR of 2.4, and that alteration was found to increase incremental costs to the commuter by 33.1 percent. Thus, each of these three phenomena could drastically alter simulation results. However, since it is highly unlikely that one of these factors would vary to a much greater extent than the others and since the total effect on incremental costs to the commuter of all three of the changes noted above is only an increase of 6.2 percent, the overall effect on the model of variations in these assumptions is probably minimal.

CONCLUSIONS

A simulation was run by using a hypothetical demand situation for the Fredericton area. The model appears to deal with the major variables in sufficient detail to produce dynamic results. In addition, a sensitivity analysis of the major variables and assumptions indicates that the model is producing reasonable estimates of what might be experienced if subscription van service were introduced. These results are encouraging.

Although development of the model itself was tedious, the actual simulation and sensitivity analyses included in this exercise were easily undertaken and could be done so in another application with a minimum of effort. The nature of APL is such that an individual who has little or no programming experience could use this simulation package after only a few hours at the terminal. Furthermore, the actual cost of applying the model to another locale would be minimal. The model could thus be a useful tool for assessing the viability of any proposed subscription van service or analyzing the variables that affect the costs of an existing service in an effort to increase efficiency.

The rather haphazard implementation of transportation services in the past has brought about the demise of many operations and contributed to developing skepticism about innovative transportation systems. In addition, the overall economic decline of transportation services in general dictates that planning decisions in the future must be more management oriented. Though specific applications should be analyzed thoroughly, this research may provide some general insight into the applicability of subscription van services in small urban communities. In fact, the technique used in this research could be applied to an analysis of the effect of implementing or expanding any transportation system.

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Economics of Vanpooling

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The concept of commuter vanpooling and the incentives that make it financially advantageous to the rider, the driver, and the company are examined. The primary incentive for riders is the money they can save on the commute to and from work. The farther the commute is, the greater are the savings. Convenience and camaraderie are also found to be important inducements for riders. For the driver, the incentives are a free commute to work, the possibility of getting rid of a second automobile, and personal use of the van on weekends. The incentives for 20 Texas firms that are currently operating approximately 310 vanpools are found to vary. Some companies initiated vanpooling to expand their labor market, some as a means of providing an increase in disposable income to employees, and some to save on parking costs. A detailed comparison of commuting and parking costs for automobile and vanpool is presented. Conditions in the state of Texas that have encouraged the use of vanpooling and future prospects for vanpooling in Texas are summarized.

Commuter vanpooling, as we know it today, was begun by the 3M Company in St. Paul, Minnesota, in 1973 (1). Since that time, vanpooling has generated a great deal of nationwide interest as an alternative mode of transporting people to and from work. Government agencies have focused on vanpooling as a means of reducing air pollution, saving energy, and easing traffic congestion. The 3M Company, however, was motivated by other needs. Specifically, Robert Owens of 3M was looking for a way to reduce parking demand so that the company would not have to build a very expensive parking garage.

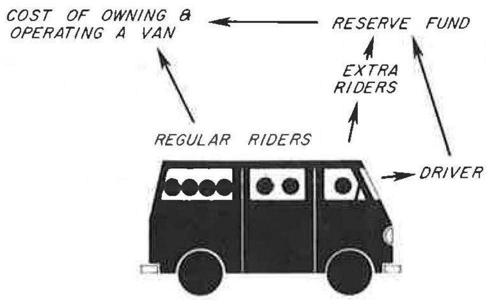
In Texas, vanpooling got its start in early 1975 when the Continental Oil Company initiated a 10-van pilot program in Houston (2). By the end of 1977, there were some 14 programs in Texas and a total of 180 vans on the road (3). Estimates for the beginning of 1979 show about 310 vans in 20 programs across the state. A poll of employers who have initiated vanpooling reveals a number of significant reasons for starting programs, most of which are financial:

1. To provide employees with a "tax-free" fringe benefit that would increase disposable income in lieu of a raise,
2. To reduce the employer's share of parking costs, and
3. To expand the labor market in a region of low unemployment.

Conserving energy, reducing pollution, shifting the balance of payments, reducing traffic congestion, and other such lofty motivations were not among the reasons given for implementing vanpool programs.

The Texas Vanpool-Carpool Program, which is being conducted by the Governor's Office of Energy Resources and funded by the U.S. Department of Energy, seeks to accelerate the growth of vanpooling (and carpooling). The state's goal is to have 1500 vans on the road by the end of 1980. The basic strategy is to sell the state's largest employers on the vanpool concept and to provide

Figure 1. Monthly vanpool cash flow.



technical assistance during implementation. The hope is that these employers, for whatever reasons, will use their own resources to implement in-house programs as quickly as possible.

Vanpooling is not a widely known concept outside transportation circles. Therefore, in discussions with employers who could potentially implement vanpool programs, it is essential that the answers to commonly asked questions be available in a single, easy-to-read document. A preliminary version of such a document (4) was developed by the Governor's Office of Energy Resources in the summer of 1978 to serve this purpose. This paper is based on that document and on subsequent data collected during the fall of 1978.

This paper is organized around the four most common questions about vanpooling:

1. What is vanpooling, and how is it different from the carpool program that we tried in 1974?
2. What is the incentive for a person to join a vanpool, and who among my employees might be interested?
3. Why would anyone volunteer to be a driver?
4. How can I offset the administrative cost of operating the program? If there is a financial risk involved, are the savings large enough to make the risk worthwhile?

Other questions concerning organizational and social aspects of vanpooling are also important, but the focus here is primarily on the financial considerations. Other topics are brought in only as they are relevant to the financial analysis.

VANPOOL CONCEPTS

A good working definition of a vanpool might be a group of from 8 to 12 employees whose residences are geographically clustered and who share the expense of owning and operating a van in which they commute to work. One of the riders serves as a volunteer driver in exchange for a free ride to work and use of the van as a second automobile. A vanpool differs from a carpool in that expenses are shared by an exchange of cash rather than by alternating vehicles.

Although each vanpool program has certain characteristics that make it unique, all vanpools fall into three major classifications:

1. The employer owns and/or leases the vans,
2. The employees own or lease the vans, or
3. A third party (a credit union, for example) owns and/or leases the vans.

The significant differences in the three are in the mode of ownership and the advantages or disadvantages of that type of ownership. Since the majority of vanpool programs use employer-owned vans, the focus of this paper is on this category. In Texas, the 20 programs can be broken down as follows: 18 owned by employers, 1 owned by employees, and 1 third-party program.

In a program in which the vans are employer owned, the vans are essentially "company cars" that are made available to employees for use as commuter vehicles. Since certain tax benefits are available only to employers (the vans become part of the depreciable assets of the company), this type of ownership is the most cost-effective because the tax benefits can substantially reduce the cost of ownership and these savings are then passed on to the riders.

Employee and third-party programs grew out of situations in which employees wanted to participate in a vanpool program but the employer was either unable or unwilling to accept the financial responsibility. For some nonprivate organizations—for example, the federal government and some of its corporate agencies, such as the Tennessee Valley Authority and the U.S. Postal Service—it is illegal to participate financially. The same is true for some state and local governments. In addition, some employers that have too few employees to form effective pools must join together with others to make pooling possible. Still, the company usually gives active administrative support to the program by helping to organize pools, providing parking, and absorbing certain administrative costs generated by the program.

Regardless of the ownership of the van, a vanpool program is operated as a formal business operation in which the participants assume very specific responsibilities. It is this formal organization that distinguishes a vanpool from a typical carpool. Most successful vanpool programs have been organized around a single large employer or work site. Carpools, however, are somewhat less likely to be tied to a single employer. It is worth noting that many social, regulatory, and insurance problems can be circumvented only if a single employer is involved.

As in other successful business operations, a successful vanpool program has a predictable, steady, and positive cash flow (see Figure 1). The main components of the program are as follows:

1. The regular riders, who usually number between 8 and 12, provide the income necessary to underwrite the cost of owning and operating the van (calculations in this paper are based on 8 riders plus the driver). Each rider's share of the cost is one-eighth (or one-twelfth) of the total cost.
2. The driver-coordinator assumes responsibility for the day-to-day operation of the vanpool. In return, he or she receives a free commute to work plus use of the van as a second automobile on weekends, holidays, and after hours for a nominal per-kilometer charge. This "extra" revenue usually goes into a reserve fund.
3. The company usually provides administrative and capital support for the entire operation. Any cost not borne by the regular riders or by the extra revenue is usually "donated" by the company. The size of such donation, which can range from a very small amount to a sizable sum, is usually determined by company policy.
4. The extra seats (the difference between the full capacity of the pool and the regular ridership) may be "sold", thus generating extra revenue for the reserve fund. At the end of the year the surplus in the reserve fund is "rebated" to the riders or given to the company to defray administrative expenses.

Regardless of who owns the van, the before-tax cash flow must reflect a break-even operation (or a slight loss) to avoid regulatory or income tax problems. In a company or third-party operation in which each van is accounted for within an operational structure, this is not usually difficult to prove. To prove that the vanpool is not a profit-making enterprise, the owner-driver must keep accurate records. Otherwise, the vanpool may be subject to taxation or come under state regulation as a common carrier.

Within these guidelines, vanpooling appears to be one of those rare situations in which everyone wins. One way to see if this is really true is to take a closer look at the benefits received—and the costs incurred—by the riders, the driver, and the company.

INCENTIVES TO THE RIDER

The key to the success of any vanpool program is its riders. If the program cannot attract enough riders to generate the cash flow necessary to support the program, there will be no program. This very simple point is often overlooked by those without first-hand knowledge of vanpooling. The fundamental issue, then, is this: Why do people sign up as vanpool riders, or why do they choose not to?

If you talk to the most experienced managers of the most successful company vanpool programs, they will tell you something like this: People get into vanpooling because of the money they save; they stay in because of the convenience and the camaraderie. What this statement really says is that people become vanpool riders if the economic incentive is great enough to overcome the social barriers. Once they get used to the idea and vanpooling becomes "ritualized", the social barriers disappear. Proof of this observation is the fact that, although it takes a great deal of effort to get vanpool programs under way, they seldom fail once they are established.

The financial incentive to the rider is the difference between his or her share of the expense of owning and operating the van (usually one-eighth) and what it costs to commute by other means. The most common other means is by private automobile or, in fewer instances, transit or carpool. The actual dollars and cents are fairly easy to calculate because there are rather complete data readily available on the cost of ownership. The real problem is in calculating the perceived cost so that the perceived incentive can be determined.

A good estimate of the perceived costs of commuting to and from work is the actual out-of-pocket expenses of making the trip. Although the costs of automobile ownership (such expenses as insurance and payments on an automobile) should be included, most commuters do not perceive these as part of the commuting costs because they "have to own the automobile anyway." Thus, commuting costs are thought of as simply the cost of fuel, oil, lubrication, tires, tune-ups, and other similar expenses. This conservative approach to costs is used in Table 1 (2), which gives the costs of various distances of round-trip commutes.

The costs of making the same trip in a vanpool are given in Table 2 (2). These costs include both the cost of operation and the cost of ownership; they are calculated on the assumption that each rider pays a one-eighth share.

The cost estimates contained in Table 2 and Figure 2 assume a 21-workday month, gasoline at $0.16/L ($0.60/gal), and fuel consumption at 3.8 km/L (9 miles/gal). Lubrication and oil and filter change are figured at 6450 km (4000 miles), with fluid changes at 56 300 km (35 000 miles). New tires are purchased every 48 300 km (30 000 miles). Maintenance per 19 300 km (12 000 miles) is $80 for an automobile and $135 for a van. Annual taxes for the van come to $60, and insurance is estimated at $600 annually.

Figure 2 shows plots of round-trip commuting costs by automobile and by vanpool. This figure illustrates two important points: (a) For long-distance commuting, vanpool costs are significantly cheaper than the costs of driving alone, and (b) if money is to be saved through vanpooling, the shortest allowable daily round-trip commute distance is about 48 km (30 miles).

It should be noted that a 48-km commute by automobile is actually shorter than a 48-km trip by van because of the extra driving that is necessary to pick up the vanpool riders. A good rule of thumb is that picking up riders should not increase the length of the trip by more than 15 percent. Thus, a 48-km commute by automobile is roughly equal to a 56-km (35-mile) commute by van.

Table 1. Average monthly cost of driving alone.

Distance Traveled per Day (km)	Fuel ($)	Lubricating Oil ($)	Tires ($)	Maintenance ($)	Total ($)
32	21.00	0.79	2.52	2.80	27.11
48	31.50	1.18	3.78	4.20	40.66
64	42.00	1.58	5.04	5.80	54.22
80	52.50	1.99	6.30	7.00	67.79
96	63.00	2.36	7.56	8.40	81.83
113	73.50	2.76	8.82	10.80	94.88

Note: 1 km = 0.62 mile.

Figure 2. Comparison of vanpool and automobile commuting.

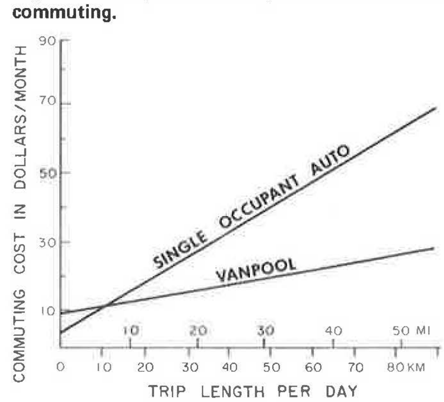


Table 2. Average monthly vanpool cost.

Distance Traveled per Day (km)	Operating Costs ($) Fuel	Lubricating Oil, Wash, and Miscellaneous	Maintenance	Tires	Amortization	Ownership Costs ($) Insurance	Total	One-Eighth Share
32	28.00	7.19	8.29	4.58	66.00	55.00	165.00	21.00
48	42.00	7.92	9.65	4.58	66.00	55.00	186.00	23.00
64	56.00	9.69	11.00	4.58	66.00	55.00	203.00	25.00
80	70.00	10.83	12.35	4.58	66.00	55.00	220.00	27.00
96	84.00	11.48	13.21	9.17	66.00	55.00	240.00	30.00
113	98.00	13.02	15.06	9.17	66.00	55.00	257.00	32.00

Note: 1 km = 0.62 mile.

Table 3. After-tax cost of van ownership.

Year	Before-Tax Cash Flow ($)	Straight-Line Depreciation ($)	Taxable Income ($)	Tax Credit ($)	After-Tax Cash Flow ($)	Monthly Amortization ($)
0	9500	-	-	950	8550	-
1	-	950	950	475	475	66
2	-	950	950	475	475	66
3	-	950	950	475	475	66
4	-	950	950	475	475	66
	5700				5700	
Net	3800	3800	3800	2850	950	3170

The extra 8 km (5 miles) or so added to the trip is apparently less important to the vanpool riders than is the extra time required to pick up all of the riders.

Any other costs applied to the vehicle, such as parking fees or tolls, increase the advantage to the van because, whereas the automobile driver must carry the full cost burden, the vanpool rider pays only a share. For example, a $20 parking fee reduces the minimum distance from 48 to 32 km (from 30 to 20 miles). Therefore, companies whose employees must pay a parking fee can usually organize vanpools that make shorter trips than those of companies that provide "free" parking.

Vanpooling really begins to pay off for the commuter who lives 24 km (15 miles) or more from work, especially if it enables the rider to get rid of a second automobile that was being used for commuting. Financial incentives become most persuasive in the longer commutes. The money saved in a 130-km (80-mile) two-way commute—about $75/month—is usually enough to counteract a long list of excuses for not wanting to pool. Pilot programs should therefore begin with the longest (most favorable) commutes. As the operation catches on and vanpooling becomes established, round-trip distances as short as 24 km become economically sound. The maximum reasonable distance seems to be about 240 km (150 miles).

INCENTIVES TO THE DRIVER

Drivers are responsible for picking up the riders, driving them to work, and returning them home at the end of the day. Usually, though not always, they are also responsible for collecting each rider's monthly share of the fee, maintaining the vehicle, keeping the pool filled, and taking care of other day-to-day chores. These responsibilities will vary from program to program depending on the policy of each company.

In exchange for these duties, the driver receives a free commute to work. The value of this, which depends on the length of the trip, can be determined from Figure 2. As a rule, the driver is allowed to use the van after hours and on weekends and holidays at a nominal charge—usually 6 cents/km (10 cents/mile)—and/or a nominal "free" distance [say, 322 km/month (200 miles/month)]. This can even allow the driver to sell his or her second automobile and thus save the ownership cost of that vehicle as well.

In some of the early programs (such as the one at 3M), the driver also received income from so-called "incentive fares"; that is, the driver "sold" the extra seats and pocketed the money as income. It was possible to generate up to $100/month of taxable income in this manner. This practice is currently being phased out of most programs because of the problems it creates. The main problem is apparently a tendency to oversell seats (as is done on the airlines), a practice that irritates the regular riders. A good alternative is to offer an "incentive distance" for free use of the van.

Still, the financial incentive to be a driver, exclusive of incentive fares, can often run as high as several hundred dollars a month. For example, a 96-km (60-mile) commute would amount to some $80/month in free rides plus the savings realized through not having to buy an equivalent $9500 vehicle. Such incentives usually mean that there are more candidates for drivers than there are vans. This seller's market allows the company to be quite selective in choosing drivers, which further strengthens the program.

INCENTIVES TO THE COMPANY

As the administrator or financial backer of a vanpool program, the company is expected to absorb the organizational and administrative costs, assume financial responsibility for the program, and furnish the "up-front" money to purchase or lease the vans. These costs can be nominal or substantial depending on the size of the program. For example, a full-time administrator may be required for a program that uses 80 or more vans. The financial risk of such a program can be substantial. So why would any company consider taking such a risk with no hope of turning a profit?

Nationwide, more than 100 companies are involved in vanpooling; 20 of them are in Texas. These companies have cited a number of ways in which they have benefited from their vanpool programs:

1. Vanpooling saves parking costs, makes space available for expansion, satisfies zoning requirements, and reduces congestion.
2. A number of individuals and companies have received nationwide publicity for their programs.
3. A number of firms have expanded their labor market or eased the shock of relocation.

Whatever the reason for starting a vanpool program, company management obviously believed the benefits outweighed the risks and the costs.

Although it is certainly possible to attach a value to the goodwill generated by the last two categories cited above, the real financial payoffs are in the tax shelter provided by ownership of the vans and in the savings generated by the reduction in parking requirements. In fact, the reason most often given for beginning a vanpool program is that the company, for one reason or another, had to make a considerable reduction in parking requirements. Such reductions can be accomplished through some form of agressive ride-sharing program—either carpools, vanpools, or subscription buses. The parking savings are the same regardless of the mode of ride sharing, but carpools, leased vans, and buses do not provide a tax shelter.

TAX SHELTER

For a better understanding of the financial incentives for vanpooling, the tax shelter generated by ownership of the vans should be examined in detail (5). Table 3 gives a typical example. Assuming that a van can be purchased for $9500, that the "blue book" wholesale value of a four-year-old van is 60 percent of the original list price (6), and that the riders generate the cash flow to offset all

Table 4. Cost of surface automobile parking.

Land ($)						Cost per Stall ($)	
Per Square Meter	Per Stall	Construction ($)	Annual Amortization ($)	Annual Taxes ($)	Annual Maintenance ($)	Per Year	Per Month
11	300	330	70	20	20	110	10
22	660	330	100	30	20	150	15
54	1650	330	200	60	20	280	25
108	3300	330	360	110	20	490	40
161	4950	330	530	160	20	710	60
215	6600	330	690	210	20	920	75
323	9900	330	1020	300	20	1350	115

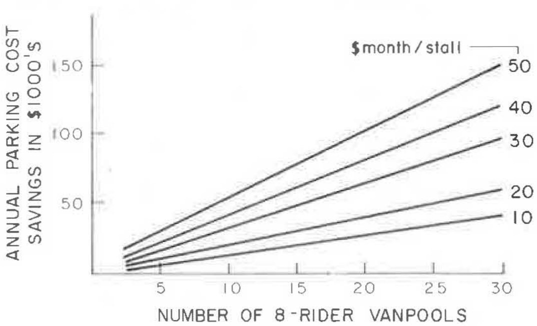
Note: 1 m^2 = 10.76 ft^2

Table 5. Cost of five-level structure for automobile parking.

Land ($)						Cost per Stall ($)	
Per Square Meter	Per Stall	Construction ($)	Annual Amortization ($)	Annual Taxes ($)	Annual Maintenance ($)	Per Year	Per Month
108/10	720	3600	430	130	36	600	50
269/25	1 800	3600	540	160	36	740	60
538/50	3 600	3600	720	215	36	970	80
807/75	5 400	3600	900	270	36	1210	100
1076/100	7 200	3600	1080	325	36	1440	120
1345/125	9 000	3600	1260	380	36	1675	140
1615/150	10 800	3600	1440	430	36	1910	160

Note: 1 m^2 = 10.76 ft^2.

Figure 3. Savings in parking cost for vanpool.



operating and maintenance expenses, the before-tax cash flow represents a break-even operation, exclusive of the depreciation of the van. If one uses straight-line depreciation (the most conservative) and takes advantage of the 10 percent investment tax credit (7), the tax shelter generates $2850 in tax credits over the four-year period. This reduces the company's out-of-pocket expense for the van from $3800 to $950.

There are two ways of looking at the cost of ownership: (a) ignore the cost of interest for four years on the up-front money (the $9500) or (b) take it into account and add it to the operating cost of the van. Either way, the actual cost of ownership (represented by the after-tax cash flow) is included in each rider's share of the expenses. If the cost of money at 9 percent interest is accounted for, the monthly cost is $66, which comes to $8.25/rider for an eight-rider van. If, however, the company absorbs the interest cost, the monthly charge for each rider is $2.50.

PARKING COSTS

There is no such thing as free parking. Someone has to absorb the cost, and that someone is usually the employer. If a company leases a facility, the parking costs are often hidden in the basic lease. Only when parking stalls are leased by the month or the year are the costs obvious. It is necessary to examine how a company calculates what free parking really costs to see what savings are possible through an aggressive vanpool program.

The first step in determining the cost of employee parking is to determine what a parking stall (or space for one automobile) costs in various situations. Perhaps the best way to do this is by using two typical examples: surface parking and a five-level parking structure (8). Both examples assume park-and-lock operation.

For the first example, assume a land value of $54/m^2$ ($5/ft^2$) and 30 m^2 (330 ft^2) required for each stall, including aisles and landscaped areas. This, of course, will vary somewhat, but the typical design standard calls for 30-31 m^2 (320-330 ft^2). The land cost is $1650/stall; paving, striping, bumper blocks, lighting, and landscaping add an additional $330 in construction costs. Amortization on the total ($1650 + $330 = $1980) at 10 percent runs $200/year. Property taxes on the total run about $60 (25 percent assessed valuation and a tax rate of 12 percent of assessed value). Maintenance expenses such as sweeping, plowing, repairing, restriping, lighting, and insurance come to about $20/stall. The total of these annual costs is $80. Dividing by 12 gives the owner a monthly cost of $25/stall. Table 4 gives the cost per stall for surface parking at various land values.

For a second example, assume valuable downtown real estate at $1076/m^2$ ($100/ft^2$) on which a five-level parking ramp is to be constructed. Design standards call for a minimum of 33.4 m^2/automobile (360 ft^2/automobile) because of stairs, columns, ramps, and so on. The land cost is 33.4 m^2 × $1076/$m^2$ ÷ 5 levels = $7200/stall. Construction of parking ramps typically runs $3600/stall, including elevators, stairs, bumper blocks, and so on. Amortization at 10 percent gives an annual cost of $1080. Property taxes (at the same rate as in the first example) are $325/year. Depreciation, maintenance, and insurance run $36 annually. The total cost is $1441/stall, or $120/month. Table 5 gives corresponding values for various values of raw land.

The parking costs given in Tables 4 and 5 are average figures. But they are accurate enough for determining approximate savings from the elimination of parking requirements. To use Figure 3, follow the diagonal line that corresponds to the monthly parking cost, and find the position on that line that corresponds with the number of vans in the program by reading up from the horizontal axis. Then determine the savings by reading the corresponding number from the vertical axis on the left. For example, at $20/stall/month, a 20-van program will result in an annual savings of $38 400. This table is based on a pool of eight riders; to adjust for another number of riders, divide the annual savings by 8 and multiply by the number of riders.

From the foregoing, it should be evident that the tax shelter provided by ownership of the vans and the savings that are realized from the reduction of parking requirements will ensure that a company can afford the administrative cost and financial risks of implementing a vanpool program. In fact, it would seem that a downtown employer who must purchase or lease expensive parking stalls can hardly afford not to implement an aggressive ride-sharing program.

So, in addition to the obvious public relations advantage and employee benefits, there are substantial financial incentives for a company to implement a vanpool program. The tax shelter provided by ownership of the vans reduces the actual cost of ownership to an amount easily borne by the van riders. Reduction of parking requirements can save the company a significant amount in parking costs, enough to provide a substantial reduction in overhead.

CONCLUSIONS AND RECOMMENDATIONS

The number of vanpools on the road in Texas increased by 80 percent (from 180 to 310 vans) during 1978. This rapid increase is evidence of much hard work and a willingness to take a risk on the part of approximately 20 program managers and their organizations. So far, all of the vanpooling in Texas has been done by private industry. Why is the private sector willing to get involved in vanpooling whereas the public sector is unwilling to participate?

We feel that, with few exceptions, the answer lies in the economic advantage that some firms can realize by implementing a program. If they do not believe that the financial risk or the cost can be economically justified, they will not implement a program. It is as simple as that. Agencies in the public sector, on the other hand, do not have the same financial incentives, and simply a desire to do the right thing does not seem to be sufficient motivation.

What are some of the conditions in Texas that have been conducive to implementation? In central Texas the skilled labor market is very sparse. Unemployment is running at about 2 percent. There is an effort to import workers from surrounding rural communities—some from as far away as 80 km (50 miles). The shared expense (sometimes referred to as "co-op" transportation) gives the employer who has a vanpool program an edge over employers who have no program. The tax shelter makes the program feasible for the employer; reduction in parking costs makes it more attractive.

For large employers in the major metropolitan areas, major concerns are parking costs and the need to offer a fringe benefit to employees. In Houston, the "hassle-free ride" is also a selling point. The reduction in parking demand often can pay for the program; the tax shelter reduces the cost even more so that daily commutes of less than 48 km (30 miles) become feasible.

In Dallas-Fort Worth, Houston, and San Antonio, large firms are under pressure to show a "good faith effort" in ride sharing to satisfy Environmental Protection Agency (EPA) clean-air regulations. Such pressure may not be sufficient reason to start a program, but the tax shelter and reduction in parking costs can make the program attractive enough to motivate these employers.

Texas employers have found that employees will become vanpool riders or drivers if they can save a significant amount of money by doing so. The 24-km (15-mile) one-way trip, though only an approximate figure, does appear to be the lower economic limit. This minimum distance, however, is not the main problem. Frequently, the problem is that the "draw" from a single location for any company may not be enough to fill up a van. In that case a smaller vehicle could be used.

We expect to see the number of vans on Texas roads continue to increase. The increase will not be a result of EPA pollution regulations or the balance-of-payments problem. New vanpool programs will be initiated as companies seek to broaden their labor market, solve parking problems, or realize economic advantages.

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