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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.

		1980 Paratransit Service Area			
Pseudonym and Scenarios	1980 Urban-Area Population	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.

		Annual Vehicle Kilometers of Travel		Automobiles Owned	
Pseudonym	Scenario	Number (000s)	Percent	Number	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.

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Review and Assessment of Paratransit Models

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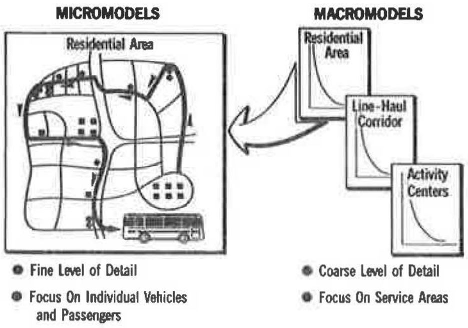
The development of integrated paratransit systems has been accompanied by the development of a wide range of modeling and analytic activities designed to shed light on the delicate balance between supply, demand, and cost in a paratransit network. Modeling and analytic approaches have ranged from complex 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