Technology of the Paratransit Vehicle

Robert E. Samuels, Planco, Inc., Glencoe, Illinois

The U.S. government and the taxi industry are considering the development of a new paratransit vehicle. In this paper, it is argued that the characteristics of the service to be provided must define the technology and performance standards sought. The desirable technological features of an accessible vehicle are discussed; those standards or performance criteria mandated by federal law or policy are emphasized. The effects of the statutory requirements of a number of agencies are examined, and it is illustrated how they can or do create conflicts, for example, between safety features and fuel-economy standards. The types of special vehicle provisions required for various groups of the handicapped are discussed, as are the ways in which different needs and desires of subgroups of the handicapped also create conflicts over technical features and standards. It is concluded that the attempt to develop a single prototype paratransit vehicle may inhibit solution of many pressing problems, and ways by which existing equipment could be modified to create vehicles that could provide a larger number of services to more groups of people (although not all services to all people) are suggested.

The taxi industry and the U.S. government are considering the development of a new, different, multimodal vehicle that will be capable of providing demand-responsive transportation to a wide spectrum of passengers that includes both the transportation disadvantaged (such as the young, the old, the poor, and the handicapped) and ordinary passengers. There is nothing new about this sort of request—the first competition for the design of a motor-driven taxi took place in Paris in 1898.

It is critical to remember, however, that it is not the vehicle that is to define the service to be rendered; it is the service to be rendered that must define the vehicle. In turn, the service to be rendered will be governed in great part by the characteristics of the passengers to be carried. Given this postulate, in order to visualize the paratransit vehicle, it is first necessary to determine the needs of the various types of passengers and the service that must be rendered to them.

Because this central issue has been ignored, the whole concept of the paratransit vehicle has become confused and hazy. In particular, ideas about the characteristics of the vehicle have been intermingled with those of the characteristics of the passengers who will occupy the vehicle. And even more important is the confusion in nomenclature that intermingles the concept of the vehicles with that of the service rendered by them. For example, an airport bus carrying 42 passengers in a one-to-many mode from the airport for a fixed charge renders to the individual passenger the same service as is rendered by a taxicab available for hire on an exclusive basis at meter rates.

Many regulatory ordinances contain the same sort of confusion by defining various public passenger vehicles according to passenger capacity. A study sponsored by the Urban Mass Transportation Administration (UMTA) avoided the issue in its entirety by defining the various forms of service without reference to the size or characteristics of the vehicle to be used (1).

PARATRANSIT SERVICES

Paratransit service, in its broadest sense, is any form of public passenger transportation that is demand responsive, usually nonscheduled, and not necessarily operated on a fixed route. The degrees of privacy, exclusivity, and fare regulation (including methods of charge and calculation of charge) span the spectrum of service.

In descending order of exclusivity, these services include the following:

1. Exclusive-ride limousine service: This service (often called livery service) is a demand-responsive, public passenger transportation service rendered on an exclusive basis, almost always by arrangements in advance, at agreed rates of fare. Traditionally, this service has been rendered by a vehicle that seats not more than six passengers plus the chauffeur, but this is not necessarily so. In recent times, when this service is at or to an airport, shared-ride may be available but not obligatory.
2. Exclusive-ride taxicab service: This service is demand responsive on an exclusive basis. In a few large cities, taxis are obtained largely by street hail and, occasionally, by a radio-dispatching system; in most urban communities, radio dispatching is common. Traditionally, this service has been rendered by a vehicle that seats not more than six passengers. In a few cities, shared-ride is permissible, usually with the consent of the first person hiring the taxicab.
3. Shared-ride taxicab service: This service is demand-responsive on a nonexclusive basis. In some cities in which this service is permitted, the person first hiring the vehicle must consent to the sharing of the service; in others, it may be prearranged or, under certain circumstances, required (i.e., at peak periods or large public gatherings).
4. Shared-ride limousine service: This service is demand-responsive on a nonexclusive basis. The passengers share the vehicle as directed by the dispatcher employed by the provider of the service. The vehicle is not available by street hail. The vehicle rarely has the capacity for more than six passengers.
5. Jitney service: This service is provided on a nonexclusive basis, and the passengers share the vehicle

Table 1. Composition of the urban transportation-handicapped population.

Item	No.	Percentage of Handicapped Population
Handicap category		
Use mechanical aids	1 938 600	26.1
Have a hearing dysfunction	1 572 800	21.1
Have a visual dysfunction	1 566 000	21
Use wheelchairs	409 200	5.5
Have other disabling problems	3 502 300	47.1
Have two dysfunctions	1 056 600	14.1
Have four dysfunctions	20 500	0.3
Total[a]	7 440 000	
Employed[b]		23[c]
Travel behavior		
Overall travel		98
For shopping or personal business		76
For leisure or recreation		69
For medical treatment		69
To work		14
To school		8
Travel mode used		
Bus		29
Subway		3
Taxicab		14
Travel barriers		
Cannot use mass transit		19
Use mass transit with difficulty		30
Use mass transit with some difficulty		51
Barriers perceived		
Bus	6.9	
Subway	6	
Taxicab	3.7[d]	

[a] Represents 5 percent of the population more than 5 years old (12.1 percent of all households).
[b] 16-64 years of age.
[c] Compared with 64 percent of total population 16-64 years of age.
[d] Cost, difficulty of entry and of exit, and difficulty of opening and closing doors.

without the consent of any of them. The vehicle operates on a route that is usually fixed; it may be scheduled (but usually is not). In the United States, the vehicle is usually a conventional automobile that seats six passengers.

6. Demand-jitney service: This service is similar to jitney service, except that the vehicle may deviate from its route on demand to pick up passengers (on telephone order) or to discharge passengers, after which it returns to the route.

7. Dial-a-ride (dial-a-bus) service: This service is demand responsive on a nonexclusive basis; the vehicle is centrally dispatched in response to telephone orders. The vehicles may operate within a zone or along a flexibly fixed route. The vehicles may be conventional taxis, vans, or small buses.

There are also other forms of paratransit service that require varying types of vehicles depending on local requirements:

1. Airport bus service,
2. School bus service,
3. Sightseeing bus service,
4. Charter bus service,
5. Ambulance (cabulance) service,
6. Vanpool and carpool arrangements, and
7. Rental automobiles.

PARATRANSIT SERVICE AND VEHICLE ISSUES

The paratransit services described above are and can be provided to a far from homogeneous group of riders. In addition to normal or average riders, there are a large number of people who are defined as transportation disadvantaged who may use such services. A Canadian study indicated that between 66 and 69 percent of the urban handicapped are either needy or poor and that 18 to 25 percent of them are employed or employable (thus needing transportation in order to work) (2). Table 1 (3) illustrates that the number and the range of disabilities among the urban handicapped is very large.

There are various definitions of handicapped used by governmental agencies, and some of them are so broad that there is an increasing number of persons who have a right to or a vested interest in specialized transportation. To illustrate, the U.S. Department of Transportation (DOT), in one of its programs, requires only that a person not be able to use facilities as effectively as others (4) while the U.S. Department of Health, Education, and Welfare (HEW) has programs that depend on income levels (5).

The diversity of physical needs presented by these groups is very clear. Hidden and intermingled are powerful political issues. For example, to what degree must the wishes of the passengers (as distinguished from their needs) be permitted to govern the design?

THE PARATRANSIT VEHICLE

There are a number of statutory requirements on the design of a paratransit vehicle:

1. It must be capable of rendering shared-ride transportation (Section 3c of the Urban Mass Transportation Act of 1964, as amended).
2. It must conform, in its structure, to safety configurations (49 Code of Federal Regulations, Parts 501-590).
3. It must be equally accessible to all passengers (Section 504 of the Rehabilitation Act of 1973).
4. It must conform to restrictions in its exhaust emissions—federal (Section 16 of the National Mass Transportation Assistance Act of 1974), state, and local.
5. It must achieve required fuel economies (corporate average fuel economy standards of the Energy Policy and Conservation Act of 1975).

(The present statutory restrictions and regulations generally relate to the sale of the vehicle, but it is possible that further restrictions limiting operations may be enacted.)

These statutory provisions generally require that the vehicle be accessible to all passengers; have sufficient space for their proper movement and the storage of their luggage, wheelchairs, and cargo; be safely constructed; and have proper seating facilities for the passengers and the driver (keeping in mind the physical handicaps of the passengers and the necessity of movement of the driver). It should also carry proper equipment, including means of entry and egress for the handicapped.

In a recent request for proposals, UMTA identified the design philosophy underlying its development of an archetypical paratransit vehicle. This vehicle should

1. Be low cost,
2. Be multimodal,
3. Have high fuel efficiency,
4. Be useful as a conventional taxicab, and
5. Be capable of providing other paratransit services—(a) those for the elderly, (b) those for the handicapped, (c) shared-ride taxicab and limousine, and (d) package delivery capability.

TECHNOLOGY OF THE PARATRANSIT VEHICLE

The configuration of a paratransit vehicle involves the

Table 2. Fuel consumption of standard automobiles that have the California package.

Compact Automobile	Engine	Fuel Consumption (km/L)	Midsize Automobile	Engine	Fuel Consumption (km/L)	Large Automobile	Engine	Fuel Consumption (km/L)
Chevrolet Nova	250/6	7.23	Dodge Monaco	318/8	6.81	Chevrolet[a]	250/6	7.23
	305/8	6.38	Ford Fairmont	200/6	8.51	Ford[a]	400/8	5.96
Dodge Aspen	225/6	6.81						
	318/8	6.81						
Ford Granada	250/6	8.09						
	302/8	7.66						
Plymouth Volare	225/6	6.81						
	318/8	6.81						

Notes: 1 km/L = 2.35 miles/gal.
Special state and local regulations governing vehicles sold in California and in New York City require additional emission controls (the "California Package") that reduce fuel efficiency by approximately 0.85 km/L.

[a] Four-door vehicle.

Table 3. Relationship between engine, axle ratio, and fuel consumption.

Engine	Axle Ratio	Fuel Consumption (km/L) City	Highway	Combined
250 federal	3.07	7.02	9.23	7.87
250 federal	2.72	7.23	9.57	8.13
250 California	3.07	6.43	8.38	7.19
305 federal	2.72	6.43	8.60	7.23
350 California	2.72	4.72	6.17	5.45
Checker diesel	2.72	8.13	10.3	8.98
Oldsmobile diesel	2.41	8.94	12.8	10.2
Oldsmobile diesel	2.73	8.94	12.8	10.2

Notes: 1 km/L = 2.35 miles/gal.
For the model year 1980 and subsequent, Chevrolet will not use the 250 CID L-6 engine.

frame, the power plant, the drive train, and the body. Each, together with equipment, must interact with the other. The UMTA request for proposal described above sought the design of a prototype paratransit vehicle that could meet a number of specific standards and performance criteria. (Only those design features that are currently controversial or have strong policy implications are discussed here.)

The Body

It is generally conceded that the form must be boxlike to achieve the most efficient use of the interior space. This permits placing the rear seat closer to the rear.

Many details of the construction are subject to regulations of the U.S. government and, as a consequence, many vehicles of foreign manufacture may not qualify. In addition to meeting the requirements of rigidity (door posts are required in some configurations), consideration should be given to an exterior design that will minimize damage from minor collisions.

There is a consensus that the desirable overall length is approximately that of a midsized sedan [i.e., about 5.1 m (200 in)]. Longer vehicles could have problems maneuvering on narrow streets. The desirable overall width is approximately 1.93 m (76 in). (All vans exceed that width as do current Fords and Chryslers; the 1979 Ford is 1.93 m wide.) There is also consensus that the minimum desirable overall height is 1.91 m (75 in) (all vans are higher), and the minimum acceptable interior height is 1.47 m (58 in)

The floor should be flat (including the sill) over the entire passenger area. Recent unofficial specifications prescribe a minimum flat space of 1.22x0.63 m (48x25 in) and a floor no more than 0.3 m (12 in) above street level.

The recent federal proposal sought a paratransit vehicle that would be convertible into three modes:

1. For four to six passengers plus 45.5 kg (100 lb) [0.42 m^3 (15 ft^3)] of cargo and "giving consideration" to use by the elderly and ambulatory handicapped,
2. For two passengers (one in a wheelchair) plus 45.5 kg of cargo, or
3. For 273-455 kg (600-1000 lb) of cargo, but no passengers.

There should also be space for storage of the ramp or lift, wheelchairs, luggage, and such. Unofficial specifications (6) provide for two loading modes: normal (two or three passengers at optimum sedan seating levels of comfort) and squeeze loading (up to four passengers and supplemental seats).

Generally, it is considered that the doors should have a minimum width of 0.86 m (34 in), although 0.91 m (36 in) has been suggested because of the 0.84-m (33-in) minimum width required for persons on crutches.

Although a minimum door height of 1.45 m (57 in) has been suggested, a minimum door height of 1.83 m (72 in) has also been suggested to provide access by persons on crutches and walkers. This presents a serious design problem because a door that can be used for entry by persons in wheelchairs using either a ramp or a lift cannot be used by persons walking or on crutches or walkers. For obvious reasons of safety, even with an attendant present, only wheelchairs can use a lift or ramp.

The number of doors is an important issue. Clearly, there must be a door at the left front for use by the driver. Unless there is a large double door on the right side, there must be at least two doors on the right side and, in either case, consideration must be given to emergency egress if, in an accident, the vehicle tips over onto the right side. Access could be provided by a rear door (with a lift), but this feature is opposed by some of the handicapped.

Access to the doors for entry (if not by ramp or lift) should be by steps that have risers not more than 17.8-20.3 cm (7-8 in) high (6). Access to the doors for egress must be either directly from the seats without passing more than one seat or by an aisle that is wide enough to accommodate wheelchairs [0.81 m (32 in)] (6), persons using crutches (0.84 m) (7), and those using walkers [0.51 m (20 in)] (6).

The Power Plant and Drive Train

The power plant that will be required to drive the paratransit vehicle will be the consequence of several parameters: the mass and configuration of the vehicle and the limitations of the Energy Policy and Conservation Act of 1975, which regulates fuel economy [see below (1 km/L = 2.35 miles/gal) and Table 2] and the regulations concerning the emissions of hydrocarbons, carbon monoxide and oxides of nitrogen.

Model Year	Fuel Consumption (km/L) Mandated	Achieved by Checker
1978	7.66	7.15
1979	8.09	7.11
1980	8.51	7.02
1981	9.36	
1982	10.2	
1983	11.1	
1984	11.5	
1985	11.7	

[The mandated fuel consumption is based on a manufacturer's model mix, i.e., the average of all vehicles manufactured. Because it is a low-volume manufacturer, the Checker Motors Corporation has an exemption for its 1978 models (taxicabs and passenger automobiles that have V-8 engines) under Section 502c of the Motor Vehicle Information and Cost Saving Act of 1972.] It would appear that, unless there is a congressional reprieve, it will be difficult to design the power plant necessary to drive heavy vehicles suitable for paratransit service. Much of the energy required to propel a vehicle is proportional to its total mass (8).

Although current internal-combustion engines will probably comply with legislative and regulatory requirements for the current model year and the next, after 1980, new and expensive controls will be necessary. The basic power plants to be considered include the following: the spark-ignition (Otto), the compression-ignition (diesel), the vapor-cycle (Rankine), the Stirling, the Brayton open-cycle, the Brayton closed-cycle, and the all-battery-electric engines. And, in addition, there are hybrids and programmed combustion types of engines. [Further information on the characteristics, potentials, and limitations of different types of engine have been described elsewhere (8).]

Automatic transmission is generally considered to be desirable for paratransit vehicles because of the safety derived from the driver keeping both hands on the wheel, which reduces fatigue, but it increases the weight of the vehicle. However, manual transmissions, which are found on many light automobiles, provide greater fuel economy.

The relationship between variables in the mass of the vehicle and its components is critical. Table 3 gives the relationship between selected engines and axle ratios with respect to fuel-consumption rates.

The estimated performance of a 1979 model Checker Motors Corporation taxicab that has a 250 CID L-6 federal engine and a 3.07:1 rear axle ratio is compared below with the performance of the same vehicle having the same engine but a 2.72:1 rear axle ratio (1 km/L = 2.35 miles/gal).

Axle Ratio	Performance (km/L) City	Highway	Combined
3.07:1	7.02	8.97	7.87
2.72:1	7.23	9.57	8.13

Radial ply tires may have a significant effect on gasoline consumption, and the size of the wheel and tire required will depend on the mass of the vehicle and its load.

Special Equipment

A significant amount of auxiliary equipment is required—wheelchair lifts and ramps, a two-way radio, and passenger and wheelchair restraints.

SERVICE CHARACTERISTICS OF PARATRANSIT

The paramount issue concerning the delivery of paratransit service lies in the question of whether it is possible to design a single paratransit vehicle that will be capable of rendering paratransit service to all who require that service.

The capacity and headway capabilities of the vehicle are parameters of the service to be rendered: i.e., it must not carry so many passengers (or so much cargo, or both) that its pickups and discharges delay the remaining passengers to such a degree that the trip becomes uneconomical in terms of time or money (or both). In turn, the degree of the handicap of the passengers becomes a parameter: i.e., the greater the handicap, the greater the interior space required and the greater the time required for loading and unloading; thus, the fewer the passengers who can be accommodated.

Paratransit service must span the entire spectrum of passengers and time, from jitney to demand-jitney to shared-ride taxi to dial-a-ride to vehicles for the slightly handicapped to vehicles for the severely handicapped. Loading and unloading times for jitneys are measured in seconds; those for the severely handicapped are measured in minutes. Thus, the limiting factor of any paratransit service is the maximum time that the first (and each succeeding) passenger can be expected to spend to get to his or her destination.

Observations of several dial-a-ride services (carrying no handicapped passengers) have led to the conclusion that a vehicle that has capacity for more than eight passengers is rarely fully occupied because it takes so long to get to the end of the run that potential passengers are discouraged.

It would appear that the ideal jitney vehicle would have a capacity for 6-12 passengers who would have direct access to doors (without using an aisle), i.e., the conventional taxi or a stretched-out vehicle; the ideal dial-a-ride vehicle would have a capacity for 8 passengers; i.e., the conventional Checker type of taxi, a stretched-out vehicle, or a converted van; the ideal vehicle for the handicapped would have a capacity for not more than four wheelchairs (or a combination of fewer wheelchairs and a number of seats); an exclusive (or shared-ride) taxi would be a vehicle capable of carrying 4 passengers (3 in back plus 1 in front).

THE IMPASSES

Some 30 000 000 people are believed to be transportation disadvantaged or transportation handicapped: that is to say, that they are too young or too old, too poor or too remote from public transportation for it to be available to them, or too limited in physical capability to make use of the public transportation that exists. For some, rich or poor, healthy or handicapped, there is no public transportation. Manifestly, paratransit service, by a paratransit vehicle, is needed.

The Congress has recognized this need and has directed DOT to provide it. Indeed, large sums of money have been provided to achieve the desired result; however, the availability of these sums is conditioned on two requirements—first, the vehicle must provide mass transportation service (which has been construed as including, in any event, shared-ride) and, second, the transportation must be available to everyone (including the physically handicapped).

The Congress has also directed that the emission of noxious gases by motor vehicles must be reduced and, to conserve petroleum resources, that the efficiency of

motor vehicles (in terms of kilometers operated per liter of fuel) must be increased.

The U.S. Department of Energy and the Environmental Protection Agency (EPA) have mandated that, year after model year, vehicles must (to be sold in the United States) be so designed as to reduce the consumption of fuel and the emission of noxious exhausts. Compliance with these mandates is being accomplished by manufacturers by reducing the size of the vehicles. The reduction in size, in turn, reduces the necessary mass of various components, all of which reduces the size of mass of the power plant (9). Of course, the smaller the vehicle, the less able it will be to furnish paratransit services and, the better able the vehicle is to furnish those services, the less able it will be to comply with emission and fuel-conservation standards.

The fuel-economy regulations mandated by EPA provide that compliance may be achieved by taking an average of a manufacturer's mix of production (i.e., a large manufacturer can average the fuel consumptions of its compacts and subcompacts with that of its larger vehicles) to comply with the standards. But a specialty manufacturer cannot. But large manufacturers cannot achieve the necessary economies of volume in the manufacture of a low-volume product such as the paratransit vehicle certainly will be.

It seems evident that regulatory and legislative adjustments are in order. The applicable "law" spans the range from congressional acts to administrative regulations and beyond into the views of the persons charged with enforcing the rules and achieving the desirable social gain. The situation impinges on a plethora of governmental departments, agencies, and such; a study that would set into perspective all of the existing statutory, administrative, and regulatory mandates would be extremely beneficial.

AN INTERIM RESOLUTION

It must be recognized, however, that it is unrealistic to expect legislative relief from these problems in the short run and that sheer number of departments involved makes administrative relief difficult.

It may well be that the route that the search for the paratransit vehicle must travel is that recently suggested by Robert H. McManus, Associate Administrator for Planning Management and Demonstrations of UMTA, when he observed (10):

> If we maintain a vigorous RF&D effort to determine what is 'possible' to be offered in the way of technology—or techniques and methods—we may in so doing achieve systems which are more affordable, and therefore assist policy resolution on what service can be offered. The history of technology development clearly demonstrates that we constantly do more with less. So we have reason to be confident that various efforts to improve system productivity,... may very well affect the outcome of such questions of affordability and such value judgments as how much is enough for civilized society.

Perhaps, what is possible is an intermediate step toward the desired social goal without awaiting the ideal paratransit vehicle. The ideal can come in good time when the legislative and engineering efforts have come to fruition.

Perhaps, the intermediate step can be taken within existing knowledge and legislative direction and in the immediate future. It may even develop that sooner is better than never!

Perhaps, rather than the ideal paratransit vehicle available to all, we can consider several paratransit vehicles that will provide different paratransit services, ensuring paratransit service to all even though not in every vehicle.

Perhaps, we can modify existing vehicles to provide this paratransit service; for example, we could develop

1. A 4-passenger vehicle (3 in back and 1 in front with the driver) for exclusive-ride and shared-ride taxi and limousine services (this would be a light vehicle with a shortened frame and front-wheel drive);
2. A 6-passenger vehicle (3 in back, 2 on jump seats, and 1 in front with the driver) for exclusive-ride or shared-ride taxi and limousine service, jitney, demand-jitney, and some dial-a-ride services (this vehicle would have front-wheel drive, a flat floor, and wider doors and would accommodate many of the ambulatory handicapped);
3. A 12-passenger (or 15-passenger) vehicle (a stretched-out version of any heavy limousine-type vehicle) for jitney, demand-jitney, and dial-a-ride services (this vehicle would have a front-wheel drive, a flat floor, wider doors, and would accommodate nearly all of the nonwheelchair handicapped); and
4. A high-roof vehicle (a Checker Motors Corporation Medicar or a modified van) for service to persons having any type of handicap.

REFERENCES

1. International Taxicab Association. A Compendium of Provisions for a Model Ordinance for the Regulation of Public Paratransit. Urban Mass Transportation Administration, Rept. UMTA-IL-06-0029-76-1, Feb. 1976. NTIS: PB 253 182.
2. D. P. Garner. Transportation for the Elderly and the Handicapped. In Demand-Responsive Transportation Systems and Services, TRB, Special Rept. 154, 1974, pp. 61-65.
3. Summary Report of Data from the National Survey of Transportation of Handicapped People. Urban Mass Transportation Administration, June 1978.
4. A. E. Kidder, I. Sen, G. Amedee, and D. McKelvey. Cost of Alternative Systems to Serve Elderly and Handicapped in Small Urban Areas. Proc., Transportation Research Forum, Vol. 17, No. 1, 1976.
5. R. F. Kirby and F. L. Tolson. Improving the Mobility of the Elderly and Handicapped Through User-Side Subsidies. TRB, Transportation Research Record 660, 1977, pp. 18-25.
6. Functional Specifications for Small Vehicles for Use by the Handicapped and the Elderly. North Central Texas Council of Governments, Sept. 1977.
7. American Standard Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped. American National Standards Institute, Specification ANSI 117-1, Oct. 1961, rev. 1971.
8. Alternative Automobile Engines. Scientific American, Vol. 239, No. 1, July 1978, p. 40.
9. More Dieting in Detroit: The Squeeze of '79—Downsizing Spreads to the Big Cars. Time, Oct. 9, 1978, p. 93.
10. Proc., 3rd UMTA R&D Priorities Conference, Transportation Systems Center, Cambridge, MA, Nov. 16-17, 1978, Office of Technology Development and Deployment, Urban Mass Transportation Administration, to be published 1979.