PEOPLE MOVERS: PLANNING AND POTENTIALS

Herbert S. Levinson, Wilbur Smith and Associates

This paper discusses the role of people movers or microsystems in the urban transport system. It develops performance requirements for people movers based on pedestrian-circulation characteristics and CBD planning needs, and it identifies some of the potential technologies and market applications. Models of the economic trade-off points between bus service and microsystems suggest the desirability of maximizing pedestrian ways and minimizing the extent of automation in most city centers. Ways of accelerating microsystem development on federal and local levels are set forth.

•CONTINUED urban growth has brought a new dimension to urban transportation planning. Revitalization of the nation's city centers and expansion of major airports have placed increased emphasis on pedestrian-oriented movement systems. People movers and microsystems are often incorporated in circulation proposals for major activity centers such as CBD's, airports, college campuses, and urban development complexes. Almost every CBD or airport plan today has its exotic, futuristic technology. Some half century ago, no city was without its electric railway; by the year 2000, no city center will be without its people mover.

Many factors contribute to this increased emphasis on new and innovative transportaion technology. The problems of reconciling the automobile with high-density city centers are widely recognized; for many, people movers are the alternative to highways and parking. Conventional public transport services (bus, streetcar, and rapid transit) have difficulty in attracting motorists; buses, in particular, are labor intensive, and bus fares correlate closely with wage rates. There is a growing awareness that the national experience in aerospace technology should be redirected to the solution of key urban transportation problems. On the federal level, the U. S. Department of Transportation has focused more sharply on technology as a complement to other urban transport solutions.

PEOPLE MOVERS—AN OVERVIEW

People movers or, preferably, microsystems provide short-haul collection and distribution in major activity centers. (All passenger transportation facilities actually are people movers. Thus, people movers include the Queen Mary, Boeing 747, Metroliner, Lexington Avenue Express, Montreal Expo Minirail, 42nd Street Shuttle, and the Empire State Building elevators.) They represent mechanical pedestrian aids that serve relatively short-distance trips—both within the centers and as connectors to other modes. They include continuous (0-headway) and intermittent (variable-headway) systems. They incorporate a variety of guideway systems and propulsion mechanisms, including both active and passive vehicles. They range from automated walkways to birail, monorail, and air-cushion train systems. They generally include automated operations.

Pedestrian Circulation Characteristics

Pedestrian movement patterns and travel preferences influence microsystem planning, design, and technology. Most pedestrian trips in major activity centers are short in length—usually less than a few blocks. They mainly reflect movements from parking and transit terminals to places of work (or air terminals) and movements among stores and offices in the retail core or among air terminals, planes, and buildings often to transact business, to eat a meal, or to change planes.

Parking space-to-building or transit stop-to-building trips are more important than trips among buildings. In downtown Seattle, for example, 56 percent of all pedestrian trips were to or from line-haul transportation facilities and 44 percent were among buildings (1). The locations of parking facilities and transit terminals, therefore, have a major influence on the patterns of walking trips within the CBD.

Pedestrian travel is highly concentrated in the downtown retail and commercial cores. Major internal travel movements take place among relatively few areas, usually within the retail shopping area. Half of all person trips and fewer than a third of all internal walking trips to the typical CBD are for work purposes.

Pedestrian volumes are far more localized than transit or automobile passenger flows. Along State Street between Madison and Washington Streets in Chicago's Loop daily sidewalk volumes exceed 80,000 persons; but 3 blocks away between Lake Street and Wacker Drive, the volumes drop to 11,000 persons. Daily crosswalk volumes exceed 25,000 persons along Market Street in Philadelphia's core area but drop to 1,000 persons within 4 blocks. Daily crosswalk volumes exceed 20,000 persons in Seattle's core area but drop to 3,000 persons within 2 blocks. Similar patterns are found in most cities.

The distributions of walking distance are generally consistent among cities of similar size (Fig. 1). In cities such as Pittsburgh and Dallas, median walking distances approximate 500 ft, and the 80 percentile values average 1,200 ft. In Boston, these values increase to 1,000 and 2,000 ft respectively; the increase is partly due to locations of commuter railway stations. Walking distances in midtown Manhattan are even longer because of block spacing and location of subway stations.

Performance Requirements

Microsystems should be designed for short-distance, high-volume conditions. System length will generally be less than 3 to 4 miles, and passenger rides will be less than a mile. (Most central business districts, for example, are less than 1.5 square miles in area.) Consequently, effective area coverage with high service frequency and close station spacings are more important than high maximum or sustained speeds.

Ideally, service should be constantly available, as it is with belt-based technologies. For intermittent operations, average waiting times should not exceed 2 to 3 min; this implies 5-min maximum headways and 1- to 2-min headways during peak periods.

Station frequency depends on system configuration, land uses served, and technology utilized. Stops on belts at 300- to 800-ft intervals and stops on other systems at 700- to 1,200-ft intervals will usually provide a high degree of service coverage.

Desired service volume (capacity) will vary according to location and type of installation. One-way peak directional capacities of 5,000 persons/hour will meet most requirements. (By 1980, the Seattle-Tacoma Airport Satellite Transit System, for example, is planned to carry 1,200 persons per 5-min peak on loop lines and 175 persons on the shuttle line. Equivalent hourly volumes are 2,400 to 14,000 persons.) Systems should accommodate peak 15-min flow rates that are twice the hourly rate. Stations must be adequately designed for peak loads. (Considerably greater capacities are necessary in Manhattan.) Adequate reserve capacity should be provided for future loading conditions.

The human dimension—the size and spatial requirements of people—influences the minimum cross-sectional requirements of microsystems. People should be able to enter and to leave vehicles in a standing position so that station dwell times are mini- however, this requirement limits the ability to penetrate existing buildings. Many microsystems have vehicle widths of 7 ft, while rapid transit cars have 8 ft 10 in. widths—a difference in scale that may be minimal when provisions for stations are taken into account [Fig. 2 and Table 1 (2)].

Systems should be capable of being built, should operate safely and reliably, should be environmentally compatible, and should meet general public acceptance. They should minimize vehicle storage requirements in core areas, allow off-line maintenance, permit automated operations, and have capital costs that are less than those for conventional rapid transit.

Figure 1. Walking distances in center city.

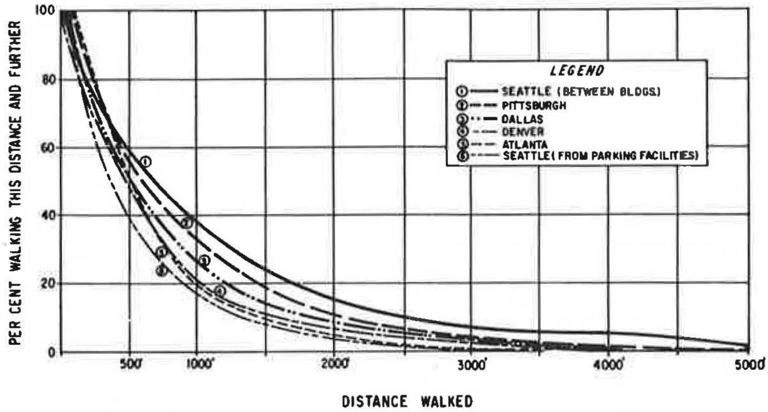


Figure 2. Comparative rapid transit and microsystem cross sections.

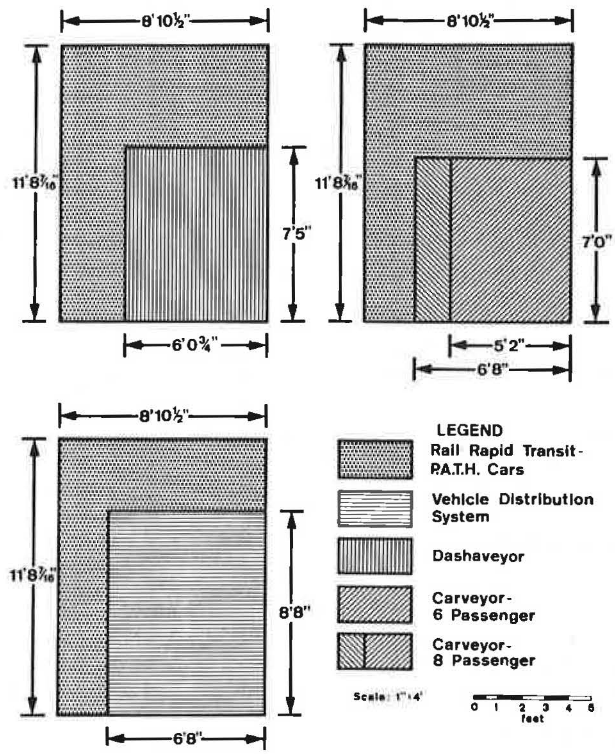


Table 1. Vehicle dimensions for selected transportation technologies.

System	Length (ft)	Width (ft)	Height (ft)
Minibus	20 to 29	8	9 to 10
Bus	25 to 45	8	10 to 11
Rail rapid transit car	50 to 70	$8\frac{5}{6}$ to 10	12 to 15
Alweg monorail car	60	10	10
Carveyor	7	$5\frac{1}{6}$ to $6\frac{2}{3}$	7
Dashaveyor	18	6	$7\frac{5}{12}$
Guidomatic bus	45[a]	5	$7\frac{1}{2}$
Jetrail	$11\frac{5}{12}$ to $18\frac{1}{4}$	6 to $6\frac{2}{3}$	$7\frac{1}{2}$
Mall bus	40[b]	8	$4\frac{2}{3}$[c]
Mini-monorail	13	6	6[c]
Minirail	12	6	6[c]
Telecanape	40	8	$9\frac{5}{6}$
Transit expressway	$30\frac{1}{2}$	$8\frac{2}{3}$	10
Transportation Technology Incorporated	10	6	N.A.
Westinghouse Vehicle Distribution System	16 to 20	$6\frac{2}{3}$	$8\frac{2}{3}$
WEDway	7	6	$4\frac{2}{3}$[c]

[a]Three-vehicle unit.
[b]Two articulated units.
[c]Precludes entering and leaving vehicles in standing position.

and buildings. Ramps, escalators, and elevators should provide necessary vertical connections.

Cost-Patronage Comparisons

The feasibility of microsystems in major activity centers depends on many factors that include the ability to attract patronage, to benefit adjacent properties, and to stimulate new investments. Their economic feasibility as an alternative to shuttle bus service also depends on the relation of capital and operating costs to existing or anticipated patronage levels. Accordingly, illustrative cost comparisons were developed to identify the ranges in break-even bus volumes and microsystem development. Illustrative cost comparisons are shown in Figure 3 for a 30-passenger bus as compared with an automated microsystem. Table 2, in turn, gives the range in break-even passenger volumes for 30- and 50-passenger buses under a variety of operating conditions. This comparison of the combined capital and operating costs per passenger mile (including amortization) for various assumed passenger loadings does not reflect direct user benefits or ancillary land use benefits that could result from microsystem development. Assumptions of the analysis are as follows:

1. Thirty-passenger buses are in continuous operation on the route, 8 hours/day, 6 days/week (Table 2 also gives break-even points for 50-passenger buses);
2. All bus passengers are seated, and additional buses are introduced into service to meet demands;
3. Bus service life is 15 years, and capital costs are about $35,000/bus;
4. Bus operating costs range from $0.70 to $1.20/bus-mile, and bus operating speeds are about 6 mph;
5. Microsystem service life is 40 years;
6. Microsystem operating cost is $0.01/passenger mile;
7. Interest rates are 6 percent for debt service (amortization) of buses and microsystems;
8. Average passenger loadings per mile of route are uniform;
9. Peak-hour dominant 1-way flow averages 10 percent of the daily (8-hour) 2-way flow (thus, the peak-hour 1-way flow would average 20 percent of the 8-hour 1-way flow); and
10. Comparable fares are charged on both services (this assumption did not enter the computations).

The cost-model comparisons clearly identify the need for high-volume pedestrian corridors to make microsystems more economical than buses. (There is, of course, considerable variability resulting from alternative peak, service, and construction cost assumptions.) For example, if bus operating costs are $1.20/mile, then

1. Construction costs of $2 million/mile would require an average 8-hour volume of 8,000 to 13,000 persons/mile of route (these volumes are common in the downtown areas of cities, such as Pittsburgh and Atlanta, having populations of more than 500,000);
2. Construction costs of $5 million/mile would require an average 8-hour passenger volume of 20,000 to 32,000 persons/mile of route (these volumes are found only in core areas of cities such as Atlanta and Pittsburgh); and
3. Construction costs of $15 million/mile would require an average 8-hour passenger volume of 60,000 to 96,000 persons/mile of route (these volumes are found only in the core areas of the largest city centers such as Chicago and New York and represent peak-hour 1-way flows that exceed the capacities that can be realistically provided by buses operating on arterial streets).

Walking Distance Factors

The distances in which intermittent microsystems can provide time savings over walking are given in Table 3. Movement distances of 700 to 1,000 ft or more are required for microsystems to make trip times significantly less than they would be by walking. These distances are longer than most pedestrian trips within major activity centers.

Figure 3. Microsystem and passenger bus cost comparisons.

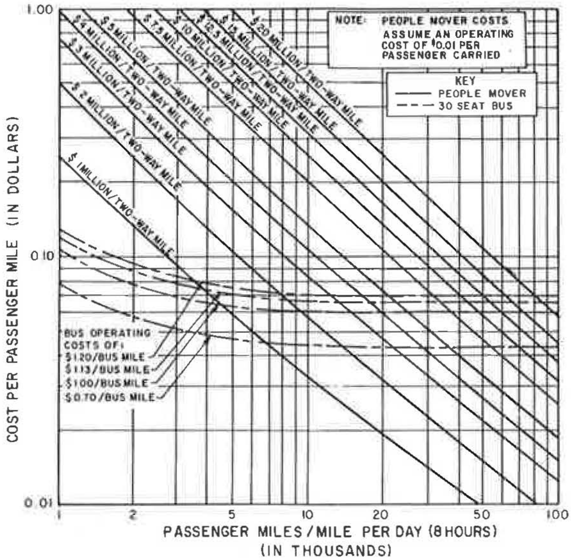


Table 2. Break-even passenger bus volumes and microsystem capital costs.

Microsystem Capital Cost/2-Way Mile ($ millions)	Passenger Mile/Route Mile[a] by Bus Type					
	30-1[b]	30-2	30-3	50-1[c]	50-2	50-3
1	7,000	4,800	4,000	12,000	8,000	6,400
2	14,000	9,600	8,000	24,000	16,000	12,800
5	35,000	24,000	20,000	60,000	40,000	32,000
10	70,000[d]	48,000[d]	40,000[d]	120,000[d]	80,000[d]	64,000[d]
15	105,000[d]	72,000[d]	60,000[d]	180,000[d]	120,000[d]	96,000[d]

Note: Operating cost of microsystem per passenger mile (i.e., per passenger earned) is $0.01; interest rate is 6 percent; and service life is 40 years for microsystem and 15 years for bus.

[a] 8-hour period.

[b] 30-passenger bus operating at $0.70 (30-1), $1.00 (30-2), and $1.20 (30-3) per bus mile.

[c] 50-passenger bus operating at $0.70 (50-1), $1.00 (50-2), and $1.20 (50-3) per bus mile.

[d] Results in peak-hour flow that exceeds capacity that can be provided by bus operating on arterial streets.

Table 3. Minimum distances at which trip time will be less by bus or microsystem than by walking.

Type of Service	Distance Traveled (ft)		
	On Microsystem or Bus	To and From Microsystem or Bus	Total
Minibus at 6 mph			
3-min headway	410	300 to 500	710 to 910
5-min headway	680	300 to 500	980 to 1,180
Microsystem at 12 mph			
3-min headway	325	500 to 700	825 to 1,025
5-min headway	540	500 to 700	1,040 to 1,240

Candidate Technologies

More than 125 candidate microsystem technologies have been proposed within the past several years. Those technologies are in varying stages of development. Some are in service at fairs or airports; others are fanciful ideas from basement workshops or drawing boards. Although there is an abundance of concepts, comparatively few new systems are in actual revenue service.

A review of the various concepts for technical feasibility, operational workability, environmental compatibility, developmental status, and relevance to transportation needs of major activity centers substantially reduces the potential candidates. Many proposals constitute operational modifications of existing technologies; some involve unduly complicated suspension propulsion systems; others appear better suited for intercity travel than for short-haul, readily available service (3). Most existing or planned installations represent loop or shuttle systems that do not require fast-acting on-line switches.

Technologies that may become available for application in major activity centers within 5 years fall into 3 broad categories: (a) new types of buses or similar multipassenger vehicles operating on existing streets, (b) beltlike systems operating continuously and always available for passengers to board, and (c) train or fixed-guideway vehicles.

Bus types and propulsion technologies include the standard internal combustion engine bus, modified to reduce emission of pollutants; the gas turbine bus; the liquid natural gas bus; and the electric (battery) bus. Prototypes of the electric bus are being tested in revenue service in Germany.

Continuous microsystem technologies include moving belts, escalators, and variable-speed systems. Moving belts are currently operating in many airports, e.g., at the San Francisco International and Love Field in Dallas, and at the San Diego Zoo. Construction costs approximate $350 to $500/linear foot. Variable-speed systems include WEDway, which is operating at Disneyland, and Carveyor and Transpallet, which are in development.

Intermittent systems include (a) the Skybus, operating experimentally at South Park near Pittsburgh and at the Tampa Airport and being installed at the Seattle-Tacoma Airport; (b) the minirail, operating at the Montreal, Munich, and Lusanne Expositions; (c) smaller scaled monorail system such as the Jetrail, operating at Love Field in Dallas; (d) personalized dual-rail system, such as the one being considered for the new Dallas-Fort Worth Regional Airport; and (e) air-cushion system, such as the one proposed by Transportation Technology, Inc.

PLANNING GUIDELINES

The installation of microsystems should be selective within the broader context of regional transportation and major activity center pedestrian plans. Regional transportation facilities must provide the basic framework for circulation and distribution systems. Economic and environmental feasibility will strongly influence system installation.

Design and Locational Factors

Microsystems should be physically separated from other movements wherever possible and protected from unauthorized use. They can traverse public rights-of-way or append or penetrate buildings. They can be located above or below grade.

Routes should be planned to provide the maximum service in the minimum distance, i.e., to carry the maximum number of passengers per mile of route. They should serve, rather than bypass, major retail and office concentrations. They should follow direct, linear movement channels whenever possible. They should avoid excessive branches and complex routing patterns. They should complement rather than compete with line-haul transit services.

Stations should be integrated with line-haul rapid transit stops, major parking complexes, and pedestrian ways. They should be easily accessible from pedestrian ways

Data given in Table 3 are based on the following formula:

$$Z = [W(Vm\ Vw)]/(Vm - Vw)$$

where

Z = distance traveled on microsystem or bus;
W = waiting time, assumed to be ½ headway between successive units, sec;
Vw = average travel speed for person walking, including delay time at intersections, ft/sec; and
Vm = average travel speed for microsystem or minibus, and including stops for passengers and traffic delays, ft/sec.

The following values were assigned to the variables: Vw = 3 ft/sec; Vm = 8.8 ft/sec (6 mph) for minibus in traffic with 1 stop per block; and Vm = 17.6 ft/sec (12 mph) for grade-separated microsystem with 1 stop per block.

Pedestrian Ways and Microsystems

The foregoing factors suggest that emphasis should be placed on maximizing the number of key pedestrian corridors (in relation to and as a stimulus for new development) and on minimizing the extent of pedestrian-way automation in most activity centers.

Primary attention should be directed to reserving pedestrian-movement corridors through proposed development complexes and to extending those corridors as buildings are modernized. Design of pedestrian-movement corridors should allow for future incorporation of existing or new microsystem technologies as demands arise and technologies are further developed.

Building codes and zoning ordinances could be modified to encourage redesign of existing buildings and design of new developments to provide or reserve pedestrian-movement channels. Advance acquisition of rights-of-way for pedestrian-movement corridors should be encouraged.

MARKET POTENTIALS

There are many emerging opportunities for microsystems in the nation's large urban centers. The location, type, and intensity of present and future developments, the expected interaction among major activity concentrations, and the community's desire to minimize fractionated parking developments influence development prospects. Factors favorable to microsystem development include extensive core-area congestion (both street and sidewalk), limited parking in core areas, major movement barriers within or near the activity center, rapid center city growth, and available movement corridors. The high capital costs of microsystems suggests the need to serve heavy pedestrian concentrations or to offset initial investments as part of redevelopment, renewal, or airport expansion projects or to do both.

Airports

Airports represent an excellent potential for microsystems. They produce relatively high passenger demands per unit of construction, provide commonality of ownership, and have minimum environmental constraints. Moreover, an airport is perhaps the fastest growth center in the urban setting and often makes ample resources available for pedestrian-related amenities. Airport parking revenues are substantial and could be used to help finance microsystems. Connections between satellite terminals and principal passenger facilities are especially conducive to microsystem development.

The Jetrail at Love Field and the Skybus at the Tampa Airport and the Seattle-Tacoma Airport represent existing installations. An illustrative microsystem plan for John F. Kennedy Airport is shown in Figure 4.

Central Business District

The best potentials for microsystems in downtown areas exist in large-scale urban development complexes where the systems can be integrally incorporated into overall development plans. Land assembly under a single developer can expedite consensus on microsystem design, locations of access points, and identification of beneficiaries. Construction costs can be shared with adjacent land uses, thereby providing a broader financial base for system rationalization. Routes and stations can be incorporated within building complexes. Size and spatial requirements of stations can produce a serious environmental constraint when stations are located in street rights-of-way (Fig. 5). The weight and vertical clearance requirements within buildings suggest special treatments for those floors or levels that incorporate microsystems. Buildings can be grouped to provide the desired horizontal and vertical alignment. Linear urban development complexes, such as the White Plains Urban Renewal Project, are especially adaptable to microsystem developments. Proposed urban development complexes such as Battery Park City in New York and Harbor Square in Toronto also would benefit from microsystems.

The greatest potentials for microsystems in existing downtown areas are in New York City. Manhattan has several major corridors with sufficient concentrations of pedestrian movements to warrant extensive capital investments, for example, the 48th Street Midtown Distribution System proposed by the Metropolitan Transit Authority.

ACCELERATING MICROSYSTEM DEVELOPMENT

Realization of microsystem potential calls for resourceful public and private approaches in development. The small scale and localized impacts of many systems as well as the many public and private groups involved often have deterred implementation. Similarly, technological innovation in microsystem development should be accelerated through cooperative federal, local, and industry efforts.

Labor Implications

Many applications will represent new services that will not reduce employment on existing transit systems. Some new automated installations, however, may replace existing labor-intensive facilities; this transition should occur gradually to ease the displacement of existing employees in general accord with Section 13(c) of the Urban Mass Transportation Act of 1964 as amended.

Codes, Safety, and Insurability

New technologies should meet commonly accepted safety standards and conform to existing safety codes. Insurance underwriters will generally not insure any system that violates local codes. The more a system deviates from the safety codes, the less likely it is to be insurable except, perhaps, at a very high premium by an underwriter specializing in high-risk coverage.

The American Standard Safety Code for Elevators, Dumbwaiters, and Escalators (ASSC) is prepared by the American Society of Mechanical Engineers in cooperation with representatives of manufacturers, insurance carriers, regulatory agencies, and technical societies. Although the document itself is advisory and has no legal significance, it has been formally adopted by many local governments as their legal code governing the use of such systems. In 1965, the ASSC added moving walks to its contents; the Code limits entry and exit to the beginning or end of the moving walk, generally requires a handrail along each travel lane, and limits the maximum speed to 180 ft/min in level operation.

Research Needs

Research and experimentation should be an iterative process focused on refining human engineering factors and design parameters; pinpointing service applications and cost limits; improving system components, performance capabilities, and environmental qualities; and identifying benefits and payoffs.

Figure 4. Microsystem plan for John F. Kennedy International Airport.

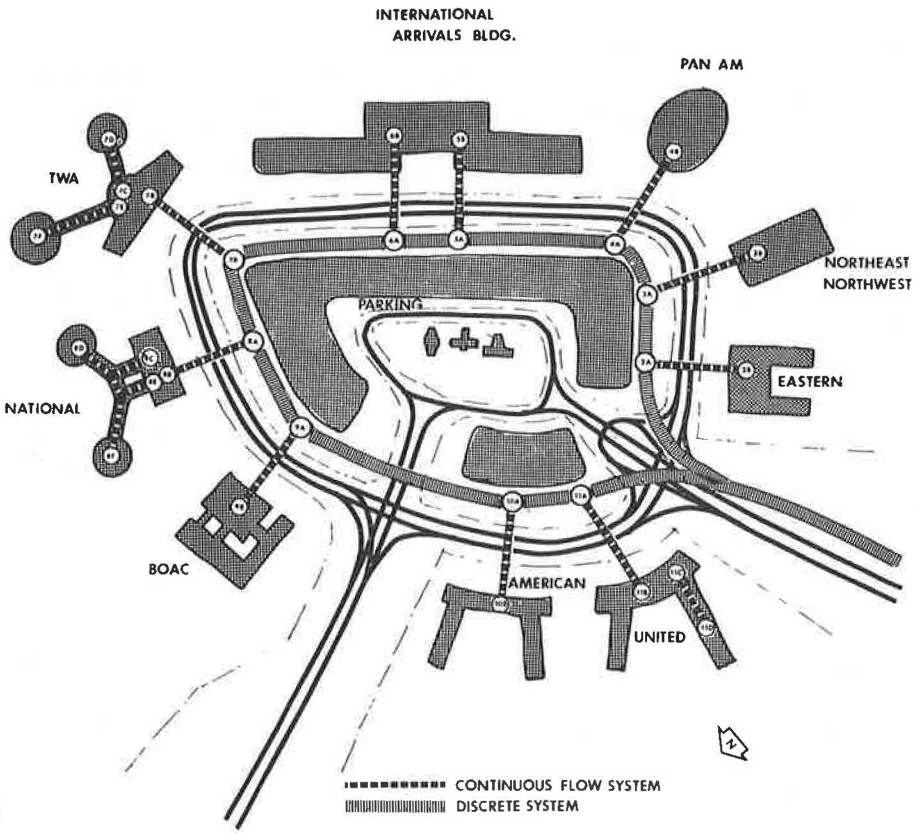
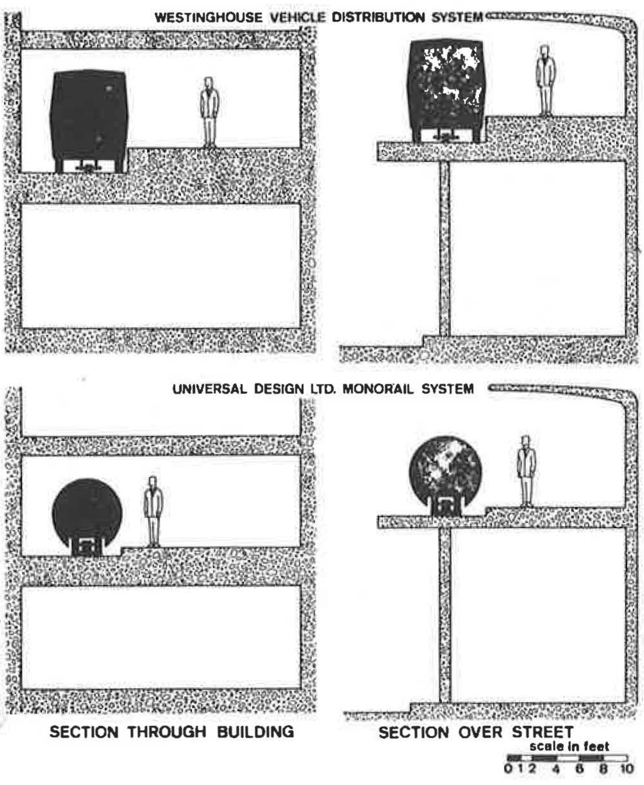


Figure 5. Microsystem station design alternatives.



There is need to obtain more precise information on the costs and operating capabilities of proposed systems. The differences between actual and simulated performance should be identified; much has been said about new urban transportation technologies, but there is little factual data on the engineering and cost characteristics of most proposals. Many systems have operated only in amusement parks or fairs where there is ample shutdown time available for maintenance and repairs. In those cases, there are no serious public impacts when the systems are inoperative for maintenance purposes.

There is a need to balance investments in limited-purpose systems against those serving regional or area-wide functions. The cost of a 2-mile microsystem in Denver, for example, would exceed that of acquiring the 200-vehicle bus system (estimated at $7.5 to $10 million).

There is need to balance the major problems of costs, environmental compatibility, and diversity of demands. At-grade or above-grade construction would reduce installation costs but requires sensitive design to overcome environmental conflicts. Penetrating buildings may be desirable where buildings have the desired structural capability and collinearity, or where pedestrian systems can be incorporated in new developments. Cost reduction is essential to maximize development potentials.

Additional study is needed on the trade-offs among costs, headways, patronage levels, and station spacing. There is need to identify optimum service frequencies, system lengths, and station spacing in relation to specific urban needs.

Research Directions

Research efforts on near-term microsystem technologies should be directed toward the following:

1. Buses with less noise and exhaust pollution emissions and with better loading systems. More extensive research on noise and pollution reduction is essential. Gas turbine and liquid natural gas propulsion systems for buses may offer some promise. Additional testing of electric and other nonpollutant engines is also desirable, especially where underground operations are involved.
2. Differential-speed, moving-belt systems that negotiate grades and curves. The continuous-motion character of the moving-belt technology is especially suitable for short-distance, high-volume center city situations.
3. Fixed-guideway systems with small and lightweight vehicles capable of train operations, reduced cross sections and structural requirements, and simplified support, suspension, and switching mechanisms. Systems could be designed for line-haul or distribution functions or both and represent a synthesis of rapid transit and microsystem services. Peak-hour, 1-way capacities ranging from 10,000 to 15,000 persons/hour would prove adequate for most urban situations. Safe, reliable, and quick-acting switches are essential to effectively serve single vehicles or trains or both operating at short headways. The current federal efforts toward developing personal rapid transit vehicles is an important step in this direction.
4. Improved control mechanisms. Design of reliable, reasonably priced control systems is essential for short-headway microsystems (4).

Cooperative Experimentation

The federal government should encourage and support research and experimentation with new transportation technologies. This may necessitate full federal funding of new systems as prototype demonstrations within center cities. Cities are confronted with a wide array of social and economic problems; they are unwilling and unable to experiment with new or unproven systems. Federal funding could serve to help reorient local efforts and reduce the barriers to innovation. A leading rather than reactive approach is required.

This calls for a federal proving ground for new technologies or substantive assistance to manufacturers or both and pilot installations in selected cities with costs borne by federal agencies or shared with cities and system suppliers. (The Morgantown, West Virginia, and Dulles International Airport personal rapid transit demonstration projects, sponsored by the U. S. Department of Transportation, are important steps in this direction.) Adequate lead time is essential because 5 or more years will probably be required before new technologies are operational.

IN PROSPECT

New microsystems will improve the accessibility and amenity within major activity centers. In multilevel cities, they will form parts that physically separate transit, pedestrian, goods, and automobile traffic. Climate-controlled skywalks, plazas, and microsystems will provide a new dimension to pedestrian mobility and amenity.

As new transport technologies are developed and as implementation capabilities are strengthened, new levels of mobility will be achieved. They will help to create an exciting, dynamic, and vital city of the future, fully responsive to the needs and aspirations of the public it serves.

ACKNOWLEDGMENTS

Many individuals contributed to the materials contained in this paper. The assistance of Theodore J. Soltman, Paul N. Bay, and F. John Devaney of Wilbur Smith and Associates, Douglas Webb of the New Jersey Department of Transportation, and Franz Gimmler of the Urban Mass Transportation Administration are especially acknowledged.

REFERENCES

1. Urban Transportation Concepts. Wilbur Smith and Associates, 1970.
2. Handman, A. L., Bush, R. L., and Bee, R. W. Transportation System Candidates for Center City and Major Activity Center Applications. MITRE Corp., Jan. 1970.
3. Innovations in Center City Transportation Technology. Wilbur Smith and Associates, 1969.
4. Technical Evaluation of Advanced Urban Transportation Systems. Applied Physics Laboratory, Johns Hopkins Univ., Summary Rept., June 1970.