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Transportation System Management

State of the Art
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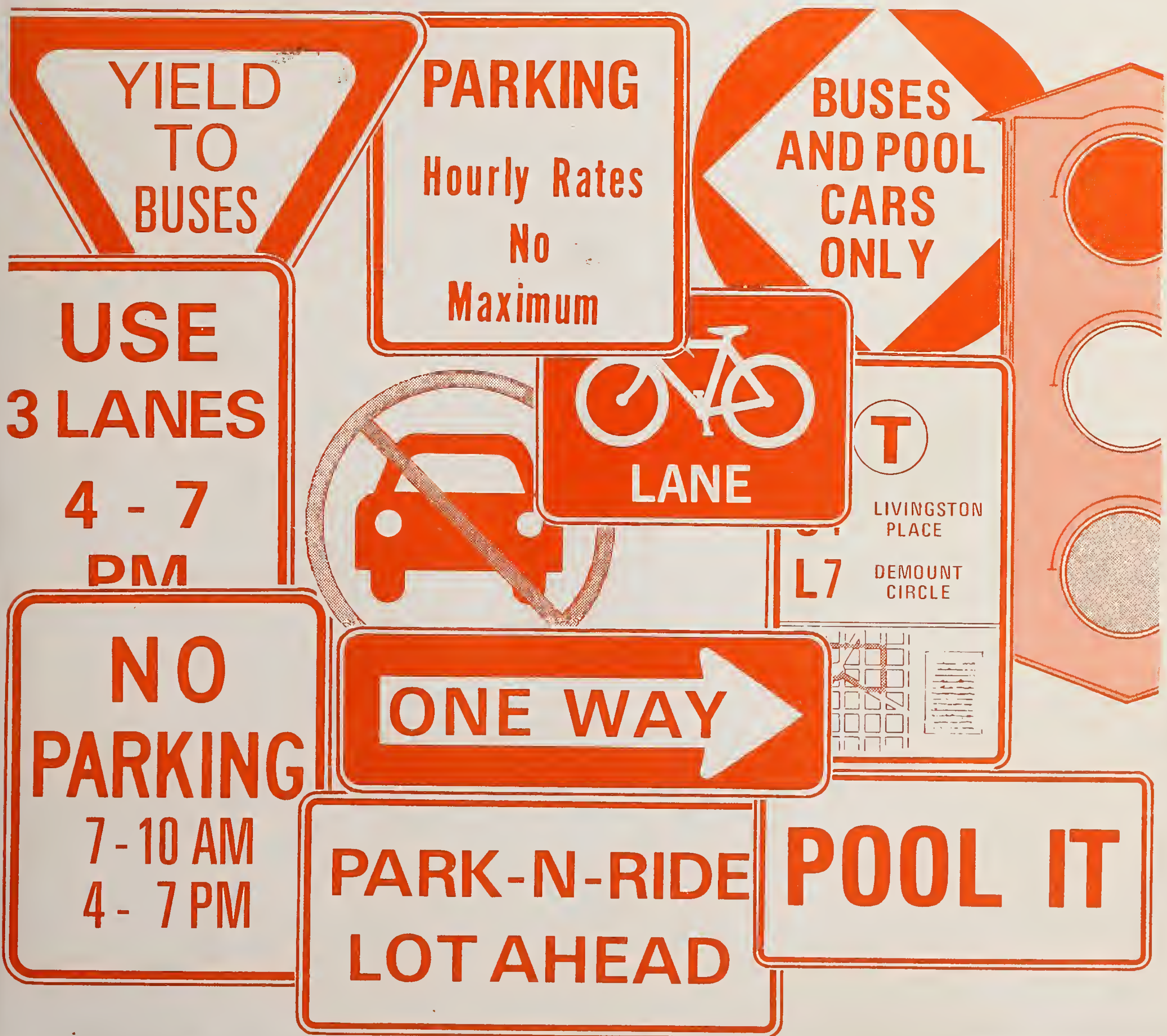

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16. Abstract

This report summarizes current information concerning the spectrum of actions that are relevant to Transportation System Management (TSM). Under Department of Transportation regulations, urban areas with population greater than 50,000 are required to develop TSM plans that document their strategy for improving air quality, conserving energy, and increasing transportation efficiency and mobility through coordinated operation and management of existing urban transportation facilities and services. TSM therefore includes actions to influence transportation demand as well as actions to manage the supply of service or its performance characteristics.

The report presents state of the art information on 31 specific TSM actions within the following seven major categories: improving vehicular flow, preferential treatment of high-occupancy vehicles, reducing peak-period travel, parking management, promoting non-auto or high-occupancy auto use, transit and paratransit service improvements, and transit management efficiency measures.

Each summary includes examples of successful experience, advantages and disadvantages, guideline conditions concerning implementation, the range of costs involved, and interrelationships with the other actions.

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TRANSPORTATION SYSTEM MANAGEMENT: STATE OF THE ART

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DISCLAIMER

FOREWORD

Many new policies and programs were initiated by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) during 1975. The newly promulgated Transportation System Management (TSM) requirement is a significant example of one such policy decision that has been taken to meet important emerging urban transportation issues. The TSM regulations, issued jointly by UMTA and FHWA, require that the TSM projects selected for implementation by urbanized areas be included in their Transportation Improvement Program (TIP) as the short-range element of this overall plan. In the case of UMTA, the development of the TSM plan and the inclusion of TSM projects in the annual element of the TIP are made a condition of future UMTA program approvals for all urbanized areas with populations over 200,000.

The TSM requirement calls upon urbanized areas to consider, in the spirit of cooperative decision making, a wide range of actions with low-capital investment requirements that can improve transportation service in the short term. The requirement reflects a growing consensus that steeply rising costs, environmental concerns, and intense competition for available resources make it imperative that better and more efficient uses for existing investments in the transportation infrastructure be found before additional investments are made in costly new facilities. Hence, a major objective of the TSM concept is to make more efficient use of the highways and transit systems already in place, thus reducing the need for new capital investments and for operating assistance.

In addition to fiscal economy, the TSM requirement provides a means for establishing a better balance among the various elements of the urban transportation system so that meaningful steps can be taken toward attaining broader local and national goals--energy conservation, environmental improvement, equity for transit dependents, and urban preservation. The transportation system management concept recognizes that the mode best suited to serve individual trip purposes varies among and within urbanized areas, depending on a number of factors--e.g., the characteristics of the existing transportation system, total demand for the trip purpose in question and its geographic distribution, the nature of the urban environment, and the locally determined goals. For instance, pooled riding in privately owned vehicles may serve the work-trip demand most effectively in a low demand density sector of an urbanized area, bus transit may serve this demand in another sector, and commuter rail may serve it in still another. The function of the TSM plan is to foster deliberately the use of the combination of modes that best represents an area's desired balance between the goals of efficient mobility, environmental amenity, and social equity in the operation of its urban transportation system.

The purpose of this document is to present the most recent information available on each of the TSM actions (tabulated on the following page) for use by local transportation planners in formulating their Transportation System Management Element of the TIP. Included are examples of successful experience, prerequisite conditions warranting implementation, ranges of costs likely to be incurred, cited advantages and disadvantages, implementation considerations, and significant interrelationships among the actions that may influence the effectiveness of the overall TSM plan.

As shown in the tabulation, the information on the spectrum of TSM actions covered is organized into seven sections. Broadly, the actions discussed in the first three sections are aimed directly at making the use of existing road space more efficient. The actions covered in Sections 4 and 5 contribute to this goal by reducing automobile use in congested areas or time periods. The last two sections address actions that, by improving transit service and transit management efficiency, will result in increased transit ridership, which in turn will cause reduced automobile use and improved transportation system efficiency. Other more detailed literature surveys and additional data sources are listed in Appendix A. Sources for the information contained in tables and figures are listed in Appendix B.

E R R A T A

- Page 88, Figure 5. Add the following citation:

  SOURCE: Bicycle Transit: Its Planning and Design, by Bruce L. Balshone, Paul L. Deering and Brian D. McCarl (NY: Praeger Publishers, 1975), pp. 86-87, Figs. 44, 46 & 47. Copyright 1975, Praeger Publishers, Inc. Reprinted by permission of the Publisher.

  Note: The captions in Figure 5 have been changed to conform to the most prevalent nomenclature.

- Page B-3. The source for Table 15 should read as follows:

  Desimone, Vincent R. "The Four-Day Work Week and Transportation" (Preprint 1480). New York: American Society of Civil Engineers, 1971.

- Page B-3. The source for Table 16 should read as follows:

  Based on Desimone, Vincent R. "The Four-Day Work Week and Transportation" (Preprint 1480). New York: American Society of Civil Engineers, 1971.

- Page B-5. Add the following to the source for Table 24:

  Vol. 18 of the A.I.A.A. Los Angeles Section Monograph Series (Western Periodicals Inc.).

- Page B-7. The source for Table 46 should read as follows:

  Heathington, Kenneth W., and James D. Brogan. Demand Responsive Transportation Systems. Tennessee Department of Transportation, Bureau of Mass Transit, 1974.

- Page B-8. Add the following to the source for Figure 4:

  Vol. 18 of the A.I.A.A. Los Angeles Section Monograph Series (Western Periodicals Inc.).

Lincoln Tunnel Bus Lane (I-495)

Golden Gate Bridge - Marin County Bus Lane (US 101)

Banfield High Occupancy Vehicle (HOV) Lane, Portland, Ore.

Minneapolis I-35W Express Bus-on-Freeway esp. Ramp Metering with Bus Bypass

Miami S. Dixie Hwy Bus/Carpool Lane

Madison, Wisc. Bus System Improvements

Arlington VA reversible lanes (eg. Wilson Blvd)

SF Oakland Bay Bridge Toll Plaza pricing/bypass

Singapore Area Licensing

Gothenburg (Sweden) Auto Restraint

SPECTRUM OF TSM ACTIONS

1. Improved Vehicular Flow

    Improvements in Signalized Intersections
    Freeway Ramp Metering
    One-Way Streets
    Removal of On-Street Parking
    Reversible Lanes
    Traffic Channelization
    Off-Street Loading
    Transit Stop Relocation

2. Preferential Treatment of High-Occupancy Vehicles

    Freeway Bus and Carpool Lanes and Access Ramps
    Bus and Carpool Lanes on City Streets and Urban Arterials
    Bus Preemption of Traffic Signals
    Toll Policies

3. Reduced Peak-Period Travel

    Work Rescheduling
    Congestion Pricing
    Peak-Period Truck Restrictions

4. Parking Management

    Parking Regulations
    Park-and-Ride Facilities

5. Promotion of Non-Auto or High-Occupancy Auto Use

    Ridesharing
    Human-Powered Travel Modes
    Auto-Restricted Zones

6. Transit and Paratransit Service Improvements

    Transit Marketing
    Security Measures
    Transit Shelters
    Transit Terminals
    Transit Fare Policies and Fare Collection Techniques
    Extension of Transit with Paratransit Services
    Integration of Transportation Services

7. Transit Management Efficiency Measures

    Route Evaluation
    Vehicle Communication and Monitoring Techniques
    Maintenance Policies
    Evaluation of System Performance

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SECTION 1

IMPROVED VEHICULAR FLOW

A major goal of all TSM actions is to improve vehicular flow by implementing low-cost measures that increase the efficiency of existing road space and thereby avoid the need for roadway expansion. The following actions discussed in this section approach this goal by modifying the way in which the movement of traffic is controlled and/or by altering the designated use of road space:

- Improvements in signalized intersections
- Freeway ramp metering
- One-way streets
- Removal of on-street parking
- Reversible lanes
- Traffic channelization
- Off-street loading
- Transit stop relocation.

Successful implementation of these actions should result in decreased congestion, increased average speeds, and reduced travel times. Their successful implementation could also postpone the need to employ additional TSM actions. However, the benefits from these actions may be negated if they serve to encourage increased use of low-occupancy autos. Thus, only if these actions are integrated into a comprehensive TSM plan will lasting benefits accrue.

IMPROVEMENTS IN SIGNALIZED INTERSECTIONS

The traffic signal cycle length--the time required for the display of all signal indications--and the control concept for the traffic network are the major elements influencing the number of vehicles that can pass through an intersection in a given period. By determining the most efficient use of signal time on an intersection-by-intersection basis, the amount of time available for individual movements at a group of intersections can be optimized, and vehicular throughput can be increased. For instance, in a computer simulation and field verification test of potential traffic signal improvements for selected Los Angeles roadways, 15 cycle-length/control-concept alternatives were analyzed. Broadly, it was learned that if the control concept were held constant, a reduction in cycle length would significantly improve average speed. The two top ranking alternatives had a 50-second cycle length and used a SIGOP (Signal Optimization Program) or modified SIGOP computerized control program. Although a reduction in cycle lengths increases traffic flow, this study found that shortening the cycle length to 40 seconds or less reduced pedestrian crossing times to unacceptable levels.

Pretimed and Traffic-Actuated Signals

The most widely used signal devices are pretimed. This type of signal directs traffic to stop and to proceed in accordance with a simple, predetermined time schedule or a series of such schedules. Thus, it is set to repeat a given sequence of signal indications regularly.

Traffic-actuated signals operate according to traffic demand. Traffic demand is registered by vehicle or pedestrian detectors that actuate the signal when the vehicle or pedestrian approaches the intersection.

The efficiency of various refinements in the signal time phasing of pretimed and traffic-actuated signals was analyzed in a study undertaken in 1966 in Sunnyvale and Redwood City, CA. The following results were obtained and subsequently formulated into recommendations for traffic signal improvements in these cities:

- Signal time phasing is not a controlling factor when narrow lanes, curb parking, and left-turn conflicts exist. However, where signal time phasing does control, refinements can improve flow.
- Greater operational efficiency can be achieved by coordinated timing of demand-actuated signals, especially on major commuter routes through or adjacent to CBDs.
- Where signal time phasing is instituted to favor a preferred route, the flow of commuter traffic is improved.
- In small cities, signal maintenance is often inadequate. For effective signal performance, either a city staff technician must be adequately trained and the maintenance task assigned appropriate priority, or the task should be contracted to a fully qualified outside firm.

Traffic-Adjusted, Computer-Controlled Signals

Although benefits can be gained through (1) progressive interconnection of traffic signals, (2) manually changing the fixed-time rate of pretimed systems, or (3) altering the demand-response cycle of traffic-actuated systems, the most efficient signalization can generally be achieved through a computerized traffic-responsive control system. In such a system, electrical impulses from traffic sensors that record traffic conditions at intersections in the network are fed into the decision program of a computer, which then selects and initiates the most efficient set of signal cycle times and timing patterns for the network. Traffic-actuated signals, tied to computerized signal systems, have now been installed in or are planned for over 115 cities. Computerized traffic control systems are suitable primarily in cities with populations over 80,000, and it is estimated that most cities of this size will install them within the next decade.

The characteristics of selected computerized traffic control systems are given in Table 1, some based on digital, others on analog computers.

Cost Effectiveness

The limited amount of information available on the cost effectiveness of computerized signal systems in presented in Table 2. The cost savings to motorists, shown in Table 2, are based on estimates of the fuel that motorists will save from reduced stop-and-go driving conditions, the value of the time motorists will save, and the reduction in accident-related costs. These data and other costs analyses indicate that computerized signal systems are usually financially justifiable for networks with over 50 intersections.

Implementation Considerations

In addition to evaluating the potential cost effectiveness of installing improved traffic signal controls, the decision to implement this action must also be weighed favorably to include a consideration of the potential energy conservation and air quality benefits that are likely to result. For example, reducing the number of stops and starts in an urban trip* and the amount of engine idling time results in significantly improved fuel efficiencies. Further, fewer pollutants are emitted during steady state driving than during accelerations and decelerations.

Although the benefits accruing from improved traffic flow are substantial, indications are that the resulting improved traffic flow conditions may stimulate additional travel demand. Therefore, the decision to implement traffic control improvements at signalized intersections must be carefully integrated into an overall transportation plan that includes adequate safeguards against such an occurrence.

When measures to increase vehicular flow by means of improving signalized intersections are undertaken as part of a TSM plan that includes actions to permit buses to preempt traffic signals (see Section 2) and actions to encourage human-powered travel (see Section 5), certain precautions must be taken to prevent any counterproductive effects. In the case of bus preemption of traffic signals, an appropriate compromise must be made between attaining maximum vehicle throughput and optimizing passenger throughput. Similarly, since vehicle throughput increases as signal cycle length decreases, care must be taken to assign the

*A 5-10 percent reduction is estimated to result from installing computerized traffic control systems.

Table 1. Characteristics of Computer-Controlled Traffic Systems

Characteristic	San Jose, CA	Wichita Falls, TX	Baltimore, MD	Washington, DC*	Charleston, SC
Status	Operational	Operational	Operational	Operational	Operational
Control Method	Digital Computer	Digital Computer	Analog Master Controllers	3-dial, fixed time	Hybrid
No. of Intersections	60	77	1050 (8 systems) some vehicle actuated	1000	86
Area (square miles)	1	1	50	80	4
Type of Area		Downtown and fringes	Entire city	Entire city	Entire city
Computer	IBM 1800	IBM 1800, 16k core card input output and typewriter 512k disc	Automatic Signal PR Controllers		DPD-81 plus Automatic Signal modular solid state master
Data Transmission	4 wiresplus 1/detector	4 wires plus 1/detector		Radio and cable	
Number: Type of Detectors	400: 320-loop, 80 pressure flow speed, lane-occupancy	51: 32 loop, 19 pressure. Measure flow, speed, lane-occupancy. 26 different locations	100: Volume and radar speed (Density calculated)	Very few	25 sampling, 60 counting, 20 local: Induction loop
Display	Network display green for major streets	Network display, red, yellow, green signals for each street, plus blue to show computer is controlling signals	Negligible	None	Real time R & G for each intersection on map. Indication of unduly noncycling controllers. 5 closed circuit TV cameras. Printout of discrepancies between time-space diagram speeds and actual avenue speed
Control Modes Run	1 and 3 dial fixed time and green adjusting system tested				Common cycle (variable); choice of 2 independent offsets for the 2 subsystems in which area is divided (each of the 2 offsets independently variable)
Present Conclusions and Remarks	3 dial better than 1. Green adjusting at critical intersections and preplanned program based on simulation better still. Evaluation based on flow data, speed and occupancy detectors. Phase skipping not permitted.	Reduced delays 31%; stops 16%. Similar systems proposed in Portland, Ore.; Austin, Texas; Baltimore County, Md.; Queens, New York. This type of computer may control up to 500 intersections.	Philadelphia, Los Angeles, Fort Worth, and 150 other cities have similar although smaller installations. Some evaluations have been made.	Many other cities including New York have fixed-time interconnected systems of various types.	Annual network decrease in vehicle operating costs = $613,191. Network travel speed increased from 17.6 mph to 21.3 mph. 30 more intersections to be included by August 1976.

*Recent expansion now includes 114 intersections in the downtown area controlled by a digital computer (34 of which are part of a bus priority system).

Table 2. Cost Effectiveness of Computer-Controlled Signal Systems

CITY	NUMBER OF INTERSECTIONS	CAPITAL OUTLAY ($)	ANNUAL MAINTENANCE ($)	ESTIMATED ANNUAL SAVINGS TO MOTORISTS ($)	TIME TO RECOVER CAPITAL OUTLAY
Toronto, Canada	864	5,000,000	297,000	20,000,000	Less than 6 months
San Jose, CA	60	1,000,000	NA	264,000	Less than 6 years
Wichita Falls, TX	77	128,000	NA	450,000	Less than 6 months
West London, England	100	1,540,000	103,600	NA	NA

NA = Not available.

appropriate priorities to bicyclists and pedestrians to ensure that the time allotted for crossing at intersections facilitates rather than deters the use of these modes.

Although this discussion has focused on actions that can be taken to improve traffic flow at intersections where traffic signals are already in place, installing traffic signals at previously unsignalized intersections can also increase vehicular throughput, depending on site-specific conditions. A source that details the traffic conditions warranting the installation of traffic signal controls is cited in Appendix A.

FREEWAY RAMP METERING

Signalizing freeway ramp intersections to control or meter the entry of vehicles onto the freeway system is an increasingly popular and successful way of improving the use of existing facilities, increasing overall vehicular flow, and decreasing total travel time. Use of ramp metering permits (1) control of the volume of vehicles entering the freeway so that the roadway capacity is not exceeded (diverting excess capacity vehicles to alternate, parallel routes or less congested ramps) and (2) a smoothing of the traffic flow since vehicles are allowed to enter only when they can be merged between platoons in the traffic stream.

Simple ramp metering involves the use of pretimed ramp signals. Computerized metering involves demand/capacity monitoring and provides a highly effective means of alleviating recurrent congestion. In tune with recent efforts to give preferential treatment to high-occupancy vehicles, the ramp metering concept has been modified in many locations to permit priority vehicles to bypass the ramp queue and immediately enter the freeway. Table 3 shows the basic characteristics of existing ramp metering installations.

Table 3. Characteristics of Existing Ramp Metering Installations

LOCATION	TYPE		BYPASS PROVISIONS
	Simple	Computerized	
New York City, NY	x		
Chula Vista, CA	x		
Los Angeles, CA	x	x	x
Atlanta, GA	x		
San Diego, CA		x	x
Chicago, IL		x	
Milwaukee, WI		x	
Detroit, MI		x	
Houston, TX		x	
Dallas, TX		x	
Minneapolis, MN*	x		x

*The Urban Corridor Demonstration Project.

Cost Experience

Initial capital costs for ramp metering vary, depending on the type and scope of the control. Table 4 presents an estimate

Table 4. Average Capital Costs for Ramp Metering (1972)

RAMP TYPE	COMPONENTS	COST/RAMP($)
Auto Entrance Ramp	Signal installation, gap detector, merge detector, input detector, demand detector, queue detector	5,000
Bus Entrance Ramp	Signal installation, gap detector, input detector, demand detector	3,800
Combination Entrance Ramp	Signal installations (2), gap detector, merge detector, input detectors (2), queue detector	8,200

of average costs that are likely to be incurred per freeway ramp for specified components. In addition to the signal and detector equipment costs shown in Table 4, computer equipment or leasing costs, maintenance and personnel costs and, in some cases, frontage road control system costs may be incurred. Annual operating and maintenance costs average about $1,000 per freeway ramp.

Insight into the probable total cost per metered ramp can be gained from experience in Los Angeles, where an average of $10,000-20,000 has been spent per ramp. At the end of 1975, Los Angeles had 160 metered onramps. The eventual goal in this project is to meter all of the 800 freeway ramps in the metropolitan area. Costs in this range were also incurred in Dallas, where $472,000 was spent on a computer-controlled ramp metering project consisting of 39 freeway ramps along a 10-mile section of the North Central Expressway--an average cost of about $12,000 per ramp.

Advantages and Planning Considerations

The main advantage of ramp metering is that it permits optimum utilization of the freeway's design capacity. By preventing too many vehicles from entering the system and by facilitating the smooth entry of the vehicles that can be accommodated, greatly improved average peak-hour speeds are attained. For instance, as the result of stop-and-go conditions, peak-hour traffic speeds on the Los Angeles Harbor Freeway averaged 15-20 mph prior to ramp metering. After metering, average speeds for the same volume of traffic increased to 40.3 mph, cutting travel time in half. Similarly, ramp metering caused Dallas's average expressway speed to increase from 14 mph to 30 mph.

Apart from the obvious benefits of improved mobility and increased system efficiency, fuel efficiency and air quality gains are undoubtedly substantial. For example, average steady-state auto fuel efficiencies in the speed ranges cited above are:

Speed (mph)	Gasoline Consumption (mpg)
10	5.7
15	8.0
20	10.5
25	13.4
30	14.4
40	13.3

Altering the average speed from 15 mph to 40 mph, as in the Los Angeles case, would save each motorist 0.05 gpm or 0.5 gallons per day if 10 miles of the daily trip distance were affected. In a 250-day work year, savings of some 125 gallons are implied--about $75.00 at a gasoline price of 60 cents per gallon. These values are likely to be conservative since the fuel consumption estimates do not include the stops and starts experienced under congested driving conditions. In addition to these advantages, in Chicago, accident rates have decreased by 75 percent on roadway sections controlled by ramp metering.

Increased freeway travel speeds are partially offset by delays incurred at metered onramps--on California freeways the delays experienced have been as long as eight to nine minutes. As a result, where bypassing of ramp signals has been offered as preferential treatment to carpools, it has become a substantial incentive to carpool formation. In Los Angeles, for example, some 80-100 new carpools were formed at a ramp where a carpool bypass lane had "queue jumping" privileges. Although these results are interesting, caution must be exercised to ensure that the practice does not become self-defeating. For example, it was observed that at ramp locations where one of two lanes is dedicated for bus and carpool priority treatment, the queue in the nonpriority lane at times extends into the entry street, causing an impedance to traffic. Also, if the proportion of priority vehicles increases substantially (or violations are not controlled), the unobstructed access of these vehicles to the freeway will at least partially negate the effectiveness of ramp metering. In the event that the unregulated entry of a large number of priority vehicles threatens the effectiveness of ramp metering, increasing the minimum number of persons per vehicle to qualify the vehicle as a carpool may provide a partial solution. Dual signals giving entry priority to high-occupancy vehicles might also function as an alternative solution.

In Los Angeles it has been observed that about five percent of the nonpriority vehicles at a ramp during the peak period violate the dedicated bypass lane provision. However, most of these vehicles do not seem to repeat the violation. Based upon the minimum level of enforcement exercised, this level of violation appears to strike a reasonable balance between the amount of violation that is tolerable and the additional enforcement required to reduce it.

Applicability Criteria and General Guidelines

As a rule, when lane densities exceed 40-50 vehicles per mile--i.e., when unstable or forced flow conditions exist--ramp metering should be considered.* Experience has also shown that metering adapts best to areas situated downstream from the major traffic generators, and to areas in which parallel streets are relatively uncrowded and can absorb traffic that chooses to avoid delay at the ramp. Contrary to original thought, increased travel time on

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*In situations where unstable or forced flow conditions exist (Level of Service D), 80 percent or more of the usable highway space is occupied and average vehicular speeds are reduced to about 40-50 mph.

adjacent streets has been negligible or nonexistent. While surface street diversion does occur, the majority of affected vehicles alter their travel pattern by entering the freeway at upstream ramps, as has been observed on the Los Angeles Harbor Freeway.

Following are some general facts and guidelines that have emerged from ramp metering experience:

- Sharp curtailment of the traffic allowed to enter a freeway at a high-demand ramp is usually not possible because of the severe congestion resulting on feeder streets. Hence, slight sacrifices in optimum freeway control sometimes must be made to ensure that local streets do not become overly congested.
- Random merging of single vehicles or small platoons, which results from the use of bypass lanes, has seldom, if ever, interfered with the overall ramp metering operation.
- It is virtually impossible for the freeway to operate at capacity and still avoid shock waves.* Thus, because of the frequency of such incidents and the difficulty of dissipating the resultant congestion, operations should be controlled to maintain volumes slightly below capacity if local street conditions can permit this. The slack provides a natural recovery capability.
- Good information on freeway traffic conditions should be provided to drivers approaching metered ramps--especially if wide traffic fluctuations occur--so that they will understand the need for such a constraint. Alternative arterial street routings are also essential.

ONE-WAY STREETS

Because the use of one-way streets is a long-standing and prevalent practice, and because conditions for implementation are extremely site specific, using one-way streets to improve vehicular flow will only be discussed in general terms.

Cost Experience

Cost information on implementing one-way streets is not usually specified in highway budgets. As a frame of reference, however, the case of Charleston, WV, can be cited. A TOPICS (Traffic Operations Program to Increase Capacity and Safety) project in Charleston provided for the construction of the Iowa Street Connector to develop a one-way street system for traffic

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*The chain reaction on upstream traffic caused by a change in downstream operations--e.g., speed change and weaving.

and to alleviate severe traffic caused by the convergence of three major through routes. Charleston's one-way couplet project cost was $506,000.

Advantages and Disadvantages

Conversion to one-way streets generally decreases the number of potential vehicular conflicts at intersections because the number of opposed turning movements is reduced. As a result, both roadway safety and the effectiveness of progressive traffic signal timing are improved. Jointly, the above factors contribute to increased traffic safety and improved flow.

From the standpoint of capacity and traffic flow, one-way operations tend to be more efficient than two-way operations of the same width. However, where narrow streets (less than 50 feet wide) without pavement markings and with parking on both sides of the street exist, maximum traffic capacity is achieved via two-way street operations. Removal of on-street parking from such streets might comprise the first TSM action taken, followed by others such as one-way streets with reserved lanes, signal preemption, and the like.

In New York City, the specific benefits attributed to one-way street conversion were a 20 percent reduction in pedestrian accidents, a 22 percent reduction in travel time, a 65 percent reduction in the number of vehicular stops, a 60 percent reduction in the time spent during stops, and a 40 percent reduction in crosstown delay. When operated in directional pairs, one-way streets can also increase the volume of traffic carried by a roadway network and enhance cross-street flow by altering signal timing. For instance, it is possible to decrease signal cycle length from 90 seconds on a two-way street to 50 seconds on a one-way street, with a change in cycle split from 60-30 on the two-way street to 35-25 on the one-way street. By so doing, improved efficiency results on the one-way street and improved capacity is gained on the cross street.

The conclusions of a Redwood City and Sunnyvale, CA, series of roadway optimization experiments on the advantages of one-way streets are presented below:

- A one-way couplet composed of a major street and a less traveled parallel street equalized the use of both streets.
- One-way street conversion resulted in improved traffic flow and turning movements and decreased delays at intersections.
- One-way street couplets were more effective than other traffic control measures in the test program (signal timing, left-turn prohibition, parking controls, etc.) in improving the operational performance of city streets.

[Additionally, one-way streets can be used in conjunction with other TSM actions to improve existing roadway conditions. For example, center city contra-flow bus lanes and traffic signalization improvements are measures that can reinforce each other in an integrated set of improvements.]

Disadvantages cited for one-way street conversion include the following:

- Increased passenger walking distance to transit lines and between transfer points, due to rerouting transit lines to serve newly formed one-way streets. This may cause a reduction in the demand for transit.
- Increased vehicles-miles traveled since motorists must travel around the block to reach their destination--a cumulative effect with regard to the number of one-way streets and the block lengths. This effect may be counterproductive to air quality and energy conservation goals unless there is an overriding increase in overall travel efficiency, caused by improved traffic flow.
- Initially, businesses may react negatively to one-way streets. However, research indicates that one-way streets are likely to increase business volumes as the result of overall improved accessibility and traffic flow. Businesses that are dependent on traffic flow--e.g., parking lots and gas stations--may be adversely affected by street reroutings that alter the direction of traffic.
- Pedestrian safety may be reduced where four or more one-way lanes do not allow for a center island to facilitate pedestrian crossings.

Implementation Considerations

Implementing one-way streets as an aspect of a TSM plan would appear to be especially useful in facilitating the following actions for the reasons given:

- Improvements in Signalized Intersections. A reduction in the number of turning movements at one-way street intersections improves the effectiveness of signalization improvements.
- Reversible Lanes. Directional segregation of traffic on separate roadways provides an opportunity to open contraflow lanes during peak hours on those streets reserved for traffic flow in the off-peak direction. From the perspective of the traffic network, the implication is that roadway use can be optimally adjusted to accommodate directional traffic volumes.
- Traffic Channelization. One-way streets and the reduction in opposed turning movements make traffic channelization and turn restriction control techniques especially effective in improving vehicular flow.

- Bus Preemption of Traffic Signals. Implementing preemptive traffic signals is easier on one-way streets since there are fewer turning movements at one-way street intersections.
- Bus and/or Carpool Lanes on City Streets and Urban Arterials. The increase in traffic flow that results from a network of one-way streets may be sufficient to enable the institution of bus-only lanes, with minimal additional congestion resulting over the previous two-way street configuration.

REMOVAL OF ON-STREET PARKING

Removing on-street parking helps to improve vehicular flow by increasing street capacity. Furthermore, by discouraging the use of automobiles in crowded central business districts (CBDs) (and concomitantly ensuring adequate access through increased transit and paratransit service), the institution of on-street parking regulations constitutes an important element of an area's overall parking policy. The other parking regulations that can be employed to obtain TSM goals are discussed in Section 4.

Current On-Street Parking Policies

The on-street parking policies now in evidence in cities in the United States were instituted to further a wide variety of goals. Concurrent with the decline in transit ridership, policies were instituted to augment the availability of parking spaces, particularly in CBDs. One of these policies, diagonal parking, permits the storage of a greater number of vehicles curbside than parallel parking but significantly reduces the road space available for transportation. In consonance with the TSM goal to increase the efficiency of existing road space, diagonal parking policies, therefore, should be critically evaluated and, where possible, eliminated since substitution of parallel parking for diagonal parking on both curbsides provides approximately one additional lane for transportation use.

As the use of private autos increased and streets became crowded with parked autos and crusing autos seeking available parking spaces, policies were instituted for retailers, employers, hotels, and other businesses to provide off-street parking facilities. The TSM actions that can be taken to manage these facilities, including measures designed to control on-street parking, are discussed on pages 59-68.

In many cities on-street parking is prevented at certain times of the day, days of the week, or on odd- or even-numbered sides of the streets on alternate days of the week. Except for peak-period parking restrictions, the abovementioned policies are usually implemented to facilitate street cleaning, snow removal, or other public works. Peak-period parking restrictions, effective in providing additional road space during periods of high travel demand, can be instituted as an interim policy prior to complete elimination of on-street parking in heavily traveled CBD corridors. However, enforcement of time-related parking restrictions is more difficult than enforcement of 24-hour parking restrictions, and violations interfere severely with peak-period traffic.

Cost Experience

The primary initial costs associated with removing on-street parking are for curb painting and signing. The principal operating cost incurred is for enforcement of the restriction. In this regard, experience has shown that eliminating on-street parking is most effective when accompanied by enforced tow-away policies.

Advantages

The principal result of removing on-street parking is a substantial increase in roadway capacity. Only 55 to 65 percent of roadway capacity is utilized on two-way streets where on-street parking is permitted. When parking is eliminated at a signalized intersection of a one-way street, roadway capacity is approximately two and one-half times greater than if parking were allowed.

Improved traffic speeds (5 mph), a reduction in peak-period travel time (25 percent for autos and 10 percent for local buses), and up to a 50 percent reduction in traffic delays and stops have been attributed to on-street parking restrictions. It is important to note, however, that the level of traffic flow improvement depends upon the existing street width. Removal of on-street parking also tends to greatly improve safety conditions since on-street parking is a causal factor in 18-19 percent of all urban traffic accidents.

Although site-specific conditions may cause different effects, in general the additional roadway space created when on-street parking is prevented facilitates or improves the efficiency of the TSM actions. For instance, the availability of an extra lane can provide an opportunity to institute right-turn- or left-turn-only lanes (see pages 16-17) and to relocate transit stops to mid-block, where interference with signalized intersections is minimized (see pages 19-21). Removal of curbside parking in itself reduces traffic hazards to bicyclists and also may enable the implementation of bike lanes (see pages 86-95).

Implementation Considerations

Before implementing on-street parking restrictions, an assessment of the effectiveness of existing restrictions should be made. Strict enforcement, particularly in well-traveled areas, is generally required in order to achieve maximum benefit from parking controls. If motorists do not perceive the penalty for violating parking restrictions to be severe (i.e., if the probability of getting fined and the cost of the ticket are considered minimal), then it is likely that repeated infringements will occur. Thus, full enforcement of existing parking restrictions might preclude further restriction or removal of on-street parking.

Because the proportion of on-street to off-street parking facilities decreases as the city size increases, the effect of removing on-street parking is greater in cities with populations of less than 250,000. In these smaller urban centers, on-street parking accounts for 40-85 percent of all parking spaces. By contrast, in many larger downtown areas, on-street parking accounts for only 15 percent of the total parking. Therefore, in small cities judicious implementation of on-street parking restrictions, in conjunction with augmented transit, may provide an adequate improvement in transportation efficiency. In larger cities, however, where on-street parking is a less significant factor, additional TSM measures will be required to achieve the desired improvement.

Restricting or removing on-street parking in downtown areas may have an adverse economic effect on CBD businesses--especially in smaller cities--unless a focused effort is made to provide alternate parking spaces or suitable transit service. In CBD areas where competition with "free-parking" suburban shopping areas is keen, this effect may be especially severe. Hence, careful attention must be given to this aspect of on-street parking restrictions to gain the community's support of the policy. An interim solution (see pages 59-68) is to control on-street parking to discourage long-term parking. This action reduces the total number of vehicles entering the CBD and provides an incentive for commuters to form riding pools or use transit.

REVERSIBLE LANES

On roadways where directional flow is unbalanced--e.g., a 65-35 directional split--reversible lanes can be used during peak periods to increase the capacity of the roadway in the peak direction of flow. Although, like contra-flow freeway lanes (see pages 23-33), the traffic in reversible lanes flows against the usual direction, reversible lanes usually refer to roadways not separated by a median strip. Thus, reversible lane operations are an effective and inexpensive way of increasing the efficiency of existing facilities since they permit additional peak-period directional capacity without roadway expansion.

Experience With Reversible Lanes

Atlanta, GA, Arlington, VA, Los Angeles, CA, Chicago, IL, and Milwaukee, WI, are among the cities in which reversible lanes have been successfully implemented. In Washington, DC, where there is a strong imbalance in directional flow, a reversible CBD street (13th Street) and a reversible arterial (Rock Creek Parkway) have been instituted. Vancouver, BC, and San Diego, CA, have installed reversible lanes on bridges.

Atlanta utilizes reversible lanes on five roadways in the city and recently converted a 3.5-mile, three-lane section of Memorial Drive from a traffic configuration of two outbound lanes and one inbound lane to one lane in each direction and a center reversible lane. Peak-period travel time has been reduced by about 25 percent in the direction of heavy flow, while opposing, light-flow directional traffic has experienced a peak-period travel time reduced by 3.5 percent during the evening and 5 percent during the morning hours.

In Arlington, VA, a 2.8-mile reversible lane system has been implemented on Wilson Bouelvard, a four-lane road where, during peak periods, reversible lane concepts and (bus-only) reserve lane concepts are jointly applied. A reduction in bus travel time of two to three minutes along the 2.8-mile route has been attributed to the action. Inbound morning autos use the two center lanes and buses use the inbound curb lane. The system operates in the same fashion in the reverse direction during evening peak hours. However, because of financial constraints, lane control signals are spaced 600-800 feet apart--i.e., at two-block intervals--and as a result, violation problems have arisen. Reportedly, the city has a serious problem with motorists who violate reversible and bus-only lanes--a problem that is compounded by a lack of policing capability along the route.

Cost Experience

Signing and lane use control devices, usually in the form of overhead lane signals, represent the basic costs for reversible lanes. Depending on the length of the system, maintenance and enforcement personnel may also be needed.

Atlanta's 3.5-mile long reversible lane along Memorial Drive required striping and signing; replacement of existing isolated signals with an interconnected, traffic-adjusted signal system; and moderization of signal head layouts, at a total cost of $195,000. Arlington's 2.8-mile hybrid system required approximately $150,000 for overhead lane controls and signing on both sides of Wilson Boulevard.

Advantages and Disadvantages

Reversible traffic lanes have been successful in improving traffic safety, reducing peak-period traffic congestion, and reducing travel time by as much as 20 percent. Apparently there are few disadvantages associated with reversible traffic lanes. However, when only one lane is available for off-peak direction flow, long queues can form behind turning or disabled vehicles.

Applicability

On an undivided arterial street of three or more lanes, the following conditions warrant considering the installation of a reversible lane system:

- Sixty-five percent of the traffic moves in one direction during peak periods.
- The remaining roadway capacity in the off-peak direction is adequate.
- There is continuity in the route and in the width of street.
- There is no median, and left turns and parking can be restricted.

Experience indicates that optimum traffic flow in the predominant direction is achieved when reversible lanes are combined with suitable progressive signal timing, e.g., a three-dial interconnected system. Signals can then be set for the most efficient progression of major traffic flow in the two peak periods. A third setting can be used to control the traffic flow during off-peak periods.

TRAFFIC CHANNELIZATION

The capacity of an intersection usually determines the capacity of the roadway. Channelization techniques, traffic controls that can help to optimize the capacity of an intersection, are discussed below.

General Channelization Techniques

Channelization—directing traffic into defined paths on roadways—can reduce or eliminate potential hazards to motorists and pedestrians and avoid confusion in traffic flow. Generally, channelization requires using islands, pavement markings, or other suitable means of facilitating traffic flow to separate potential areas of conflict, improve safety, provide for the maximum utilization of available space, and regulate traffic movement and speed. In fact, effective channelization can increase traffic speed up to 10 mph. Where turning volumes are heavy, specially designated turning lanes can promote smooth vehicular flow by removing turning movements from through lanes. Left-turn lanes, particularly when accompanied by separate turn signal indicators, are highly effective in decreasing the left-turning vehicle's exposure to oncoming through traffic, thereby reducing the number of accidents at intersections. Right-turn-on-red provisions and special turning signals (arrows) increase the effectiveness of right-turn lanes.

Costs

Channelization techniques have been employed in virtually every city in the United States. For example, some 754 cities have instituted channelization projects under the TOPICS program since its institution in 1968. During fiscal year 1974 alone, over $11 million of TOPICS funds were allocated for channelization projects. These projects are typically non-capital intensive, but costs vary according to roadway conditions and the type of work that must be done—e.g., raised barrier construction versus painted islands.

Turn Restrictions

When turning movements conflict with and impede through traffic, turn restrictions, a common form of channelization, may provide a suitable solution. Basically, preventing right turns minimizes vehicle/pedestrian conflicts, whereas preventing left turns minimizes vehicle/vehicle conflicts. Indications are that part-time turn restrictions can be effective during peak periods; however, public compliance is reportedly better where turn restrictions are maintained full time.

San Diego experimented with the joint application of turn restrictions and reserved lanes for certain priority vehicles and concluded that the arrangement facilitated bus movements in the downtown area. For approximately 30 days in 1974, the curb lanes along eight blocks of a major downtown street were converted to through lanes for buses and taxis. All other vehicles using the street were prohibited from making left and right turns. The arrangement was effective in increasing the efficiency of bus operations since buses saved up to six minutes of running time through the downtown area. However, protests from downtown merchants caused the experiment to be discontinued. Nevertheless, the San Diego Transit Corporation hopes to re-institute the scheme by working closely with these merchants.

While there are no widely accepted criteria for justifying the institution of turn restrictions, the following are conditions that may warrant establishing them:

- The left-turn volume exceeds 20 percent of the total approach volume.
- Left turns constitute 10 percent of the total movement on a given street.
- Left-turn movements interfere with straight-through movements of 15,000 vehicles per day, regardless of the number of lanes.
- A left-turn or right-turn movement interferes with pedestrian crosswalk volumes in excess of 2,000 persons per hour.
- 600 vehicles conflict with 1,000 or more pedestrians per hour.
- Seven vehicles turn per green interval for several successive signal changes.
- More than three intersection accidents that involve turning vehicles occur within a 12-month period.
- The number of traffic lanes available at the intersection will accommodate only a single movement in each direction, and there is an appreciable demand for left turns.
- Periodic gaps in opposing traffic do not occur due to traffic signals ahead.

The Redwood City and Sunnyvale roadway optimization experiments with left-turn prohibitions concluded that:

- When left turns are prohibited at all intersections along a major street within the core area, left-turning traffic can be successfully diverted if a convenient alternate route is available. Traffic flow on the major streets is improved because of reduced volume and elimination of turning delays.
- When no alternate route is available, left-turning traffic must turn right to circle the block. Traffic flow is improved only if pedestrian interference with right-turning vehicles does not increase turning delay. Traffic volume on the major street is usually not reduced.
- Drivers can be expected to observe the continuous left-turn prohibition when an alternate route is available; conversely, drivers can be expected to resist this left-turn prohibition when the alternate route is not convenient unless such a prohibition is strictly enforced.

OFF-STREET LOADING

Although preventing curbside truck loading and unloading removes a traffic impedance, providing off-street loading facilities in established CBDs is generally too costly to be included in the TSM plan. Thus, many cities can only modify urban zoning ordinances to require that new developments provide facilities for off-street loading and unloading and/or restrict or prohibit loading and unloading during peak periods. Dallas and Philadelphia are among the cities requiring that off-street berths be in proportion to commercial and office building floor space. The nationwide status of this policy is shown in Table 5.

Table 5. Nationwide Status of Off-Street Truck-Loading Facility Policies

STATUS	CITY POPULATION			
	Under 100,000	100,000-250,000	250,000-500,000	Over 500,000
Percent of cities having buildings in CBDs with off-street, on-site loading facilities.	22	16	6	12
Percent of cities requiring off-street, on-site loading facilities by building code.	50	40	56	80

TRANSIT STOP RELOCATION

Curbside loading and unloading of transit and paratransit passengers, especially at intersections, can seriously impede traffic flow. Turnout bays near transit route junctions provide an ideal solution. However, in many established CBDs this solution is impossible since adequate space may not be available. In these cases, relocating transit stops may provide an equally effective solution.

Basically there are five places where transit stops can be located: the near-side of an intersection, the far-side across from an intersection, the far-side of an intersection after right turn, midblock, and in turnouts. These locations and the average amount of curb space recommended for each are illustrated in Figure 1. For the most part, bus stops are now located near intersections. However, where blocks are exceptionally long or where bus patrons are destined for midblock employment or residence, relocating the transit stop to midblock would be a suitable alternative, especially when accompanied by a midblock crosswalk.

Due to the visual obstruction created by the bus, motorists may find sight conditions at near-side stops unfavorable. This is an important problem at intersections since the bus may block the motorist's view of traffic signals. Near-side stops also pose hazards for

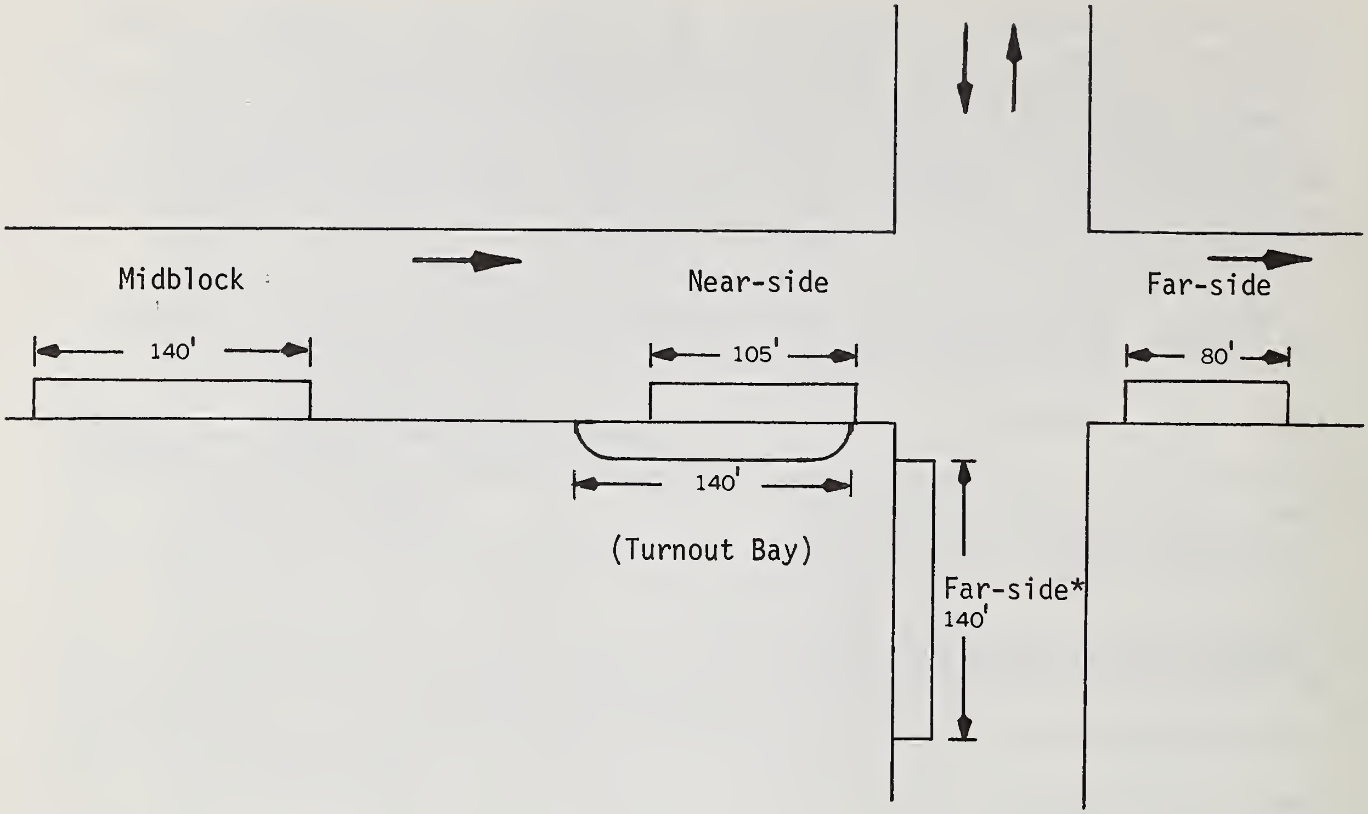

Figure 1. Alternative Single Bus Stop Locations and Space Requirements
* After right turn.

other vehicles when a bus is loading since vehicles often attempt to bypass the loading bus, thereby interfering with other traffic and/or the bus as it leaves the stop. Nonetheless, near-side stops can reduce travel time if passenger loading and unloading occurs when the bus is waiting at a red light. Additionally, near-side stops make a convenient transfer point for passengers to and from a far-side stop on the cross street.

Far-side stops are advantageous at intersections where (a) other buses may turn in either direction, (b) turning movements--especially right turns--from the arterial in the direction being considered are heavy, (c) cross traffic is heavy and the curb lane and other lanes are needed for storage when the signal is red, and (d) several streets meet at the intersection. Also, sight-distance*

*Sight-distance is the length of roadway ahead that is visible to the driver. Three important sight-distance considerations are minimum safe stopping distance, distance required for passing another vehicle, and visibility at intersections.

conditions tend to favor far-side bus stops, particularly at unsignalized intersections. Relocating transit stops away from the near side of the intersection can also improve the effectiveness of right-turn-only lanes and may permit implementation of right-turn-on-red controls that would otherwise be impossible.

Experience in Louisville, KY, illustrated that a simple change in bus stop locations improved travel times for both the bus and the surrounding traffic. An operational analysis at eight Louisville bus stops showed that bus operations were improved and delay was reduced when a far-side location was used at an intersection with a two-way street or a one-way street with traffic coming from the left.

SECTION 2

PREFERENTIAL TREATMENT OF HIGH-OCCUPANCY VEHICLES

The following four TSM actions improve the flow of high-occupancy vehicles during peak travel periods:

- Freeway bus and carpool lanes and access ramps
- Bus and carpool lanes on city streets and urban arterials
- Bus preemption of traffic signals
- Toll policies.

The travel time savings and improved transit service levels resulting from these actions enhance the attractiveness of high-occupancy modes. Ultimately, if these actions are successfully incorporated into a systemwide TSM plan, containing other actions designed to encourage high-occupancy travel modes, significant shifts away from the use of low-occupancy autos and an overall improvement in vehicular flow can be expected to result.

FREEWAY BUS AND CARPOOL LANES AND ACCESS RAMPS

Dedicating freeway lanes for the exclusive use of buses and/or carpools during peak travel periods permits these vehicles to bypass congested sections of roadway and substantially decreases the passenger's travel time. Preferential treatment was first afforded to bus traffic, and the bulk of documented experience refers to buses. However, within the past year the concept has been extended in many places to include riding pools.

Documented Experience

Basically, the techniques used to give preferential treatment to high-occupancy vehicles on freeways and expressways involve instituting:

- Exclusive rights-of-way that can also be combined with exclusive use of access ramps.
- A reserved with-flow lane(s), whereby a portion of the roadway is designated solely for the use of high-occupancy vehicles.
- A reserved contra-flow lane(s), whereby a portion of the roadway that normally serves opposing traffic flow is used to supplement peak-direction capacity, and one or more of these lanes is designated for the exclusive use of high-occupancy vehicles.

Table 6 shows some of the bus priority techniques that have been used and where they have been implemented. Table 7 presents the operational and market characteristics of an exclusive right-of-way for buses (busway) in Los Angeles and of a dedicated freeway bus ramp in Seattle. Experience with reserved with-flow and contra-flow freeway lanes in New York, Boston, and San Francisco is documented in Table 8.

It should be noted that exclusive rights-of-way such as the San Bernardino, CA, and Shirley Highway (Washington, DC) busways represent capital- and time-intensive projects that should be implemented only where the efficiency of existing roadway space cannot be improved to accommodate travel demand. Although the characteristics of a busway have been documented here for purposes of comparison, the construction of a busway comprises a major addition to an area's transportation system rather than an improvement in the management of the existing system.

The Seattle Blue Streak, an express bus operation linking Seattle's northern suburban area to the CBD, uses an exclusive freeway access ramp on its route into the CBD. Bus patronage has increased substantially since the project began in September 1970.

Similarly, in April 1974 Minneapolis, MN, constructed nine exclusive bus ramps to give express buses unobstructed entry to the otherwise metered-access freeway. Each Minneapolis ramp

Table 6. Significant Examples of Existing Freeway-Related Bus Priority Treatments

TYPE OF TREATMENT	LOCATION
Busways	
Busway on special right-of-way	Runcorn, England
Busway on freeway median	San Bernardino Busway, El Monte to Los Angeles, CA
Reserved Lanes and Ramps	
Bus lanes on freeways, normal flow	9th Street Expressway, Washington, DC
Bus lanes on freeways, contra-flow	Southeast Expressway, Boston; I-495, NJ; Long Island Expressway, NY; US 101, Marin County, CA
Bus lane bypass of toll plaza	San Francisco-Oakland Bay Bridge, CA
Exclusive bus access to non-reserved freeway (or arterial) lanes	Seattle Blue Streak express bus service and bus ramp
Metered freeway ramps with bus bypass lanes	Harbor Freeway, Los Angeles; I-35, Minneapolis, MN
Bus stops along freeways	Hollywood Freeway, Los Angeles

Table 7. Operating and Market Characteristics of an Exclusive Bus Right-of-Way and Freeway Ramp

CHARACTERISTICS	EXCLUSIVE RIGHT-OF-WAY	EXCLUSIVE BUS FREEWAY RAMP
	San Bernardino Busway El Monte to Los Angeles CBD	Seattle "Blue Streak" Project, suburbs to Seattle CBD
OPERATIONS		
Number of lanes	2 lanes; 2-way operation	2 reversible lanes (shared with mixed traffic)
Hours of operation	24	7:00 a.m. to 7:00 p.m. (express bus)
Special features	Uses contra-flow bus lane in L.A. CBD. Fringe parking for 1,400 cars. Carpools will experimentally share the lane with buses 5-1-77 to 5-1-79.	Exclusive use of reversible CBD freeway ramp; special express bus service from 525-space park-and-ride lot; now planning additional 1,000-space lot.
Miles of facility	11.2	8 (from park-and-ride lot).
Vehicles:		
Per a.m. peak period	132	NA
Per day	486	81
Average speed (mph)	55	NA
MARKET		
Passengers:		
Per a.m. peak period	3,000 during peak hour	3,083 (count on exclusive bus ramp)
	15,500	10,000 (up from 7,500 at beginning of project)
Market share	About 33%	NA
PASSENGERS DIVERTED FROM OTHER MODES		
Auto	61%	22% (50% of patrons using the park-and-ride lot were diverted from autos.)
Carpools	13%	NA
Other bus	10%	NA
New trips	12%	10%
SAVINGS		
Peak-period travel time savings:		
Over autos—minutes	About 20	NA
—percent	50	NA
Over former bus		
—minutes	About 15 (However, subsequent route and fleet expansion affect comparison over former bus.)	5-11
—percent	About 40	11-23

NA = Not available.

Table 8. Operating and Market Characteristics of Contra-Flow and With-Flow Lanes

CHARACTERISTIC	CONTRA-FLOW BUS LANES ON EXISTING ROADWAYS			WITH-FLOW LANES
	Approach to Lincoln Tunnel, New Jersey to New York City	Long Island Expressway, New York City	Southeast Expressway Boston, MA	San Francisco-Oakland Bay Bridge, CA
OPERATIONS				
Number of lanes	1 contra-flow lane	1 contra-flow lane	1 contra-flow lane	1 bus lane; 2 carpool lanes (carpool = vehicle with 3+ users)
Hours of Operation	a.m. peak only (7:30-9:30)	a.m. peak only (7:15-10:00)	a.m. peak only (7:00-9:30)	6:00 a.m.-9:00 a.m.
Special features	Lane terminates at N.Y. Port Authority Bus Terminal that interfaces with other transportation.	NA	Only in operation from April to October for safety reasons (short daylight hours in winter).	Bus/carpool lanes are nonmetered (and toll free) and allow cars to bypass delays at toll barrier and in lane convergence area downstream from it.
Miles of facility	2.5	2.2	8.4	1.0
Vehicles:				
Per a.m. peak period	Average: 818; High: 1,096 (597 for 8:00-9:00 a.m.)	180	82	500 buses per peak period Approximately 2,050 carpools per peak period
Per day	a.m. only	a.m. operation only	a.m. operation only	NA
Average speed (mph)	45	30-40	45	NA
MARKET				
Passengers:				
Per a.m. peak period	Average: 34,350; High: 47,800	7,500	3,160	Buses: NA; carpools: 5,700.
Per day	6% increase in daily peak-period bus riders	a.m. operation only	a.m. operation only	80 to 120% increase in carpools.
Per vehicle	42.2	NA	NA	
Market Share	Bus lane carries 10 times more passengers than regular tunnel-bound auto lanes.	NA	NA	
PASSENGERS DIVERTED FROM OTHER MODES				Modal Distribution (%) 1974 / 1975
Auto / Carpools	4%	NA	NA	
Other bus	9% (81% rode same bus as before.)	NA	NA	Auto 56 52 Greyhound 10 2
New trips	3%	NA	NA	A.C. Transit 34 21 BART 0 25
SAVINGS				
Travel time savings:				
Over auto				
Minutes	NA	5-15	7.5	5-8
Percent	NA	22-75	42	
Over former bus				
Minutes	7.5-10	NA	14	NA
Percent	NA	NA	58	
Increase in auto mph since facility opened	Speeds on several approaches to the tunnel increased from 4 to 40 mph in one case; from 10 to 30 mph in two other cases.	NA	Travel time for autos dropped from 22 to 17.5 minutes.	

NA = Not available.

consists of two separate ramps--one for buses and one for autos--that merge before entering the freeway. All of the ramps provide for bus preemption of traffic signals. As a bus enters the ramp, it triggers the metering device on the adjoining auto ramp to hold the red signal on the auto ramp until the bus has passed. The buses then join mixed-flow traffic. The Minneapolis project has successfully combined express bus service, exclusive access ramps, bus preemption of traffic signals, and ramp metering to create an efficient and effective priority treatment. Partially, as a result of the improved service, bus patronage has increased from 2,000 to approximately 9,000 riders per day.

In Marin County, north of San Francisco, reserved with-flow and contra-flow bus lane concepts have been combined to form a hybrid bus priority lane system. Originating in the town of Greenbrae, a 3.7-mile San Francisco-bound, reserved with-flow bus lane carries commuters south along U.S. Highway 101. The reserved bus lane then ends and mixed traffic moves along for 3.9-miles to the Golden Gate Bridge and across it to San Francisco. During the morning peak period, the six-lane bridge is converted to four southbound lanes and two northbound lanes. During afternoon peak hours, the bridge is again converted from its off-peak flow pattern of three lanes in each direction to four northbound lanes and two southbound lanes. A 3.9-mile reserved northbound contra-flow lane is then designated, on which buses travel into Marin County on the usually southbound side of U.S. 101. Only buses with Caltrans permits are allowed to use the contra-flow lane. The contra-flow lane is then channeled back onto the regular northbound section of the freeway where, for 3.8 miles, it becomes a with-flow reserved bus lane. Permits are not needed on this reserved lane section of U.S. 101, and all lanes are used by mixed traffic during off-peak hours.

The Marin County and Minneapolis projects are highly successful and exemplify the possibility of jointly implementing two or more priority treatments. Bus-only arterial streets, queue jumping privileges at freeway entry ramps, bus-only entry ramps, and bus preemption of traffic signals are among the additional traffic system management options that lend themselves to joint implementation. Other supportive actions designed to facilitate bus priority freeway lanes and access ramps include shorter bus headways, improved direct service, and the construction of park-and-ride facilities near freeways.

While geographical factors, demand, cost, and policy considerations are among the elements that determine which technique or set of techniques are implementable for a given urban area, variables such as quality of service, reliability, practicality, and user costs and time savings ultimately determine the technique's "success" in enticing motorists from low- to high-occupancy vehicles. As illustrated in Table 9, the promotion of high-occupancy travel, including the use of preferential treatment, has been particularly effective in New York, where over 80 percent of the travelers using the Lincoln Tunnel and Interstate 495 arrive by bus.

Table 9. Peak-Hour Traffic Volumes on Urban Freeways and Expressways with a Priority Bus Lane

BUS PRIORITY SYSTEM	ROADWAY	LOCATION	VEHICLES PER HOUR		PASSENGERS CARRIED			PERCENT CARRIED BY BUS
			Bus	Auto	Bus	Auto	Total	
Contra-flow lane	Lincoln Tunnel Approach	New York	735	3,200	32,560	5,065	37,625	85.5
Contra-flow lane	I-495	New York	490	3,000	21,600	4,750	26,350	82.0
With-flow lane	San Francisco-Oakland Bay Bridge[1]	San Francisco-Oakland	327	8,115	13,000	10,400	23,400	55.5
Exclusive right-of-way	Shirley Highway (I-95)	Washington, DC	110	3,200	5,550	4,500	10,050	53.0
With-flow lane	Ben Franklin Bridge	Philadelphia	137	4,490	5,065	5,620	10,685	47.5
Contra-flow lane	Long Island Expressway	New York	89	2,710	3,560	4,100	7,660	46.5
Contra-flow lane	Southeast Expressway	Boston	65	4,200	2,450	6,000	8,450	29.0

[1] One bus and two carpool lanes.

Costs

The cost of establishing bus-only access ramps in Minneapolis ranged from approximately $20,000 per ramp for ramp widening, to approximately $200,000 per ramp where new construction was necessary.

The Marin County bus priority system, a relatively inexpensive, readily implementable measure, required a total capital expenditure of $3,410,000 for 11.4 miles of contra-flow and with-flow bus lanes. An existing unused right-of-way along U.S. 101 was used for constructing new lanes. However, in instances where excess paved roadway capacity exists and substantial construction costs are not necessary, reserving a freeway lane during congested periods requires only signs, lane directional signals, traffic cones and/or posts, and traffic surveying and design work. Depending upon site requirements, signs may cost approximately $1,200 per mile. Traffic posts average approximately $15 per placement (post plus labor).

Because signs must be changed, cones placed, etc., to designate lane reversals before morning and evening peak periods, operating costs for reversible lanes can range from $5,000 to $12,000 per month. By contrast, San Francisco's with-flow lanes on the Bay Bridge cost only $2,000 per month for operation since traffic cones are removed only on weekends.

Another expenditure related to the success of reserved freeway lanes for high-occupancy vehicles is traffic enforcement. However, because police surveillance is not directly associated with the operation of priority lanes, manpower costs for enforcement are not included in project cost assessments--even though heavy enforcement is required periodically to maintain lane effectiveness and to prevent unsafe conditions. For example, the San Francisco-Oakland Bay Bridge with-flow carpool lanes were initially subject to 600-1,500 violations each three-hour morning peak period. The problem was approached by increasing enforcement capabilities, apprehending violators, implementing certain geometric and signing revisions, and reducing stanchion spacing. As a result, violations have been minimized, and carpool lane effectiveness has been restored.

The capital and operating costs associated with giving preferential treatment to high-occupancy vehicles differ considerably among projects (as shown in Table 10), depending on the priority technique used, the prevailing costs at the time of implementation, the differences in existing roadway design, and other site-specific conditions, including variations in construction costs.

Although with-flow and contra-flow lanes and freeway ramp entrances require some capital expenditure, their average construction cost per mile is substantially less than the construction cost for busways. For example, the cost of the Shirley

Table 10. Capital and Operating Costs of Reserved Lanes and Exclusive Freeway Bus Ramps

EXAMPLE	PRIORITY TREATMENT	PROJECT DISTANCE (Miles)	CAPITAL COSTS		OPERATING COSTS
			Construction	Other	
Marin County Greenbrae to San Francisco, CA	With-flow and Contra-flow lanes (B)[1]	3.9 contra-flow; 7.5 with-flow	$46,154/contra-flow mile; $426,667/with-flow mile[2]	$30,000 traffic signing	$5,000/month to operate lane reversal system plus $4,200 for traffic enforcement
Interstate 35W Minneapolis, MN	9 freeway ramps (B)	15	Average = $83,333/ramp	None	None
Approach to Lincoln Tunnel NJ to New York City	Contra-flow lane (B)	2.5	Access to bus lane $53,600/mile	$556,000 traffic controls	Approximately $11,000/month for crew to change lane directions each morning
Long Island Expressway New York City	Contra-flow lane (B)	2.2	$25,000/mile	None	Approximately $11,000/month
Southeast Expressway Boston, MA	Contra-flow lane (B)	8.4	$4,700/mile	None	Approximately $12,000/month
San Francisco-Oakland Bay Bridge San Francisco, CA	With-flow lanes (B&C)[1]	1	$58,000/mile	$3,000 carpool matching (12-71) plus $350,000-installation of a metering system (3-74)	$2,000/month roadway-related costs plus $300/month metering expense

1 (B) = bus only; (B&C) = bus and carpool.

2 Includes construction of 7.5 miles of with-flow bus lane.

Highway busway in Virginia averaged approximately $720,000 per mile, and the San Bernardino Freeway busway in California averaged approximately $4.9 million per mile.

Advantages

By reserving bus and carpool freeway lanes and ramps, several measurable benefits are achieved, the most important of which is the time saved by the passenger. As documented in Tables 7 and 8, freeway bus and carpool priority techniques have reduced travel time by 5-20 minutes, depending on the length of the project and previous conditions. Trip time savings in the 10-20 minute range are considered a major commuter improvement that provides an incentive for users of low-occupancy vehicles to consider changing to high-occupancy, priority modes of travel.

In addition to travel time savings, other user benefits attributed to bus and carpool preferential treatments include smaller variations in trip travel time, user out-of-pocket savings resulting from decreased parking costs, and a reduced need for second cars. Bus transit operation benefits include increased bus patronage, greater service reliability, a reduction in vehicle maintenance--due to fewer drive train and engine overhauls and increased mileage between brake repairs--and improved productivity due to the relative absence of congestion and delay.

Applicability Criteria

The most important reasons for reserving freeway lanes and access ramps for the exclusive use of high-occupancy vehicles during peak travel periods are to:

1. Enable more efficient use of existing roadway space by increasing the number of persons transported per lane.
2. Reduce roadway congestion and minimize average person travel time.
3. Induce increased use of high-occupancy modes.

The concept of giving preferential treatment to high-occupancy vehicles has occasioned much discussion in traffic engineering and transportation planning literature concerning the conditions that should exist before reserved lanes are instituted. In general, the trend in the discussion has been toward decreasing the volumes of high-occupancy vehicles required for lane reservation and toward devising lane reservation criteria based on the future level and kind of traffic that is expected to result from the entire set of TSM improvements (e.g., improved transit service levels, carpooling and other paratranist improvements, parking management, staggered and/or flexible work hours). Since preferential treatment has been applied predominantly to buses, criteria for the installation of reserved bus lanes have been most extensively developed. While these are tabulated below for general guidance, examples of successful TSM actions that violate nearly all of these criteria can be found.

<u>Traffic Engineering Criteria for Dedicated Bus Lanes</u>

With-Flow Freeway Bus Lanes:

- The number of person-minutes saved by bus riders must be greater than the number of person-minutes lost by general traffic.
- Where a with-flow lane is added, the bus lane should be expected to carry at least 60 buses during its busiest hour.

Contra-Flow Freeway Bus Lanes:

- The number of person-minutes saved by bus riders must be greater than the number of person-minutes lost by traffic in the off-peak direction.
- Contra-flow bus lanes should only be implemented on freeways with more than four lanes and when peak-hour traffic is highly unbalanced.
- Freeway travel in the off-peak direction should be operating at level of service D* or better.
- On eight-lane freeways where off-peak traffic can be accommodated in two lanes, a buffer lane should separate the contra-flow lane and off-peak travel lanes.
- A minimum of 40 buses per hour should be expected to use the reserved lane.

Bus Bypass Lane at a Metered Freeway Ramp or Exclusive Bus Ramp:

- A minimum of 10 buses per hour should be expected to use the bypass lane at a metered ramp.
- Bypasses can be provided on existing ramps where the ramp width, including the shoulder, is at least 20 feet wide.
- An exclusive bus ramp should be provided when such an access (1) will be subjected to high travel demand, (2) will be more direct than the existing route, and/or (3) would accommodate as many passengers as cars would carry.

In all other instances, the kind of interpretation given to these criteria should reflect local goals and policies. For instance, in areas where concern for the urban environment, air quality, and energy conservation is high, a very liberal interpretation of prerequisite criteria is appropriate.

Three points should be borne in mind when evaluating site-specific conditions in conjunction with these criteria:

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*Eighty percent or more of the usable highway space is occupied, and average vehicular speeds are 40-50 mph.

- The reserved lane concept is applicable to a wider range of circumstances if various types of high-occupancy vehicles are permitted to share the lane instead of reserving the lane for buses only.
- The cited criteria apply to the projected traffic flow that will be influenced by the future effect of priority treatments and complementary TSM actions.
- Special considerations can and should override traffic engineering criteria.

BUS AND CARPOOL LANES ON CITY STREETS AND URBAN ARTERIALS

Like their freeway counterparts, reserved lanes on city streets and urban arterials expedite the movement of high-occupancy vehicles through congested areas in or near the center city. When dedicated freeway lanes can be extended onto principal urban arterials and city streets, the benefits of this preferential treatment are optimized--i.e., qualifying vehicles realize time savings for the entire trip.

Like dedicated freeway lanes, reserved lanes on city streets and urban arterials were first instituted for bus traffic. Even though many areas now have dedicated lanes for riding pools or for mixed riding pool and bus traffic, the only experience documented applies to bus lanes. As the following discussion shows, reserved bus lanes on urban roadways have been successful in improving travel time, increasing the utilization of existing facilities, improving bus service levels, and reducing stop-and-go driving for qualifying vehicles.

Documented Experience with Bus Lanes on Urban Roadways

The benefits reported for nine reserved arterial or center city bus lanes are documented in Table 11. The characteristics of reserved bus lanes, depending on their location on the roadway, are given in Table 12 and briefly discussed below.

WITH-FLOW BUS LANES. Reserving the curb lane on city streets for bus traffic is relatively easy and inexpensive to implement and requires a minimum number of changes in established bus routes. Possibly for these reasons the most widespread application of the reserved lane concept to urban roadways has been at the curbside and in the normal direction of traffic flow. However, the fact that bus traffic flows in the same direction as other traffic makes it easy for other vehicles to violate the lane restriction, and thus enforcement of the reserved lane concept is necessary to maintain its effectiveness. In addition, unless restrictions on right turns can be instituted concurrently, conflicts with right-turning vehicles result. It is clear that instituting a curb

Table 11. Reported Benefits of Nine Reserved Arterial or Center City Bus Lanes

LOCATION	BENEFITS		
	Travel Time Savings	Increased Occupancy	Operator Efficiencies
With-Flow Bus Lane			
Baltimore, MD 11 streets, aggregating 60 blocks	Savings range between 17 and 21%.	NA	Increased bus schedule reliability.
Dallas, TX Elm/Commerce one-way couplet	5-10% increase in a.m. bus speeds; 10-20% increase in p.m. speeds.	NA	DTS claims efficiencies, but none are documented.
New York, NY First, Second, Fifth, and Madison Avenues	Savings range between 22 and 42%.	No significant change in number of passengers recorded.	NA
Vancouver, B.C. Georgia Street	20% reduction (1971 figure).	12% increase in patronage recorded after first four months.	NA
Contra-Flow Bus Lane			
Louisville, KY Second and Third Streets	25% time savings between CBD and park-and-ride lots.	Increase in patronage on express route recorded, but no statistics available.	NA
Miami, FL South Dixie Highway	15-20 minutes.	Increased patronage by 1,700 riders per day. Apparent modal shift from auto to bus by many new transit patrons.	45% of riders use park-and-ride facilities.
San Juan, PR Fernandez Juncos and Ponce de Leon Avenues	35% improvement (passengers save 20-30 minutes on the 15.8-mile route).	Rate of decline in ridership has been decreasing while revenues have risen.*	Implied improvement in trip reliability because of time savings.
Median Bus Lane			
Chicago, IL Washington Street	14.5% increase during a.m. rush period; 28.3% increase during day; 15.4% increase in bus speeds during p.m. rush.**	NA	Eliminated one bus during peak period because of travel time savings.

NA = Not available.
*Revenue increases due to factors other than bus lane.
**Percentage calculated 10 years ago.

Table 12. Characteristics of With-Flow, Contra-Flow, and Median Bus Lanes

CITY AND LOCATION	DATE STARTED OR STATUS	LENGTH (Miles)	HOURS OF OPERATION[1]	PEAK-HOUR BUS VOLUMES	REMARKS
With-Flow Bus Lane					
Chicago, IL Cermak Road-47th Avenue Turnaround	Existing	0.03	24	12	Bus turnaround with special bus signal controls.
New York, NY Hillside Avenue, Queens Francis Lewis Boulevard 167th Street	ca. 1969	2.0	7-9 a.m. 4-7 p.m.	170	10-foot lanes in flow direction only on six-lane street. 120 buses/hour observed in curb lanes.
Livingston Street, Brooklyn Flatbush Avenue-Boerm Place	1963	0.68	7-9 a.m. 4-7 p.m.	77	10-foot lanes.
Victory Boulevard, Staten Island Bay Street-Forest Avenue	1963	1.0	7-9 a.m. 4-7 p.m.	64	10-foot lanes.
Contra-Flow Bus Lane					
Chicago, IL North Sheridan Road	1939	1.25	7-9:30 a.m. 4-6:30 p.m.	32	Local traffic allowed with buses.
Indianapolis, IN	1965	2.75	24	10	
Louisville, KY Third Street between Breckenridge and Avery	1971	1.50	7-9 a.m.	12[2]	$4,600 cost. Three express bus lines.
Madison, WI University Avenue	1966	2.0	24	15	Limited-use lane. Seven stops; Four far-side, three near-side.
San Juan, PR Ponce de Leon, Fernandez Juncos, and Munoz Rivera Avenues	1971	10.8	24	NA	$70,000 implementation; $30,000 publicity and administration costs. Police scooters allowed on lane.
Miami, FL South Dixie Highway	1974 demonstration	5.5	7-9 a.m. 4-6 p.m.	NA	Six police officers patrol corridor during the peak period. Park-and-ride lots and an extensive feeder system.
Median Bus Lane					
Atlanta, GA Walton Street Broad-Forsythe	1958	.08	7-9 a.m. 4-6:30 p.m.	30	
Chicago, IL Washington Street Wacker Drive-Michigan Avenue	1956	0.60	24	108	One-way street. Eight near-side stops.
State Street Wacker Drive-Congress Street	1958	0.60	24		Two-way street. Buses and mixed traffic. Carry-over from streetcar operations.
New Orleans, LA Canal Street. Neutral ground between Mississippi River and North Claiborne Street.	1966	1.25	24	55	Track removal and street resurfacing. Cost $4 million. 375 buses/day.
Philadelphia, PA Market Street; Sixth-Broad	1956	0.65	24	120	Two-way street buses and mixed traffic. Carry-over from streetcar operations.

[1]Hours of lane operation; hours of bus operation may vary.

[2]Express bus volume.

lane will require the removal of on-street parking and the prevention of curbside vehicle stops during the time the reserve lane restrictions apply. The characteristics of curbside with-flow bus lanes in Chicago, IL, and in three boroughs of New York City are given in Table 12.

CONTRA-FLOW BUS LANES. The contra-flow bus lane--reserving one lane of a one-way street for buses moving in the opposite direction to normal traffic flow--is proving to be an effective manifestation of the reserved lane concept. Contra-flow bus lanes are virtually self-enforcing. Furthermore, these lanes are usually installed on one-way streets carrying the light-flow direction of peak-period travel, which minimizes delays experienced at signalized intersections during peak periods. However, when contra-flow bus lanes are installed on one-way streets, a conflict with left-turning traffic, which the implementation of the one-way street had eliminated, is created. As in the case of with-flow bus lanes, the institution of a curbside contra-flow bus lane will require the removal of on-street parking and the prevention of curbside vehicle stops during affected hours. The characteristics of contra-flow bus lanes in Chicago, IL, Indianapolis, IN, Louisville, KY, Madison, WI, Miami, FL, and San Juan, PR, are given in Table 12.

MEDIAN BUS LANES. Median bus lanes are frequently instituted in the right-of-way previously assigned to streetcar traffic. While this practice constitutes an efficient use of roadway space, all passengers must cross traffic to board or leave buses (as they did with streetcar operations). An interference with left-turning traffic may also be created. The details of median bus lanes in Atlanta, GA, Chicago, IL, New Orleans, LA, and Philadelphia, PA, are given in Table 12.

Bus Streets

Bus streets represent the full development of the urban roadway, reserved bus lane concept. Though not often found in the United States, bus-only streets are gaining acceptance in several large urban centers. The best examples of this technique in the United States are the Nicollet Mall in Minneapolis, 63rd Street in Chicago, Halsted Street in Chicago, the Chestnut Street Transit Mall in Philadelphia, and a one-block section of a street in downtown Washington, DC.

Bus streets provide relatively easy access to and egress from buses because buses are not vying for street space with autos. In addition, bus streets are largely self-enforcing. The principal disadvantage is that auto and truck access to adjacent buildings is eliminated, and as such, alternate, parallel traffic routes may be required.

Joint Applications

In Miami, FL, a with-flow carpool lane and a contra-flow bus lane have been jointly implemented along a 5.5-mile section of the South Dixie Highway during peak periods. The contra-flow bus lane is reported to have reduced travel time by 10-16 minutes and the carpool lane has improved travel time by 6-8 minutes. Some 9,000 poolers use the lane daily, and bus patronage on the reserved lane route has increased by 1,700 riders per day. The efficiency of the system is demonstrated by the fact that the two priority lanes carry approximately half of the total peak direction passenger volume in about 28 percent of the total vehicular volume.

Cost Experience and Applicability Criteria

General information on the characteristics, costs, and applicability of urban bus lanes and bus streets is given in Table 13. Use of the traffic engineering warrants presented in Table 13 as guidelines for initiating reserved bus lanes is subject to the same caveats given on page 31 for the traffic engineering warrants related to instituting reserved freeway lanes. Recently bus volumes as low as 25 buses per hour have been deemed sufficient to warrant dedicating urban lanes and streets to bus-only traffic. For instance, in 1971 in Louisville, KY, the contra-flow bus lanes served less than 20 buses during the peak hour.

BUS PREEMPTION OF TRAFFIC SIGNALS

About 10-20 percent of bus travel time on CBD routes is spent waiting at traffic signals. In order to reduce this delay, signal systems that allow the bus to preempt normal traffic signal timing patterns have been developed.

In such systems, the signal heads are equipped with optically or electronically actuated detectors that respond to signals transmitted from a device on the bus. This device causes the signal's phase selector to lengthen the green interval or to shorten the red interval so that the bus can proceed uninterruptedly through the intersection. Once the bus has passed, the signal returns to normal operation.

Examples

In 1967, a pilot project in Los Angeles demonstrated that allowing buses to preempt normal signal timing patterns could reduce the rider's travel time by five to seven percent. Another experiment with bus signal preemption at Kent State University resulted

Table 13. General Characteristics, Costs, and Applicability of Urban Bus Lanes and Bus Streets

ITEM	CURB BUS LANES NORMAL FLOW	CURB BUS LANES CONTRA-FLOW (Extended)	MEDIAN BUS LANES	BUS STREETS
Traffic Engineering Warrants*	Generally 30-40 buses/hour; 1,200-1,600 people/hour/one-way. Preferably two lanes available for other traffic in same direction. Ability to restrict turns.	40-60 buses/hour; 1,600-2,400 persons/hour/one-way. At least two lanes available for other traffic. Signal spacing greater than 500-foot intervals.	60-90 buses/hour; 2,400-3,600 persons/hour/one-way. At least two lanes available for other traffic. Ability to separate turn conflicts from buses.	60-90 buses/hour; 2,400-3,600 persons/hour/one-way. Commercially oriented frontage. Ability to service buildings (from alternate locations or in off-peak periods). Minimum garage access requirements along street.
Principal Design Features	10-foot lanes delineated by paint and signs.	Lanes separated by paint or physical barrier. Opposing left turns prohibited or specially treated.	Lanes separated by paint and/or block-long pedestrian islands at least 5-feet wide with access at adjacent intersections.	Minimum 22-33 feet wide. Four-lane operation on wide street.
Capacity	60-90 buses/hour/lane. (4,500 people) 90-120 maximum (6,000 people)	60-90 buses/hour/lane. (4,500 people) 90-120 maximum (6,000 people)	60-90 buses/hour/lane. (4,500 people) 90-120 maximum (6,000 people)	60-90 buses/hour/lane. For two lanes one-way: 60 buses/hour/lane desirable.
Construction Cost per Mile ($)	3,000-6,000	4,000-100,000	15,000-100,000	500,000-2,000,000. Costs may be lower where existing streets can be used without physical changes.
Speed Miles/hour Minutes/mile Minutes/mile saved	 6-12 5-10 1.5-5.0	 7-12 5-8 1.5-6.5	 7-12 5-8 1.5-6.5	 8-12 5-7 1.5-8
Remarks	May impact curb access and deliveries. Difficult to enforce.	May impact curb access and deliveries. Self-enforcing. Buses operate against signals.	Difficult for buses to leave lanes in central area. Passengers must cross traffic to board buses. Excellent potential for express service on approaches to city center.	Requires alternate traffic routes. May enhance CBD by removing cars and increasing sidewalk width. Excellent visibility. Self-enforcing. Optimal distribution in medium-sized cities.

*These warrants should be considered in the context of traffic engineering warrants and should be evaluated in the same light as the discussion on preferential freeway lanes, as discussed in pages 31-33.

in a 10 percent reduction in travel time. These findings indicate that bus preemption of normal signal timing patterns improves transit service substantially. Thus, if such preferential treatment is extended to express buses on the CBD portion of the trip and/or at freeway ramp signals, the improved service will enhance the effectiveness of the express bus service.

In a 1971 urban corridor demonstration project in Louisville, KY, traffic signal preemption devices were installed at eight intersections* in a congested section of the corridor. The travel time of nine express buses, equipped to preempt these signals, was 9-19 percent less than the other express buses not equipped and 17-26 percent less than local buses operating in this section of the corridor. An analysis of traffic flow showed that the treatment did not cause a significant increase in congestion at the intersections.

A major demonstration of signal preemption and bus priority techniques is currently underway in Miami, FL, on a 10-mile section of Northwest Seventh Avenue. Thirty-six intersections have been equipped with signal preemption devices, and buses operating on this route travel on a dedicated median lane. Another extensive demonstration of signal preemption is in operation in Washington, DC, where 114 major intersections in the CBD are interconnected by a computerized area control traffic signal system. Thirty-four of these signals are equipped with bus signal preemptive devices.

Bus preemption of traffic signals can also be applied successfully to locations other than the CBD. For example, bus signal preemption devices were recently installed on nine signalized freeway ramps in Minneapolis, MN.

Cost Experience

In the Louisville, KY, experiment seven of the eight signal preemption devices cost from $605 to $833 per device. The device at the eighth intersection cost $1,023. Each of the nine transmitters installed in the buses cost $500. The total project equipment cost was $10,710. The Louisville and Jefferson County Traffic Engineering Department installed the equipment as an "in-kind" contribution of service.

Intersection equipment costs in the Washington, DC, project ran approximately $312.00 for an average of two and one-half detector receivers and loop antennas per intersection. Bus trans-

*The signals at these intersections are demand actuated. The city did not want to install traffic preemption equipment on signals that were fixed time and were part of a progression system.

mitters cost about $125.00 each, and the telemetry equipment associated with each intersection cost approximately $1,350 per intersection. Leased lines and central computer facility costs are not yet available. Kent State's bus signal preemption project cost approximately $1,000 per intersection.

Advantages and Implementation Consideration

The principal advantage gained from using bus preemption systems is the resulting reduction in bus travel time. Partially counteracting this advantage is the fact that bus signal preemption generally results in increasing auto delay at the intersection. For instance, the Kent State project showed a decrease in average auto speed of about four percent. This decrease and the implied increase in idling time will result in some increase in auto emissions and a slight increase in fuel consumption.

Besides the possibility of causing an impediment to auto traffic flow, bus preemption of signals may also be of little value if the downstream traffic on the side streets is backed up to the extent that buses cannot proceed once they have preempted the light. Grouping buses so that a five- or six-bus platoon can preempt a signal cycle has begun in Rochester, NY, and Cincinnati, OH, and may result in an effective solution to these adverse effects.

Bus preemption systems are likely to be most effective when implemented on contra-flow bus lane routes since only buses use the lane and since the nonpeak direction of traffic flow is likely to be light. Under these circumstances, the problem of delaying side-street traffic is less critical.

As a general guideline, when 10-15 buses per hour pass through an intersection, installation of signal preemption equipment is usually warranted.

TOLL POLICIES

Preferential treatment at toll collection points can be accorded to high-occupancy vehicles by (1) permitting nonstop passage through toll stations or (2) instituting differential tolls that favor high-occupancy vehicles. Generally, these toll policies enhance the attractiveness of group travel by offering economic incentives to users of high-occupancy vehicles. The first alternative also offers the added advantage of travel time savings. But, combining preferential treatment at toll stations with other preferential treatments can provide an even stronger incentive to shift to high-occupancy modes.

Nonstop Provisions

In September 1973 a one-mile reserved lane was established on the approach to the Evergreen Point Bridge toll plaza in Seattle, WA. The lane, instituted on the paved shoulder, is open only during the morning peak period and only to buses. Although the Seattle Metro Transit buses do not pay a toll at the collection point, the transit company is billed on the basis of the toll collector's tally of the number of buses passing the toll station. Time savings amount to approximately five minutes per trip for transit users.

Nonstop provisions also exist at the toll collection facility on the San Francisco-Oakland Bay Bridge. Currently, three of the bridge's seventeen lanes are designated as bus and carpool* lanes from 6:00 to 9:00 a.m. each weekday. In March 1974, a metering system was installed at the toll plaza to monitor and control peak-period traffic flow onto the bridge. The metering system, comprised of overhead traffic signals at each lane, permits vehicles in the priority lanes to proceed nonstop onto the bridge and regulates the entry of traffic in nonpriority lanes. High-occupancy vehicles traveling in the priority lanes are generally accorded a green traffic signal throughout the peak period unless an emergency requires that all traffic be stopped. A positive by-product of the toll priority treatment has been a 15 percent reduction in accidents occurring downstream from the toll station. In addition to this priority treatment, the 50-cent round-trip toll was eliminated for buses and carpools as of March 1, 1975.

Passengers of high-occupancy vehicles derive three main benefits from the abovementioned preferential treatment. First, the time required to cross the bridge has been reduced by 5-10 minutes in the morning. Secondly, the number of late-arriving buses has decreased from 84 to 45 percent during the peak period. Thirdly, the elimination of the toll has encouraged commuters to form carpools. In fact, the number of carpools has increased by five percent.

Although carpooling has increased, the increase has not been accompanied by a decrease in the total number of vehicles using the bridge each morning. However, since the auto occupancy level has increased from approximately 1.33 to 1.45 persons per auto, the bridge has carried more people during the peak period with no increase in congestion--a good example of more efficient use of existing roadway space.

The success of the San Francisco-Oakland Bay Bridge project has resulted in the implementation of toll-free passage for high-occupancy vehicles on the nearby San Mateo-Hayward and Dumbarton Bridges during the morning and evening peak period.

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*Three or more persons per auto comprise a carpool.

The capital outlay for the preferential lanes on the San Francisco-Oakland Bay Bridge was $48,000 (which includes $3,000 for a carpool matching program). The lane operating costs (e.g., daily placement and removal of stanchions) are $2,000 per month. The installation of the metering system cost $350,000. The operating cost for the system is $300 per month. Because tolls for high-occupancy vehicles have been eliminated, the State of California is losing toll revenues of approximately $30,000 per month on carpools and $1,400 per month on buses.

Differential Tolls

In line with efforts to reduce congestion, air pollution, and fuel consumption, the New York and New Jersey Port Authority recently initiated differential tolls favoring high-occupancy vehicles. The round trip toll for low-occupancy vehicles was raised from $1.00 to $1.50. Special 50-cent round-trip rates were initiated for carpools, while bus rates remain unchanged at $1.80 per round trip. The toll price differential, applicable all day long, is in effect on six interstate tunnels and bridges. Additional revenues of $39 million annually are anticipated and will be used for other public transit projects.

SECTION 3

REDUCED PEAK-PERIOD TRAVEL

The following TSM actions discussed in this section can improve peak-period traffic flow by reducing the number of vehicle-miles traveled (VMT) during peak periods:

- Work rescheduling
- Congestion pricing
- Peak-period truck restrictions.

Altering work schedules would eliminate the need for some workers to travel during peak periods. Imposing higher charges during peak periods (e.g., tolls, transit fares, and roadway use fees) would make it more costly and, hence, less desirable to travel at these times. Finally, restricting the times when trucks can pick up and deliver merchandise to off-peak periods would remove an impedance to peak-period traffic flow. Other complementary TSM actions that aim to reduce peak-period VMT include (1) increasing work-trip vehicle occupancy (e.g., preferential treatment of high-occupancy vehicles, ridesharing, improved transit service), (2) instituting higher parking fees for long-term parking (a form of congestion pricing), and (3) encouraging walking and bicycling for short work trips.

WORK RESCHEDULING

Rescheduling work hours to reduce the amount of work-related peak-period travel can be accomplished by:

- Staggering or rearranging employee starting and quitting times to achieve a more even distribution of arrivals and departures over a longer period of time.
- Reducing the work week to four days and, as is commonly practiced, increasing the number of hours worked per day.

Information on these techniques is presented below.

Staggered or Flexible Work Hour Programs

In a staggered work hour program, employee starting and quitting times are scheduled to occur at more frequent intervals than usual (e.g., at 15-minute rather than 30-minute intervals) and either before or after the normal peak period. Such scheduling is done without changing the number of days and hours the employees presently work.

In a flexible work hour program, employees are permitted to adjust their working schedules according to personal preference, as long as the hours worked are included in a specified block of time during which all employees must be present (e.g., between 10:00 a.m. and 3:00 p.m.). Also, the total hours worked weekly must remain as previously agreed upon.

RECENT EXPERIENCE. In the past, work rescheduling programs have been implemented primarily to reduce peak-period congestion at company sites (e.g., at points of ingress and egress, in parking lots, etc.) and/or on transit facilities. The location of several U.S. staggered and flexible work hour programs and the approximate number of employees participating in each are given in Table 14.

The most ambitious staggered work hour program to date was implemented in New York City to relieve peak-period congestion on subways and buses and in elevators. According to surveys taken before and after initiation of the Manhattan Staggered Work Hours Program, the program successfully achieved its objective. On the lower Manhattan subway lines, six percent fewer passengers were carried during the busiest 10-minute period. At the Port Authority Trans Hudson (PATH) terminal, the passenger volume during the busiest 15-minute evening period dropped from 7,500 to 6,500, while passenger volume during the lightest 15-minute period rose from 3,100 to 4,600.

A staggered work hour demonstration program, with objectives similar to those of the Manhattan Staggered Work Hours Program, was initiated in October 1973 in Toronto, Canada. The program, which involved 11,000 public employees of the city's Queen's Park complex, was also effective in distributing the demand for transportation facilities over a longer period of time. As a result, one-third of the employees experienced a decrease in travel time, and about the same number felt that their travel was more comfortable and convenient. All in all, over 90 percent of the employees involved expressed a favorable reaction to the demonstration program. Furthermore, in its 1975 final evaluation of the demonstration, the Ontario Ministry of Transportation and Communications considered the program highly successful and recommended that it be continued and extended to all public employees in the Queen's Park area.

In St. Paul, MN, the 3M Company implemented a staggered work hour program to reduce peak-period auto congestion on roads in the vicinity of the plant. After the program had been in effect for some time, the highway department took a traffic count on these roads, which revealed that peak-period traffic volumes had, in fact, been reduced. Apart from this example, no information is available on how effective work rescheduling programs have been in reducing peak-period congestion.

Table 14. Examples of Staggered and Flexible Work Hour Programs in the United States

LOCATION	NUMBER OF EMPLOYEES	
	Staggered Work Hours	Flexible Work Hours
Chicago, IL		
Montgomery Ward		500
East Hanover, NJ		
Sandoz Inc.		1,300
East Meadow, NY		
Lufthansa Airlines (executive office)		300
Madison, WI		
city/county/state employees	17,000	
Minneapolis, MN		
Control Data Corporation (and most of its U.S. offices)		20,000
New York, NY		
400 Manhattan firms	220,000	
Palo Alto, CA		
Hewlett-Packard (15 facilities)		16,000
Philadelphia, PA		
center city employees	33,500	
St. Paul, MN		
3M Company	12,000	
St. Paul Company (and several of its regional offices)		5,000
Washington, DC		
six federal departments	50,000	
White Plains, NY		
Nestlé Company		700

COST IMPLICATIONS. Generally, employers have found that the cost of implementing a staggered or flexible work hour program is negligible, and that once the planning stage is completed, the program can be quickly put into effect. Some costs may be incurred for data collection and processing if surveys are included in the planning or evaluation procedure. For example, the Downtown Lower Manhattan Association spent about $50,000 on transit user surveys before implementing the Manhattan Staggered Work Hours Program.

ADVANTAGES. A principal advantage of work rescheduling programs is that they can be readily implemented at a relatively low cost.

If work rescheduling can be successfully implemented on an areawide basis, it is possible that peak-period congestion on roadways and transit facilities will be reduced and that the need to construct new roadways and transit facilities will be delayed or even eliminated. In addition, it is probable that work rescheduling will reduce congestion in other public places--e.g., in restaurants, lobbies, elevators, and stores. Furthermore, if these results are obtained, participating employees will experience shorter work-trip travel times and more pleasant travel conditions.

Besides shorter travel times and more pleasant travel conditions, evidence from the European work rescheduling experience indicates that flexible work hours, or "flexitime," improve employee morale since the employee is given some control over his or her work schedule.

To the extent that work rescheduling causes improved traffic flow, increased speeds, and reduced idling, some fairly substantial, yet indirect improvements in energy consumption and air quality will result. Moreover, because the intensity of air pollution is directly related to the temporal concentration of pollutants, it may be diminished simply by changing the temporal distribution of pollutants, even though the total amount of pollutants emitted may be reduced only marginally.

IMPLEMENTATION CONSIDERATIONS. Firms that have instituted work schedule changes have not experienced difficulty in varying starting and quitting times by roughly 15 minutes. More extensive changes--for example, varying a number of schedules by an hour or so--might be accomplished more effectively only by large firms or public agencies.

Since changes in work schedules imply the disruption of riding pools based on former work schedules, careful attention must be given to the effect that a staggered work hour program will have on ridesharing efforts. The Toronto program demonstrated that, although some car pools were disrupted because of the changes in work schedules, the number of new car pools subsequently formed increased the overall amount of ridesharing. In fact, more than twice as many employees joined carpools than abandoned them.

The same precautions relating to ridesharing must be applied to a flexible work hour program. However, to the extent that the desire to carpool influences an employee's choice of his or her work schedule, a flexible work hour program can facilitate the formation of riding pools, particularly home-based riding pools.

Work rescheduling programs must also be carefully coordinated with local transit authorities. First of all, transit operators can help identify the locations where work rescheduling programs would be most effective in reducing congestion on transit facilities. Secondly, unless transit operators are aware of the probable changes in the time(s) of transit demand that will result from the work rescheduling program, some employees who formerly used transit may find that the service at their new hours is inadequate or inconvenient.

It should be noted that in the case of both staggered and flexible work hour programs, if peak-period congestion is significantly reduced by work rescheduling, some commuters may shift from transit and carpools back to single-occupancy autos. Hence, any program to reschedule work hours to reduce peak-period congestion must also include actions to offset this potentially counterproductive effect.

Successful work rescheduling programs have involved a large employer or a group of employers located in close proximity to each other. These programs have mainly been undertaken to relieve congestion on buses and subways, in parking lots, elevators, etc. In these cases the congested facility was close enough to the employment site that starting and quitting times were virtually identical to the time of the employee's arrival at or departure from the facility. As a result, the probable effect that the proposed work schedule changes would have on the facilities could be predicted.

Predicting the effect of a staggered or flexible work hour program on roadway congestion is more complex since the worker's time of arrival on the congested freeway section is a function of both the work schedule and the trip distance. Theoretically, lack of such information could result in increased rather than decreased congestion, particuarly on roadway sections that are quite a distance from the employment site. This rationale suggests that a staggered work hour program is likely to be most successful in reducing congestion on a roadway section close to the employment site, and that instituting a regional or citywide staggered work hour program could be counterproductive. The possibility of this problem is lessened when flexible work hour schedules are instituted since the employee knows when and where congestion is encountered in the work trip. Hence, he is in a position to reschedule his own working hours to avoid congested conditions.

The kind of work rescheduling program that a firm can implement and the extent to which differences among employee starting and quitting times can be tolerated depend largely on the type of work activity performed by the firm. Although this judgment must be made on a case-by-case basis, in general, work that requires little interaction among employees or with customers is most adaptable to work rescheduling programs.

The Shortened Workweek

Two forms of the shortened workweek have been implemented: the four-day, ten-hour day schedule--the 4-10 plan--and the four-day schedule in which less than 40 hours are worked per week. The former has been more widely used and is discussed here in some detail. The latter, although backed by labor interests, has not been widely practiced.

Some businesses can adapt fairly easily to a four-day workweek, while others may find it difficult or almost impossible. As with staggered and flexible work hour programs, businesses that are primarily administrative adapt well to a four-day workweek, while businesses that cater to customers' hours or are tied to delivery schedules or interindustry requirements may not be able to adapt at all.

EFFECT OF THE SHORTENED WORKWEEK ON TRAFFIC VOLUMES. The 4-10 plan reduces peak-period traffic in two ways. First, since the additional two hours in the work day occur in the middle of the day, employees usually start work one hour earlier and leave one hour later. Secondly, reducing the number of work days reduces the number of work trips that employees must make. Although universal adoption of a four-day workweek would reduce work-trip VMT by 20 percent, the amount of travel on any given day will depend on how the employees' working days are scheduled.

Table 15 lists five alternative ways of arranging four-day workweek schedules, which are tantamount to staggering work days. As the table shows, the way in which the work days are scheduled will cause different effects on daily traffic volumes. For instance, equally rotating the extra day off among employees, as in schedules 1 and 3, results in an equal daily reduction in work-trip VMT. This result contrasts sharply with the results of schedule 2, where half of the employees work Monday through Thursday and half work Tuesday through Friday. Under the latter schedule, there would be no change in the peak highway and transit capacity needed to serve work trips on Tuesday, Wednesday, or Thursday.

Table 15. Percentage of Employees Working Each Day on Alternative Four-Day Work Schedules

FOUR-DAY WORK SCHEDULE	PERCENT OF FOUR-DAY EMPLOYEES WORKING ON A GIVEN DAY					
	M	Tu	W	Th	F	S
1. Equally rotated M-F	80	80	80	80	80	-
2. 1/2 M-Th; 1/2 Tu-F	50	100	100	100	50	-
3. Equally rotated M-S	67	67	67	67	67	67
4. 1/3 M-Th; 1/3 Tu-F; 1/3 W-S	33	67	100	100	67	33
5. 1/2 M-Th; 1/2 W-S	50	50	100	100	50	50

Table 16 interprets the results given in Table 15 in terms of the effect that the different work schedules would have on peak-period congestion if 35 percent of the work force were on a four-day schedule. As shown in Table 16, even on days when all

Table 16. Daily Effect of Alternative Four-Day Work Schedules on Conditions at a Freeway Bottleneck—35 Percent Work Force Participation

FOUR-DAY WORK SCHEDULES	PERCENT OF FOUR-DAY EMPLOYEES AT WORK EACH DAY	NUMBER OF 15-MINUTE PERIODS DEMAND EXCEEDS CAPACITY	EXCESS DEMAND OVER CAPACITY (VEHICLES)	PERCENT REDUCTION IN OVERLOAD*
1/3-1/3-1/3 plan; half-and-half plans	100	8	1,181	35
Equally rotated M-F	80	3	577	68
Equally rotated M-S; 1/3-1/3-1/3 plan	67	2	414	77
Half-and-half plans	50	2	234	87
1/3-1/3-1/3 plan	33	1	69	96

*Under the current five-day work schedule, the number of 15-minute periods in which demand exceeds capacity is 12, and the number of vehicles in excess of capacity is 1,815 for a given day. Percentage reduction value is based on excess demand over capacity.

Note: Based on traffic flows on Los Angeles's Hollywood Freeway at Highland Avenue.

four-day employees are working, there is a 33 percent reduction in congestion. This occurs because the part of the labor force on the four-day week schedule begins work earlier and leaves work later than the part of the labor force whose schedules have not been changed. The effect is the same as staggering work hours.

EXISTING PROGRAMS. The 4-10 plan is reportedly in effect for more than a million workers at an estimated 3,000 private firms in the United States. Experience indicates that 85-95 percent of the firms that have instituted the 4-10 plan have retained it. Among the firms that have adopted it are Samsonite Corporation in Murfreesboro, TN, and the Morgan Guaranty Trust Company, Group Health Incorporated, and the Teachers Insurance Annuity Association in New York City.

RELATED EFFECTS. As with staggered and flexible work hour programs, there are virtually no implementation costs associated with the 4-10 plan other than possible survey and data collection costs that might be incurred before program implementation.

Among the advantages claimed for the four-day workweek are increased employee and management morale, reduced absenteeism, decreased overtime requirements, and increased leisure time. Problems inherent in the four-day workweek, which might partially offset these advantages, are managerial scheduling problems, employee fatigue, and childcare hardships for working mothers.

Major benefits of four-day workweeks would, of course, accrue from reduced and more evenly distributed travel volumes. Not only would roadway congestion be reduced, but transit companies would experience improved efficiency in their operations due to greater vehicle and driver productivity. Naturally, commensurate adjustments in transit service would be required to meet the changes in the temporal distribution of travel demand.

Although the four-day workweek would reduce the number of work trips and peak-period congestion, it might not significantly reduce total daily VMT and, in fact, might actually increase it. Increased recreational travel on the extra day off and work trips made by persons using their day(s) off to work a second part-time job would cancel out theoretical decreases in VMT. Decreased travel time, another benefit of the four-day workweek, might also influence some commuters to live even further from their jobs, especially since they would only need to commute four days a week instead of five.

It has been estimated that the four-day workweek could reduce transportation-related petroleum consumption substantially if it is assumed that no additional recreational travel were to take place as a result of increased leisure time. If adoption of the four-day workweek does cause an increase in total VMT, most of it will probably occur during off-peak hours in less congested areas. Hence, such an increase will probably not cause congestion-related increases in fuel consumption.

As in the case of staggered and/or flexible work hours, care must be taken to avoid interference with ridesharing efforts. Although this can be partially overcome by planning for the reorganization of carpools before instituting the altered work schedule, there will be less opportunity for organizing new pools since potential carpool members may not be scheduled to work on the same days.

Altering the standard 40-hour, five-day workweek will also require consideration of related legislation--which may have to be altered--and the position of organized labor. For example, among the laws encouraging a limit on the number of hours worked per day (by requiring premium pay after eight hours of work per day) are the Contract Work Hours and Safety Standards Act and the Walsh-Healey Public Contracts Act. Also, Title 5 of the U.S. Code "prohibits or impedes virtually all forms of altered schedules." The Fair Labor Standards Act requires that interstate commerce and public administration employees be paid overtime after 40 hours of work per week. The provisions of this Act, combined with other legal and collective bargaining provisions regarding overtime, encourage a five-day workweek. Organized labor, firmly in favor of the standard eight-hour work day, naturally opposes the 4-10 plan but would support a four-day schedule that reduced the workweek to 35 hours. Labor unions may also be adverse to four-day plans that do not guarantee three consecutive days off.

CONGESTION PRICING

Congestion pricing--charging peak-period users of the transportation system more than off-peak users--can be employed to decrease peak-period traffic volumes and to influence modal choice. Controlling roadway use by applying differential pricing policies has also long been advocated by economists as a way to equitably distribute the external costs imposed on society as a result of peak-period congestion--e.g., air pollution, noise, discomfort, and the lowered quality of the urban environment that results from excessive roadway expansion.

Congestion pricing can be applied to a variety of situations. For instance, higher tolls might be imposed on all peak-period users at toll collection points on bridges and toll roads. The differential toll policies (discussed in Section 2, page 42), which give preferential treatment to high-occupancy vehicles, are a means of using congestion pricing to influence modal choice. Raising peak-period transit fares also represents an effective congestion pricing strategy since the transit system inefficiencies that result from the need to serve peak-period demand (i.e., unused off-peak vehicles and labor) are charged back to the peak-period user. An example of the application of this kind of transit fare policy in Washington, DC, is discussed in Section 6, page 124. Parking surcharges on long-term parking and other parking policies that aim to discourage commuting in low-occupancy vehicles, also aspects of congestion pricing, are discussed in Section 4.

Theoretically, congestion prices should be continually adjusted to reflect the actual traffic volume on the roadway. However, before such a practice can be implemented, substantial technical problems must be overcome. As a result, congestion pricing policies usually represent the application of a higher flat-rate charge for use of the roadway during congested time periods.

Supplementary Licensing

Adopting congestion pricing on an areawide basis is perhaps the most comprehensive application of the concept. Supplementary licensing--requiring that vehicles obtain licenses to enter congested areas--is a promising means of areawide congestion pricing. Supplementary licensing usually involves the pre-purchase of a windshield or bumper sticker that permits the vehicle's unobstructed entry into the restricted area. Many colleges have employed supplementary licensing to discourage through traffic and/or parking. Yet, using supplementary licensing to reduce urban congestion is a relatively new idea. The Urban Mass Transportation Administration is currently developing an urban road pricing demonstration program based on supplementary licensing and other pricing policies. However, the only supplementary licensing plan currently in operation is in Singapore, Malaysia, the details of which are given below.

Experience

In response to an increasing problem of CBD roadway congestion, the government of Singapore recently developed a comprehensive transportation policy to restrain the use of private automobiles in congested areas. The primary component of this policy is congestion pricing through the use of supplementary licenses. Other aspects of the transportation policy are:

- Adoption of land use development strategies to minimize the need to travel.
- Implementation of a modest road construction program within the framework of a long-range road network plan, scaled to be compatible with urban environment goals.
- Traffic management measures to maximize available roadway capacity.
- Analysis and revamping of existing public bus services.

- Public declaration of the government's intent to restrain the growth rate of private car ownership and incremental implementation of this policy through various taxes on privately owned autos.

Since May 1975, motorists traveling to the CBD during the morning peak period have been required to have valid stickers affixed to the vehicle's windshield in order to enter a well-defined, 150-acre restricted zone encompassing the CBD. These stickers, the supplementary licenses, are available from post offices and selected curbside booths along the major routes to the restricted zone. The license fee is $26.40* per month or $1.32 per day and applies to all passenger cars entering the restricted zone. Vehicles carrying four or more persons are exempt from the restriction to encourage carpooling. Exemptions are also extended to all public transit vehicles; motorcycles; private buses; emergency, police, and military vehicles; and two-axle commercial vehicles.

Having determined that workers commuting in private autos were the primary source of center city congestion, the traffic restraint plan was initially designed to operate between 7:30 a.m. and 9:30 a.m. However, after the plan was implemented, congestion developed after 9:30 a.m. and the time period was extended to 10:15 a.m.

Once within the restricted zone, motorists are free to drive anywhere within it or to leave the area. Nonlicensed residents of the zone are affected only if they leave the zone and return again during the hours of restriction. Policing occurs at all points of entry (there are a total of 22) during the hours of restriction. Additionally, all route approaches and points of entry have "restricted zone" signs, and two amber lights are lit during the affected hours to ensure that motorists are aware that the restrictions are in force. Motorists who violate the restrictions are charged a fine equivalent to $24.20.

Parking charges were increased within the restricted zone from a flat hourly rate, equal to $0.18, to a higher rate reflecting the location of the parking space in the zone and the length of parking time. In a defined "core" area of the restricted zone, parking rates are $0.22 for the first hour and $0.44 for the second hour and each subsequent half hour. In other parts of the restricted zone, the parking rate is $0.22 for the first hour and each subsequent half hour. Thus, there is a greater disincentive to long-term parking in the restricted area of the core than there is on the periphery of the core. The monthly rate for all-day parking in the restricted zone has also been increased from $17.60-26.40 to $22.00-35.20.

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*$1.00 Singapore equals $0.44 United States. All the cost information presented here is given in equivalent U.S. dollars.

The most significant result of the supplementary licensing scheme is the reduction in peak-period traffic. The government's objective was to reduce morning peak-period traffic by 25-30 percent; however, the actual overall reduction was 40 percent. Initially, planners anticipated a comparable reduction in evening peak-period travel (a mirror-image effect); however, evening traffic volumes have only been reduced by 3-4 percent. This is attributed to the through travel that occurs during the evening hours when restrictions are not in effect, to peripheral parking, and to family members who pick up workers in the CBD and transport them to their home. Consequently, the question of imposing evening restrictions is currently being considered.

Numerous benefits have resulted from the supplementary licensing plan. For instance, the plan has improved the overall urban environment, and indications are that bus travel time has been reduced. The plan is inexpensive and easy to administer and enforce. Revenue is generated, and the question of equity is minimized since exemptions are provided for carpools and motorcycles, which counters the argument that driving into the center city is only possible for the affluent.

Successful implementation of a supplementary licensing plan requires careful delineation of the restricted zone. Ideally, the congested area should have a minimum number of entry points. Alternate routes should be available to motorists who are not required to enter the restricted zone and, where available, existing facilities should be used as fringe parking lots. The following implementation considerations, arising from Singapore's experience, are presented to assist transportation planners in tailoring supplementary licensing programs to local needs:

- Trial and error helps to determine if the licensing fee is improperly set or if the time period of application is inadequate. Hence, flexibility in planning must be maintained.
- In order to delineate the restricted zone and the span of time during which controls should be imposed, a knowledge of traffic patterns is reqired. Monitoring traffic flow conditions after implementing supplementary licensing can help to pinpoint problem areas.
- Complementary actions should be implemented to encourage travel in high-occupancy vehicles--e.g., improved transit service, park-and-ride lots, etc.

PEAK-PERIOD TRUCK RESTRICTIONS

Whether trucks are moving on heavily traveled arterials, maneuvering through narrow streets, or parking to load or unload commodities, truck movement in the CBD is frequently viewed as a significant contributor to traffic congestion. In order to reduce the level of congestion attributed to truck movement, regulatory measures, such as instituting truck routes and preventing truck travel on certain streets, have been used in the past by most urban areas. For instance, in San Diego, CA, trucks weighing one ton or more have been prohibited from using a congested section of Route 163 during the peak period since they cannot easily negotiate the grades along that roadway. As a result, congestion and travel time on this section of the route have been reduced during the peak period.

Temporal restrictions generally have been established to accommodate merchants who desire deliveries during their normal hours of business. For example, 75 percent of cities with populations over 500,000 have regulations requiring that CBD truck deliveries be made between 7:00 a.m. and 6:30 p.m. However, since the most acceptable delivery times for merchants encompass peak travel periods, these measures do not help to alleviate congestion.

Restricting all truck pickups and deliveries to nighttime hours was tried for a brief time in London and subsequently abandoned because of numerous objections. Among the major objections to this scheme, which make it appear infeasible at this time, are the public's objection to nighttime truck noise and the merchant's objection to the additional costs incurred for nighttime goods handling (e.g., costs for employing nighttime personnel and the increased cost for after-hour labor). The trucking industry also objects to these additional costs.

Alternatively, consideration should be given to the possibility of altering existing temporal truck restrictions to permit truck loading and unloading only during off-peak periods. Because many light trucks are used for purposes other than commercial trucking and because trucks providing services unrelated to cargo handling are usually summoned for time-urgent reasons, the action is considered to apply only to trucks providing pickup and delivery services. Figure 2 shows the magnitude of the effect that such an action would have on the number of vehicles in the peak-period traffic stream if truck traffic were restricted to the period between 9:00 a.m. and 2:00 p.m. As Figure 2 indicates, the actual number of vehicles affected is quite small. However, the impact of this action on peak-period congestion is likely to be far greater than implied by the change shown in Figure 2 since the parking maneuvers of trucks, rather than the trucks in the traffic stream per se, cause the greatest obstacle to traffic flow. Under certain circumstances, restricting peak-period loading and unloading (like providing off-street loading facilities, see pages 18-19) may cause a substantial reduction in truck-related CBD congestion.

While peak-period truck restrictions have not actually been imposed in any urban areas to reduce congestion, EPA and some local governments have considered imposing similar selective

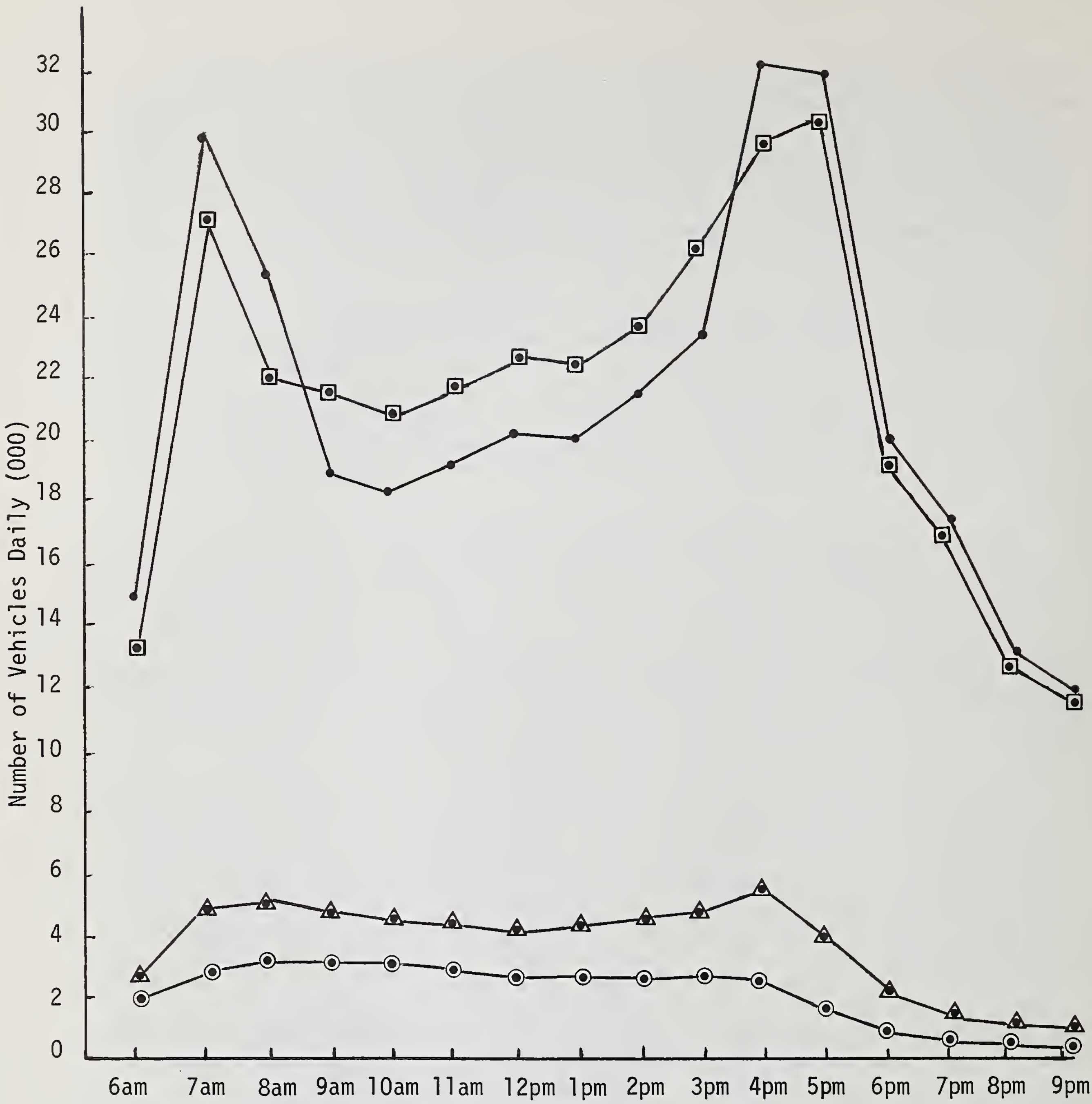

Figure 2. Urban Truck and Automobile Travel Patterns Showing Impact of Shifting Urban Pickup and Delivery Truck Travel to Off-Peak Periods

Existing Pattern of Urban Automobile and Truck Traffic

Pickup and Delivery Trucks

All Urban Trucks

Urban Vehicular Movement with Pickup and Delivery Restricted to Off-Peak Periods

Note: Aggregate number of vehicles based on ground counts taken in Little Rock, Chattanooga, Lexington, Knoxville, and Columbia.

truck delivery restrictions to reduce pollutants. For example, EPA proposed rulemaking to ban heavy duty delivery trucks during the morning hours in northern New Jersey. However, the adverse comments received from the affected industries were sufficient to cause a withdrawl of the proposal. Based on this experience, it would appear that attempts to institute peak-period truck delivery restrictions are likely to face severe opposition.

SECTION 4
PARKING MANAGEMENT

No other operational control can have as dramatic an effect on traffic flow as the proper management of an area's parking supply. Decisions on (1) the location of parking, (2) the amount of on- and off-street space allocated to parking, (3) the parking charges applied to the allocated space, and (4) the length of time parking is permitted affect nearly all of the TSM actions. For this reason, the comprehensive parking policy of an urban area should be viewed as a versatile and dynamic tool that can be coordinated with other TSM actions to foster short-term transportation goals and adapted over time to help attain long-term objectives.

Parking regulations and the development of park-and-ride facilities are the aspects of parking management discussed in this section. Information on regulating parking through the removal of on-street parking space was presented in Section 1.

PARKING REGULATIONS

Parking regulations are instituted to control the number and type of vehicles entering congested activity centers. When parking restrictions are imposed and carefully coordinated with other complementary TSM actions—e.g., improved transit and paratransit service and preferential treatment for high-occupancy vehicles—the number of vehicles entering congested areas can be reduced and, at the same time, mobility can be increased.

Although this discussion of parking regulations focuses on the elements that would be included in an urban parking policy, virtually all urban areas now regulate parking in some way. Before instituting new regulations an assessment should be made of the extent to which the current regulations are being enforced. Where existing parking regulations are not being strictly enforced, more stringent enforcement may avoid the need to impose additional regulations.

Parking Charges

Like congestion pricing (see pages 51-54), parking charges can be imposed to regulate the number of vehicles entering the CBD and the trip purposes these vehicles serve. For instance, long-term parking charges can be stipulated to deter commuter travel in low-occupancy vehicles, thus effecting a more equitable distribution of costs among roadway users. However, the degree to which parking charges are effective in regulating commuter traffic depends upon the number of commuter parking spaces that can be subjected to such charges. Nationwide, as shown in Table 17, over 90 percent of commuter auto trips end in parking facilities that do not charge for parking.

Table 17. Distribution of Commuters by Type of Parking Facility

TYPE OF FACILITY	PERCENTAGE OF COMMUTERS USING FACILITY	CHARGE FOR FACILITY	
		Yes	No
Commercial parking	6.0	63.1	2.3
Employer-provided spaces	75.6	11.3	79.6
Fringe parking	0.5	0.0	0.6
Other lots	3.1	8.5	2.8
On-the-street	12.1	14.6	12.0
No all-day parking used	0.9	0.5	0.9
All other	1.8	2.0	1.8
Total	100.0	100.0	100.0
Percent of Total	100.0	7.3	92.7

However, the largest proportion of commuters who do sustain a charge for parking park in privately owned facilities located in large cities. Currently these facilities are not subject to public control; however, because of the urgent need to solve the problem of center city congestion, it is possible that local, state, or federal legislation allowing some public sector control of privately owned parking facilities may emerge. In the interim, especially in large cities, transportation planners and the owners of private parking facilities will have to make a cooperative effort in order to capitalize on the use of parking charges as a means of reducing auto travel in congested urban areas.

The mechanisms that can be used to impose effective parking charges on public and private parking facilities are shown in Table 18.

PARKING METERS. Installing parking meters and/or increasing their rates are relatively easy ways of adjusting on-street parking charges in order to regulate parking supply. Experience with the effects of this action, though limited, has been documented for London and Washington, DC. In London, meter rates were doubled or quadrupled in a 1.7-square mile portion of the CBD. In areas of the fourfold increase, auto crusing time was diminished approximately 83 percent because less time was needed to find a vacant parking space. In addition, the entire park-and-visit trip time decreased by some two-thirds. This was

Table 18. Examples of Cost-Related Parking Policy Mechanisms

TYPE OF FACILITY	APPLICABLE POLICY MECHANISM
Municipal parking facilities:	
Off-Street	• Increase cost per hour directly or indirectly via parking taxes (flat or selective rate based on location, day of week, or elapsed time). • Impose surcharges for all-day (over 4-hour) use.
On-street	• Increase meter cost per hour.
Private commercial lots:	• Impose parking taxes. • Reduce or remove parking subsidies. • Impose surcharges (flat or selective).
Free parking spaces provided by:	
Employers for staff	• Impose a surcharge on employees for single-passenger vehicle parking; reduce to half for two-passenger carpools and to zero for carpools with three or more members; subsidize transit-riding employees.
Businesses for customers	• Impose a surcharge on owner equivalent to estimated surcharge proceeds from commercial lots. • Reduce or remove parking subsidies.

attributed to the fact that motorists were able to park closer to their desired destination and/or that increased parking costs influenced the length of the CBD visit. However, the data were confined to an off-peak trip analysis and, therefore, the effect on peak-period congestion is unknown.

Data from Washington, DC, show that the number of parkers in a metered area increased more than two and one-half times after the introduction of meters, reflecting the fact that meters, by providing an easy way of enforcing short-term parking restrictions, can cause a more frequent turnover of spaces. A similar increase in turnover (53 percent) was noted in mid-town Manhattan after meter rates were increased to 25 cents per hour. Such increases result in an increase in parking space availability that does not require the expansion of existing parking facilities.

As a rule, traffic engineers recommend installing parking meters where all of the following circumstances exist:

- Parking time limits exist and are enforced. (Parking meters that restrict parking to 15 or 30 minutes are not very effective unless the restriction is strongly enforced; meters in one- and two-hour zones appear to be effective without strict enforcement.)
- High demand is shown by the use of at least 70 percent of the available space-hours during the time of limited parking.
- The block side is within walking distance of the generators of high, short-term parking demands such as stores and office buildings.
- Observation shows a need for greater turnover. This is indicated by high average parking duration, high-level enforcement to prevent parking violations, and excessive cruising by drivers who desire parking space.

Parking meters cost between $40 and $65 per meter. (There are additional costs for installation and maintenance.)

LONG- AND SHORT-TERM PARKING. Parking charges can also be adjusted to give preference to certain trip purposes—e.g., to discourage long-term parking by commuters and to favor short-term parking for other trip purposes. A demonstration of the effect of instituting this kind of differential parking charge (which could also be considered a form of congestion pricing) was conducted in the Philadelphia CBD from 1970 to 1973. Two parking garages altered their rate structure by applying a significantly higher rate to long-term parking than to short-term parking. The results showed that long-term parking had decreased and short-term parking increased and that the loss in long-term parking revenues was more than compensated for by the increase in short-term revenues.

Although a parking rate structure that favors short-term parking will probably reduce commuter parking, it must be assumed that the turnover resulting from an increase in the number of short-term parkers will cause an increase in the number of vehicle-miles traveled in the congested area. Thus, although parking rates favoring short-term parkers may alleviate current congestion problems, in line with long-term urban transportation and parking policy objectives, reducing the supply of both long- and short-term parking may be warranted in the future, especially when viable transit alternatives for short-term trip purposes become available.

PARKING TAXES. Although somewhat uncommon, imposing a citywide tax is another way of regulating parking in congested urban areas. Table 19 shows the estimated effect of imposing a parking tax in the Los Angeles area on vehicle-miles traveled and auto trips.

Table 19. Estimated Effects of a Los Angeles Parking Tax on VMT and Auto Trips

PARKING COST INCREASE ($)	CHANGE IN VMT (%)	CHANGE IN AUTO TRIPS (%)	TOTAL VMT[1] (Millions per Weekday)
.25	- 5.04	- 7.66	59.416
.50	- 9.58	-14.46	56.576
.75	-13.07	-19.18	54.392
1.00	-15.43	-21.33	52.915

[1]Based on an estimated total VMT of 62.570 million miles per average weekday in 1974.

However, since there has been little actual experience with parking taxes, the effects of parking taxes cannot be conclusively defined. San Francisco, CA, is the only known example of a city in which the implementation of a parking tax caused a sudden and considerable increase in parking prices on a citywide basis. In October of 1970 the city levied a two-year, 25 percent tax on all parking for which a fee was charged (except residential, hotel, and metered parking). The tax was reduced to 10 percent in 1972. Reportedly, as a result of the tax, the parking industry's gross revenues were approximately 31 percent less than the year before the tax was instituted; only a two percent reduction in center city VMT could be attributed to it. Because the tax was applicable only to lots that charged parkers, it was concluded that in order to discourage private auto use, a parking tax, per se, must be broadly based. That is, the supply of "free," reduced-rate, and on-street parking must also be regulated in a comprehensive manner.

PARKING SURCHARGES. Applying a surcharge on certain users of parking facilities is another way of applying parking charges to influence modal choice. Although there is no experience with this policy, it has been suggested that employers might levy a parking surcharge on employees with single-passenger vehicles. The surcharge would be reduced or eliminated for those employees using high-occupancy vehicles. Such an action would serve as a strong disincentive to commuter use of low-occupancy vehicles and also as a strong inducement to pooled riding or transit. The EPA recently proposed rule-making to this effect in conjunction with their transportation control plans but withdrew the proposal due to severe public opposition. Therefore, it seems clear that before employers will voluntarily charge their employees for parking in company-owned lots, they must be convinced that such an action is in the best public interest. Involving employers in the development of the urban area's parking policy is, of course, one way in which such conviction might be fostered. It might be noted that employers who give preferential parking spaces to high-occupancy vehicles are already involved in their urban area's parking policy.

INCREASED PARKING RATES. General increases in parking rates tend to reduce the total number of auto trips into the congested area by making auto trips more costly. Table 20 presents the anticipated effect of an increase in parking rates on auto VMT and pollutant emissions in four urban areas. The increase in transit use that is also forecast to result from increasing parking rates in Washington, DC, is shown in Table 21.

Table 20. Predicted Effects of an Increase in Parking Rates on VMT and Pollutant Emissions

CITY	AMOUNT OF RATE INCREASE	PROJECTED REDUCTION IN CBD VMT (%)	PROJECTED REDUCTION IN POLLUTANT EMISSIONS
Pittsburgh, PA	87¢ daily increase.	5.3	NA
Baltimore, MD	From current $1.83 per day to $2.50 per day.	7	Same as reduction in VMT.
Boston, MA	$1 per day increase	3	Same as reduction in VMT.
Washington, DC	Parking rates doubled.	Minor reduction —not more than 5.	Same as reduction in VMT.
	Rates for <u>all</u> spaces tripled or quadrupled.	Motor vehicle traffic might be reduced 20-25.	

NA = Not available.

Table 21. Estimated Effect on Auto and Transit Trips of Increasing Parking Charges in Washington, DC

INCREASE IN AVERAGE PARKING COST ($)	PERCENTAGE CHANGE IN	
	Auto Driver Trips	Transit Trips
.25	- 4	+ 3
.50	- 8	+ 6
.75	-12	+10
1.00	-15	+13
1.50	-20	+20
2.00	-23	+26
2.50	-26	+33
3.00	-29	+38
3.50	-31	+42
4.00	-34	+47
4.50	-36	+51
5.00	-37	+55

INTERRELATED EFFECTS. The philosophy underlying the selective application of parking charges is that the substantially higher charges sustained by certain users will reduce the number of trips they make to the CBD. Individuals who are willing or are forced to pay the higher fees will find it less difficult to locate a place to park and thus will reduce their cruising time, which also reduces congestion. A general increase in the cost of parking should also divert trips from auto to other modes of transportation, as indicated in Table 21.

IMPLEMENTATION CONSIDERATIONS. In order for increased parking charges to be effective, they must be instituted in a fairly large control area. Otherwise parking simply shifts to surrounding areas. Thus, a careful analysis must be made to determine the effective size of the control area to ensure that parkers will not be able to avoid the regulations.

Care also must be taken to insure that parking charges applied to favor short-term parking and discourage long-term parking do not increase congestion by increasing through traffic or delivery trips. TSM actions that can be implemented simultaneously to lessen these counterproductive effects include supplementary licensing (discussed on page 52), improved transit service to the CBD, and a circulator service within the CBD.

Because such a small proportion of the urban area's parking space can be regulated through parking charges, instituting parking charges, per se, is not likely to reduce congestion measurably. However, to the extent that parking charges can be implemented to encourage drivers to shift to high-occupancy modes, congestion will be reduced.

Limiting Parking Space

While increased parking charges represent an economic disincentive to reduce parking demand, limiting parking space restricts supply. The objective of both actions is to discourage driving to activity centers. When parking is restricted, traffic will be diverted either to other (suburban) locations or to other modes of travel.

EXPERIENCE. There are a great many more proposals and plans for limiting parking spaces than actual experience. However, the experience that does exist seems to confirm the effectiveness of this technique.

One brief experience with the effect of limiting CBD parking spaces occurred by accident rather than design. Specifically, Pittsburgh felt the effect of limited parking space in August of 1972 when a three-day parking garage operators' strike caused approximately 80 percent of the city's parking lots and most of the fringe area lots to close. As a result of the strike, peak-period CBD traffic declined by 25 percent, and approximately 75 percent of the city's commuters switched to public transit. There were no lasting effects; however, the experience shows that when parking spaces are severely limited, downtown traffic can be reduced to weekend levels.

Pittsburgh's experience indicates that, when adequate transit service is available, limiting parking space can divert commuters to transit. However, if transit patronage is to be increased by intentionally limiting parking space, it is essential that the amenities offered by transit approach those offered by private auto travel and that a sufficient number of parking spaces be controlled.

To reduce vehicular congestion and air pollution in highly congested urban areas, the EPA has initiated proposals to limit center city parking space. For example, the EPA mandated that New York City reduce its parking spaces in mid-town Manhattan and that Boston limit the number of commercial parking spaces in a designated area to the October 1973 level. However, the First Circuit Court of Appeals has since suspended the freeze on Boston parking spaces until further order. The EPA's Transportation Control Plan for Boston also requires that employers with 50 or more employees and educational institutions with 250 or more commuting students implement and maintain incentives to reduce the use of single-passenger commuter vehicles by 25 percent. Essentially, employers and educational institutions have a responsibility to encourage the use of alternate travel modes among their employees or students. Furnishing transit service information, promoting commuter transit pass programs, creating dial-a-ride and pooling programs, and providing bicycling incentives are among the eight actions that EPA has directed these cities to take to reduce vehicular use. The EPA does not require that these actions be implemented once the 25 percent reduction has been achieved and maintained; however, failure to maximize the chance of achieving the goal by not implementing some or all of the measures is subject to penalty (daily fines of up to $25,000 can be levied).

City zoning ordinances also can and have been used to limit the number of future parking spaces that will be available. For instance, zoning regulations in London place a ceiling on the maximum number of parking spaces that can be provided in new office developments. Similarly, Glasgow, Scotland, and Leicester, England, have used zoning ordinances to limit their planned parking facility accommodations to 41 and 51 percent, respectively, of the estimated future demand. Additionally, Seattle's zoning regulations prohibit open parking lots in the heart of the CBD and restrict parking in new developments to not more than 10 percent of planned floor space.

IMPLEMENTATION CONSIDERATIONS. The site-specific characteristics of the urban area will, of course, determine how effective a policy to reduce parking spaces will be in improving traffic flow. In general, limiting on-street parking (discussed in Section 1) will be more effective in smaller urban areas, where on-street parking represents a major proportion of the total parking space. The policy will be less effective in larger urban areas, where privately owned parking facilities represent a significant proportion of the total parking space. In these instances instituting zoning ordinances to restrict future parking space may be the most effective course to pursue--even though the benefits of such an action will not be immediately apparent.

When contemplating a substantial reduction in parking space, equal consideration must be given to providing adequate travel alternatives so that mobility is not impaired. Ensuring ready access to business in the parking control area is, of course, of paramount importance. For instance, if parking spaces are limited in the CBD, available spaces may be monopolized by commuting vehicles that arrive before or at the start of the day's business. This situation can be avoided if, as in many urban areas in England, parking facilities are prevented from opening until after 9:30 a.m. Naturally, if this action is taken, transit and paratransit service levels must be increased to satisfy the increase in commuter travel demand.

When limited parking supply causes commuters to monopolize on-street parking in residential areas adjoining the CBD, the possibility of instituting parking permit systems may be explored. This action, in combination with other on-street commuter parking restrictions, has been suggested as one component of Washington, DC's parking management plan. Also, the San Francisco Board of Supervisors recently passed an ordinance that allows residents of specified congested areas to buy stickers that exempt them from timed parking regulations. The stickers cost $10 per year per car. Munich, Germany, is also considering a residential parking permit system that would eliminate the nonlocal traffic parked in the marginal districts of the inner city.

Enforcing a policy to limit parking space is paramount to the action's success in improving traffic flow. It is especially important to the effectiveness of regulations banning or restricting on-street parking. In this case, the product of the fine imposed on the violator and the probability of receiving that fine becomes the effective cost of parking. Unless the result is perceived to be excessive, many motorists will prefer to violate the regulation rather than seek a legal parking space or use a high-occupancy mode of travel.

As with increased parking charges, the effectiveness of a policy to limit parking space also depends on the size of the control area selected. As a general rule the control area should extend at least one-third mile beyond the perimeter of the activity center. Otherwise motorists will simply park outside and walk in.

PARK-AND-RIDE FACILITIES

Coupling fringe or corridor parking facilities with express transit service to activity centers can contribute significantly to the success of parking policies designed to reduce the number of CBD-directed automobiles. Such an action can also aid other TSM actions designed to reduce automobile use in congested areas and time periods. Park-and-ride lots, located along the perimeter of an urban center, serve as relatively uncongested collection points where users are subsequently shuttled to their destinations on express transit buses, which often operate on reserved lanes. The development of new park-and-ride facilities may not be required when transit companies can share existing parking lots. For example, churches, drive-in theaters, and shopping centers adjacent to commuter routes may be willing to share their parking facilities with the transit company at little or no cost.

Examples

Park-and-ride transit service is becoming increasingly common in the United States. For instance, Toledo, OH, has 36 park-and-ride sites with a total of 1,245 parking spaces. In Toledo the "Superbus," an express service, operates between park-and-ride lots and the CBD during peak periods. The service, initiated March 13, 1972, is routed along three major corridors and serves five shared-use park-and-ride lots. Four of the outlying parking areas are in the parking lots of existing shopping centers while the fifth is in a suburban church parking lot. There is no charge for parking. Superbus ridership has increased from an average of 154 patrons when the project began to its current level of 1,019 daily riders. The success of Superbus is attributed to five elements: a reasonable fare (35 cents, the standard bus fare), frequent service (five-minute headways), strategically located park-and-ride lots that serve the adjacent express corridors, vigorous promotional campaigns, and the nonstop express service. Superbus is a viable alternative to the automobile in terms of efficiency, convenience, and cost. Because parking is free and bus fares are low, commuters can save over $1,000 per year in transportation costs by using the service.

Los Angeles has also successfully developed a park-and-ride program that takes advantage of the shared-use parking concept. The Los Angeles RTD express transit picks up riders from 14 park-and-ride facilities along eight freeway systems. Eleven of the lots are shared-use facilities: eight drive-in theaters, one shopping center, one heliport parking lot, and one municipal parking lot. A parking fee is charged at only one of the lots. The one-way fare on the express bus is 75 cents, compared to a regular RTD bus fare of 50 cents. Ridership has been steadily increasing. For example, in April 1976 the average daily ridership was 5,691 in the morning peak hour, compared to 4,608 in September 1975, and an average of 1,211 cars parked at the park-and-ride facilities, compared to 967 in September 1975.

In September 1975 Atlanta's transit authority (MARTA) opened the largest of its three park-and-ride lots. The new lot accommodates 357 autos, while the previous two have a combined parking space total of 530. The new park-and-ride lot cost $482,412 to build. Parking is free and users pay only the regular one-way bus fare of 15 cents. The first park-and-ride lot has been in operation since February 1975 and the second opened in July 1975. Reportedly, some 18 percent of the park-and-ride users did not previously use public transportation. According to a transit survey, the primary reasons given for using the park-and-ride facility were to save money or time, to avoid excessive driving, or a combination of the three. As the result of improved transit service and park-and-ride facilities, approximately 1,200 cars have been removed from the CBD vehicle stream.

Seattle operates "Blue Streak" express buses between a park-and-ride lot and the CBD. In Seattle the availability of fringe parking is a key factor in the success of the service. Seattle's Blue Streak system reported that of patrons surveyed at the park-and-ride lot, 50 percent were former auto commuters; former auto commuters represented only 22 percent of total transit ridership.

Park-and-ride facilities also have been successful in a number of other cities. In Boston, approximately 11,000 cars per day park in the city's 17,000 fringe-lot parking spaces. The fringe lots serve as tranfer points for rail, subway, or bus routes. In Chicago, a shuttle bus system serves two of the city's parking lots and one parking garage--a combined total of 10,200 parking spaces. Cleveland's Loop Bus serves the city's fringe parking lots and the CBD. Milwaukee's Freeway Flyer serves six suburban shopping centers and the CBD. Hartford, St. Louis, and Trenton are among other urban centers served by park-and-ride facilities. Philadelphia's park-and-ride concept uses express transit in the form of the Lindenwold Hi-Speed Rail Line, operating between the CBD and six suburban fringe parking lots located along a New Jersey corridor. Expansion programs are underway in these and other areas.

Costs

In some instances, like Philadelphia's Lindenwold Hi-Speed Rail Line and the Seattle Transit System, fringe parking facilities have been included as one of the costs of a larger transit plan. Generally, however, peripheral parking facilities represent a later addition to transit plans. Table 22 presents estimates of the total annual costs that will be incurred in constructing and operating a self-park surface parking lot. Usually, self-park surface lots require approximately 330 square feet per vehicle. In most cases the parking fees that are reasonable to charge are not sufficient to meet construction and operating expenses, and many lots do not charge a parking fee in order to encourage ridership. Thus, a subsidy usually is required to support the parking element of park-and-ride service unless a shared-use, no-cost arrangement can be made.

Table 22. Total Estimated Annual Costs of a 500-Vehicle, Surface Level, Self-Park Fringe Parking Lot

COST FACTOR		UNDER PUBLIC OWNERSHIP[1]	UNDER PRIVATE OWNERSHIP[2]
Amortization ($000)			
Cost of land/sq.ft.:	$ 2.50	$ 29.0	$ 41.3
	5.00	58.5	82.5
	7.50	88.5	124.0
	10.00	117.5	165.0
	12.50	145.5	206.0
Improvements and Equipment ($000)		17.5	18.1
Operating Costs ($000)		22.5	22.5
Taxes ($000)		--	32.0
Total Annual Cost ($000)			
Cost of land/sq.ft.:	2.50	69.0	113.9
	5.00	98.5	155.1
	7.50	128.5	196.6
	10.00	157.5	237.6
	12.50	185.5	278.6
Daily Cost per Vehicle Parked ($)[3]			
Cost of land/sq.ft.:	2.50	0.49	0.81
	5.00	0.70	1.11
	7.50	0.92	1.40
	10.00	1.13	1.70
	12.50	1.32	1.99

[1]Assumes interest rate = 5%; amortization period = 25 years for land, = 10 years for improvements.
[2]Assumes interest rate = 7%; amortization period = 10 years; and land value yield = 10%.
[3]Assumes at-capacity operation for 280 days/year.

Advantages

Park-and-ride facilities shift parking from the center city to outlying areas. Additionally, they help reduce VMT and congestion in urban activity centers. As a result, concomitant benefits, such as energy conservation and improved air quality, are realized. In Dallas, CBD-directed private auto travel has been reduced and transit ridership increased through the use of a dial-a-bus feeder service to the park-and-ride lot. Dallas's demonstration program is designed to encourage commuters to use a dial-a-bus for the home-to-park-and-ride station portion of the trip. Commuters then connect to regular transit service at the park-and-ride station.

Where express transit shuttles to the CBD are combined with other TSM bus priority measures, such as bus preemption of traffic signals or bus only lanes on city streets, the additional commuter time savings make park-and-ride an unusually attractive alternative to private home-to-CBD auto travel.

Planning Guidelines

Once the decision has been made to construct a park-and-ride lot, planning for the lot itself and coordination with transit service are required. Following are various conditions that need to be considered in the development of park-and-ride lots.

A park-and-ride lot should be:

- Large enough to permit proper traffic circulation and pedestrian safety and convenience.
- As close to the major activity center as land value distribution will permit, but no closer to the center than one mile.
- Located in a dense travel corridor approaching a high density activity center and adjacent to a radial freeway or arterial beyond service congestion.
- Located so as to minimize the cost of development to the public and to enable the use of existing available parking facilities if possible (e.g., church parking lots, drive-in theaters, and shopping centers).
- Located so that it does not compete with other service areas.
- Located so as to minimize adverse effects on adjacent areas. Particular attention should be given to the effect on local traffic circulation.

The lot should also provide:

- Convenient access and egress for buses and automobiles.

- Transit service on five-minute headways during the peak hour. Off-peak headways should be maintained at no less than one bus per hour. Alternate routing of nearby local bus service, with minimum headways of one bus per hour or demand-responsive service in the off-peak, should also be considered.
- "Free" parking, if possible, since parking fees discourage park-and-ride use. Only rarely have park-and-ride services included a charge for parking.

SECTION 5

PROMOTION OF HIGH-OCCUPANCY AND NONVEHICULAR TRAVEL MODES

Information on the following three TSM actions is presented in this section:

- Ridesharing
- Human-powered travel modes
- Auto-restricted zones.

All of these actions approach the goal of improving the efficiency of the existing transportation system by reducing the number of vehicle-miles traveled in congested areas or time periods without altering mobility. Reducing VMT also reduces energy consumption and air pollution in two ways. First, because fewer vehicle-miles are traveled, less fuel is consumed. Secondly, a reduction in VMT improves traffic flow, which in turn improves vehicular fuel efficiency and reduces vehicular emissions.

RIDESHARING

Ridesharing, a form of paratransit (see page 133 for a discussion of other aspects of paratransit), entails prearranging shared rides for people traveling at similar times from approximately the same origin to approximately the same destination. In lightly populated areas, ridesharing in cars or vans can complement the transit operators' goal of improving transit efficiency since underutilized and unprofitable bus routes to these areas may not be required if a ridesharing program is successful. In fact, provision of a subscription van or bus service to such areas could be viewed as a natural extension of existing transit or paratransit service.

In the most common carpool arrangement, participants use their own cars and rotate driving duties. Usually such an arrangement does not involve a cash exchange because participants exchange a driving service for a ride.* However, in the common vanpool arrangement, participants usually cannot exchange a driving service for a ride because the van is generally owned by the driver, an employer, or possibly a paratransit company. Thus, the participants normally pay a fee for the cost of providing the service.

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*Of course many other arrangements exist. For instance, individuals who do not own an auto or who do not want to (or cannot) drive participate in carpools by paying a fee to other driving members of the carpool. Also, in some instances, a single individual arranges to drive all the members of a carpool in return for a fee that covers the cost of the carpool operation.

Carpools

Although it is not known how many people are currently participating in carpools, it has been estimated that organized carpool programs exist in about half of the 278 urbanized areas in the United States. Many of these programs are sponsored by employers and include incentives to encourage employee participation. For example, the Prudential Insurance Company in Boston, MA, and the Port Authority of Portland, OR, provide free carpool parking facilities for their employees. The savings that these employees realize from not having to pay commercial parking fees are sizeable. The Portland Port Authority also contributes 14 cents per mile to carpools with four or more persons traveling a daily round-trip distance of up to 20 miles and offers a reduced bus fare program for employees using transit. (Other financial incentives offered by employers to encourage employees to use transit are discussed on page 127 in Section 6.)

Carpool programs have also been coordinated on an areawide basis. An example of an areawide program is the Metropolitan Area Carpool Project in Portland, OR, which attracted 22,007 persons to carpools. As a result, 13,169 autos per day were removed from the roads. The program was also estimated to result in an annual savings of six million gallons of gasoline. A similar areawide carpooling program was initiated in Sacramento, CA, on July 1, 1974. Initially, 1,573 persons participated in the program; eight months later, 1,310 were participating. The program has been credited with reducing the number of vehicle-miles traveled per year by 5,766,500 and with conserving 443,600 gallons of fuel per year.

Vanpools

Generally, for one-way trip distances over 10 miles, vans carrying 10-12 passengers are more efficient than three carpools each with three to four riders since the vehicle-miles saved on the "line-haul" portion of the trip by 10-12 vanpool exceed the additional vehicle-miles that must be traveled to pick up and deliver a larger number of passengers.

It is estimated that about 3,600 commuters currently are participating in vanpool programs. Table 23 lists the vanpools known to be in operation as of February 1976.

The vanpool program of the 3M Company (St. Paul, MN), initiated in April 1973, is a good example of a successful employer-sponsored vanpool program. Under the 3M Commute-A-Van program, the company furnishes a standard 12-passenger van to any employee who is willing to drive at least eight employees to and from work. The fare structure is designed to produce sufficient revenue to break even on capital and operating costs based on a ridership of

Table 23. Existing Commuter Van Operations*

OPERATION/LOCATION	DATE STARTED	NUMBER OF VANS	HOW VEHICLES PROVIDED	NUMBER OF RIDERS	NUMBER OF EMPLOYEES**	EMPLOYMENT LOCATION	ROUND-TRIP LENGTH (miles)
Private Company							
3-M Company St. Paul, MN	4-73	75	Purchased	780	10,000	Suburban	5-150
Ralph M. Parsons Company Pasadena, CA	3-74	31	Leased	310	4,000	Suburban	45-70
CENEX St. Paul, MN	10-73	21	Leased	175	700	Suburban	10-100
General Mills Minneapolis, MN	1-74	15	Purchased	165	1,800	Suburban	18-110
Hoffman LaRoche Pharmaceuticals Nutley, NJ	5-74	16	Lease-buy	120	6,000	Suburban	10-140
Aerospace Corporation El Segundo, CA	4-75	11	Leased	110	6,000	Suburban	25-75
Continental Oil Company Houston, TX	3-75	10	Purchased	103	1,400	Suburban	20-70
Texas Instruments Dallas, TX	3-74	10	Purchased	120	15,000	Suburban	55-130
Winnebago Industries Forest City, TX	10-74	15	Company Manufactured	250	2,700	Small Town	20-60
Sperry Flight Systems Phoenix, AZ	3-74	10	Leased	120	3,100	Suburban	27-65
Corning Glassworks Corning, NY	12-73	10	Purchased	110	4,000	Small Town	50-140
Prudential Insurance Newark, NJ	7-75	8	Purchased	85	2,000	Urban	50-110
Erving Paper Mills Erving, MA	3-74	6	Purchased	130	300	Rural	25-35
Montgomery Ward Chicago, IL	9-74	6	Leased	70	4,000	Urban	30-90
Scott Paper Co. Philadelphia, PA	8-75	2	Leased	19	1,500	Suburban	25-45
Cooper & Woodruff Amarillo, TX	2-74	4	Purchased	40	90	Rural	60-200
Gulf Research and Development Pittsburgh, PA	8-74	3	Leased	36	1,600	Suburban	5-80
American Can Company Greenwich, CT	7-74	1	Purchased	11	1,800	Suburban	70

Table No. 23. (continued)

OPERATION/LOCATION	DATE STARTED	NUMBER OF VANS	HOW VEHICLES PROVIDED	NUMBER OF RIDERS	NUMBER OF EMPLOYEES**	EMPLOYMENT LOCATION	ROUND-TRIP LENGTH (miles)
Government Agency							
Tennessee Valley Authority Knoxville, TN	4-74	22	Leased & Purchased	264	3,200	Urban	40-140
Caltrans Sacramento, CA	9-74	3	Leased	30	--	Urban	100-120
Utah County Van Pooling Provo, UT	11-74	2	County Owned	24	120	Small Town	40-45
Nonprofit Group							
Reston Commuter Bus Reston, VA	1974	3	Purchased	35	30,000 popula.	New Town	50-60
Polisar Commuter Cooperatives Sarnia, Ontario	1966	16	Purchased	500	57,000 popula.	Urban Surrounded by Small Towns & Rural Areas	15+
Private Bus Operator							
Southern California Commuter Bus Service Los Angeles area, CA	1972	8	Owned & Leased	--	--	Urban-Suburban	40-130
MODNAR Atlanta, GA	1973	4	Owned	70	--	Urban-Suburban	20-70
Private Individuals							
Navy Shipyard Portsmouth, VA	1940s	30	Owned	--	--	Suburban-Rural	40+
Browns Ferry Nuclear Power Plant Decatur, AL	1970	40+	Owned	--	--	Rural	70-80
Sussex Commuter Club Sussex, NJ	1970	1	Leased	7	--	Urban-Suburban	120
FHWA Group Washington, DC	1967	1	Owned	--	--	Urban	--

*As of February 1976.
**At site of van operations.

eight. The employee/driver is not charged a fare and is allowed to retain the fares collected from any additional riders. The driver also is permitted to use the van for personal purposes at a cost of seven cents per mile.

Vanpools also are given preferential treatment at 3M's parking lots. Vanpoolers do not have to pay the $15.00 monthly parking fee levied on all other vehicles, including carpools. This financial incentive was offered to compensate for the anticipated increase in the vanpooler's overall trip time (due to the longer time required for pickups and deliveries)--estimated to be up to 30 percent greater than comparable trips in single-occupancy autos.

As of June 1, 1976, nine percent of 3M's 9,000 employees were commuting in one of the firm's 77 vans and another 22 percent were commuting in carpools. As a result of 3M's pooled riding program, congestion has been reduced near the company's plant site. Also the reduced demand for parking has saved the company $2.5 million since construction of a planned parking facility is now unnecessary.

A more recently instituted and very promising vanpool program is being jointly sponsored by the Aerospace Corporation and the Air Force's Space and Missile Systems Organization (SAMSO) in El Segundo, CA. By June 1, 1976 Aerospace expects to have 18 commuter vans in operation. Although many elements of the Aerospace program resemble the 3M program (break-even fare structure, door-to-door pickup and delivery, driver incentives, etc.), the Aerospace program has been tailored to the special needs of Aerospace employees. For example, although a fixed monthly charge is easy to administer, such a plan penalizes the rider who, for personal or business reasons, is unable to utilize the service each day. Since about half of the Aerospace/SAMSO employees are regularly scheduled riders and half are irregular riders, Aerospace devised a fare structure that accommodates both types of users. The fare structure is based on a fixed monthly subscription fee combined with a daily fare. This arrangement has proved an effective compromise for regular riders and riders who cannot use the service every day. To reserve a seat under this fare structure, riders pay a monthly subscription fee amounting to approximately one-third of the projected total monthly cost. The remaining two-thirds of the total monthly cost is divided by 17 (approximately 80 percent of the normal 21 work days per month) to obtain the daily fare. "Casual" riders are encouraged to participate and fill otherwise vacant seats.* This strategy has been successful in maintaining the 80 percent ridership level needed for the vanpool operation to break even.

Table 24 presents the details of the Aerospace/SAMSO commuter vanpool fare structure for 10- and 12-passenger vans. The 10-passenger vanpool fare structure is designed to break even with eight

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*Vanpool drivers, who are largely responsible for finding casual riders, are allowed to keep 40 percent of the casual rider's fare.

Table 24. Aerospace Commute-A-Van Fare Structure by Daily Round-Trip Mileage

RIDER CHARACTERISTICS	VANPOOL RATE ($)						
	12-Passenger Van			10-Passenger Van			
	25 mi.	30 mi.	35 mi.	40 mi.	60 mi.	80 mi.	100 mi.
Regular Rider							
Monthly Subscription	8.00	8.25	8.50	11.00	12.50	13.50	15.00
(Plus) Daily Fare	0.90	0.95	1.00	1.25	1.40	1.60	1.75
Casual Rider							
Per Day	1.50	1.60	1.65	2.25	2.50	2.75	3.00

regular riders who commute 40-100 miles, and the 12-passenger vanpool fare is devised to break even with 10 regular riders who commute 25-35 miles. The driver in each case is permitted to keep the fare collected from the 9th and 11th rider, respectively.

The Aerospace/SAMSO vanpool fare structure reflects a self-supporting vanpool program. It was essential that the program be self-supporting if SAMSO employees were going to participate since it would have been illegal for Aerospace to provide a subsidy benefitting SAMSO civilian and military employees.

The 10- and 12-passenger vans have approximately the same interior space and both are air-conditioned. However, those used for long-distance trips, i.e., the 10-passenger vans, are equipped with airline-type reclining seats, which provide additional comfort for the long-distance commuter. The cost of the reclining seat, which amounts to approximately 10 cents per person per day, is reflected in the fare structure.

Aerospace reserves preferentially located parking spaces for vanpool participants. This priority treatment provides only a marginal inducement for employees to join the vanpool program since readily accessible free parking space is available for all employees. A more valuable aid to Aerospace poolers is the shuttle service that was instituted to transport poolers from outlying buildings to their vehicles at the end of the working day.

No costs were incurred by Aerospace for developing the data base for route planning since a free areawide carpool matching service was available. The company used this data to compile a master list of potential riders. Each vanpool driver was given the list and used it to solicit vanpool participants. Thus, costs for developing routes and matching riders to vans were negligible.

Costs

Promotional costs will be incurred in initiating almost all pooled riding programs. Promotional campaigns for employer-sponsored programs can be carried out at relatively low cost, using company newsletters, staff meetings, intraoffice memoranda, etc. Areawide programs may also incur costs for media advertising. If employees of the residential area to be served are widely dispersed, time may also be required to locate and arrange for the use of suitable supplementary park-and-ride lots (e.g., church parking lots, drive-in theaters, shopping center parking lots, or business areas with evening patronage).

Manual or computerized matching procedures, which identify and correlate commuters' origins and destinations, are usually essential to the success of pooled riding programs. Manual matching methods, the most commonly used means of forming carpools, can be quickly implemented at a low cost. Essentially, with the aid of questionnaires, maps, etc., potential poolers are identified and then encouraged to commute with other interested individuals whose origin and destination points roughly coincide. Although Hallmark Card Company in Kansas City used the manual method at a plant that employs 4,500 persons, the technique is generally used when the potential number of poolers is less than 1,000. The headquarters of the National Aeronautics and Space Administration, and the town of Vienna, VA, have also successfully used manual matching procedures for their pooled riding programs.

Manual matching programs are rarely effective when the potential number of carpoolers exceeds 1,000. In response to the need to organize large-scale ridesharing programs, a number of government agencies and firms have devised computerized carpool matching programs: for example, the Federal Highway Administration (FHWA), the Washington Regional Council of Governments, the Connecticut Department of Transportation, the University of California at Los Angeles, and Aerojet Corporation. Many of these programs are written in FORTRAN and use coordinates or grid systems for geocoding. The FHWA computer program appears best suited for general application. It is programmed in COBOL and while it was initially designed to run on IBM equipment, it has been successfully converted to run on other computers. Table 25 shows the average costs incurred with an areawide computerized carpool matching program.

The amount of time and the skills required to develop a pooled riding program depend on the size of the contemplated program, who sponsors the program (i.e., employers or the community), and whether the vehicles are privately owned or are owned or leased by a sponsoring firm. For instance, in the planning and implementation phases of an employer-sponsored vanpool program, a steering committee using the part-time services of company personnel familiar with purchasing, vehicle maintenance, accounting, publicity, and insurance and legal requirements will probably be required. Aerospace vanpool planners estimate that establishing

Table 25. Estimated Annual Budget for Operating and Maintaining an Areawide Computerized Carpool Matching Service (6000 participants)

Personnel	
Administrator[1]	$1,500
Secretary-clerk[2]	3,600
Two temporary clerks (2 weeks per year)	1,000
Employment taxes and benefits (25%)	1,525
Subtotal	$7,625
Advertising	5,000
Computer time	3,000
Keypunch	1,000
Office and supplies	2,000
Telephone	300
Contingencies	5,000
TOTAL BUDGET	$23,925

[1]Based on a 10 percent application of time.
[2]Based on a 50 percent application of time.

and operating a 25-vehicle vanpool program can be successfully accomplished as a part-time endeavor by about a dozen people. Although the need for staff personnel diminishes once the ridesharing program has been established, in order to insure its continued success, promotional efforts must continue, matching lists must be updated, and other aspects of the program must be maintained.

Benefits from Ridesharing

The rider, the employer, and the community can realize sizeable benefits from a ridesharing program. The rider's most tangible benefits are a reduction in travel costs and a reduction in the use of his own vehicle for commuting. Figure 3 shows how the cost savings from these benefits vary according to the type of riding pool, the trip distance, and the number of participants in the riding pool. The cost savings in Figure 3 are based on the assumption that the average total cost per mile to drive an auto is 12 cents and that a 12-passenger van can be driven for an average total cost of 15 cents per mile. According to estimates made in the course of planning the Aerospace vanpool program, fuel- and insurance-related cost savings would be as shown in Figure 4 for riders who previously commuted in single-occupancy

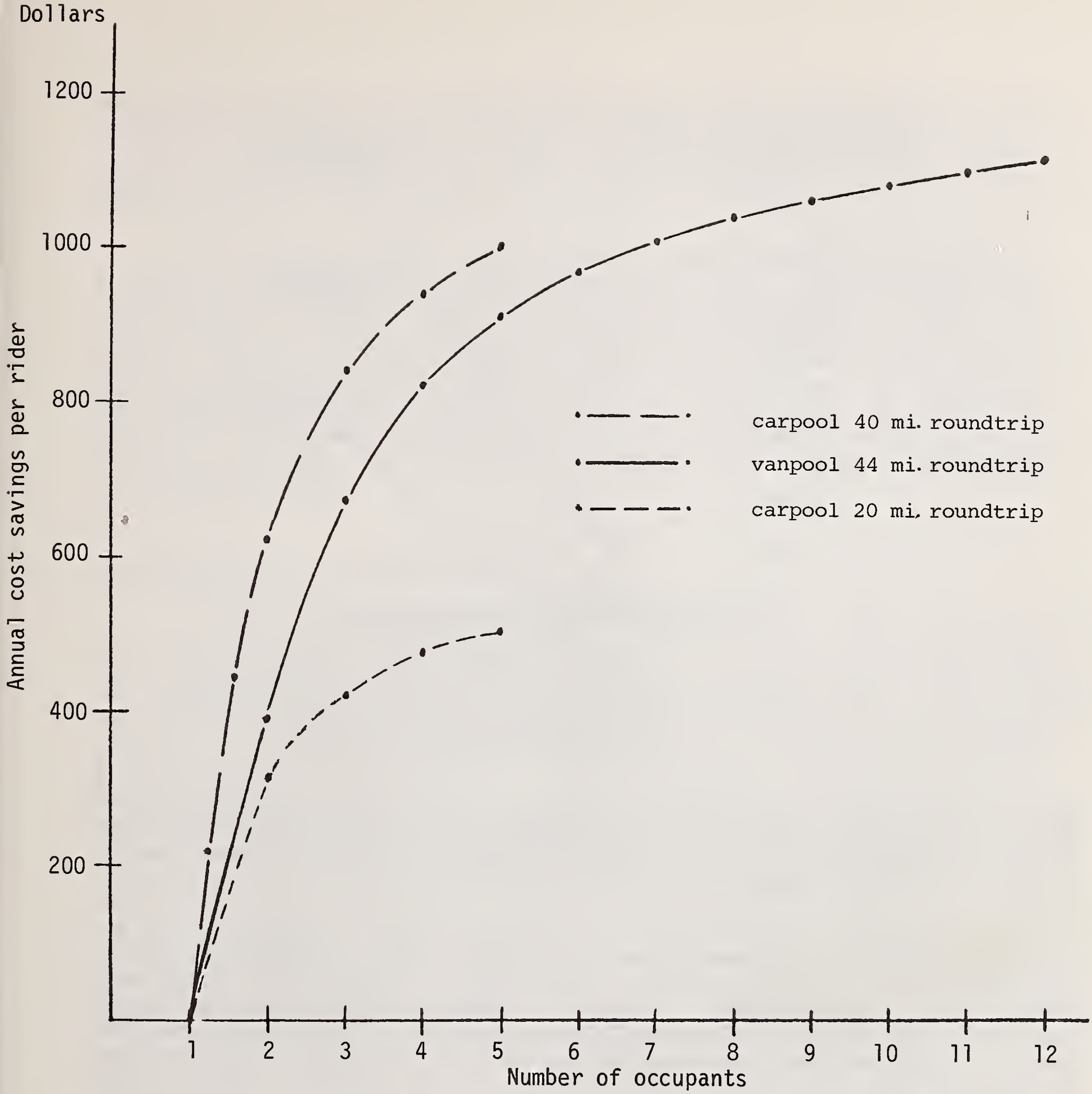

Figure 3. Annual Carpool and Vanpool Cost Savings as Affected by the Number of Occupants and Commuting Distance

Notes: Vanpool VMT assumed to be 10 percent greater than carpool.

$$\text{Cost of driving car} = x \text{ miles} \cdot \frac{12¢}{\text{mile}} \cdot 260 \text{ work days}$$

$$\text{Cost of driving van} = x \text{ miles} \cdot \frac{15¢}{\text{mile}} \cdot 260 \text{ work days}$$

$$\text{Carpool savings} = \frac{\text{cost of driving car}}{\text{1 driver}} - \frac{\text{cost of driving carpool}}{\text{number of occupants}}$$

$$\text{Vanpool savings} = \frac{\text{cost of driving car}}{\text{1 driver}} - \frac{\text{cost of driving vanpool}}{\text{number of occupants}}$$

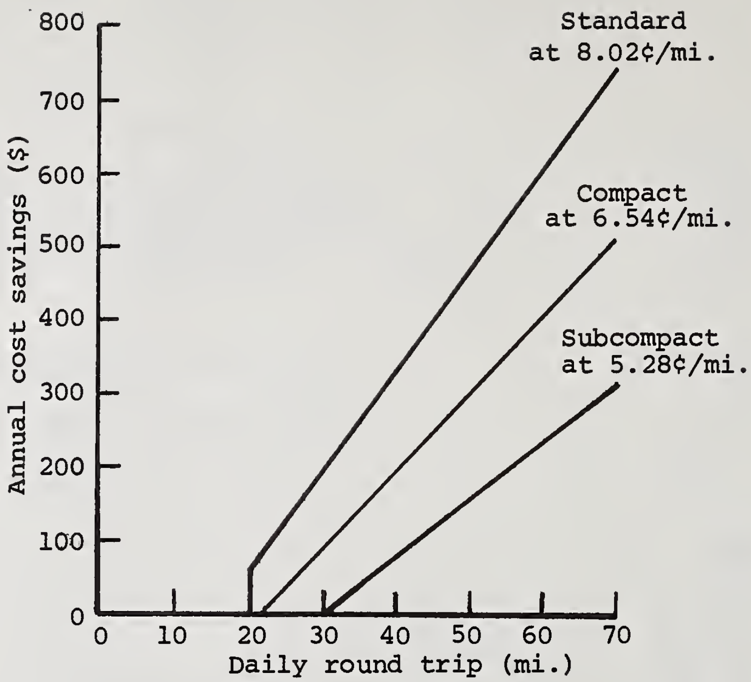

Figure 4. Aerospace Vanpool Fuel- and Insurance-Related Cost Savings per Rider

standard, compact, or subcompact vehicles. These estimates assume that the cost of fuel will be 59.9 cents per gallon and that the cost of insurance will be reduced because the former commuting vehicle will be reclassified as a pleasure vehicle.

The employer who sponsors a ridesharing program will also benefit from the program in several ways. The principal financial effect of the program will be a reduced demand for parking facilities. In addition, congestion near the employment site will probably be reduced. Also employer-owned or -leased vans can be used to display company advertising and for company business trips during the day.

The public and the community will also accrue benefits from ridesharing programs. For example, if some residents of low density areas not now served by transit participate in pooled riding programs, they may be able to satisfy their travel needs with one auto rather than two. Also, if through pooled riding programs the average vehicle occupancy is changed from 1.40 to 1.56, the traffic volume will be reduced by 10 percent. This change will in turn result in saving 10 percent of the fuel formerly used for the trip purpose served by the pooled riding arrangement. Considering that nationwide about 165 billion vehicle-miles are traveled annually in urbanized areas for work-related purposes, at an assumed average fuel efficiency of 12 mpg, a 10 percent reduction in VMT implies fuel savings of close to 90 thousand barrels per day. Instituting the 55-mph speed limit is also estimated to be responsible for saving 90 thousand barrels of fuel per day.

In addition, if former driving conditions were congested, a reduction in traffic volume would result in additional fuel savings and a reduction in air pollution, which would be due to the improvement in fuel efficiency experienced under free-flow conditions. Study results indicate that, when traffic conditions are congested, reducing traffic volumes by 10 percent can cause a 2-mpg improvement in fuel efficiency. Nationwide it is estimated that a 10 percent reduction in traffic volumes on congested sections of roadway could save on the order of 30 thousand barrels of fuel per day.

Implementation Considerations

INTERRELATIONSHIPS WITH OTHER TSM ACTIONS. When considering the implementation of a pooled riding program, it is also necessary to consider other TSM actions that could be undertaken concurrently to foster participation in the program. These, of course, should be tailored to complement the goals of the ridesharing program. For example, TSM actions discussed in Section 2, which give preferential treatment to high-occupancy vehicles, may be assessed in terms of their applicability to a ridesharing program. If work rescheduling programs (discussed in Section 3) are considered as fostering actions, their potential effect on a planned pooled riding program should be evaluated from the onset. Steps can then be taken to insure that a smooth transition occurs as work schedules and ridesharing arrangements change and that new ridesharing arrangements reflect new work schedules. Various forms of congestion pricing, including differential parking fees that favor short-term parking over long-term parking, should also be evaluated to determine if implementing such measures will constitute an incentive to the ridesharing effort and, if so, whether these measures are in consonance with other local goals. Finally, as discussed previously in this section, park-and-ride facilities may be necessary to promote ridesharing efforts in lightly populated areas.

AREAWIDE POOLING PROGRAMS. Plans for an areawide ridesharing program should be coordinated with the local transit and paratransit operators for several reasons. First, intensive promotion of ridesharing in areas already well served by transit may be counterproductive--i.e., transit operations may be adversely affected, or the attempt to form ridesharing arrangements may not be very successful. By discussing the planned ridesharing effort with transit representatives, the areas that seem best suited to transit and the areas that seem best suited to paratransit can be identified. The results of such a discussion should be useful in determining where and how the pooled riding promotional campaign should be focused and should also apprise paratransit operators of the enhanced opportunity to offer subscription services.

The areawide ridesharing program in Knoxville, TN, exemplifies this kind of coordinated planning. Knoxville was faced with a number of problems: inadequate downtown parking supply, declining transit ridership and rapidly increasing transit deficits, increasing peak-hour traffic congestion, and an inability to provide transit service in many low density areas. In the fall of 1973 a concerted attempt to solve these problems--by implementing an urbanwide ridesharing program--was jointly undertaken by the city of Knoxville, the Knoxville Transit Authority (KTA), the University of Tennessee, major employers in the area, and various homeowners' associations. The purpose of the program extended beyond merely promoting the pooled riding concept to an evaluation of the forms of ride-sharing that seemed most appropriate to specific travel needs. As a result of the evaluation, KTA worked with the community to develop several new consumer-oriented express bus routes. Three express buses now take urban workers to suburban company sites (e.g., Levi Strauss and the Camel Manufacturing Company) at 6:50 a.m. and return downtown at 7:50 a.m. with suburban employees who are destined for work at the Knoxville offices of the Tennessee Valley Authority (TVA). Although most of the bus passengers are employees traveling to work, the bus service can be used by anyone. The effect of the ride-sharing program on the travel habits of TVA employees is shown in Table 26.

LEGAL CONSIDERATIONS. Since many vanpooling arrangements and some carpooling arrangements involve the payment of a fare to the driver/owner of a vehicle for a transportation service, some states may question whether such arrangements fall within the purview of the Public Utility Commission (PUC). However, because of the critical need to conserve energy and reduce urban traffic congestion and air pollution, there has been a trend toward exempting these arrangements from regulation. For example, in 1974 a California commuter bus service brought suit against a vanpool operation organized by an individual for 8 to 10 fellow workers, charging that the vanpool service actually constituted a bus service and, hence, required a PUC license. A subsequent cease and desist order was later rescinded, and the vanpool was allowed to continue operating. As a result, in California, shared ride arrangements involving "the transportation of persons in a passenger vehicle having a seating capacity of 15 passengers or fewer from place of residence to place of employment, if the driver, himself, is on the way to or from his place of employment," are now exempt from PUC regulation. Including transit and paratransit operators in the planning and operational phases of pooled riding programs should diminish the likelihood that such conflicts will arise.

Table 26. Effect of the Knoxville, TN, Ride-Sharing Program on the Travel Modes of TVA Employees

TRAVEL MODE	PERCENTAGE BY MODE		
	Fall 1973*	December 1974	March 1975
Single-occupancy auto	56	36	28
Vanpool	--	2	2
Express bus	--	13	17
Carpools	39	43	45
Traditional transit	3½	4	6
Motorcycle, Bicycle, Walk, etc.	1½	2	2

*TVA employed 2,900 people in the fall of 1973 and 3,000 from December 1974 to March 1975.

FEDERAL FUNDING OF URBAN POOLED RIDING PROGRAMS. Several major pieces of legislation have enabled Federal-level actions to be taken to encourage pooled riding. For instance, Section 3 of the Emergency Highway Energy Conservation Act authorizes the Secretary of Transportation to approve demonstration projects that would encourage urban area carpooling in order to conserve fuel, decrease rush-hour traffic congestion, improve air quality, and enhance the use of existing highways and parking facilities. Urban System funds were made available at 90% Federal Funding. The 1976 Federal-aid Highway Amendments (1) made these provisions permanent, (2) allowed the initial capital cost of vans to be an eligible project cost subject to payback from user fees, and (3) allowed States to finance these projects from Urban System and Primary System funds.

As of January 1975, FHWA has funded 86 carpooling projects in 29 states, using over $10 million of Urban System funds. The Federal Energy Administration has also initiated a vanpool demonstration program and has allocated some $32 million in "pass-through" funds to encourage large employers to sponsor vanpools for their firms.

The specific activities for which these funds may be used include maintaining and monitoring the progress of existing programs, fostering the expansion of existing programs, and initiating new programs in areas where pooled riding modes can efficiently serve existing trip characteristics and transportation needs. Although Federal funds can be obtained for these activities, in some situations local public agencies may wish to become the financial sponsor.

HUMAN-POWERED TRAVEL MODES

The recent surge of interest in the health and recreational benefits gained from bicycling and walking has resulted in a substantial increase in the use of these modes. This spontaneous interest on the part of the public dovetails well with Federal, state, and local governments' interest in causing modal shifts from autos to human-powered travel modes to reduce urban auto congestion and air pollution, to conserve fuel, and to upgrade the urban environment.

The potential effect that a substantial shift from autos to human-powered travel modes could have on reducing traffic congestion is great. For instance, recent estimates indicate that short-distance bicycle trips (i.e., less than five miles) for trip purposes usually served by autos* now represent over one billion vehicle-miles annually. In 1970, pedestrian work trips alone accounted for about two million miles in urban areas. This amount of walking and bicycling is estimated to save over 14 thousand barrels of fuel daily.

The actions discussed below focus on improving bicycle and pedestrian facilities and on encouraging increased use of these facilities. The high level of Federal interest in these actions is indicated by the number of funding sources (tablulated in Table 27) available to implement these actions.

Bicycling as a Substitute for Auto Travel

BICYCLE FACILITIES. A number of actions can be taken to promote safe and unobstructed flow of bicycle traffic and, hence, to encourage increased bicycling. For instance, bikeways can be designated or constructed to physically separate bicycle traffic from pedestrian and vehicular traffic. The design of a bikeway naturally depends on site-specific circumstances. Three commonly used bikeway configurations are illustrated in Figure 5. These are defined and listed below in decreasing order with respect to their effectiveness in reducing bicycle conflicts with other traffic:

- Class I: A completely separated right-of-way designated for the exclusive use of bicycles. Pedestrian and motorist crossflows are minimized.
- Class II: A restricted right-of-way designated for the exclusive or semi-exclusive use of bicycles. Auto and bicycle lanes frequently are designated by signs and street markings. Through travel by motor vehicles or pedestrians is not allowed on Class II facilities. However, vehicle parking may be allowed. Crossflows by motorists (to gain access to

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*Referred to here as auto-substitution trips.

Table 27. Summary of Existing and Proposed Governmental Programs Designed to Increase the Use of Human-Powered Travel Modes

ENABLING LEGISLATION	PROGRAM DESCRIPTION	FUNDING PROVISIONS
DEPARTMENT OF TRANSPORTATION: FEDERAL HIGHWAY ADMINISTRATION		
Federal-Aid Highway Act of 1973; Section 124; as amended in 1976	Permits construction of bikeways and pedestrian walkways independent of highway construction projects.	A maximum of $2½ million annually per state and $45 million annually for the nation may be used for these projects. A total of $120 million is allotted for 1974-76. A 70% Federal, 30% State matching ratio is required.
Federal-Aid High-Way Program.	Bicycle and pedestrian facilities may be constructed as incidental features of highway construction projects. The bikeway or walkway must be within the right-of-way of the highway.	Financed with Federal-Aid funds used for the basic highway project. Projects are not subject to the funding limitations for independent bikeway or walkway projects.
Federal-Aid Highway Amendments Act of 1974, Sec. 119; Bikeway Demonstration Program.	Eligible projects must be suitable for commuting and/or recreation and located in urban or urbanized areas. Projects must be in accordance with the continuing comprehensive transportation planning process.	Funds were made available November 24, 1975 from a Congressional appropriation through the Department of Transportation and Related Agencies Appropriation Act of 1976. $10 million was authorized and $6 million has been appropriated. Federal share of any demonstration project is 80% of the total eligible cost of such program. Federal participation may include the cost of preliminary engineering, rights-of-way, construction, and evaluation.
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT		
Community Development Block Grants (replaces a number of programs such as the Open Space Land Program and Urban Renewal Program).	Construction of bikeways and walkways if the community determines that the projects are viable community development activities.	$2.8 billion is available during FY76. The funds are distributed on a formula basis between communities with populations over 50,000 and those communities with populations less than 50,000 who previously received funds from the Urban Renewal or the Open Space Program.
DEPARTMENT OF THE INTERIOR: BUREAU OF OUTDOOR RECREATION		
Land and Water Conservation Fund Act of 1965.	Bikeways and walkways in urban and rural areas as part of projects heavily oriented toward recreation and resource development.	A 50% Federal/50% State matching ratio is required. The State may use the funds or pass them through local governments.

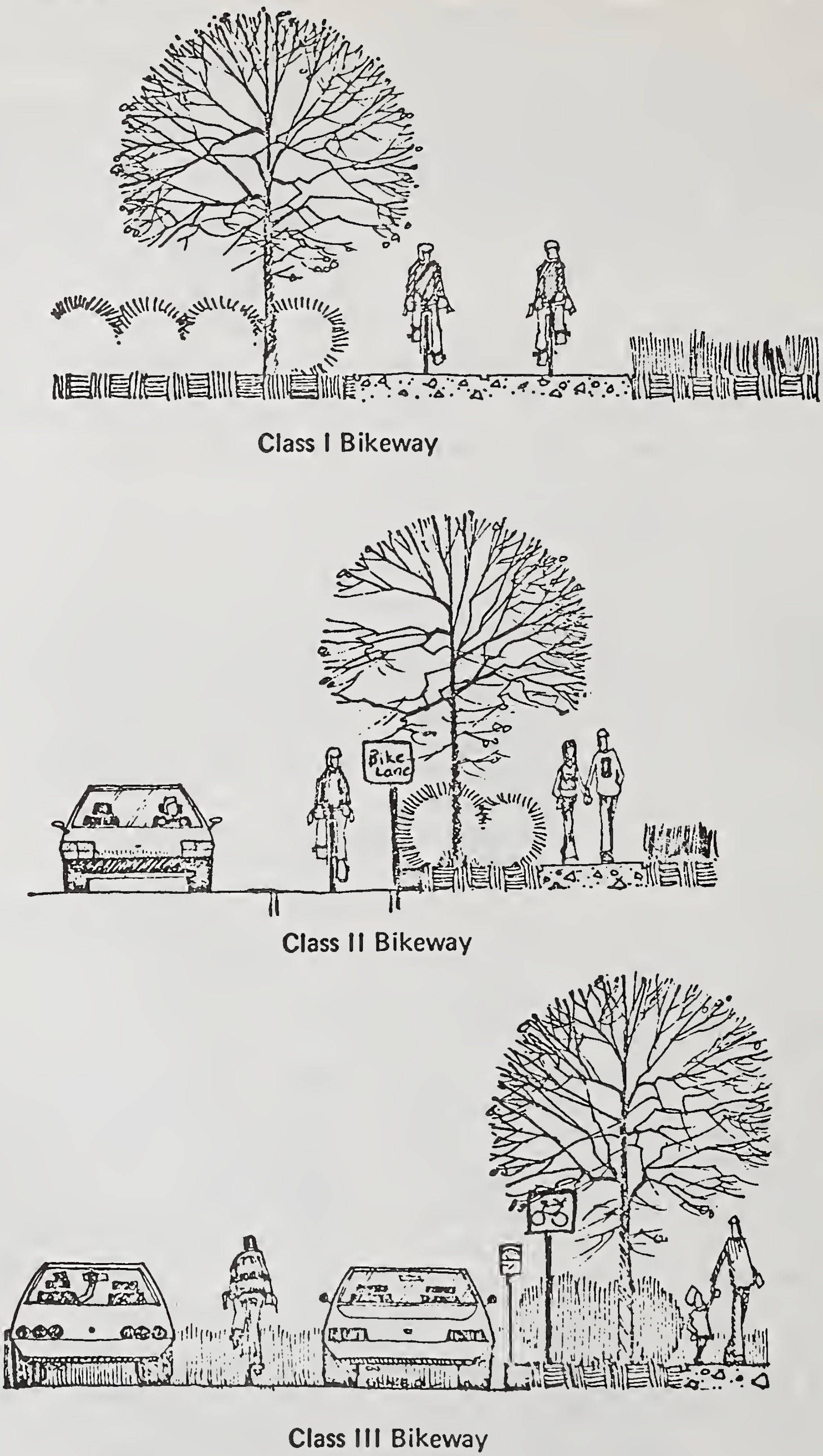

Figure 5. Class I, II, and III Bikeway Configurations

driveways, parking facilities, etc.) and pedestrians (to gain access to parked vehicles, bus stops, etc.) are allowed.

- Class III: A shared right-of-way designated by signs placed on vertical posts or stenciled on the pavement. Any bikeway sharing the through-traffic right-of-way with moving motor vehicles (not parked) and/or pedestrians is considered a Class III bikeway.

Although separate bicycle rights-of-way completely remove bicycles from the stream of the traffic (except at intersections), in urban areas it is often not feasible or desirable to do so. An approach based on designating the shared use of a roadway (or sidewalk) is usually more appropriate in these areas.

If an urban bicycle route system is to be an attractive alternative to auto travel,it must provide ready access to major trip-generating locations. Hence, providing clearly marked, uninterrupted routes from residential areas to activity centers should be a principal planning objective. This objective is reflected in the bicycle route networks planned by several communities in their attempts to shift some auto trips to bicycling. For instance, the plan for a citywide network of bicycle routes in Seattle, WA, emphasizes serving commuter needs by providing bikeway corridors from residential locations to principal employment centers. A highly successful commuter-oriented network of bicycle routes also has been established in Davis, CA. Davis's mild and dry climate, flat terrain, wide streets, and college town setting provide an ideal environment for bicycling. Therefore, it is not surprising that approximately three-fourths of the city's population own and use bicycles. In fact, on one major arterial bicycles were found to represent 40 percent of the peak-period traffic volume. Ninety percent of those bicycles were ridden by adults. Currently Davis has approximately 11.5 miles of Class II bicycle lanes and 6.5 miles of Class I bicycle paths. Also, all new housing developments are required to include bicycle paths. In Ann Arbor, MI, 16 miles of a planned 91-mile bicycle commuter network have recently been constructed. The 16 miles of Class I and Class II bicycle paths will soon be supplemented with a crosstown bicycle route.

Chicago, IL, has also developed an extensive urban bikeway system consisting of 130 miles of bicycle paths, on-street routes, and special purpose bike lanes that form the hub of a rapidly growing regional network. Commuter bike lanes within the network serve CBD-directed peak-period bicycle traffic. These lanes link a residential area, which has a high concentration of cyclists, to the downtown area.

The availability of convenient and secure storage and parking facilities for bicycles is very important in promoting bicycle use, and installation of these facilities should be included in any set of actions designed to increase bicycle use. According to a

Philadelphia Coalition survey of bicycling, 38 percent of the bicycle owners queried stated they would commute by bicycle if safe bikeways and secure parking were available. The survey also revealed that, if a modest investment in bicycle lanes and parking facilities were made, 5-10 percent of the auto commuters to the central city would commute by bicycle.

Bicycle parking facilities should be located near major trip generators--e.g., office buildings or shopping centers--and change-of-mode terminals such as bus stops and subway stations. Bicycle parking facilities also should be located where the possibility of theft is reduced. For instance, public parking garages and lots are good locations. However, when monitored locations are not available, placing bicycle racks in clear public view can be an effective solution.

The installation of bicycle lockers or racks at transit stops is reported to increase the area serviced by that stop by at least 15 times. In a Denver, CO, demonstration of a bicycle feeder system to transit routes, bicycle racks were installed at 21 bus stops. In San Francisco, CA, all BART subway stations are similarly equipped. Also, San Diego, CA, is planning to place completely enclosed bicycle lockers at a number of planned park-and-ride lots and at key transfer points along the transit network as part of a "bike-and-ride" program.

Transit/bicycle "piggyback" arrangements have also been successful in serving the needs of bicyclists who want to ride a bus but who must use their bicycle after leaving the bus. For example, in Santa Barbara, CA, a 14-bicycle trailer is attached to an express minibus that travels between the Santa Barbara CBD and the University of California, eight miles from the CBD. Cyclists pay a 15-cent surcharge for the service in addition to the 25-cent bus fare. The "Bike-Bus" carries approximately 125 bicycles per day on weekdays and 25 per day on weekends. A second trailer, which is expected to cost $2,000-4,000, is currently planned for operation along the same route. A similar service using a nine-passenger van was initiated across San Diego's Coronado Bridge in April 1975. The shuttle van carried 72 users daily during the fall of 1975.

"Piggyback" arrangements, carrying the bicycle on board the transit vehicle, have been implemented in Oakland and San Francisco, CA. In Oakland, CA, seats were removed from some buses to provide the "Pedal Hopper" service. After a successful year-long demonstration ending in December 1975, San Francisco's "Bikes-on-BART" program has become a regular transit service. In the Bikes-on-BART service, bicycles are carried in the rear section of the last subway car. Both of these services are offered only in specified off-peak periods. However, when sufficient peak-period transit capacity exists, providing space for bicycles to be carried on board during peak periods may also be feasible.

PROMOTING BICYCLING AS AN AUTO-SUBSTITUTION TRAVEL MODE. Despite the many social and private benefits gained through bicycling, experience has shown that construction or designation of bikeways in congested urban areas, in itself, may not be enough to cause a significant number of persons to switch to bicycle use--or even to assure reasonable use of the routes.

Promotional campaigns advertising the availability of bicycling facilities are commonly used to gain the public's interest. The advantages bicycling offers to the user and the community often are cited in these campaigns, which can be conducted by means of newspaper releases, film presentations, driver training and bicycle awareness courses, billboards, etc. Some of the benefits cited for bicycling in such campaigns are that the bicycle:

- Is inexpensive to own, operate, and maintain. For instance, it is estimated that a commuter who makes a four-mile round trip daily would save over $2,000 each year by riding a bicycle rather than driving.
- Consumes few natural resources in its production, operation, and maintenance.
- Contributes to the physiological well-being of the rider.
- Produces little noise and no air pollution.
- Requires little space to operate or to park, which reduces congestion and the need for parking facilities.

Even if bicycle promotional campaigns are successful in heightening interest in bicycling, a number of circumstances exist in urban (and rural) areas that could deter the prospective bicycle user. The degree of success attained in increasing auto-substitution bicycle trips depends both on the seriousness of the deterrents to bicycling in the local areas and the degree to which they can be ameliorated. For instance, the condition of the street surface, lighting, and potential conflicts between bicycles and pedestrians and motor vehicles often inhibit bicycle use. In Fresno, CA, 814 persons--322 of whom owned bicycles--were asked which of several factors discouraged them from using a bicycle for commuting purposes. Seventy-three percent of the bicycle owners and 64 percent of those who did not own a bicycle cited traffic hazards as an important factor in their decision not to commute by bicycle. It was the most important factor noted in the survey.

The bicyclist may encounter traffic conflicts with moving and parked vehicles when moving parallel to the traffic stream. However, the greatest danger to the bicyclist's safety occurs at intersections because of turning movements and the usually undefined rights-of-way of bicycles and motor vehicles making these movements. The specific traffic hazards the bicyclist faces at intersections are exemplified by the following questions, not addressed in most motor vehicle codes:

- Who has the right-of-way when a bicyclist is proceeding straight through an intersection and a driver is turning right? In the same situation, who has the right-of-way when there is a right-turn-only lane, when an exclusive bike lane has been placed at the edge of the roadway, or when the main roadway curves to the left and a minor roadway proceeds straight ahead?
- Should a bicyclist be permitted to pass a line of vehicles stopped in traffic, or should the bicyclist be required to wait in line with them?
- Most vehicle codes specify that, in executing left turns, bicycles moving in the space nearest the rightmost curb should cross over to the leftmost space allotted to traffic moving in that direction and should execute the turning maneuver in conformance with regulations governing motor vehicles (i.e., they should turn into the leftmost space allotted to vehicles moving in the direction turned). However should the vehicle alongside the bicycle yield the right-of-way to the bicyclist, permitting the bicyclist to cross ahead of the vehicle, or should the bicyclist stop and yield the right-of-way to the following motorists, crossing only when the way is clear?

One approach that can be taken to reduce bicycle traffic hazards, then, is to carefully review and possibly revise existing local ordinances to ensure that they clearly specify how bicycles and motorized vehicles should move in mixed traffic. Another approach is to use signs and lane markings to inform bicyclists and motorists of how they should interact in the traffic stream. Figure 6 shows how this approach might be implemented to reduce the hazards associated with right and left turning movements at intersections. As shown in Figure 6, bikeway lane markings should continue through the intersection. Another approach that can be effective in providing bikeway continuity is shown in Figure 7.

COSTS. Table 28 presents estimated costs per mile for the types of bikeways defined on pages 86 and 89. In estimating the total cost of a bicycle program, the kind and number of bicycle racks to be installed should be carefully considered. While the cost of bicycle racks is relatively low, it varies depending on size and design. For example, some bicycle racks can be purchased for as little as $20 per unit, while sturdier more sophisticated storage units may cost several hundred dollars. Hence, if the use of a large number of the more expensive storage units is contemplated, the total cost for bicycle racks can be fairly high.

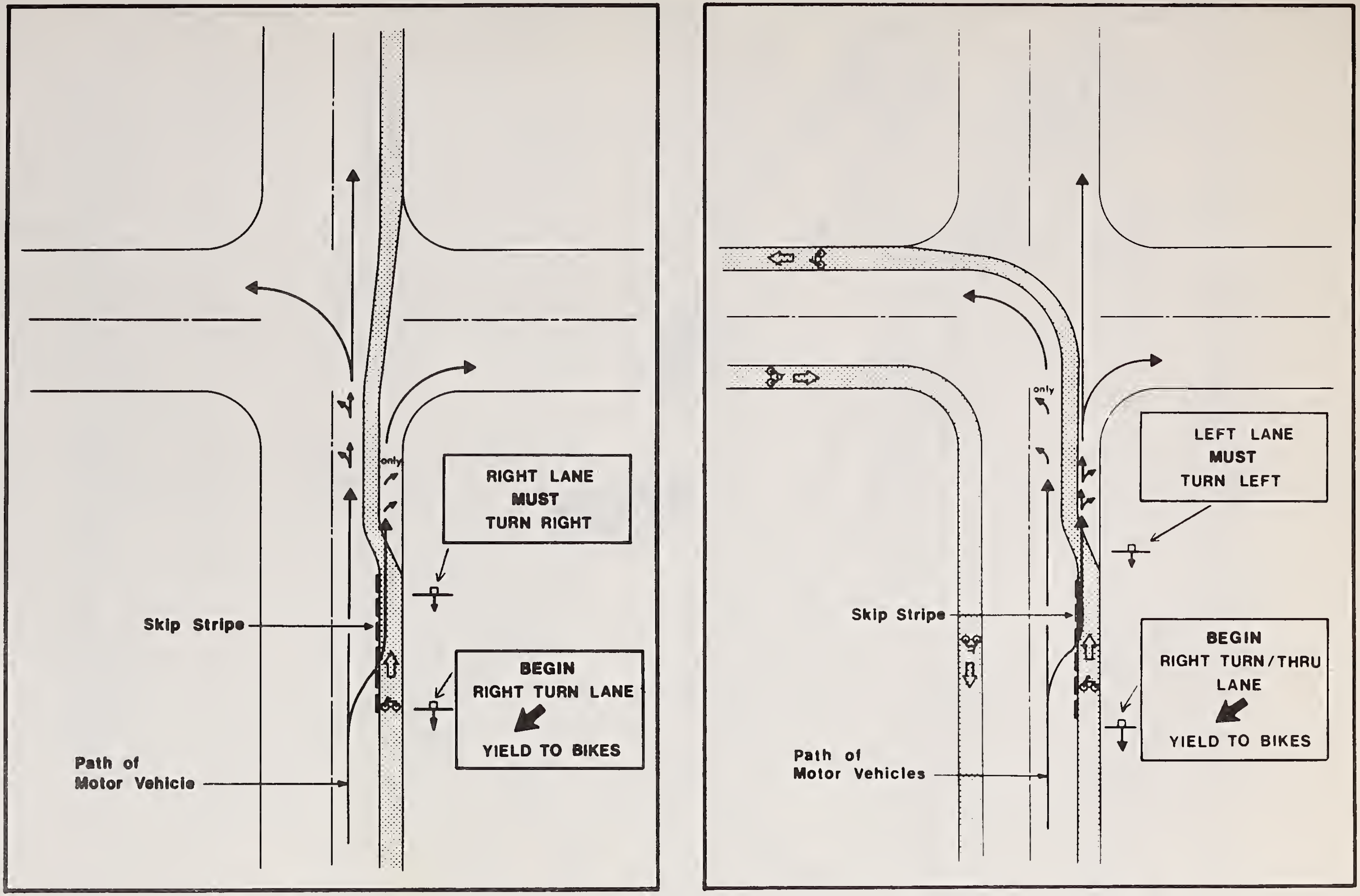

Figure 6. Channelization Techniques to Reduce Bicycle/Vehicle Right and Left-Turn Conflicts at Intersections

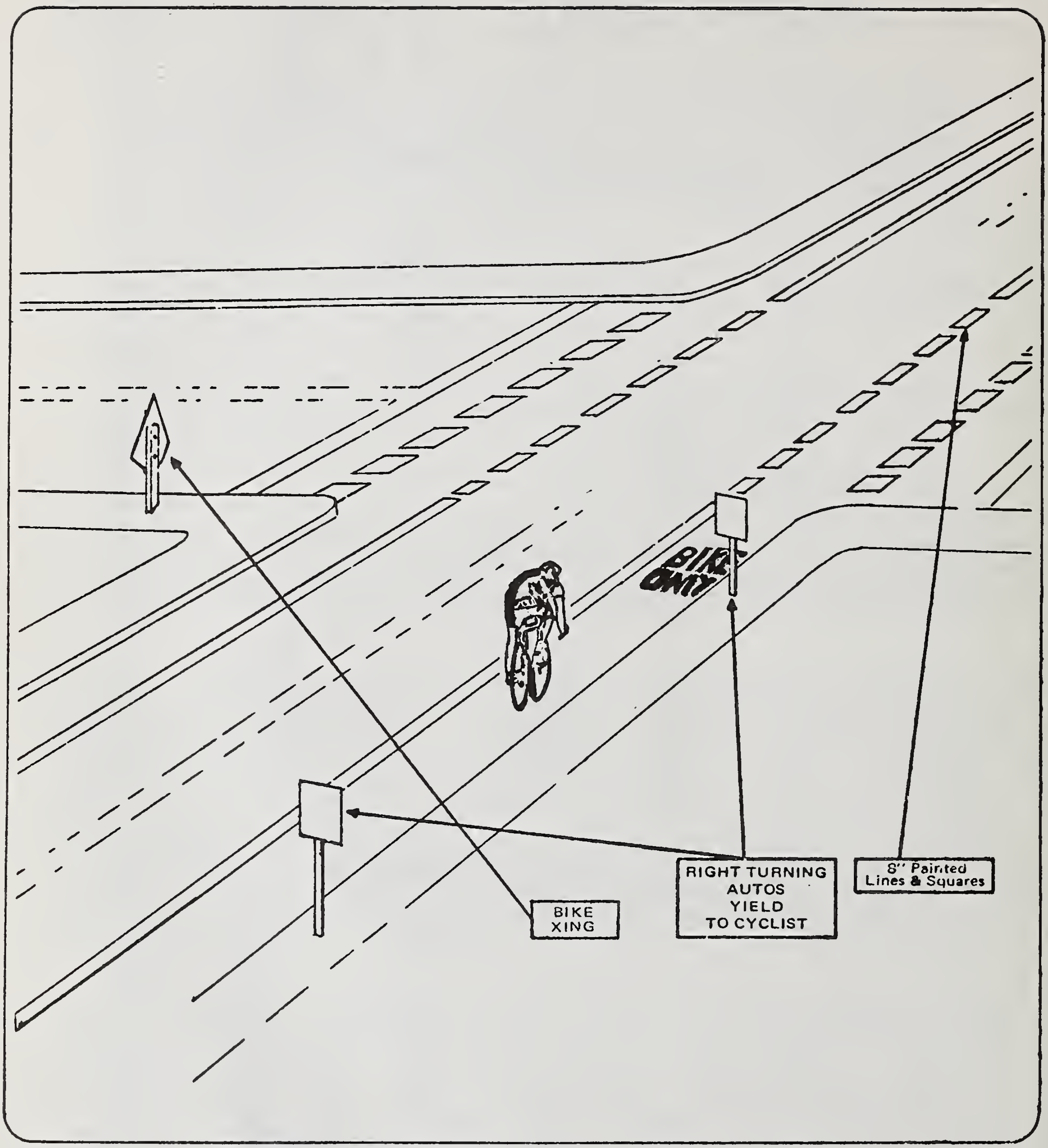

Figure 7. An Approach to Providing Bikeway Continuity at Intersections

Table 28. Estimated Bikeway Costs

BIKEWAY CLASS	ESTIMATED COST PER MILE ($)*					
	Signing	Striping	Barrier	Pavement and Base	Right-of-Way	Total
Class I	400	0	0	10,560	12,100**	22,660
Class II:						
Protected	400	0	2,650	0	0	3,050
Unprotected	500	500	0	0	0	1,000
Class III	500	0	0	0	0	500

*Costs vary depending upon actual design treatment and local conditions.
**Right-of-way cost for a 10-foot wide strip estimated at a land value of $10,000 per acre.

BIKEWAY DESIGN. Site-specific conditions and local priorities will largely determine which bikeway designs are most suitable for different locations. Table 29 shows how levels of service vary with the width of a bikeway. As a general guideline, levels of service less than "C" should be avoided, if possible.

When sufficient space is not available to install a multiple-lane facility, but 42 or more inches can be reserved for bikeway use, installation of a single-lane bikeway is recommended. In addition to the lane widths shown in Table 29, space must be allowed to permit the bicyclist to clear adjacent objects. Table 30 presents guidelines on the clearance distance recommended for different circumstances. An overhead clearance distance of 8-10 feet is desirable when objects, such as tree branches, are present over the bikeway. Greater clearance is recommended for continuous overhead obstructions--e.g., when a bikeway passes under a roadway.

Walking as a Substitute for Auto Travel

PEDESTRIAN FACILITIES. As discussed earlier, measures to upgrade the pedestrians' environment and to improve pedestrian traffic flow and safety, coupled with other measures designed to motivate the public to walk short distances rather than to drive, can have a significant effect on reducing urban congestion and air pollution and on conserving fuel. Improving the existing pedestrian circulation system and constructing new facilities--such as pedestrian overpasses and underpasses, malls, and skywalks--provide physical conditions conducive to walking by improving pedestrian safety, relieving congestion, reducing pedestrian conflicts with other modes and, in some cases, providing shelter from inclement weather.

Table 29. Bikeway Levels of Service Associated with Bicycle Lane Widths

LEVEL OF SERVICE		MINIMUM LANE WIDTH (Inches)
A*	Free flow with low volumes and full choice of velocity and lateral lane position. Average velocity usually above 11 miles per hour.	48
B*	Stable flow with significant volumes and slight slowing of average stream velocity (10.6 to 11 miles per hour), but there is still a reasonably wide range of velocities present.	45
C	Flow is still stable, but speeds are markedly depressed. Maneuverability is restricted and velocity is largely determined by stream/velocity rather than choice. Average velocity is in the 9.5- to 10.5-mile per hour range.	42
D	Flow speed is greatly depressed and maneuverability is highly restricted. Velocity is in the 8- to 9.5-mile per hour range.	38
E	Flow speed is tremendously reduced. Maintaining balance may become a factor. Velocity is in the 6- to 8-mile per hour range.	30

*Lane width refers to the width of a single lane in a multiple-lane facility.

Table 30. Recommended Clearance Distances for Bikeways

BOUNDARY CONDITION	CLEARANCE (inches)
Parked vehicle	14.5
Continuous lateral obstruction (walls, fences)	12.0
Intermittent lateral obstruction (poles, trees)	18.0
Curb/Gutter	12.0, or width of gutter if unrideable

Existing urban pedestrian facilities can be improved by widening sidewalks, clearing them of impediments to pedestrian traffic, providing better lighting, and/or making it easier for pedestrians to cross streets (e.g., by providing midblock crossings and increasing the time allotted to make the crossing). In many urban areas where it is not feasible to widen the existing sidewalks, it often is possible to improve pedestrian circulation by relocating refuse containers, fire hydrants, newsstands, mail boxes, phone booths, etc. Where many tall buildings are located close together, skywalks can be constructed to connect the buildings, reducing the need for pedestrians to cross streets at street level. Atlanta, Cincinanti, Minneapolis, and St. Paul are among the cities that have successfully used skywalks to improve pedestrian flow. In Minneapolis nine completely enclosed and climate-controlled, second-story skyway bridges connect 17 major buildings in a 10-block area. Five more skywalks are proposed.

In developing urban areas, communities can ensure that the desired attention is given to pedestrian facilities without increasing public costs by incorporating bonus zoning provisions into the building code. Under these provisions the floor space of a development can be increased--over the amount permitted by zoning regulations--by an amount equivalent to the total number of pedestrian improvement "units" included in the development. These improvements include sidewalk widening, multiple building entrances, access to transit or parking garages, subsurface concourse or overhead bridge connections to other buildings or transit facilities, arcades, malls, plazas, off-street taxi and bus passenger loading areas, off-street truck berths, and midblock connectors. Each improvement has a rated unit value. Bonus zoning has been successfully used to improve the pedestrian environment in New York City's theater district.

In some urban areas the installation of people mover systems may be successful in helping to promote walking as a viable substitute for auto travel. People mover systems include electric carts, pedestrian conveyor belt systems, and other types of fixed guideway systems. Pedestrian conveyor belt systems have generally been used only in large airports; to date, their applicability to weather-exposed areas has not been tested. UMTA currently is planning to demonstrate the feasibility of using fully automated people movers on exclusive guideways in a number of cities to help solve the problem of circulation in congested CBDs. These people mover systems will be up to three miles long and are expected to enhance the downtown pedestrian environment as well as to strengthen the central city's economic position.

Many urban areas have created pedestrian-only environments in establishing urban areas to encourage walking rather than auto travel and to make the urban setting more aesthetically satisfying. For example, in Washington, DC, the objective of the "Streets for People" program is to develop, where feasible, pedestrian-oriented areas with decorative pavement, plantings, fountains, kiosks, outdoor furniture, and information centers. The plan is to eliminate autos from these areas and to attract the public to them with exhibits of fine arts and crafts, fairs, and performing arts presentations. San Diego also plans to undertake a substantial downtown redevelopment project that will include widening sidewalks and prohibiting auto travel in certain areas. The Los Angeles Bunker Hill development is also pedestrian oriented since underground parking and peripheral parking facilities with shuttle bus service reduce auto use in the vicinity of Bunker Hill's shops, theaters, and restaurants. Pedestrian plazas have also been successfully implemented in many areas--e.g., Ghiradelli Square in San Francisco, Charles Center in Baltimore, Constitution Square in Hartford, and the Chase Manhattan Plaza in New York.

Below-surface pedestrian circulation networks have been developed in several urban areas. For example, Montreal's system of pedestrian passageways links CBD stores and hotels to public transportation facilities and contains a number of underground commercial establishments. The network is completely enclosed and climate controlled. A similar network in Toronto, scheduled for completion by 1980, will also link major CBD trip-generating locations with public transportation facilities.

In Chicago the planned Illinois Center development, which is being constructed on an 83-acre site near the CBD, includes an underground pedestrian concourse. The Center will contain offices, apartments, condominiums, and hotels and will be located near parks and the harbor. The pedestrian concourse will link the entire development together and will offer opportunities for shopping and entertainment.

Very little data exists on how effective pedestrian-only environments are in increasing auto-substitution pedestrian trips. However, in Europe, pedestrian volumes increased 20-50 percent on streets where auto traffic was prohibited. Similarly, the experimental closing of New York's Madison Avenue to weekend vehicular travel more than doubled pedestrian volumes without decreasing pedestrian volumes on the nearby (and more popular) Fifth Avenue. This evidence at least indicates that people will walk more if the environment is conducive to walking. Increased pedestrian volumes have also been shown to increase the sales volumes of stores located in the auto-free environment.

COSTS. Many of the measures discussed above to improve the pedestrian's environment are relatively inexpensive or can be implemented at no cost to the public. For instance, little capital outlay is required to relocate sidewalk impediments. Constructing or widening sidewalks and walkways is also relatively inexpensive if the city owns the right-of-way. Concrete work for sidewalks now costs about $1.00 per square foot. Grading costs, of course, vary according to site-specific conditions. Sidewalk curbs and gutters currently cost about $3.00 per linear foot.

More extensive pedestrian facilities like overpasses and underpasses, skywalks, and malls are, of course, more costly. For example, Minneapolis's skywalks cost about $100,000 each. Costs incurred in developing five pedestrian malls are presented in the discussion on auto-restricted zones (see Table 32, page 103).

DESIGN SPECIFICATION FOR SIDEWALKS AND WALKWAYS. In general, traffic engineering standards indicate that sidewalks in residential areas should be no less than four feet wide. However, in commercial areas or on major school routes, a minimum width of six feet is recommended. In densely populated areas the effective sidewalk width is usually about two feet less than the actual width due to the objects that must be placed on the sidewalk.

Table 31 shows the levels of service that can be expected on sidewalks and walkways of different widths, depending on the number of pedestrians using the facility. The average flow volume can be used to determine the number of pedestrians that can pass over a sidewalk or walkway in a given period of time at each level of service. For example, as many as 4,200 persons per hour can travel on a sidewalk with a net effective width of 10 feet at an "A" level of service.

AUTO-RESTRICTED ZONES

Restricting vehicles from entering or traveling through specified zones is a technique that has been applied widely in Europe to reduce auto traffic in congested urban areas. This technique has been successfully applied to a few cities in the United States, and a growing number of U.S. cities plan to create auto-restricted zones in their CBDs in the near future. As discussed below, the auto-restricted zone concept can also be applied to reduce vehicular traffic in residential areas in order to improve urban living conditions.

To date, auto-restricted zones in the United States have been small and most exclude all vehicles. Hence, when implemented in activity centers, the zones resemble the pedestrian malls discussed above. However, the auto-restricted zone concept actually entails controlling the movement of vehicles in a fairly large area and includes the possibility that certain types of vehicular traffic will be permitted. Although supplemental licensing schemes (discussed in pages 52-54) also restrict auto travel in designated zones, they differ from the

Table 31. Pedestrian Levels of Service on Sidewalks and Walkways

LEVEL OF SERVICE	AVERAGE PEDESTRIAN AREA OCCUPANCY	AVERAGE FLOW VOLUME	CHARACTERISTICS
A	35 square feet per person or greater	7 PFM or less*	Pedestrian can select speed, bypass others, avoid conflicts, etc. Public buildings or plazas without severe peaking or space limitations fit in this level.
B	25-35 square feet per person	7-10 PFM	Equal to level "A" in one direction flow; minor conflicts will appear with reverse direction or cross flow. Level "B" is consistent with transportation terminals and buildings with recurrent, but not severe, peaks.
C	15-25 square feet per person	10-15 PFM	In level "C", freedom to select speed and passing is restricted; cross and reverse flows can lead to conflict, requiring frequent adjustment of speed and directions. This is a recommended design level for heavily used transportation terminals, public buildings, or open space when severe peaking plus space restrictions limit design flexibility.
D	10-15 square feet per person	15-20 PFM	Here the majority of pedestrians are hindered, with those involved in cross and reverse flow severely restricted. Multiple conflicts are common. An example of this design level is our most crowded public areas.
E	5-10 square feet per person	20-25 PFM	In level "E", all pedestrians would be hindered. Only shuffling is possible. Reverse and cross movements would be extremely difficult. Level "E" should only be used where peaks are very short.
F	5 square feet per person or less	variable up to 25 PFM	Shuffling is the only possible method of movement. Frequent and unavoidable contact; not recommended in any case.

*PFM = Pedestrians per foot width of walkway per minute.

auto-restricted zone concept. The latter concept usually involves physical restraints rather than economic and these restaints are applied to all travel periods, not only peak periods.

Vehicle Restraints in Residential Areas

In August 1975 a vehicle restraint plan was implemented on certain residential streets in Berkeley, CA, in order to divert through traffic to main thoroughfares. The plan uses diverters, signals, and signs to impede auto travel on narrow neighborhood streets. Approximately $600,000 was allocated for purchase of the traffic control devices, over half of which have now been installed. After the plan was implemented, it was criticized by some residents, principally because the traffic diversions caused emergency vehicles to delay in responding to calls. However, a June 1976 referendum to end the traffic diversion plan was defeated decisively, showing that the community continued to be in favor of the plan and its objectives. A growing number of urban areas are using techniques similar to the Berkeley plan to restrain auto traffic in residential areas. For example, restraints on auto traffic have been implemented successfully in Portland, OR, Seattle, WA, Isla Vista, CA, and are planned in San Francisco, CA.

AUTO-RESTRICTED ZONES IN THE UNITED STATES. A number of cities have created relatively small auto-free zones in congested areas of the CBD. Most of these provide for fringe parking and increased transit service to and from the zones. In Miami Beach, FL, and Kalamazoo, MI, pedestrian trains are available within the zone to aid pedestrian circulation. In Kalamazoo the pedestrian trains also shuttle between the auto-free zone and nearby parking lots.

A demonstration of the auto restricted zone concept in fairly large zones of several cities is currently being planned by UMTA. Providence, RI, Memphis, TN, Boston, MA, Burlington, VT, and Tuscon, AZ, are participating in the feasibility study phase of the demonstration. Implementation plans are currently being drawn up for the last three cities cited. However, only two of those cities will be selected for the initial demonstration. Automobile traffic will not be totally eliminated from the zone in the demonstration, nor will off-street parking be restricted. Rather, some of the streets in the zone will be transformed into pedestrian- and transit-only streets, and automobiles will be permitted to use the remaining streets. The demonstration is not expected to affect businesses in the zone adversely since a number of measures have been included to insure that the viability of the center city is maintained and/or enhanced. These include making provisions for the pick up and delivery of goods, improving access by public transportation, and improving pedestrian circulation.

Costs. Two major investment costs are incurred when auto restricted zones are implemented in established urban areas: the cost of altering subsurface facilities and the cost for surface improvements. Generally the greatest proportion of the total cost is subsurface related (e.g., improving and/or moving utilities and changing drainage facilities). As shown in Table 32, the cost of instituting auto-free zones in many U.S. cities has not been unduly capital intensive. However, the most comprehensive auto-free zone in the United States--the Nicollet Mall in Minneapolis, MN--required $3.87 million to complete. Of this amount, $2.57 million was required for subsurface construction and $1.3 million was required for surface improvements.

Ancillary Benefits. Auto-restricted zones frequently can be used to attain a number of community goals in addition to reducing congestion. For example, Atlanta restored a four square block area that was part of a long-forgotten, century-old commercial section, thereby promoting the city's historic past in addition to creating a novel, high-interest pedestrian-only precinct. Generally, auto-restricted zones also have a positive effect on auto emissions and noise levels in the zone. For example, Tokyo banned autos from four shopping districts on Sunday, the busiest shopping day, and found that carbon monoxide levels and noise levels dropped considerably as a result. New York City also recorded a 90 percent reduction in carbon monoxide levels on some auto-free streets, and a temporary ban on autos on Fifth Avenue caused noise levels to drop from 78 decibels to 58 decibels. During a 1971, 10-day vehicle-free zone experiment in Marseilles, France, carbon monoxide emissions were reduced to approximately 20 percent of their former level.

Applicability Criteria and Planning Considerations. Small and medium-sized cities are generally considered most amenable to auto-restricted or auto-free zones that encompass the entire CBD. In large cities the concept is usually practical only if implemented in especially congested sections of the CBD.

As the size of the zone increases, increasing consideration must be given to raising the level of transit and paratransit service to, from, and within the zone and to providing for alternate transportation modes such as bicycling and walking, pedestrian trains or trams, and people movers.

Perhaps the most important consideration in evaluating the feasibility of a proposed traffic restraint area is whether the capacity of the overall roadway network is adequate to handle traffic that would be diverted from or rerouted around a vehicle-free zone. If displaced traffic creates congestion and air pollution problems in surrounding areas, as has occurred in New York City and in Rome, the action becomes self-defeating. Hence, adequate planning for traffic movement at the periphery of the zone is essential to the success of the project.

Table 32. Costs and Characteristics of Five Auto-Free Zones in the United States

LOCATION	LENGTH		CAPITAL COSTS	IMPACTS	REMARKS
	Blocks	Feet			
Atchison, KS	2½	NA	$330,000	Business increased 25% for mall stores.	Off-street parking provided for 1,100 vehicles. Rear door truck access.
Pomona, CA	9	NA	$640,000	Within first year retail sales up 18% and department store sales up 36%.	2,000 parking spaces provided. Mall Commission established to oversee merchandising and coordinate activities.
Kalamazoo, MI Burdick Mall	3	1,200	$114,000 general utility work, landscaping and traffic improvement.	15% sales increase.	Rear door or nearby cross-street truck access. Pedes-Train takes pedestrians through mall and to nearby parking lots.
Miami Beach, FL Lincoln Road Mall	8	3,000	$400,000 landscaping and art work; $200,000 public works. ($150,000/year maintenance)	Percent of sales increase not available.	2,000 rear door parking places. Rear door truck access. Pedes-Train. Less activity at west end of the mall where parking is limited.
Providence, RI Westminster Mall	4	950	$530,000	35% increase in sales.	1,000 nearby parking spaces. One-way bus street that crosses mall and provides good mall transit service.

NA = Not available.

Other actions that could be implemented in conjunction with auto-restricted zones include controlling the supply and/or price of available parking near or in the zone, making traffic flow improvements on streets adjacent to the restricted zone, encouraging the use of human-powered travel, and promoting the use of public transit, particularly through the concept of peripheral parking and express transit service.

THE EUROPEAN TRAFFIC CELL CONCEPT. Restricting the flow of traffic through crowded CBDs, while permitting auto access to zones or traffic cells in the CBD, is another form of the auto-restricted zone concept that has been used successfully in European cities. The traffic cell technique involves dividing a city or a section of a city into zones or cells and placing physical barriers at the cell boundaries to prevent traffic from passing between cells. The restricted zone is usually surrounded by a circumferential road, and entry to or egress from a cell is permitted only at designated points on this road.

Bremen, Germany, and Göthenburg, Sweden, have successfully used the traffic cell concept to reduce through traffic and to improve the pedestrian environment in their CBDs. In 1960, the historical city center of Bremen, an area approximately 0.6 by 0.4 miles, was divided into four traffic cells. The two streets forming the boundaries were reserved for the use of buses and trams. Pedestrian areas were created in portions of each cell, and the remaining streets were converted to one-way flow. After a decade of operation, business in the area has not been adversely affected, nor has the center city become decentralized, as some had feared would occur.

Göthenburg's traffic cells were established in 1970 and promoted as an improvement plan to reduce congestion and maintain center city viability. The Göthenburg core, an area approximately 0.25 by 0.5 miles, is divided into five zones, each separated by physical barriers to prohibit the passage of through-vehicles (except transit and emergency vehicles). Figure 8 is a schematic representation of the plan showing the changes in traffic volumes that occurred along the major arterials following implementation of the plan. The traffic cell plan has been favorably received by most of the people affected. An interim study conducted in 1975 showed that automobile volumes within the area were reduced by as much as 70 percent. Indications are that approximately one-third of the businesses in the area have been affected positively and one-third have been affected adversely, the remainder have noticed no change in business activity. Public sentiment seems to be in favor of enlarging the traffic cell area to include adjacent areas, which would make the total area about six times larger than at present. Liverpool, England, is reportedly planning a two-cell version of Göthenburg's vehicle restraint scheme.

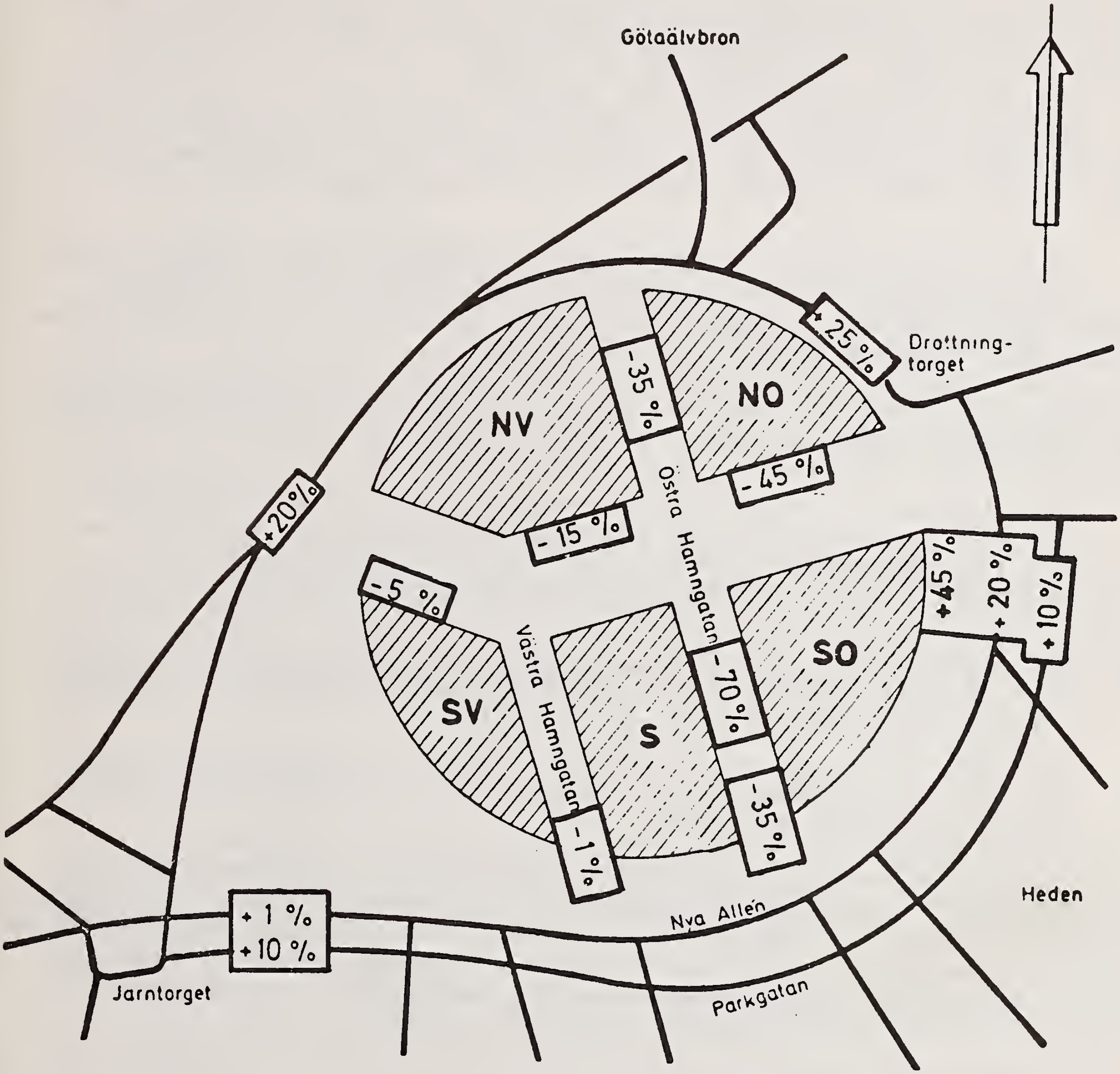

Figure 8. Schematic Representation of Göthenburg, Sweden, Traffic Restraint System

Note: Hatched areas for quadrants; lines represent major arterials. Numbers refer to the percentage of change in vehicle volume along central area routes eight weeks after introducing the scheme on August 18, 1970.

Göthenburg's traffic cell scheme has also greatly improved the speed and regularity of public transit. For instance, a six percent increase in transit trips to the CBD was recorded on weekdays after the traffic cells were implemented and a two percent increase in transit trips was recorded on Saturdays. Polls revealed that people had switched to transit primarily because of problems they had encountered in parking--i.e., if they were unable to find a parking space in the first cell they entered, they were forced to drive to the perimeter, get on the ring road, drive into another cell to park, and then walk back into the desired cell.

As a result of the traffic cells, Göthenburg has experienced a 10 percent reduction in accidents, carbon monoxide concentrations reportedly have been reduced from 30 ppm to 5 ppm, and noise levels have dropped from 75 to 72 decibels.

The experience gained in Bremen and Göthenburg indicates that the following items must be considered in the development of traffic cells:

- Any attempt to create traffic cells requires considerable planning to work out the many details involved, such as rerouting of traffic in the area, providing reasonable parking facilities, improving public transit service, etc.

- It is essential that adequate road space adjacent to the traffic cells be available to absorb diverted traffic. Ideally, a ring road should surround the cells.
- The idea of using traffic cells should be promoted as a central city improvement plan rather than primarily as an automobile restraint measure.

The total cost of the Gothenburg program is reported to have been $220,000, including the cost of an extensive public information program ($140,000), setting up traffic barriers, locating tram stops, painting zone borderlines and transit routes on streets, erecting signs, and enlarging and improving the perfpheral streets to ensure that they could handle diverted traffic.

SECTION 6
TRANSIT AND PARATRANSIT SERVICE IMPROVEMENTS

A number of aspects of transit and paratransit operations can be improved to enhance the level of service. Those discussed here are:

- Transit marketing
- Security measures
- Transit shelters
- Transit terminals
- Transit fare policies and fare collection techniques.

In addition to these improvements, a number of actions must be taken to enhance the level of service provided by the entire public transportation system. These, discussed later in this section, center on (1) extending the service provided by transit operations with paratransit operations and (2) integrating the services provided by transit and paratransit operations into a unified network of services.

All of these actions should complement the actions discussed in previous sections, which aim to improve traffic flow by causing a modal shift from the use of low-occupancy autos to high-occupancy modes. A corollary objective of the transit service improvements is to provide a reasonable level of service for those dependent on public transportation.

TRANSIT MARKETING

Transit marketing involves not only selling the transit system to prospective riders but also continually monitoring and evaluating it in terms of its responsiveness to the patrons' service needs. Hence, the primary objectives of transit marketing are to:

- Develop a favorable image of the transit system and its activities.
- Make the public aware of the scope of services available.
- Promote and increase ridership--i.e., attract new riders and encourage present riders to use transit more frequently--by continually responding to the patrons' service needs. This will, in turn, improve the quality of transit system's service.

Essential to the realization of these objectives is the development of a comprehensive marketing program that integrates market research information with pricing policies, communication programs, and of course, program monitoring and evaluation. Although transit ridership can be influenced by other variables, there have been instances where transit operators have largely attributed increases in ridership to comprehensive marketing programs based on aggressive promotional campaigns. These instances are documented in Table 33.

Table 33. Ridership Increases in Six Bus Systems Attributed to Transit Marketing

LOCATION	INCREASE IN RIDERSHIP (%)	MONTHS COMPARED	OTHER PROMOTIONAL PROGRAMS
Nashville, TN	25.8	10/74;10/75	Continuing service improvements (e.g., new routes and schedules); special fare programs (Nickel Day and reduced student fares); fareless flyer.
Duluth, MI	26.6	9/74;9/75	Instituted a telephone information center.
Pittsburgh, PA	22.2 9.2	9/73;9/75 9/74;9/75	Inexpensive weekend travel pass good for all travel modes; free fare on roving wild card bus; several free or reduced fare programs during off-peak hours (Tuesday Special, First Day of Spring); special fare programs.
Seattle, WA	19.1 4.7	10/73;10/75 10/74;10/75	Free "Magic Carpet" service in downtown area.
Portland, OR	20	1/75;10/75	Change from zonal to flat fare; institution of monthly transit pass; fare-free transit zones in CBD; new park-and-ride lots.
Akron, OH	19.2	10/74;10/75	Several new buses; several buses painted red/white/blue to help celebrate local centennial; fareless zone along downtown area; annual newspaper promotional supplement providing information on transit; special fare programs (Nickel Day, Dime Day); "Ride-Metro" iron-on decals placed in local paper.

Market Research

Market research can help develop an urban transportation strategy that links service planning or service improvements with the needs of potential users. For existing systems, the transit agency can use demographic profiles, passenger counts, interviews, and questionnaires to obtain basic data on transit use, passenger attitudes and preferences, the price the consumer is willing to pay, trip purpose, etc. Attitude and awareness studies, for instance, have been used in Seattle, WA, and West Lafayette, IN, to gauge feelings about local transit and the effectiveness of promotional programs as well as to obtain descriptions of the characteristics of riders and nonriders. The Metropolitan Transit Commission in St. Paul, MN, used many ways to identify consumer needs and desires: for example, it formed citizens advisory committees, interviewed consumers and potential consumers, worked with major employers to identify the transportation needs of their employees, and conducted numerous transportation-related studies.

From an analysis of the market research data, transit management can determine the riders' transportation needs--e.g., clean, comfortable vehicles, convenient routes and schedules, adequate shelters and/or benches at transit stops, equitable fare plans, and reliable express service during peak periods. Using this information as a basis, it can then create a transportation system that is responsive to these needs and that is within the scope of the transit company's capabilities. Such a system would, of course, improve the quality of transit services, which is perhaps the most important objective of any transit marketing program.

Pricing Policies

Once attainable service parameters have been established, product pricing policies must be determined. Based on market research data on (1) the consumer's product expectations and (2) what he considers a reasonable fare for transit service, it is possible to develop a pricing policy that can be used to increase transit ridership. Usually this is done by employing special low-fare programs for certain segments of the market and/or at certain times of the day or week. Dime Time, Nickel Day, Fareless Flyers, and the Big Buck Weekend are just a few examples of this technique. However, in order for these and other similar programs to produce and maintain increases in ridership, they must be accompanied by service and equipment improvements, which will in turn mean greater convenience for the rider.

Reducing fares or employing promotional fares only on underutilized routes and/or reducing fares during off-peak periods are other ways of using pricing policies to increase ridership. Successful examples of reduced off-peak period fares are documented in Table 34.

Table 34. The Effect of Fare Programs in Five Cities Where Off-Peak Period Fares Were Decreased

LOCATION	AFFECTED OFF-PEAK HOURS	FARE		COMMENTS
		Peak (¢)	Off-Peak (¢)	
Chicago Transit Authority Chicago, IL	All day Sunday	45	25	Increase in Sunday ridership.
Lehigh and Northampton Transit Authority Allentown, PA	10 a.m. to 3 p.m. weekdays; all day Saturday	35	25	Saturday ridership increased 110%. Off-peak weekday ridership increased 73%.
Louisville Transit Company Louisville, KY	10 a.m. to 2 p.m. weekdays; all day on weekends	50	25	Overall ridership increased by 25%. Off-peak ridership increased from 55% to 67% of all ridership.
Mercer Metro Trenton, NJ	10 a.m. to 2 p.m. and after 6 p.m. Monday through Saturday; all day Sunday	30	15	Off-peak ridership increased 50%.
Metropolitan Transportation Authority New York, NY	All day Sunday	35 one-way	35 round-trip	Sunday ridership increased. Sunday revenues declined.

Communication Programs

Once a responsive transit system is devised, a communication program is essential. A transit communication program should serve two purposes. First, it should inform the general public of the scope of the transit services available and advertise its benefits. Second it should tell the potential rider how to use the system. Hence, the communication program should convey the message that transit riding is beneficial and easily used, thus promoting public transit as a viable alternative to the private automobile. A successful communication program might include an aggressive, media-oriented promotional campaign, improved dissemination of basic transit information, such as time schedules and routing patterns, and improved identification of the system.

ADVERTISING AND PROMOTION. Mass advertising can be effective in informing the public of transit benefits, special fare programs, and, of even greater importance, the range of routing and scheduling options and how to use the transit system. For example, in Seattle, WA, the transit system is promoting ridership by means of an aggressive marketing effort, new facilities, expanded routes, and special services. In order to keep the public informed about the transit services, some 4.5 million pieces of information--e.g., transit schedules, maps, newsletters, and press releases--are being disseminated annually. Transit ridership is increasing at an annual rate of 10.4 percent--which is attributed to improved service and improved information on the system.

Generally, marketing efforts are directed toward making the consumer aware that mass transit is, indeed, a valid alternative to private auto use. In order to ensure that passengers acquire that knowledge first-hand, bus company- or merchant-sponsored travel inducements in the form of free or reduced fares are generally used to encourage transit patronage. Button days, coupons, fareless zones, and fare-free buses are only a few of the techniques used in promotional campaigns.

The presence of the transit vehicle can function as an advertising medium in itself. It tells the potential patron that service exists in that location. Through the use of trade exchanges, the transit fleet can be used to increase the company's advertising coverage. For example, Akron's (OH) Metropolitan Regional Transit and local radio stations entered into an advertisement trade exchange whereby radio station call letters are posted on six promotional buses and the transit company gains an equivalent amount of "free" radio air time for transit commercials. The air time granted Metro during 1975 was estimated to be worth $40,000. A transit company in Pittsburgh, PA, engages in a similar trade exchange. In exchange for free traffic reports to local radio stations, the transit company acquires free prime time radio advertising.

USER INFORMATION AIDS. The dissemination of information to transit users is essential to a successful marketing program. Since a lack of easily obtainable, clearly understandable information can discourage potential patrons, clearly written route and schedule plans should be made easily accessible. For instance, timetables and system maps can be permanently affixed to transit shelters, benches, and buses; made available through a telephone "hotline"; posted throughout transit terminals; printed in local newspapers; and distributed in pocket-sized form at transit information centers and other public places.

Many communities also have found that a manned transit information center is highly effective for disseminating information. For example, Norfolk, VA, and Madison, WI, have permanent facilities for staff personnel who provide personal service to walk-ins or telephone queries. Portable information centers have also proved popular in serving the walk-in consumer. For example, in an effort to encourage ridership and to increase public awareness of the transit system, Pennsylvania's Lehigh and Northampton Transportation Authority (LANTA) is using a portable information center in the central business districts of Allentown, Bethlehem, or Easton, the three metropolitan areas served by LANTA. The center complements the existing services, which include a telephone number for information and schedule racks placed in most of the major department stores, shopping malls, government buildings, and banks in the three areas.

Similarly, San Francisco's AC Transit, in cooperation with the University of California at Berkeley, staged a promotional campaign during UC Berkeley's registration week. Bus timetables, route maps, and brochures on how to ride transit to the campus were made available at an AC Transit information booth on campus.

SYSTEM IDENTIFICATION. The promotion of transit through the availability of information must also be complemented by a campaign to improve the identification of the system. Several transit systems have used graphics to create a strong visual image. The creation of a distinctive logogram and the use of colors and/or word symbols for transit vehicles and facilities can aid in system identification and public awareness of transit improvements and modernization. For instance, San Francisco's Municipal Railway (MUNI) surveyed consumer attitudes and found a general antipathy toward the system's visual image. Consequently, a modern logogram and complementary color scheme were designed to identify all MUNI vehicles, facilities, and informational literature. As part of Boston's Massachusetts Bay Transportation Authority's (MBTA) modernization campaign, identifying colors and symbols were employed to make the transit system quickly identifiable to the passenger and to assist in locating routes, stations, etc. In addition to a concentrated promotional campaign for its buses, Des Moines, IA, designed new maps and color-coded routes and adopted uniform schedules in an attempt to standardize areawide service, eliminate confusion, and attract new riders. To date, ridership on Des Moines buses has increased by eight percent compared to a prepromotional week.

In addition to color/logo system identification, attention must be given to the location of destination signs appearing on the vehicle itself. Destination and, if possible, route information should be clearly and instantly visible on the front, side, and rear of the transit vehicle.

Program Monitoring and Evaluation

Throughout the marketing process, project monitoring is necessary in order to evaluate effectiveness of the service and, if necessary, initiate corrective action. In order to capitalize on ridership increases gained through promotional campaigns, it is important that weak points in the system and areas for improvement be evaluated periodically. Service evaluations, which might be incorporated as part of a market survey effort, can aid in determining the responsiveness of the system to customer needs and should be a continuing process since travel habits and passenger requirements are subject to change. Evaluations may include surveys of passenger levels during the week and weekends and at transfer points. They may also include surveys on the transit rider's opinion of the service.

As part of a systemwide transit operational analysis, Nashville, TN, has used the type of portable information booth mentioned earlier to gather data on consumer attitudes rather than to disseminate information. The booths were located at heavily traveled public places to solicit public opinion on desired improvement in Nashville's bus service. Miami, FL, has provided "Tell MTA What You Think" cards in all buses as a means of soliciting customer comments. The cards are reviewed by the transportation coordinator's office and then forwarded to the appropriate MTA department for consideration. The previously described MUNI survey revealed dissatisfaction with the system's level of service (e.g., worn-out vehicles, vandalism, and discourteous personnel). In response to these complaints, MUNI is making an effort to correct these problems.

Marketing Costs

The number of marketing aids available to a transit system is limited only by imagination. Examples of several types of marketing aids used in promotional campaigns and the costs of these aids are presented in Table 35.

SECURITY MEASURES

In order to encourage single-occupant automobile users to shift to public transit, thought must be given to the myriad of elements that influence the traveler's decision to use transit (quality of service, monetary costs, time, etc.). The perceived exposure to crime while waiting at transit stops and during the course of travel is known to influence the potential user's modal choice. Although indications are that the feeling of personal security in buses is, to some extent, less important than service factors such as the convenience of routes, frequency of service, fare level, and travel time, variables such as the volume of crime or vandalism, the degree of perceived threat, the availability of other transportation alternatives, and the hours when transit is used are all influential factors in determining the relative severity of the problem. Where the problem of crime exists, patrons are deterred from riding transit, and measures to restore passenger security can obviously be crucial

Table 35. Examples of Marketing Aids

LOCATION	TYPE OF PROMOTION	COST ($)
Madison, WI	Information Center Staff of 4 One-year state demonstration	61,700
San Francisco, CA	Improve Physical Image New color scheme and logogram on transit vehicles and facilities, staff uniforms, information guides, transit maps, improved identification of transit stops.	100,000
Duluth, MI	Information Center Staff of two, each @ $6,000/yr.; $200 for staff training; $500 for facility improvement.	12,700
Portland, OR	Advertising Monthly Pass Eight months advertising	37,474
Oakland, CA	Provision of Pocket-sized Timetables Three million timetables	50,000
Akron, OH	Transit Stop Bulletin Boards Four bulletin boards	600

to the success of other actions to attract transit ridership. Under such circumstances, security measures should be part of the TSM plan.

Regardless of the relationship between crime and ridership, there is little doubt that transit systems incur substantial costs because of it. For instance, the American Public Transit Association estimates that in 1971 costs to transit operators due to vandalism nationwide ranged from $7.7 million to $10 million. This does not include the cost of claims filed against transit systems as a consequence of incidents of crime and valdalism, which were estimated to be from $1.85 million to $2.33 million.

Many approaches can be taken to control transit crime and vandalism. Use of vandal-resistant materials, deterrence, protection, surveillance, and apprehension are some of the possibilities. Because local needs vary, each individual transit system must design its own most effective package of security measures for local conditions. To do so, transit operators must maintain accurate records to detail the dimensions of the problem within the particular system.

A number of TSM actions can help reduce exposure to crime. For example, improved scheduling information and reliable and frequent service can help reduce the amount of time spent waiting at transit stops. Transit shelters that promote visibility and exact fare policies that tend to discourage robberies (discussed on pages 118 and 125, respectively) are also valuable assists. Table 36 lists examples of other security measures that might also be of value to transit operators. Each is discussed in the following text--except for vehicle monitoring systems and two-way radios, which are discussed in Section 7.

Table 36. Examples of Criminal Deterrence and Detection Measures for Use on Transit Systems

LOCATION	TECHNIQUE
Vehicle and/or Station	Police or security force patrol and surveillance Nonprofessional surveillance Police dogs
Vehicle	Alarms and signals Automatic vehicle monitoring systems Two-way radio systems Aerial surveillance
Station	Station design factors Closed circuit television

Station and Vehicle Patrol

The patrolling of transit stations and vehicles by uniformed security forces is more effective as a deterrent than as an apprehension technique since a uniformed man assigned to oversee a station is unlikely to spot a crime in progress. Los Angeles's Rapid Transit District (RTD) has employed undercover police surveillance teams on RTD buses in problem areas, and San Francisco's Bay Area Rapid Transit system (BART) has used both uniformed and undercover officers on BART vehicles.

By and large, man-and-dog teams have been used by police departments rather than by transit systems, particularly bus systems. However, PATCO and MBTA rail systems (Camden, NJ, and Boston, MA) regularly use dogs on vehicles as crime deterrents. Both systems have found the dogs useful, especially since the majority of riders feel a sense of security at the sight of a canine patrol. The Mass Transit Unit of the Chicago Police Department has used canine teams on CTA vehicles as part of a trial program. In the past, San Francisco's BART agents, accompanied by trained dogs, were assigned to patrol transit stations. Due to political opposition, dogs are not currently being used; however, BART's security office reports that the program was highly successful. In addition to the increased sense of security felt by passengers and security officers, the use of dogs helps to improve patrol coverage. By replacing the usual two-man patrol teams, the dog-and-man team frees the second patrolman to work elsewhere. Additionally, in crowded situations where the patrolman is unable to fire a weapon, the dogs can be used to pursue the suspect. Trained dogs are also inexpensive to maintain. San Francisco's BART security office reported that handlers required only about $50.00 each month for dog-related expenses. However, dogs do require several months to train, may need periodic retraining, and can be handled successfully by only one trainer.

While there seems to be a potential for using dogs in the policing of transit systems, particularly in terminals, yards, and stations, actual implementation experience is limited. Nonetheless, transit management might find it useful to consider the possibility of using dogs in transit operations.

Alarms and Signals

Although simple, audible alarms and emergency signals are relatively low-cost anti-crime measures that have been tried by a number of transit companies, there are no known data on their effectiveness in deterring or apprehending criminals. In addition, the noise of audible alarms can tip off the offender, false alarms may occur, witnesses may hesitate to use the alarm to avoid involvement, and in noisy areas the exact location of an alarm may not be readily discernible.

The silent alarm systems associated with two-way radios are more expensive, but they are also more sophisticated and can relay critical information on vehicle location directly to the police or to the transit dispatcher who, in turn, can relay the information. For instance, the emergency alarm system in the Metropolitan Atlanta Rapid Transit Authority's (MARTA) bus radio system requires only 90 seconds to notify the police department and MARTA's security force of an incident. Once the emergency alarm system is activated by the operator, the alarm data are automatically fed into a computer that immediately displays the bus identification number and route assignment information on a screen in front of the radio dispatcher. The dispatcher can then pinpoint the location of the bus and transmit the information to the police department and the MARTA security office. The use of the silent alarm system resulted in a 180 percent increase in arrests for serious incidents during the first six months of 1975 (as compared to the last six months of 1974 when the system was not yet operational). Also, assaults on operators and/or passengers declined by 21.3 percent during the same period.

Aerial Surveillance

In addition to being valuable in traffic supervision, aerial surveillance, particularly by helicopter, has proved useful in thwarting criminal activity and facilitating apprehension. To help maintain driver and passenger security, Los Angeles's RTD, Atlanta's MARTA, and Oakland's AC Transit painted large identification numbers on their bus tops that are easily spotted by helicopter. A one-year helicopter surveillance demonstration program undertaken by New York's Metropolitan Transportation Authority (MTA) resulted in a sharp decrease in the number of broken windows, fires, and tampering with equipment along the railroad rights-of-way. The program was considered successful in detecting criminal and vandalistic actions; however, MTA discovered that numerous ground personnel and patrol cars had to be readily at hand to apprehend suspects in order for such a surveillance program to be successful. Philadelphia's SEPTA has also benefitted from its helicopter surveillance demonstration project. Substantial decreases in the number of vandal-related stone-throwing incidents, broken windows, and personal injuries to passengers were attributed to the helicopter surveillance program. Since a small (two- to three-person) helicopter costs approximately the same as a conventional 50-passenger bus, transit companies in large urban areas might consider purchasing a helicopter for the security of the entire transit fleet in place of purchasing a new bus.

Station Design Features

In addition to crime deterrent devices and security features associated with transit vehicles, the design of passenger waiting areas (terminals, stations, shelters, etc.) is important to the safety of transit users. Essentially, such security measures are based on the concept of visibility. Minimizing the number of locations where a person might be concealed (e.g., structural columns, stairways, corridors), improving lighting, concentrating the number of passenger waiting areas and entry/exit points, increasing the transparency of shelters and other enclosed areas, and optimizing lines of sight are some of the design considerations that can help minimize the opportunity for harassment. In an effort to reduce assault, the Metro stations in Washington, DC, have been designed so that no area in a station is beyond the view of an attendant.

Closed Circuit Television

Surveillance of transit stations by closed circuit television can provide authorities with visual information on all events taking place within the area surveyed. For instance, San Francisco's BART stations use television monitors to scan areas that BART agents in booths are unable to see. Television monitoring can also provide security forces with reliable information on a situation in question, particularly when the system is combined with automatic video taping. Although television monitoring is an effective security technique, it is fairly costly and labor intensive. Also, care must be taken to ensure that circuit operators do not become fatigued and, as a result, overlook potentially criminal situations.

Other Possible Measures

The aforementioned measures are only a few of the possibilities for improved security on transit systems. Numerous other techniques are feasible. For instance, private guards could ride buses in communities where local police forces are too small to spare men for such duties. San Francisco's MUNI has used unarmed transit system personnel to accompany the driver on certain runs. Paid and/or nonpaid volunteer riders might also be used, as in Alexandria, VA. Finally, some communities might find it feasible to train personnel so that each bus driver is potentially an armed special policeman, as in Dayton, OH.

Whatever security measures are selected none will be effective in controlling crime unless police respond rapidly to detected incidents. Transit users tend to feel most secure when they know that assistance can be readily obtained in an emergency. Table 37 summarizes several advantages and disadvantages generally associated with certain of the more important security techniques and the relative effectiveness of these techniques.

TRANSIT SHELTERS

One factor known to influence travel decisions is the amount of excess time (time spent getting to the pickup point and/or waiting for the vehicle) associated with different modes of travel. Research indicates that the amount of excess time involved in waiting for transit is generally perceived to be at least twice the value attached to travel time. For example, studies in Los Angeles, Baltimore, and San Diego determined that the perceived cost of one minute of excess time is nearly twice that of one minute of line-haul time. Since the amount of excess time can function as a deterrent to transit travel, transit companies can reduce excess time by (1) reducing the amount of waiting time (i.e. decrease vehicle headways), (2) reducing the amount of riding time (i.e., institute preferential treatment measures to increase vehicle travel speeds), and/or (3) adding amenities at transit stops that tend to reduce the disutility of waiting. This section will focus on the provision of transit shelters (and other ancillary facilities) as one means of increasing amenities at waiting points.

Passenger shelters at stops along well-traveled routes and at interchange points can increase the attractiveness of transit service by diminishing the discomfort passengers experience while waiting to board. Usually shelters serve two main purposes: they provide protection against inclement weather and

Table 37. Advantages and Disadvantages Associated with Several Examples of Security Techniques

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Patrol and Surveillance Teams	Serves as an effective deterrent.	Depending on manpower and equipment needs, patrol forces can be expensive.
Police Dogs	Very effective as a deterrent and useful for patrol. Allows greater dispersal of manpower and is relatively inexpensive.	Some local opposition may be encountered. Dog works successfully with only one handler, requires several months to train, and may require periodic retraining.
Audible Alarms and Emergency Signals	Simple and inexpensive; boost to driver morale.	Noise may tip off offender; subject to false alarms. Witnesses may not use the alarm to avoid involvement. In areas with competing noise, the exact location of an alarm may not be easily discernible; effectiveness not yet documented.
Aerial Surveillance	Very useful in crime control and traffic supervision.	In the case of crime control, effectiveness depends on the availability of ground forces. Costly technique.
Closed Circuit Television	Provides authorities with visual identification; may reduce the number of false alarms. Physical presence of a TV camera may in itself be a deterrent.	Monitor operators subject to fatigue; continuous monitoring requires considerable manpower. Costly technique.

offer seating facilities. However, many other passenger amenities can be incorporated into shelter design to enhance its utility--e.g., lighting, telephones, heating, and trash receptacles. Posting route system maps and schedules in shelters can also aid in increasing the use of the system. Bicycle racks in or near the shelter and the clear marking of the shelter as a transit stop (e.g., use of colorful "T" signs) are also beneficial improvements. The construction and maintenance costs of bus shelters in five cities are given in Table 38.

Clear visibility from the shelter has been isolated as an important design goal because it enables waiting passengers to see and identify oncoming transit vehicles, and it provides them with a sense of personal safety from possible molesters. For this reason, many new model shelters are being constructed with plexiglass panels on anodized aluminum frames.

Table 38. Transit Shelter Costs in Five Cities

CITY	DESCRIPTION	CONSTRUCTION		ANNUAL MAINTENANCE	
		Total Cost ($)	Cost Per Shelter ($)	Total Cost ($)	Cost Per Shelter ($)
Cincinnati, OH	11 curbside shelters with lighting	65,738	5,976	2,200	200
	Park-and-ride terminal station shelter at Beechmont Mall	14,217	14,217	200	200
Louisville, KY	47 curbside shelters with benches	71,675	1,526	16,800	357
Minneapolis, MN	33 shelters with heating and lighting	122,000	3,667	6,000	182
Philadelphia, PA	14 curbside shelters	37,000	2,642	3,000	214
Washington, DC	27 curbside shelters	81,000	3,000	6,000	222

In themselves, shelters do not improve bus operations by decreasing travel time; nor do they significantly change boarding volumes. It is feasible, however, to consider the use of shelters to mark the stops of a "limited" or "skip stop" bus service. For instance, during rush hours an otherwise "local" bus could be changed to semi-express by only stopping at certain shelters along a route. Such a service would improve transit efficiency and reduce travel time. The availability of the comfortable shelter and the reduced trip time are likely to motivate passengers to walk the added distance to the shelter to use the service. Thus, sheltered stops can be combined with bus service programs so that the efficiency of passenger transport is increased and equipment and driver needs are reduced.

TRANSIT TERMINALS

The collection, distribution, and transfer functions within a transit network can be achieved through the use of transit terminals. Depending on the local situation, outlying transfer terminals and/or central area off-street bus terminals can be developed to accommodate transit needs. Examples of nine off-street bus terminals are presented in Table 39.

Table 39. Characteristics and Costs of Nine Bus Terminals in the United States

NAME OF TERMINAL	DATE AND STATUS	DEVELOPMENT COSTS[1] ($)	NUMBER OF BUS LOADING DOCKS	TYPE OF BUS SERVICE	CONTIGUOUS TRANSPORTATION FACILITIES	ACCESS CONNECTIONS	NUMBER OF PASSENGERS[2]	
							Daily	Peak Hour
Port Authority Bus Terminal, New York, NY	1950	58,000,000	184	Commuter and intercity[3]	Subway, local bus, auto parking	Direct ramp connections with Lincoln Tunnel	105,500	32,600
George Washington Bridge Bus Terminal, New York, NY	1963	15,300,300	43	Commuter and intercity	Subway, local bus	Direct ramp connections with George Washington Bridge	20,000	4,200
Greyhound Bus Terminal, Clark and Randolph Streets Chicago, IL	1952	8,000,000	30	Mainly intercity	Subway, local bus, curb parking	Tunnel and ramp connections with Garvey Street & Wacker Drive	NA	10,000
Transbay Bus Terminal, San Francisco, CA	1960	11,000,000	37	Commuter and intercity	Streetcar and bus, auto parking	Direct ramp connections with San Francisco-Oakland Bay Bridge	44,000	13,000
Kenmore Square Bus Terminal, Boston, MA	1967	280,000	4	Local	MBTA, Subway	Arterial streets	NA	1,500
69th Street Terminal Dan Ryan Expressway Chicago, IL	1969	550,000	4	Primarily local	Dan Ryan Rapid Transit	Arterial streets and freeway frontage roads	8,000	2,000
95th Street Terminal Dan Ryan Expressway Chicago, IL	1969	1,300,000	22	Primarily local	Dan Ryan Rapid Transit	Arterial streets and freeway frontage roads	20,000	5,000
69th Street and West Chester Pike Terminal Philadelphia, PA	Before 1930	NA	10[4]	Local	Market Street Rapid Transit Suburban Rail	Arterial streets	15,000	3,700
S.W. Bus Terminal Washington, DC	1970	232,000	10	Suburban	Local Transit	Arterial streets	700	400

NA = Not available.
[1]Data on maintenance costs and revenues are unavailable.
[2]One-way only--passengers entering station.
[3]Terminal saves buses 30 minutes over previous operations.
[4]Some berths shared with streetcars.

A common form of transfer terminal is the park-and-ride transfer station, which has been shown to be a cost-effective approach to solving passenger collection and distribution functions in small cities and low-density areas. In outlying areas, mode transfer terminals serve as neighborhood collection points for line-haul transit. Within the urban setting, off-street bus terminals should be considered as a means of minimizing in-town delay of buses where bus stop congestion is considered serious and bus volumes are high. Central area transit terminals provide an interchange facility for improved downtown distribution of radial express bus operations.

Central Area Terminals

Central area terminals have long been viewed as a means of increasing transit ease, decreasing travel time, and/or facilitating passenger transfer and distribution within the central city. Traditionally, downtown terminals have been large-scale, cost-intensive projects that provide a multiplicity of services to a range of users (the local user, the commuter, and the long-distance traveler). Large-scale facilities are often constructed in order to accommodate the integration of transit modes (e.g., rail and bus) or the service of numerous intercity and intracity lines. In many communities the development of large-scale facilities is being re-examined in light of factors such as local development goals, disparity between peak and off-peak transit needs, high construction costs, and the availability of urban land, which generally precludes the development of massive, multipurpose downtown terminals.

Among the possible alternatives to the traditional concept of transit terminals being explored are the expansion, upgrading, and/or improved management of existing facilities; the expansion of sheltered areas; and/or the development of simple, low-cost, off-street terminals. Washington, DC's Southwest Bus terminal epitomizes the latter solution: it is a simple, "no frills," commuter-oriented facility.

Prompted by a rapidly growing work force within the southwest employment sector of the city, the D.C. Department of Highways and Traffic* completed a simple, low-cost, off-street terminal in June 1970. The terminal serves users throughout the day; however, the bulk of users are suburban commuters who arrive and depart during the peak travel periods. It consists of three aisles with three loading berths for passenger loading and unloading. The terminal can accommodate a total of 10 buses at one time. Given the relatively short waiting times characteristic of commuter transit service, extensive ancillary provisions

*Now known as the District of Columbia Department of Transportation.

(separate waiting areas, eating facilities, etc.) are unwarranted. The chief amenity offered at the Southwest Terminal is the translucent fiberglass canopy over each passenger platform (the sides of each platform are open and exposed to the weather). Construction costs for the Southwest Terminal amounted to $198,000 (land was provided free by the D.C. Redevelopment Land Agency), thus resulting in a low-cost, off-street terminal that is within easy walking distance of more than 30,000 workers.

Outlying Transfer Terminals

Outlying transfer terminals, usually located at park-and-ride lots (discussed in pages 68 to 72), transit interchanges, or points along or at the end of transit routes, function as collection centers for private, paratransit, and local public transit vehicles where passengers can transfer to trunk line transit. As a rule, outlying transfer terminals are small, cost-effective facilities that necessitate only a modest expenditure for construction. In order to enhance the convenience of transfer terminals, planners might include a range of transportation- or amenity-related facilities such as benches, adequate parking, provisions for bicycle and motorcycle storage, kiss-and-ride facilities, restrooms, and food and newsstand concessions.

Advantages and Applicability

In general, terminals facilitate route consolidation, which results in a more efficient transit operation. In addition, the following advantages can be cited specifically for central terminals:

- Off-street distribution of passengers permits substantial time savings for transit patrons.
- Off-street passenger distribution frees curb lanes for use by other vehicles.
- Multi-use terminals can encourage bus patronage since they provide a large number of other transportation-related services and amenities.

The principal advantages of outlying terminals are that they aid in consolidating bus routes and thus help reduce vehicular traffic destined for the center city.

Generally, consideration of off-street central bus terminals is warranted in situations where:

- Downtown curb loading capacity is limited.
- Large volumes of express buses aggregate.
- On-street bus routing is slow, unattractive, unreliable, and cannot be improved through bus priority measures.

Outlying transfer terminals linking local express transit are usually considered most appropriate to medium density areas and generally apply where:

- Express transit and local bus lines intersect.
- Large volumes of potential passengers pass or aggregate.
- Bus routes converge naturally on approaches to an express transit station.
- The transfer simplifies service scheduling and dependability over a direct bus routing.

Once the need for a terminal has been determined, the issue should not be resolved solely on the basis of the immediate apparent need, but on the basis of a broad evaluation of the role a new terminal might play in the restructuring and rationalization of all bus routes. In this way, the terminal size and design can be responsive to medium- or long-term planning considerations.

TRANSIT FARE POLICIES AND FARE COLLECTION TECHNIQUES

Transit fare policies and fare collection techniques are treated separately here, although it is clear that they are additional aspects of marketing since they affect the level of service provided and, hence, can be used to attract transit ridership.

Fare Levels

Combining a policy to reduce off-peak-period fares with a policy to increase peak-period fares can increase transit ridership and at the same time help maintain the financial viability of a transit operation. Lowering fares during off-peak periods has already been discussed as a viable means of increasing transit ridership (page 109). Raising peak-period fares, which can be viewed as a type of congestion pricing, benefits the transit company financially since the additional investment made to meet peak-period travel demand is more equitably charged back to the peak-period user. An increase in peak-period fares may cause some peak-period users to travel during off-peak hours. However, since in many transit systems most peak-period users are transit captives, an increase in peak-period fares should cause little, if any, decline in peak-period ridership.

The transit company in Washington, DC, has increased peak-period fares without incurring a substantial loss in ridership largely because limited downtown parking and peak-period congestion on incoming highways have deterred shifts back to private auto travel. Presently, Baltimore, MD, is considering a five-cent increase in the peak-period fare in an effort to create a more equitable pricing system. As such, the peak-period fare will be 40 cents; the fare at all other times will be 35 cents.

Fare Collection Techniques

The aspects of fare collection included here are fare structure and innovations in fare collection equipment. By improving the methods of fare collection, transit operators can improve the efficiency and attractiveness of service--i.e., they can reduce theft and reduce boarding time (and thus the time spent at transit stops). Reduced boarding time translates into time savings that benefit both the user and the operator, who can use the same vehicle to make an increased number of trips.

FARE STRUCTURE. The way the fare is structured and collected can have a significant effect on transit ridership and on the level of service provided. The structure of a pricing policy can be based on flat fares or fares based on the distance traveled. A flat fare is a single fare charged without regard to the distance traveled or number of transfers. It is considered easy to implement and administer and is particularly applicable in small service areas. In large service areas, the flat fare results in an inequitable charge for the short-distance traveler since he/she must bear the cost attributed to the long-distance traveler.

Distance-based fares consist of a base fare plus the number of miles traveled. The two types of distance-based fares are stage fares, in which the rider pays according to the number of stops traveled, and zone fares, which are based on the crossing of zone boundaries. The stage fare is easy to implement when few stops are made; however, problems with fare collection arise when there are many stops, as in urban bus systems. It is most applicable to commuter rail systems and long-distance suburban bus lines. Distance-based fares are generally considered equitable since the fare level increases with the amount of service received by the user.

FARE COLLECTION METHODS. Four efficient and low-cost ways of collecting fares discussed here are exact fare systems, prepaid fare systems, postpaid fare systems, and no-barrier fare collection systems.

Exact Fare Systems. Many transit systems have adopted exact fare policies in order to reduce the risk of robbery (the driver does not carry money to make change and does not have access to cash on the bus). Although the exact fare is inconvenient for patrons who do not carry the correct amount of change, it is one of the most efficient ways of reducing boarding time.

Prepaid Fare Systems. The prepayment of transit fares can be achieved through the advance sale of tokens, punch cards, ticket books, and passes for use in lieu of cash fares. A variation of this approach, which is particularly applicable to zone fares, is the use of permits. Basically, the passenger shows the permit to the driver and then deposits a certain sum of cash into the farebox. In Pittsburgh, PA, regular commuters (those using PAT 40 to 50 times a month) with monthly permits drop 10 cents in the farebox, saving up to 17 cents on each ride. Oftentimes, permits are used to designate patrons who are entitled to discount rates (e.g., senior citizens and students).

Prepaid fare systems are a successful means of promoting transit travel. Prepayment of the fare has the advantage of encouraging transit ridership since once the trip has been paid for, it will likely be taken. Prepayment of the fare also improves the cash flow for the transit operator and simplifies the administration of fare collection. Table 40 summarizes the features of five prepaid fare systems.

Table 40. Features of Five Prepaid Fare Systems

PRE-PAYMENT TYPE	ADVANTAGES	DISADVANTAGES	SAFEGUARDS AGAINST ABUSE
Tickets	Usually no expiration date. Attractive to infrequent riders.	Cumbersome to separate from coins and count.	"Safety" paper, multicolor printing. Sometimes expiration date.
Tokens	Usually counted along with coins. Easy to carry.	Hard to revalue.	Slug detection mechanism in turnstile. Monitor turnstiles in stations with consistent slug use. Dye or replace tokens to revalue.
Punch Cards	Easy to carry (compared with tickets). Usually no expiration date. Attractive to infrequent riders.	Easy to counterfeit. Become multilated and thus time consuming for driver to straighten and punch.	"Safety" paper, multicolor printing. Sometimes expiration date.
Passes	Easy to carry. May induce off-peak use of transit. Gives some persons a sense of membership and loyalty.	Make passenger counts difficult. Most are easy to counterfeit and abuse. Usually attractive only to frequent riders.	Sometimes photo-ID or signature if not transferable. Coding of male vs female. Change design and colors with every new pass.
Permits	Most equitable for zoned systems. Gives some persons a sense of membership and loyalty.	Cash drop is inconvenient. Passenger counts difficult. Most are easy to counterfeit and abuse. Usually attractive only to frequent riders.	Sometimes photo-ID or signature if not transferable. Coding of male vs female. Change design and colors with every new pass.

In order to promote transit convenience, many business establishments have agreed to function as prepayment locations. Oftentimes, advance fares can be acquired through banks, savings and loan institutions, retail store outlets, insurance companies employers, and even by mail. For instance, numerous employers in Boston, MA, and Pittsburgh participate in a company payroll deduction program. Employees of participating organizations have the monthly pass fare deducted from their paychecks each month for 11 months--the twelfth month is free. Over 21,000 employees in more than 115 Boston companies participate in the "Prepaid Pass" program. Portland, Oregon's monthly prepaid pass program has proven to be very popular. Passes for this program can be purchased by mail and at over 130 designated sales locations. Effective July 1976, Denver's RTD implemented a computerized bus pass mail order system for transit users. Once the patron's application is processed and approved, RTD automatically sends the customer a monthly pass for the type of bus service desired (express, local, senior citizens, handicapped, etc.). A monthly bill, which is enclosed with the pass, must be paid before the 10th of the transit pass month or else the customer is dropped from the system.

The introduction of a prepaid fare system can be most successful when combined with an aggressive marketing campaign. The cost per ride of a prepaid fare is usually the same as a regular daily fare; however, when linked to promotional campaigns, the cost per ride of the prepaid fare is often lower. For instance, to encourage commuters to use public transit, Allentown, Pennsylvania's Lehigh and Northampton Transportation Authority (LANTA) recently devised a "Ride-to-Work" plan that enables employees of participating firms to commute for less than the regular fare. The plan was introduced in order to accomplish several objectives: increase peak-hour ridership; make it easier and more economical for employees to commute; help reduce traffic, air pollution and energy consumption; and reduce downtown area parking problems. Under the plan, LANTA offers its 14-dollar, 40-ride ticket to employers for $12 if the employer agrees to offer the ticket to employees for $10. Thus far, five firms with close to 6,500 employees have agreed to participate in the plan. The plan is particularly favored by employers who presently subsidize employee parking. Since parking costs in downtown areas can run as high as $18 per month per car, the "Ride-to-Work" cost represents a considerable savings for employers and employees alike.

Numerous employers have committed themselves, in varying degrees, to providing incentives for employees who use public transportation to get to and from work. While some employers provide information services to their employees, others subsidize or pay the entire employee bus fare. In Houston, TX, the United Gas Pipe Line Company (UGPL) and the local transit system have joined forces to encourage ridership by providing "free" transit for employees. In order to demonstrate its concern for energy conservation and reduced pollution, the company pays the transit system an allowance equal to the basic round-trip bus fare for each employee who applies for the benefit. As of January 1976, 43 percent of the firm's 685 employees are participating in the program. In addition to paying employee bus fares, UGPL also provides priority parking and partially reimburses carpoolers for parking costs.

The Midwest Federal Bank of Minneapolis, MN, developed a program that offers to reimburse its 500 employees for their bus fare. The program has proved to be the company's most popular fringe benefit. Since the program was initiated, the percentage of employees commuting by bus has risen from 56 percent to 72 percent. In Seattle, WA, the Safeco Insurance Company subsidizes the employees' transit trip to work by offering four-dollar monthly Metro Transit permits for $1.00. In view of the fact that employee parking fees are subsidized, the architectural/engineering firm of Daniel, Mann, Johnson, and Mendenhall in Los Angeles, CA, is attempting to equalize fringe benefits by subsidizing the public transportation costs of their non-driving employees (participating employees receive up to $9.00 per month).

Postpaid Fare Systems. The idea of consolidating and paying transit fares "after the fact" is an innovative approach currently in the demonstration stage. In place of conventional fareboxes, buses are equipped with service recorders that accept credit cards in lieu of cash. The credit card system can also serve as a valuable management tool in data gathering as well as help minimize the problem of farebox robbery.

The Valley Transit District (VTD) in Derby, VT, is currently in the midst of its second, three-year UMTA-sponsored demonstration of such a prototype system. The prototype hardware consists of two primary elements: a service recorder carried on the bus in place of a farebox and the computer facilities necessary to transform the records into monthly billings. The bus driver enters service information on a magnetic tape cassette, which is printed out daily, providing a complete record of all transactions. The actual monthly invoice is reproduced in Figure 9.

VTD management has benefitted from the system by using the data generated on passenger origin-destination, price information, time of ride, length of ride, etc. to improve the scope of the route service area. Although the system is a prototype and the mechanical flaws in the system are currently being resolved, VTD considers the system highly successful, particularly in improving the level of service. Currently, about 4,000 credit cardholders are served by the six buses equipped for this form of fare collection. The default rate on payments has only been about three percent of gross receipts. One of the chief inconveniences experienced is the replacement of lost credit cards. During 1976, VTD plans to expand the system by adding eight more collection units. Reportedly, the credit card

Valley Transit District

To [Name
Address]

Customer ID: 11431

$1.26
Pay this amount

If you have any questions about your bill, please call 735 6824.

For Rent-a-Bus and Door-to-Door service, please call 735 6408.

Thank you

Detach here — To insure proper credit, please return above portion with your remittance — Detach here

Date	Start Time	Origin	Destination	Total Cost	Cost to Customer	Date	Start Time	Origin	Destination	Total Cost	Cost to Customer
DOOR-TO-DOOR TRIPS											
04/19	10-43AM	G2	F2	.48	.39						
04/19	2-33PM	F2	G2	.45	.36						
04/25	1-43PM	G2	F2	.38	.31						
04/25	3-49PM	F2	G2	.25	.20						

AVERAGE PRICE OF DOOR-TO-DOOR RIDES .31

Previous Balance		Scheduled Route		Rent-a-bus		Door-to-Door		Deposits		Pay this amount
.00	+	.00	+	.00	+	1.26	-	.00	=	1.26

Valley Transit District

Figure 9. Facsimile of a Credit Card Fare Collection Monthly Invoice Statement

fare collection system has cut boarding time by one-third, although the rider's card must be registered upon exit as well as entrance.

The VTD system has a special feature called faresharing, whereby a sponsoring agency can be billed for all or a part of a customer's ride. For example, an employer may offer to pay a percentage of an employee's bus trip to work each day. Sponsor agencies can specify a number of varying conditions to avoid blanket responsibility for all of an individual's transportation. Under this program, constraints on use or conditions of use can be established according to the day, time, location, and maximum cost for the month.

The following costs have been incurred by VTD in installing the system:

Source	Expenditure
Purchase of six credit card collection units for installation on VTD buses.	$70,000
Modification of the original six collection units (provisions for coin collection); purchase of eight new collection units; purchase of 15 cash vaults.	77,000

In addition to the above, substantial computer-related costs are incurred for keypunch personnel and processing time as well as for credit card distribution, billing, and mailing. Use of the credit card as a fare collection method costs the VTD $0.05 per passenger, as opposed to the $.004 cost incurred using a standard fare collection system.

The VTD prototype system is a unique transit fare collection method that has been successfully used in a small community and was designed particularly to address a select clientele (the elderly, the handicapped, and other social service groups). Due to the specialized nature of the program, its application in larger settings is still a matter of speculation.

A larger general-use system might be expected to incur costs such as the estimates given in Table 41. The positive and negative aspects of credit card collection systems are summarized in Table 42.

No-Barrier Fare Collection Systems. No-barrier fare collection systems have been widely used in Europe but, as yet, have not been used in the United States. Under this system there are no fare gates for control of entry and exit. Rather, roving ticket inspectors ride buses on a random schedule and check to see that passengers are carrying valid tickets. A strict penalty fare (generally 20 times the base fare) is levied on those who evade payment. This system frees the driver from the entire fare collection process and it reduces boarding time by temporally separating the boarding and fare collection processes. In fact, vehicle speeds can increase as much as 10 percent as a result of the rapid boarding ability fostered by the no-barrier fare collection system. In Europe, the rate of checking is relatively low (about five percent of the daily passengers), and the amount of detected fraud is also low (averaging less than two percent of the riders).

No-barrier fare collection systems provide substantial benefits in terms of passenger appeal and convenience, flexibility in fares, public relations, and security. In order to dimish the threat of fraud and at the same time provide convenience to both the users and operator, the extensive use of passes or other prepaid trip options can be used to complement the no-barrier fare collection systems.

Table 41. Estimated Annualized Cost of Operating an Automatic Credit Card Fare Collection System for a 180-Vehicle Fleet

COST FACTOR	CAPITAL COST ($)	ANNUALIZED COST ($)*
Investment Costs		
On-board hardware (180 @ $1,000)	180,000	26,800
Tape drive and controller	10,000	1,500
Magnetic cassette tape reader	5,000	750
Magnetic cassette tapes	3,750	550
Operating Costs		
Computer associated costs		6,000
Maintenance		2,000
Finance Costs		4,700
(Assuming a ridership of 1,300,000/year of which 75% use credit cards.)		
TOTAL ANNUALIZED COST		42,300

*For purchased equipment, the assumption is made of a 10-year life, no salvage value, and an eight percent cost-of-capital.

Note: Based on the design of a system for the Santa Clara County, CA, Transit District bus system.

Table 42. Advantages and Disadvantages of a Credit Card Fare Collection System

ADVANTAGES	DISADVANTAGES
• Simple and convenient to use. • Shortens boarding time. • Provides valuable data on operations. • Causes perceived reduction in "out-of-pocket" transit costs. • Diminishes threat of robbery and fraud. • Facilitates introduction and monitoring of new fare policies. • Permits faresharing by employers and/or social agencies.	• Billing and collection procedures must be established. • Replacement of lost credit cards is troublesome. • Coin collection provisions are still necessary to accommodate transients and new users. • Payment delinquencies occur. • More costly than conventional systems.

INNOVATIONS IN FARE COLLECTION EQUIPMENT. Currently, the standard fare collection equipment consists of registering or nonregistering fareboxes with onboard vaults. Among the innovations that can help streamline fare collection procedures is the vacuum revenue/data collection system.

In response to problems of theft and fraudulent use of fares, a vacuum revenue system has been designed to eliminate direct access to fares. The system, which is available on the market, consists of two units; one installed in the vehicle and the other in the garage. The vehicle unit stores all collected revenues and cannot be opened until it is connected to the garage unit. The garage unit is usually located at or near the service area so that fares can be easily extracted while the bus is being serviced and refueled. The garage unit is self-contained, housing the master vault, sorter, pump, motor, and all controls and security interlocks. After the bus is positioned at the servicing island's vacuum revenue extracting probe, the operator inserts a magnetically coded card in the probe lock mechanism that automatically turns on the vacuum equipment. Once a series of interlock functions are satisfied, revenue removal begins. A high-velocity air stream removes all stored revenue (tickets and tokens included) through the vacuum hose at a rate of $150 in less than 20 seconds. The vacuum hose transports the revenue to an enclosed mechanical sorter, which then discharges all sorted revenue into a master revenue vault. The master vault locks automatically when removed from the central island unit housing. The securely locked master revenue vault is moved to a bank or an in-house facility to be counted, bagged, or rolled. In addition to eliminating the task of revenue sorting, counting time is usually reduced by over 80 percent.

In addition to the revenue handling feature, valuable data can also be collected. The system is equipped to gather information on bus number, passenger counts, automated revenue computation, bus mileage, and consumables (fuel, oil coolant, transmission fluid, etc.). Such fare collection and/or automatic data recording systems have been used by transit companies in Syracuse, NY; Jamaica, NY; Philadelphia, PA; and Kansas City, MS. In Syracuse, a special security provision has been added to combat vandalism. In the event of trouble, a radio system, tied to a fare box sensor, automatically prints out the bus number and time of the alarm at transit headquarters.

The vacuum revenue/data collection system, which varies in cost depending on transit company needs and design considerations, may range in price from $500,000 to $600,000. Reportedly, on the average, the system pays for itself within 18 months. The detailed characteristics of this system, its manufacturer, and other farebox developments are further described in sources cited in the "Transit Fare Policies and Fare Collection Techniques" section of Appendix A.

THEFT AND FRAUDULENT USE OF FARES. All fare collection systems must address the problems of theft and fraudulent use of fares. Exact fare or token-only systems minimize the prospect of robbery by persons outside the system since the driver generally carries no cash. In order to counter farebox theft by transit personnel, manufacturers inhibit direct access to cash by using farebox labyrinths that prevent "fishing" and by providing for tamper-proof revenue storage within the farebox. High security cash transfer systems, such as the vacuum revenue process discussed above, further reduce the opportunity for theft and fraud.

While farebox design can help to counter theft, the problem of passenger fraud is more difficult to approach. Insertion of less than the required amount of fare or intentionally misstating the destination results in farebox shortchanging. Cash systems tend to be particularly susceptible to shortchanging. Some suppliers have responded to this problem by including audio and/or visual indicators of the amount of fare received.

EXTENSION OF TRANSIT WITH PARATRANSIT SERVICES

An effective urban transportation system--one that assures a uniformly high level of service at a reasonable cost--requires a combination of modes, vehicle sizes and types, service levels, and operating procedures designed to meet the different demand conditions and travel patterns existing in an urban area. Such a system can be realized by the extension of transit services with paratransit services.

Types of Paratransit Services

The term "paratransit" was coined to describe the public transportation services provided by a spectrum of vehicles ranging from the automobile to the minibus. These services, characterized by routing flexibility, comfort, convenience, and privacy features, more closely approximate the personalized service of the private automobile than do bus or rail transit. Also, like the private automobile, such services are well suited to operation in low-demand, low-density areas. Thus pooled riding (discussed in Section 5, pages 73-85) qualifies as a form of paratransit.

In the United States paratransit services are most commonly furnished by private companies, although frequently these services are executed under contract to a municipality (i.e., the city or transit operator). Under such an arrangement the paratransit company usually provides drivers, dispatching services, vehicle maintenance, fuel, and all aspects of system management for which the public agency is charged at a rate calculated to include a profit margin. Under such contracts the public agency is in an advantageous position to control the quantity and level of service provided and to insure that the services provided are coordinated with other transit service.

Three promising paratransit modes--dial-a-ride, shared-ride taxis, and jitney services--are discussed briefly below.

DIAL-A-RIDE. Using minibuses, vans, or autos, dial-a-ride-type services generally incorporate the demand-responsive characteristics of a regular taxi by providing door-to-door service at telephone request, yet differ from taxis in that the travel demands of several passengers are satisfied by tailoring routes to combine several pickups and deliveries. A dial-a-ride type operation may also offer a subscription service whereby the patron registers a written or phoned order for door-to-door pick up and delivery on a scheduled basis. Some operators offer more prompt pick up services and reduced travel times if requests are registered 24 hours in advance.

Variations in dial-a-ride services are often based on the characteristics of the origin or destination: many-to-one services function between individual homes and single focal points; many-to-few services provide transportation between individual homes and a few activity centers where transfers to other transit routes can be made; and many-to-many services carry passengers from individual homes to any destination within a specified area. Table 43 documents the principal features of six major dial-a-ride systems, all of which provide many-to-many services except the Regina operation, which provides many-to-one and one-to-many services during peak periods and many-to-many and many-to-few services during off-peak periods.

SHARED-RIDE TAXIS. As the name implies, shared-ride taxis extend the single demand response of the customary taxi service to include--at the driver's option--serving one or more additional passengers, if the destinations do not cause serious route deviations. Shared-ride taxis operate in two ways: with and without dispatching assistance. The operational structure of the paratransit systems in Washington, DC, exemplifies the latter. Taxis cruise the streets and respond to hails, picking up second parties if they are traveling in a direction compatible to the route of the initial passenger. In smaller cities, however, shared-ride taxi arrangements are often operationally analogous to dial-a-ride systems in that they are controlled by centralized dispatching systems. In these cases demand densities are usually too low to permit cruising. Despite the improved efficiency implicit in the shared-ride option, protection regulations prohibiting shared-ride taxi operations exist in many cities. Table 44 summarizes the major characteristics of five shared-ride taxi systems.

JITNEYS. Using a variety of vehicles such as small buses, vans, or specially designed taxicabs, jitneys generally operate along a fixed route, yet are not scheduled, thus allowing for occasional deviations from the route to respond to special travel needs. Jitneys do have defined pick-up points, but most can also be hailed for pick up at any point along the route.

Table 43. Selected Characteristics of Six Major Dial-a-Ride Systems

CHARACTERISTIC	Ann Arbor, MI	Batavia, NY	La Mirada, CA	La Habra, CA	Columbus, OH	Regina, Saskatchewan (Canada)
OPERATION						
Date initiated	September 1971	October 1971	May 1973	February 1973	October 1971	September 1971
Operator	Ann Arbor Transportation Authority	Batavia Bus Service, Inc. (A subsidiary of Rochester-Genesee Regional Transportation Authority)	City of La Mirada	Orange County Transit District (OCTD)	Dial-a-Ride Transit Corporation of Columbus, Inc. (Model Cities demonstration project)	Regina Transit System
DEMOGRAPHY						
Population served	100,000	18,000	39,000	47,000	37,000	32,000 (peak) 68,000 (off-peak)
Service area (sq.mi.)	22	5.5	7	7	2.5	5 (peak) 10 (off-peak)
Service area density (persons/sq.mi.)	4,545	3,272	5,571	7,460	14,800	6,400 (peak) 7,750 (off-peak)
SERVICE						
Hours of service	6:30 a.m.–6:00 p.m. (Mon.-Fri.) 8:00 a.m.–6:00 p.m. (Sat.)	6:00 a.m.–6:00 p.m. (Mon.-Fri.)	7:00 a.m.–7:00 p.m. (Mon.-Fri.) 9:00 a.m.–5:00 p.m. (Sat.)	7:00 a.m.–7:00 p.m. (Mon.-Sat.) Service extended to 10:00 p.m. during Christmas season	6:00 a.m.–8:35 p.m. (Mon.-Fri.) 8:00 a.m.–4:30 p.m. (Sat.) 8:00 a.m.–4:00 p.m. (Sun.)	5:25 a.m.–12:00 a.m. (Mon.-Fri.) 6:40 a.m.–12:00 a.m. (Sat.) 1:00 p.m.–8:40 p.m. (Sun.)
Special services	Subscription for school and work trips; citywide handicapped service	Subscription, package delivery; charter for senior citizens; free bus service on holidays	Shuttle, subscription, package delivery, monthly senior citizens pass	Subscription for work and school trips	Service provided to 3 hospitals, 5 neighborhood supermarkets, 6 clinics, 22 schools and day care centers, 3 banks, and 9 nursing homes	Subscription for school
Number of vehicles (capacity and type)	43 (10-16-seat buses)	7 (23-seat buses) (14-seat vans)	3 (18-seat buses) 3 (10-seat vans)	6 (19-seat buses) 1 (8-seat van)	4 (19-seat buses) 1 (15-seat bus)	27 (16-seat vans) (23-seat buses)
Dispatch and Control	Digital; automated	Manual	Manual	Manual	Manual	Manual

Table 43. (continued)

CHARACTERISTIC	Ann Arbor, MI	Batavia, NY	La Mirada, CA	La Habra, CA	Columbus, OH	Regina, Saskatchewan (Canada)
MARKET						
Average ridership/day	750	455	435	475	485	3,400
Average demand density (person trips/sq.mi./day)	261	83	73	72	195	444
Average wait time (min.)	15-20	11	17	20	27	15-30
Average productivity (person trips/veh.hr.)	12	11	9	8-10	10.7	19
TRANSIT INTEGRATION	Feeder to fixed route, fixed schedule and express buses	Transfers made to Batavia fixed route, fixed schedule system and Regional Transit Service	Feeder to Southern California RTD, Orange County RTD, and Norwalk Transit System	Transfers to and from fixed route, fixed schedule buses operated by OCTD	Connects with fixed route, fixed schedule buses	Connects with fixed route, fixed schedule buses
LABOR						
Drivers	Union	Non-Union	N/A	N/A	Union[1]	Union
Hourly wage	$5.50	$3.30	N/A	N/A	N/A	$5.00-6.00
COSTS, REVENUES, DEFICITS						
Planning & engineering cost	$45,000	N/A	N/A	$300,000.00	$42,000.00	$42,500.00
Market introduction cost	$26,000	N/A	$700.00		$ 1,400.00	$25,000.00
Amortized capital cost ($/veh.hr.)	N/C	N/A	N/A	$0.56	$0.74	$1.35
Noncapital cost ($/veh.hr.)	$16.47	N/A		$12.25	$15.24	$13.13
Total cost ($/veh.hr.)	N/A	$7.50	$20.00	$12.81	$15.98	$14.48
Average cost/passenger	$1.20	$.61	$1.16	$1.81	$1.49	$.71
Average revenue/passenger	$.29	$.50	$.21	$.50	$.17	$.31
Average deficit/passenger	$.91	$.11	$.95	$1.23	$1.32	$.40

N/C = Not calculated.
N/A = Not available.
[1]Drivers are contracted from the Central Ohio Transit Authority.

Table 44. Selected Characteristics of Five Shared-Ride Taxi Systems

CHARACTERISTIC	Davenport, IA	Hicksville, NY	Madison, WI[1]	El Cajon, CA	La Mesa, CA
OPERATION					
Date initiated	ca 1930	1961	ca 1933	December 1973	March 1974
Operator	Royal Cab Co. (private)	Orange and White Taxi (private)	Badger Cab Co. (private)	San Diego Yellow Cab	San Diego Yellow Cab
Sponsor				City of El Cajon	City of San Diego
DEMOGRAPHY					
Population served	98,500	48,100	173,000	60,000	45,000
Service area (sq.mi.)	20	6.8	48.5	17	7
Service area density (person/sq.mi.)	4,925	7,073	3,567	3,529	6,428
SERVICE					
Hours of service	24 hrs/day; 7 days/week	24 hrs/day; 7 days/week	24 hrs/day; 7 days/week	24 hrs/day; 7 days/week	6:00 a.m.–8:00 p.m. (Mon.-Fri.) 8:00 a.m.–6:00 p.m. (Sat.) 7:30 a.m.–1:30 p.m. (Sun.)
Special services	Package and telegram delivery, regular taxi service, ambulance substitute	Telegram delivery, school bus, freight, airport, and ambulance services	Subscription	--	--
Number of vehicles (capacity and type)	23 (7-seat Checker Cabs)	40 (5-passenger Taxicabs)	25 (4-passenger Chryslers, Plymouths, Dodges)	14 (5-passenger Taxicabs)	5 (Chevrolet Novas)
Dispatch and Control	Manual with computer assist and radio	Manual, radio, conveyor belt	Manual	Manual	Manual
MARKET					
Average ridership/day	1,425	814	--	600	200
Average demand density (person trips/sq.mi.)	71	120	--	35	29
Average wait time (min.)	10-20	9	--	15	10
Average productivity (person trips/veh-hr.)	4.5	4.2	--	--	--
LABOR					
Drivers	Non-Union	Non-Union	--	--	--
Hourly wage	$2.65	$2.29	--	--	--

[1]Originated as a jitney operation. Shared-ride taxi service was instituted when jitneys became illegal, about 1933.

Between 1914 and 1915 the jitney experienced considerable popularity and provided strong competition to streetcar operations since it successfully carried passengers over short distances more rapidly than the streetcar and charged more competitive fares. However, as a result of intense political pressure from endangered streetcar and labor interests, they were ultimately regulated out of existence in most metropolitan areas by the early 1920s. Today, the only formal jitney operations are in Chicago, San Francisco, and Atlantic City (see Table 45 for a summary of the features of the latter two). However, a number of jitneys (gypsy cabs) operate without formal authority in ghetto areas of Pittsburgh, Cleveland, Chattanooga, and probably in other cities as well.

Although existing regulations in some cities may inhibit their near-term implementation, jitney services are increasingly gaining recognition as a potentially viable paratransit mode that promises to provide needed public transportation to certain urban areas--particularly low-income neighborhoods.

Paratransit as an Adjunct to Transit

Because of their flexible scheduling and routing capability, paratransit modes lend themselves especially well to the diffuse travel patterns prevailing in low-density areas. In fact, in small towns paratransit services may provide the only form of public transportation. The largest scope for paratransit, however, lies in performing those functions that will improve the level of service of other transportation modes. Specifically, paratransit can:

- Provide feeder services to line-haul commuter buses and rail.
- Provide additional peak-period capacity along major travel corridors of the urban area.
- Extend transit area coverage in areas with low-demand density where the expansion of fixed routes is uneconomical.
- Provide short-haul transit within the CBD.
- Provide service at times of low demand.
- Substitute for suburban auto travel.
- Meet the needs of limited mobility groups.

The ways in which paratransit might provide such services and existing experience are presented below.

LINE-HAUL FEEDER SERVICES. Conceptually, the effectiveness of conventional mass transit should be enhanced considerably by the provision of paratransit feeder services to line-haul commuter bus and rail services. In the United States and Canada such a concept is receiving increased application as

Table 45. Major Features of Two Jitney Services

ATLANTIC CITY, NJ; THE JITNEYMEN's ASSOCIATION	SAN FRANCISCO, CA; MISSION STREET JITNEY OWNERS ASSOCIATION
SYSTEM DESCRIPTION	
Operates according to demand in both directions along a 4.2-mile linear route that serves a commercial district. Stops are marked by signs at all intersections, though some drivers will stop when hailed. No fixed service schedule. Headways are adjusted by fixing the maximum number of vehicles in service at one time.	Operates 24 hrs./day in both directions along two routes: one a heavily traveled 9.5-mile route, the other a 4-mile route. Vehicles stop at the far end of existing bus stops, yet will stop in midblock if requested.
OWNERSHIP AND ORGANIZATION	
Ownership: A private entrepreneur who owns his vehicle and retains all passenger receipts. Organization: Jitneymen's Association sets rules, schedules, and operating periods. Regulation: Must be approved by the membership at large. Association rules include: - Jitneys may not overtake one another unless the overtaken vehicle has 10 passengers or is stopped with its door open to allow passenger ingress or egress. - Jitneys enter the system at one end of the route only; yet at the start of a shift a driver may enter at a point nearest his home. - Operators are not allowed to converse with each other while in service.	Ownership: A private entrepreneur who owns his vehicle and retains all passenger receipts. Organization: Jitney Owners Association sets rules, which include the number of hours each driver must work. Regulation: Driver works up to 10 hrs./day, 6 days/week; a rear window sticker indicates the days he may not work. Peak-hour headways are not regulated; however, an Association-employed starter dispatches vehicles between 9 a.m. and 4 p.m. at 3.5-or 4-min. intervals. Routes can be shortened for some vehicles.
LICENSING	
City issues a limited number of mercantile licenses at an annual fee of $85.00. The jitney owner must carry a minimum level of public liability insurance. Vehicles have omnibus tags issued by the State ($34.00/hr.) and are subject to annual safety inspection.	Annual license fee of $22.50 is paid to the city. Vehicles display California automobile tags. City's police code limits the number of jitney licenses to 700; in practice, licenses have been limited to 120.

Table 45. (continued)

ATLANTIC CITY, NJ; THE JITNEYMEN'S ASSOCIATION	SAN FRANCISCO, CA; MISSION STREET JITNEY OWNERS ASSOCIATION
COSTS, REVENUES, AND PROFITS	
Amortized vehicle costs:	
$1,255/yr., $1.57/veh.hr., $0.084/veh.mi.	$1,255/yr., $0.80/veh.hr., $0.04/veh.mi.
Non-capital cost (exclusive of labor):	
$1,765/yr., $2.20/veh.hr., $0.118/veh.mi.	$2,683/yr., $1.72/veh.hr., $0.126/veh.mi.
Average cost/passenger-trip:	
$0.086	$0.087
Revenue/passenger-trip:	
$0.30; $10,500/yr., $13.13/veh.hr., $0.70/veh.mi.	$0.29; $13,752/yr., $8.38/veh.hr., $0.442/veh.mi.
Profit/passenger-trip:	
$0.214; $7.48/hr., $9.36/veh.hr.; $0.498/veh.mi.	$0.203; $9,814/yr., $5.86/veh.hr.; $0.355/veh.mi.

major cities upgrade their public transit systems. For example, the Hicksville, NY, shared-ride taxi system distributes and collects passengers at the three major commuter rail stations in the service area. Similarly, Ann Arbor's hybrid bus and demand-responsive Tel-Tran service (in operation since 1973) functions as a feeder to express buses traveling on major urban arterials during peak periods. And, in La Habra, CA, the city-controlled dial-a-ride system feeds bus routes into three neighboring transit districts: Los Angeles's Southern California Rapid Transit District (RTD), the Orange County Rapid Transit District, and the Norwalk Transit System.

AUGMENTATION OF PEAK-PERIOD CAPACITY. Paratransit services, especially controlled and well-regulated jitneys, could enhance the efficiency of bus modes during peak periods by supplying some of the additional capacity required during commuting hours. This might relieve transit authorities of the need to provide extra vehicles and drivers used to meet increased demand during peak periods but underutilized for the remainder of the day. Furthermore, operating jitney vehicles along major travel corridors at peak hours, preferably on streets parallel or adjacent to established transit routes, could (1) avoid aggrevating traffic congestion on these routes and (2) improve access to public transportation.

LOW DEMAND DENSITY SERVICES. Transit systems that are presently required by municipalities to operate poorly patronized bus routes in low-density areas would improve their efficiency if dial-a-ride or shared-ride taxi services were substituted for one or more of these routes. For example, Columbus, OH, and Batavia, NY, both with deteriorating fixed route bus systems and declining patronage, reversed this trend with the substitution of dial-a-ride services. Similarly, in Regina, Saskatchewan, use of transit rose from five to six rides per capita per year before the introduction of dial-a-ride, to 17 to 20 rides per capita per year at the present time.

SHORT-HAUL TRANSIT WITHIN THE CBD. Mobility within central commercial and business districts can be greatly facilitated by appropriately configured paratransit services. The Los Angeles, CA, circulator system, which provides a quick, inexpensive downtown shuttle service, is a comprehensive example of this type of paratransit application. Thirty-three minibuses owned and operated by the RTD ply the streets in two downtown loops, connecting the area's largest employment centers with various shopping and recreational attractions. Service is provided every four minutes from 7:00 a.m. to 7:00 p.m., Monday through Friday, and from 9:00 a.m. to 4:00 p.m. on Saturday. The fare is 10 cents and a free transfer is issued for connections between the two loops. Sixty percent of the project's operation is funded by the City of Los Angeles, 20 percent by the County of Los Angeles, and 20 percent by the Community Redevelopment Agency. These three local organizations have budgeted a total of $1.3 million to subsidize the system's operation.

The Regional Transit Service (RTS) of Rochester, NY, uses regular route buses to provide a free, 24-hour circulator system within the downtown Inner Loop area. The goals of the system are to encourage transit ridership and to improve the general mien of the CBD. According to recent passenger counts, the free-fare circulator system seems successful, averaging about 4,337 riders between the hours of 9:30 a.m. and 3:30 p.m.

Metro Transit of Seattle, WA, provides the Magic Carpet Service, a downtown free-fare bus and trolley service operating 24 hours a day, seven days a week. Like Rochester's RTS Inner Loop service, the Magic Carpet service applies only in Seattle's CBD. The freefare circulator system, subsidized by a contribution of $115,000 a year from the city of Seattle, began as a year-long demonstration project in 1973 and, due to its success, was extended for operation by a two-year contract.

Short-haul paratransit can also be used to connect fringe parking lots or park-and-ride lots to the CBD when auto restriction or parking management programs are in effect. In San Antonio, TX, for example, the San Antonio's Transit System's (SATS) El Centro service operates as two interlocking loop routes connecting two downtown park-and-ride lots to the downtown shopping district. The buses run every 10 minutes and the fare is 10 cents. Free transfers from other SATS bus routes to El Centro buses are available, although reciprocal transfers, i.e., from El Centro buses to regular routes, are not permitted.

SERVICE AT LOW-DEMAND TIMES. In the early morning and late evening hours when there is insufficient ridership to justify the use of fixed route transit, paratransit can provide viable public transportation services. An apparently unique example of such an application is the evening dial-a-bus service operated by the Kingston Transit System (Ontario, Canada) from 6:30 p.m. to 11:30 p.m. The service was initiated in October 1972 as a two-zone operation on an experimental basis and was subsequently expanded to a four-zone operation in August 1973. By September 1974, coverage was extended to the entire city, which was finally divided into five zones with one bus operating in each.

The zones link residential areas to a suburban shopping center where the dial-a-bus vehicles commence and where transfers can be made to other dial-a-bus vehicles or to a regular line-haul bus serving the University campus and adjacent institutional locations. The dial-a-bus vehicle will stop at any address in its service area unless the address is on a dead-end street. Reservations to board the bus must be made at least one hour in advance, although at times a half hour's notice is acceptable. Passengers can also arrange to be picked up on either a daily or weekly basis at a specific, prearranged time. The dial-a-bus fare is 35 cents; however, passengers transferring from a regular route bus pay a 10-cent surcharge upon boarding the dial-a-bus. These passengers, as well as those who board at the shopping center, are not required to make reservations to ride any of the five buses.

Because of the evening bus service, Kingston Transit was able to reduce its base night bus fleet from 14 to 10 buses and to institute a 40 percent fare increase (from 25 cents to 35 cents) on a poorly patronized service without experiencing losses in ridership.

SUBURBAN AUTO TRAVEL ALTERNATIVES. Even for the relatively affluent, demand-responsive paratransit transportation can provide an appealing alternative to using a private automobile for such trip purposes as shopping, chauffering children, attending meetings, and commuting to work. Paratransit modes such as dial-a-ride adapt well to nonradial and off-peak suburban trips not served adequately by traditional transit and can offer the convenience of subscription services. Characteristics of some successful dial-a-ride services are shown in Table 43, cited earlier.

MOBILITY FOR NONDRIVERS. Paratransit services can play a major role in providing and/or improving transportation for those with limited mobility: low income groups, the elderly, the very young, and the handicapped. For example, the Detroit Dial-A-Ride Resident Program, specially geared to meet the travel needs of such persons, provides a many-to-many transportation service for neighborhood residents in the metropolitan area, using a fleet of 12 vehicles (station wagons, vans, and a school bus). Well used by those to whom it caters, the service averages 327 passengers per day, 6 days per week. Although almost 80 percent of the trips are to medical and social service centers, ridership surveys indicate that the service is also used for making trips to and from shopping, recreational and education centers, and business districts.

The Detroit dial-a-ride system and others like it have been implemented under the federally assisted Model Cities Program. Still others are funded by local governments as part of community efforts to improve the living conditions of low income groups. Fares are minimized or omitted entirely in order to provide the maximum mobility for those who would otherwise be unable to travel. When the operation is contracted to a local taxi company, fares are sometimes paid by tokens or coupons provided at no charge to passengers making essential trips. The taxi operators then turn these in to the local agency and receive payment for the services that covers the actual cost and includes a small profit. Some form of subsidization is always required for the operation of these services.

Specially equipped services provided by the Haddonfield and Batavia dial-a-ride systems also demonstrate that paratransit can successfully serve short trips made by handicapped persons who require assistance in finding, boarding, or leaving vehicles. Such services are generally subsidized by the local government but can also be undertaken by large health facilities or non-profit service organizations. The operator usually contracts with the sponsoring organization to provide the service at a low fare, which is compensated for at a rate that allows the operator a profit.

Applicability

An insight into how various parameters might affect the level of service of demand-responsive systems is presented in Table 46.

INTEGRATION OF TRANSPORTATION SERVICES

The integration of public transportation services can assume two basic forms: intermodal and interagency. "Intermodal integration" connotes coordinating two or more different transit modes whose services are provided by the same or different operators. "Interagency integration" describes the joint action of

Table 46. Potential Effect of Service Parameters on the Demand-Responsive Levels of Service

PARAMETER	LEVELS OF SERVICE		
	Minimum	Desirable	Maximum
Service Area (square miles)	1.0	5.0 - 8.0	20.0
Population Density (persons/square mile)	1,000	>3,000	*
Demand Density (demands/sq.mile/hour)	10	20	*
Average Productivity (passengers/sq.mile/hour)	10	20	**
Average Wait Time (minutes)	*	10-15	30
Average Ride Time (minutes)	*	<2.0 times auto trip time	<4.0 times auto trip time
Vehicle Size (number of passengers)	5	5-12	20-25

*No limit.
**Apparently no systems have reached capacity.

two or more operators to provide coordinated services based on the same or different modes. Thus, there are four possible means of integrating transit services:

1. Intramodal, intra-agency: Within a single agency, unifying the network of a single mode (e.g., bus services provided by the Area Transportation Authority in Kansas City, MO).

2. Intermodal, intra-agency: Within a single agency, connecting the networks of two or more modes (e.g., bus and rail services provided by London Transport).

3. Intramodal, interagency: Connecting the networks of a single mode operated by two or more agencies (e.g., BART and MUNI trains in San Francisco).

4. Intermodal, interagency: Connecting networks of two or more modes operated by two or more agencies (e.g., BART trains and AC Transit buses in San Francisco).

The integration of transit systems can be approached at three different levels: the organizational structure under which the operators function, the services provided, and the facilities and equipment used. These are termed "institutional," "operational," and "physical" integration, respectively. While transit systems can be integrated at three levels, the existing operational and physical standards must be high if integration efforts are to succeed. Conversely, institutional integration between several operators must be established before operational or physical integration can be truly effective.

Achievement of institutional integration usually is the most difficult and time-consuming process. European experience reveals that it can take several years to realize total institutional integration and that it may involve formation of mergers, transit federations, transit associations, and/or transit communities. Mergers are the most prevalent approach to institutional coordination of transit services in the United States, while transit federations, with delegated authority over transit planning, tariffs, and revenue distribution, are becoming more common in Europe. The airline industry has established a few tariff associations wherein joint tariffs and the distribution of jointly collected revenue can be applied when partners do not compete but rather make end-to-end connections. U.S. railroads have also organized a few transit communities in which partners agree to a common tariff, coordinate routes and schedules, and, as appropriate, pool or exchange some rolling stock.

Operational integration entails creation of (1) a single transportation network that avoids duplication of service, (2) a common fare structure, (3) coordinated schedules to ensure smooth and reliable transfers, and (4) an areawide public and management information system. Physical integration may include standardization of vehicles, fare collection equipment and system signs, joint use of rolling stock, and construction of multi-user terminals. Physical and operational integration are often evidenced in a single service; for example, a park-and-ride facility (physical) may be coupled with a systemwide honor payment system (operational).

The foregoing discussion of the ways in which public transportation services (transit and paratransit) can be integrated to enhance the efficiency of the overall transportation system is presented to aid planners in determining the kind of integration effort that would be applicable to the specific circumstances existing in various urban areas. It is pointed out, however, that transportation system management also includes consideration of the interface between low- and high-occupancy private vehicular modes and higher density modes--i.e., the scope of the TSM plan includes improving the efficiency of the entire spectrum of transportation modes.

SECTION 7

TRANSIT MANAGEMENT EFFICIENCY MEASURES

A number of a actions can be taken to improve the internal efficiency of transit operations. The following are discussed in this section:

- Route evaluation
- Vehicle communication and monitoring techniques
- Maintenance policies
- Evaluation of system performance.

ROUTE EVALUATION

The reason for periodically reevaluating routes is to determine the degree to which existing routes and schedules respond to demand. Adjusting routes to increase service levels and system efficiency will likely attract more riders to the public transportation system. The major parameters of the evaluation entail spacing of route and transit stops, determining headways and route layout, and assessing vehicle loading standards. In the ensuing discussion, the performance standards of two large transit companies are used to illustrate the relationships between these parameters and the levels of service considered desirable in two urban areas. They are not presented as guidelines or criteria for use in any local area but rather as an indication of the kind of performance standards urban areas might develop as an expression of local goals.

Adjustments Leading to Desirable Levels of Service

ROUTE SPACING. Spacing of routes should be consonant with user characteristics--i.e., closely spaced in areas of high population density and low automobile ownership and widely spaced in areas of low population density and high automobile ownership. Table 47 presents the Denver Regional Transportation District's

Table 47. Denver Regional Transportation District's Proposed Route Spacing According to Socio-Economic Status (miles)

MEDIAN HOUSEHOLD INCOME ($/year)	POPULATION DENSITY (DWELLING UNITS PER ACRE)		
	>10	6 to 10	0.5 to 6
Less than 6,000	0.4	0.4	0.6
6,000 to 10,000	0.4	0.6	0.6
10,000 to 14,000	0.6	0.6	1.0
Over 14,000	0.6	1.0	1.0

Note: Less than 0.5 units per acre requires individual analysis.

(RTD) proposed distance between routes for regions with different socio-economic characteristics.

TRANSIT STOP SPACING. Studies indicate that the maximum acceptable walking distance for transit users is approximately 1,300 feet, or one-quarter mile, which is equivalent to a five-minute walk at normal walking speed. This average must, of course, be adjusted for certain regions--e.g., regions with inclement weather. It should also be borne in mind that too frequent transit stops, while providing short walking distances, also make the service less attractive because of resulting low travel speeds.

The Twin Cities Area Metropolitan Transit Commission (MTC), St. Paul, MN, has adopted a service policy for bus stop spacing. According to this policy, stops should be no more than 700 feet apart in normal residential areas and, considering the route and street configuration, no patron should need to walk more than 1,350 feet to reach a stop. In commercial and industrial areas, MTC's policy for locating bus stops is based on the concentration of patrons, rather than on the foregoing spacing standard.

HEADWAYS. It appears preferable to operate fewer routes with frequent service than a dense network of routes (one or two blocks apart) with long headways. Table 48 documents RTD's performance standard for headways, which is based on regular clock intervals such as 15, 30, or 60 minutes. Intermediate headways (e.g., 18 minutes) are not used because they are difficult for patrons to remember and calculate. Because so many of RTD's existing express and regional routes only provide one or two round trips daily, no standard for express/regional headways has been proposed.

Table 48. Denver Regional Transportation District's Headway Performance Standards, Local Routes (minutes)

ROUTE TYPE	WEEKDAY			SATURDAY		SUNDAY
	Peak	Base	Evening	Day	Evening	All Day
Radial	15	30	60	30	60	60
Crosstown	20	30	60	30	60	60
Circulator	30	60	60	60	60	60

Schedules should be formulated so that ample time is available for the vehicle to complete the trip on time under average traffic conditions. Where street traffic varies, either seasonally or by day of the week and hour of the day, schedules should be adjusted accordingly. However, schedule adherence can vary depending on the volume of service. Table 49 depicts RTD's policy for schedule adherence, as established by its performance standards. As reflected in RTD experience, where headways are less than 10 minutes, 75 percent "on time" (five minutes late or less) service is permissible. Where service is less frequent, schedule adherence should increase significantly. In no case should early departures occur.

Table 49. Denver Regional Transportation District's Schedule Adherence Standards (Minimum Percentage of Service on Time)

TIME PERIOD	HEADWAY		
	0-10 Minutes	10-30 Minutes	Special*
Peak hours	75	85	95
Off-peak hours	80	95	95
Weekend	80	95	95

*Unscheduled service (special runs).

ROUTE LAYOUT. Transit lines should cover all major traffic generators (office and residential complexes, shopping centers, factories) and connect them as much as possible to heavily traveled transit routes. Directness of service can be gauged by the percentage of transfers made on the system. Where a large percentage of the system's ridership must transfer to complete a trip (excluding transfers to express or rapid transit service), there would seem to be a potential for through routing or establishment of new routes to provide more direct service. RTD's performance standards for directness of service include the following:

- The maximum number of riders requiring transfers for the entire bus system should not exceed 20 percent.
- At least 90 percent of the transfers for the entire bus system should be made within an average transfer time of 7.5 minutes.
- If more than 20 percent of a route's riders require a specific transfer, new or through routes should be established and transfer service with a five-minute maximum waiting time should be created.

VEHICLE LOADING. While the objective of scheduled transit service is to provide a seat for every passenger, it is frequently not economically feasible during peak travel periods. Nevertheless, even during peak periods passengers should be assured a seat for at least the major portion of their trip. Loading standards should also differentiate by type of service; for example, an express route--a service of generally longer travel distance for which a premium fare is assessed--should provide every patron with a seat even during peak periods. Table 50 presents the Twin Cities Area Metropolitan Transit Commission's service standards policy for vehicle loading.

Table 50. Twin Cities Area Metropolitan Transit Commission's Maximum Vehicle Loading Standards (Percent of Seats Provided)*

OPERATING PERIOD	TYPE OF SERVICE		
	Express	Arterial	Circulation/ Distribution
Peak 30 minutes	100	125	150
Peak hour	100	100	125
Base (nonpeak)	75	75	100
Night	75	75	75
Saturday/Sunday	75	75	75

*Passengers as a percent of the seats provided for the designed time--standards may be exceeded for individual trips within the time period.

Improved Rescheduling Techniques

Traditionally, public transportation service is rescheduled four times a year--fall, holiday season, spring, and summer. Rescheduling procedures include revision of timetables on the basis of ridership patterns, with reallocation of vehicles and drivers to accompany revised timetables. In the past, evaluation and rescheduling procedures have been accomplished manually, being executed by a few highly experienced people in the scheduling department. The complexity of the factors involved (multiplicity of choices, limitations of time, driver selection preferences, and labor restrictions), however, provides an impetus to find a more efficient and economic means of carrying out the evaluation and rescheduling procedures. Within the recent past, computer technology has been applied to this aspect of transit operation. Though some smaller operators still employ manual evaluation and rescheduling techniques, many of the larger companies now use modern computer technology.

RUCUS, an acronym for "RUn CUtting and Scheduling," was developed for transit operations in 1970 under government contract and consists of a set of computer programs designed to assist in headway sheet development, vehicle scheduling, and driver run cutting. Since it is designed to operate on large-scale equipment, it is primarily suitable for large transit operations. However, many of its utility programs can be run on in-house computers operated by smaller properties. Several attempts have been made in the past to computerize various portions of the scheduling department's activities, generally with unsatisfactory results. RUCUS, however, being a modular package, is designed to cover all phases of the scheduling department's activities yet is suitable for implementation in stages or for partial implementation.

Briefly, the RUCUS package comprises the following programs: TRIPS, BLOCKS, RUNS, and DATA MANAGEMENT. The BLOCKS, RUNS, and TRIPS programs can be operated individually, while the DATA MANAGEMENT program provides for the interchange of information among the other three. The TRIPS module adjusts headway sheets on the basis of passenger demand and company policies. The BLOCKS component assigns vehicles to the headway sheets, using an optimization technique that requires deadhead times, layover policies and cost values for layovers, deadheads, and pullouts. The RUNS component assigns drivers to vehicles in accordance with the Drivers' Labor Agreement and other informal constraints.

EXPERIENCE. A unique route profile manual system for route evaluation has been developed by the Kanawha Valley Regional Transportation Authority (KRT), WV, to assist in solving the problems of monitoring route changes and growth. The system combines a series of surveys into one categorized package, providing schedule specialists with indexed reference data to evaluate the impact of any changes contemplated on a route. It eliminates the need for time-consuming research by combining available history data with daily, monthly, and yearly perpetual reports. Origin and destination and attitude surveys are compiled and tabulated by routes and trips, providing a foundation for each route profile, while a comprehensive revenue study produces an accurate picture of revenue production on a trip and route basis.

The surveys include a total passenger origin and destination survey, tabulated by routes and trips; a senior citizens' and handicapped persons' origin and destination survey; and an attitude study, again separated by routes and trips, which gauges seniors' reactions to various fare plans and KRT's operations in general. These data will eventually be coupled with day-to-day revenue data gathered from newly installed registering fareboxes (see pages 132 and 133) and will provide information upon which recommendations for service reductions or additions can be based. The senior citizen surveys can be used to determine whether routes primarily serve seniors; the revenue surveys to show what routes are revenue producing and whether passengers are willing to pay more for service, if necessary. The route surveys also separate individual route problems from the performance of the total system. Through the use of data processing and already available county or state computers, an almost daily record of route performance can be established.

This system can provide an accurate periodic readout that shows revenue production for each route, percentage of increase or decrease for previous years, average passenger counts, tickets collected, and other vital information used by the schedule specialists to continually review routes. In essence the route profile enables the small transit system to operate more efficiently and to minimize operation costs through judicious use of equipment and manpower.

Portland, Oregon's Tri-County Metropolitan Transportation District (Tri-Met) is successfully employing RUCUS to analyze the performance of each of Tri-Met's 57 routes: how many miles they cover, how many trips are taken, how many passengers are carried per vehicle-mile, and how many vehicle-miles are deadheaded. In the first few months of RUCUS operation, Tri-Met increased its runs and hours of vehicle operation 2.57 percent, while drivers' salaries rose less than half as much--only 1.09 percent. Other transit systems that have implemented a RUCUS program are: San Diego Transit Corporation (June 1975); CITRAN, Ft. Worth, TX (June 9, 1975); CNY Centro, Syracuse, NY (September 1975).

The Metropolitan Bay Transit Authority, Boston, MA, the Southern California Rapid Transit District, Los Angeles, CA, the Metropolitan Tulsa Transit Authority, Tulsa, OK, and the Mass Transit Administration, Baltimore, MD, are among the operating companies that have already implemented or are planning to implement RUCUS-type computer technology to handle a large amount of quantitative work, thus enabling more precise, effective, and economic scheduling.

Costs

The RUCUS project was developed under the sponsorship of UMTA. Therefore, since the software costs have been paid by the Federal government, the only costs borne in adopting the method would be the cost to adapt the program to individual requirements and the cost to organize the schedules department.

VEHICLE COMMUNICATION AND MONITORING TECHNIQUES

The provision of fleet-to-base realtime information exchange permits transit management to supervise and monitor route operations more effectively, thus improving internal management efficiency. The ability to respond rapidly to vehicle breakdowns and emergency situations enhances the productivity, safety, and security of the transit operation. Two-way radios are now commonly used for these purposes, although automatic vehicle monitoring devices, currently in the demonstration stage, also promise to yield useful results. Bus "checkers" or street supervisors also provide a low cost means of monitoring bus operations. Each of these techniques is described briefly below.

Two-Way Radio Systems

Radio communications between en route vehicles and the base station are being employed by a number of bus systems. AM or FM radios are used, depending on the location and the funds available. AM units, using the "citizen" or business bands, are less costly than FM installations but are subject to channel interference and, hence, are less useful in areas with high population density. Conversely, FM transmissions are blocked by topographical features that obstruct their line-of-sight requirements. For these reasons and because they require less channel capacity and are not as subject to interference, single-side band installations are becoming more popular.

In addition to the voice-only communications usually provided by such systems, voice/data sets are also available. Depending on the manufacturer, automatic data transmission can include vehicle identification and location, emergency alarms, and mechanical alarms that alert the dispatcher of poor engine performance and other mechanical malfunctions. Automatic data transmission reduces the need for driver voice communication, generally increases the amount and kind of information transmitted, improves dispatcher efficiency, and enhances overall supervisory control.

Experience shows that two-way communications, by providing reliable information on bus movements, create more effective control of fleet operations, which increases passenger and driver safety and provides better customer service. Reportedly, vandalism, hold-ups, and disturbances on buses are discouraged by the presence of radio equipment. Two-way radio systems have been used for reporting vehicle breakdowns, accidents, traffic conditions, schedule changes and reroutings, overloads, lost and found articles, and transit and nontransit emergencies.

Seattle's Metro Transit determined that driver morale rose because the drivers no longer felt isolated in the field; instead they felt closer to and part of the total system operation. Fort Worth's CITRAN discovered that, in some transfer situations, two-way radios can help to improve customer service. For instance, if a bus is behind schedule and transfer passengers are on board, the driver can notify the dispatcher that he is behind schedule and ask the dispatcher to relay a request to the connecting bus to wait, if possible.

Unless equipped with a silent alarm, two-way voice communications are frequently not useful in reporting certain emergencies such as robberies. Also, being subject to human error, driver reports of vehicle locations may not be entirely reliable.

Table 51 gives the cost and characteristics of four two-way radio systems. Users contend that the advantages of improved transit system control more than offset the cost of these systems and, reportedly, operational costs are minimal.

Table 51. Costs and Characteristics of Four, Two-Way Radio Systems

LOCATION	COST ($)	NUMBER OF RADIO UNITS	SYSTEM CHARACTERISTICS
Ft. Worth, TX	250,000	133	"MASTR II" UHF mobile radios for buses and supervisory vehicles, base stations, a dispatchers' console, and satellite receivers
Denver, CO	606,312	306	Mobile bus radio units, data transmission system (mechanical malfunction alert), and internal bus public address units.
St. Louis, MO	960,000 (approx.)	300 (400 more planned by December 1976)	Cost includes equipment, installation, and retrofit of base station. Plan to eventually equip all of the fleet of 900 with 2-way radios and tie them into the existing Dictalog System.
(Modification)	3,800		"Dictalog 400" (a 6-channel system that permanently records radio conversations and telephone trouble calls: 3 channels handle bus radio calls, 3 channels connect to 3 telephone lines).
Santa Barbara, CA	40,206	36	"Motorcom 70" UHF radios in buses. Cost includes base station transmission system.

Automatic Vehicle Monitoring

Automatic vehicle monitoring (AVM) systems, now under development, promise to provide a more accurate and reliable means of monitoring vehicle location. Using electronic sensors, the vehicle's location is automatically and independently checked and reported without the need for voice communication with the central dispatcher. The UMTA has sponsored research on the use of AVM systems, and Chicago and Philadelphia have staged UMTA fixed-route and citywide vehicle tracking demonstration projects.

The AVM system functions through use of roadway transmitters that feed electronic signals into a computer. The computer then determines the vehicle's location. Basically, transmitters are placed at various timepoints throughout a city--designated locations that buses are scheduled to pass at specified times. Each transmitter sends a constant electronic signal to a computer that, in turn, translates the electronic signal into a particular geographic location. Buses are outfitted with specially designed timers incorporated in the bus radio equipment. When the bus receives an electronic message asking for its location, the timer is automatically activated and counts the intervals of time from the moment the bus passes the last timepoint. Hence, the response to an electronic location query might be "timepoint 30 plus 10 seconds." Since the computer is programmed to know the time each bus should pass a particular timepoint, it can print out the location of the bus at the time of query and inform the central dispatcher whether it is ahead of, behind, or on schedule. The central dispatcher can then contact the driver by voice radio and ask him to slow down or speed up, as appropriate.

The potential benefits that mass transit operations can receive from AVM systems include:

- Improved adherence to bus schedules through continuous, realtime control of all bus operations.
- Increased reliability because of immediate knowledge of and response to mechanical malfunctions.
- Increased passenger safety from the provision of silent alarms that can summon help in case of criminal incidents.
- Reduced manpower and vehicle costs through improved vehicle allocation.

While the AVM systems have a demonstrated value, their application is presently limited by such factors as relatively high cost, lack of the ability to present only significant information (executive-only type, filtered information), and the channel capacity required by large-scale operations.

An automatic vehicle identification (AVI) project has also been tested by the Port Authority of New York and New Jersey (with UMTA sponsorship) as part of an urban corridor demonstration program. The project was designed to assist bus movements on the New Jersey Turnpike and along the I-495 corridor between the turnpike and the Port Authority Bus Terminal. In order to minimize project costs, the Port invited potential AVI suppliers to demonstrate their equipment. Ultimately, four manufacturers (General Electric, Glenayre, Philips, and WABCO) participated in the test program. The demonstration concluded that AVI system results were accurate (the lowest accuracy performance level of the four systems was 98.7 percent) under conditions in which the system could be expected to operate.

Because automatic vehicle monitoring and identification systems are still in the demonstration stage, detailed implementation and operational cost data are not yet available.

Street Monitoring

Transit checkers are a valuable assist in collecting data and overseeing on-street bus operations. For instance, in Clearwater, FL, the Central Pinellas Transit Authority (CPTA) uses a street supervisor as an operations trouble shooter, whose job is to keep service on schedule and reliable. Bus drivers report any mechanical or schedule programs to the street supervisor, who in turn corrects the situation, if possible, or conveys the information to CPTA headquarters through the use of a nearby public phone. The supervisor, who is capable of responding to passenger schedule queries, is situated at CPTA's downtown Clearwater transfer station, where all but one of CPTA's routes converge.

Atlanta's MARTA employs a team of 10 traffic checkers to collect data on passenger volumes, clock the running time of passing buses, monitor schedule adherence, and inventory park-and-ride lots. The information is used to determine route additions or changes, the necessity for shelters, and the alteration of service frequency. It allows MARTA to utilize existing capabilities more efficiently by steamlining low-patronage routes and increasing service in high-demand areas.

MAINTENANCE POLICIES

The kind of maintenance policy employed in a transit operation significantly affects both the internal efficiency of the system and the external image it presents to the public. Effective maintenance minimizes repair and operating costs, reduces the number of vehicles out of service, and simultaneously improves the reliability and dependability of the vehicles in service. The inside and outside appearance and the cleanliness of the vehicles are also important in attracting and retaining ridership. Hence, maintenance practices can be viewed as an adjunct to marketing.

The main element of a coordinated and comprehensive maintenance program is improved scheduling of maintenance. Another important consideration is the adequacy of the facilities required to perform maintenance functions. Also included, although discussed briefly, are the aspects of maintenance that can become marketing assets. These subjects apply equally well to the entire spectrum of paratransit and transit vehicles comprising the urban transportation system. They are presented here in the context of bus operations only, however, since the predominantly private ownership of paratransit operations and vehicles has inhibited formulation of standard maintenance policies and practices for paratransit modes.

Scheduling of Maintenance

A schedule of the type and frequency of maintenance to be performed on a fleet of vehciles should aim to achieve a low level of vehicle failures. It should also minimize the total cost of planned and unexpected repairs and replacements as well as the amount of consumables used (i.e., fuel, oil, grease, and coolant). To do so, servicing requirements for each vehicle must be tabulated and the performance of each vehicle monitored. Vehicle performance is influenced by factors such as route length, road and weather conditions, average distance between stops, loading, traffic density, driving styles, and the age and type of vehicle. Vehicle performance records and maintenance costs will jointly determine the best schedule to employ.

The number of variables that can influence the type of maintenance required and the frequency of the maintenance interval, coupled with the data collection and evaluation requirements, make the maintenance scheduling task especially complex, particularly in larger fleets of vehicles. The estimate that about 10 percent of the nation's urban bus fleet is currently out of service because of repair needs attests to the importance of maintenance to internal management efficiency and gives an idea of the potential savings that might be realized if maintenance and related activities were more closely coordinated and monitored.

MAINTENANCE SCHEDULING AIDS. Several devices that can aid in maintenance scheduling are available. For example, the farebox data collection device, described on page 132, automatically records the vehicle's need for consumables. The tachograph, currently in widespread use in buses, makes a chart recording speed and mileage versus time, which provides valuable data on driver habits that increase maintenance and operating costs (e.g., excessive idling, repeated acceleration and deceleration). It also records the location of traffic bottlenecks and the driving conditions that precede a bus accident.

Perhaps of greatest significance to the field of fleet vehicle maintenance is the emerging availability of computerized management tools that automate the tasks of collecting vehicle service information and monitoring inventory and repair costs. Such systems have been used successfully by at least three transit properties in the United States. The Alameda Contra-Costa Transit District (ACTD), Oakland, CA, and the Dallas Transit System (DTS), Dallas, TX, are using the Service, Inventory, and Maintenance System (SIMS). New York's Metropolitan Suburban Bus Authority (MSBA) is using a computer program specially tailored to its needs. The ACTD fleet contains 800 buses; DTS, 400; and MSBA, 400.

SIMS was originally initiated as an UMTA demonstration project for ACTD in 1971 and for DTS in 1972. However, it has functioned as an effective operational tool for over two years. Basically, SIMS consists of three computer programs (written in a modified COBOL language), which are described below, and is designed to run on an IBM 360/50 or larger computer.

Service/Unit Change System (S/U). This program module uses bus-miles as the basic unit to describe vehicle and component performance. The "service" element compiles data on vehicle consumption of fuel, coolant, oil, and other expendable items in order to record fleet use and indicate excessive individual vehicle use of consumables. The "unit change" element provides data on the replacement or repair of parts (such as generators and brakes). Continuing use of the program results in the development of individual coach histories.

Inventory Program. By recording parts issue and receipt transactions, this module maintains active status records on all materials and is used to assist management in reordering, purchase order monitoring, and financial control. The use and cost of parts in the repair of buses is recorded through issue transactions, and these records become an input into the "repair cost" module described below.

Repair Cost Program. This module records all labor transactions in the maintenance department and reports how labor costs have been allocated among revenue vehicles (general bus repair, inspections, cleaning), maintenance department tasks (maintaining shops and equipment), support of other organizations in the transit property, and the employees' fringe benefit program. Labor costs incurred in the repair and maintenance of buses are combined with materials cost data from the inventory module to provide a summary of costs incurred for repair and maintenance of individual buses.

Structured to accept data via keypunched cards or magnetic tape, SIMS reports can be produced on a daily, weekly, and/or monthly basis. Figure 10 shows the information presented on a daily commodity report, and Figure 11 presents an example of a monthly bus analysis report.

SIMS simplifies the task of information gathering and processing to monitor maintenance needs and eliminates the guesswork and trial and error inherent in manual maintenance scheduling of transit vehicles. Although SIMS was designed for widespread applicability, its use can be constrained by local circumstance. For example, while ACTD finds the inventory module an effective asset to operations, DTS is prevented from using the module due to local purchasing regulations.

COMMODITY REPORT
FOR DAY 07/31/73 08/02/73

DIVISION 01

BUS NO	ACCUM MILE	MILES SINCE LAST INSP	INSP DUE TYPE	INSP DUE STEP	MILES TODAY	* COMMODITIES DISPENSED * FUEL GALS	OIL QTS	COOL QTS	TERM ID
296	288.619	6.977	24K	1-04	67	20.5	0.0	6*	103-
297	275.524	2.115	6K	1-03	163	37.5	0.0	0	103-
298	279.184	6.929	24K	1-04	164	38.5	0.1	0	103-
299	289.772	1.650	6K	1-05	152	45.5	0.0	0	101-
337	145.148	5.668	6K	1-03	0	0.0	0.0	0	-
343	145.180	6.027	6K	1-11	23	25.5	0.0	0	101-
344	155.394	2.441	72K	1-12	118	5.5	0.0	0	101-
344						39.5	0.0	0	101-
345	150.129	2.509	6K	1-11	64	24.5	0.0	0	103-
346	149.122	2.309	72K	1-12	24	0.0*	0.0	0	-
347	149.075	2.069	72K	1-12	86	25.5	0.0	0	103-
348	146.300	2.474	6K	1-11	86	12.5	0.0	0	103-
349	153.756	6.172	72K	1-12	86	22.5	0.0	0	103-
350	146.629	0	6K	1-11	0*	16.5	0.0	0	101-
351	138.498	5.168	6K	1-09	86	24.5	0.0	0	102-

COMMODITY SUMMARY
FOR DAY 07/31/73 08/02/73

	MILES TODAY	* COMMODITIES DISPENSED * FUEL GALS	OIL QTS	COOL QTS
DIVISION 01	24.430	6.897.0	38.0	37
DIVISION 02	18.506	5.235.5	52.2	10
SYSTEM TOTALS	42.936	12.132.5	90.2	47

Figure 10. Example of a SIMS Daily Commodity Report

BUS ANALYSIS
FOR MONTH ENDING 07/31/73 08/02/73

FLEET 01 DIVISION 02

FUEL COST#$.236/GAL
OIL COST#$.093/QT
COOLANT COST#$.048/QT

		THIS MONTH						OIL MPQ LAST 3 MOS.			MILES
BUS NO.	YR	CENTS /MILE	MILES	FUEL GALS	FUEL MPG	OIL QTS	OIL MPQ	LAST MONTH	2ND MONTH	3RD MONTH	SINCE RE-RING
006	64	6.35	2.862	768.5	3.72	5.0	572	193	406	269	154K
008	64	7.45	2.419	762.0	3.17	3.0	806	187	137	201	176K
011	64	8.69	2.970	1.078.5	2.75	19.6	152	482	295	1.268	150K
014	64	9.34	2.788	1.098.5	2.54	10.0	279	263	250	448	183K
019	64	6.74	2.627	743.5	3.53	15.6	168	279	141	445	142K
024	64	6.10	2.366	596.0	3.97	12.9	183	176	133	437	142K
026	64	6.87	2.818	807.0	3.49	10.5	268	607	391	0	155K
027	64	8.27	1.854	637.5	2.91	19.0	98	126	359	214	197K
030	64	7.08	2.756	825.5	3.34	3.0	919	163	263	253	163K
037	64	7.15	2.170	649.5	3.34	18.1	120	535	257	205	184K
040	64	6.94	2.737	801.5	3.41	8.4	326	206	297	0	202K
FLEET 01 TOTALSO			28.367	8.768.0		125.1					
AVERAGE		7.36	2.579	797	3.24	11.3	227	233	223	338	

Figure 11. Example of a SIMS Monthly Bus Analysis Report

Specially tailored computer programs developed for use in transit maintenance have also proved to be highly beneficial management tools. For instance, MSBA uses a customized computer program written in COBOL for an IBM 370/155 in place of the prior manual record-keeping system. The maintenance element of the program includes three SIMS-like modules and is only part of the total management information system. For example, the program also prepares the payroll, annual budget, and timetables, and contains a RUCUS-like route, scheduling, and planning module.

Another computer decision-making tool is the Maintenance Planning System (MPS). MPS, a rapid transit management aid, is designed to assist management in controlling maintenance operations and modification programs and in establishing effective failure recording and analysis programs. MPS generates the following user reports:

- Maintenance Control Reports. These are scheduling assists that identify the preventive maintenance and major repairs to be performed.
- Equipment Status Reports. These include maintenance history, configuration control, and modification programs.
- Failure Analysis Reports. These identify items having a high failure rate so that changes in scheduled maintenance or a modification program can be adopted.

This system was initially installed in the San Francisco Bay Area Rapid Transit District and has been modified to operate on an IBM 360/370 series computer under OS. The programs are written in a modified COBOL language.

COSTS. The implementation costs for the SIMS and other computerized maintenance systems are not available, but computerizing a manually scheduled maintenance program undoubtedly requires a significant amount of labor initially. For instance, the SIMS inventory module usually entails a thorough cataloging and complete physical inventory of stock. The conversion task naturally will be less time consuming where careful records have been previously kept.

The approximate cost for data processing under the SIMS program can be estimated from the experience of the two current users. ACTD uses a computer service bureau to process its data at a monthly cost of $1,800-$2,000. DTS uses a municipally owned computer to process its reports at a monthly cost of $600-$700. Since the cost of data processing is proportional to the amount of data processed, which in turn is roughly proportional to the number of buses in the system, a cost range of $1.50-$2.40 per bus per month is implied, depending on data-processing charges and the number of reports required.

The impact of a computerized maintenance program on reducing staff costs is not yet certain; however, indications are that staffing decreases will be slight, if any. Although ACTD and MSBA noted no change in staffing, DTS found that fewer personnel were needed in the record-keeping area despite the fact that the number of reports generated increased after SIMS was implemented.

ADVANTAGES and DISADVANTAGES. Computerized procedures for maintenance scheduling and control, undoubtedly, are powerful management tools. All relevant data is collected, recorded, and processed in a systematic fashion, and due to the frequency of reporting and the orderly review procedure inherent in the system, oversights are less likely to occur. The result is improved effectiveness in preventive maintenance inspections since vehicles are less likely to "slip by" their scheduled inspection. Also, because complete vehicle case histories are readily available, the incidence of a recurring problem within the fleet is easily discernible.

As mentioned previously, variations in procedures or other differences in the transit authority's structure can reduce the effectiveness of standardized computer programs. For instance, the inventory module of the SIMS program is applicable to ACTD operations but inapplicable in Dallas because of DTS purchasing regulations.

Both DTS and ACTD have been affected by the delay that occurs between the time the computer detects a problem and the time management becomes aware of it. The delay occurs because of the time required for off-site data processing (at least one and one-half days in the ACTD system and three to five days in the DTS system), and as a result, problem areas may not be noted for several days.

Bus Maintenance Facilities

Replacing, expanding, and/or updating maintenance facilities may be necessary in order to accommodate present and future fleet needs, especially if increased maintenance is contemplated to improve internal management efficiency. Fleet and vehicle size have increased over the years, and many storage and maintenance facilities have since become inadequate, either because of age or design or both. A recent survey of 54 transit properties determined that 12 percent of their maintenance facilities were 21-29 years of age, while 49 percent were 30 years of age or older.

There are many inexpensive ways of enhancing the productivity of an existing maintenance garage. For instance, changes in layout, reorganization of space, alterations in work flow patterns, and addition of materials-handling aids (such as vehicle hoists, bus bays, or overhead trolleys that function as parts conveyors) may adequately adapt an outmoded facility to new needs. Where simple renovations are inadequate, a larger scale modernization and/or expansion program may be required. For example, CITRAN, the City Transit Service of Fort Worth, TX, recently renovated and expanded its service complex, at a cost of $1.16 million, to include administrative offices, operations facilities, and service and maintenance areas. One of the most notable new features of the expansion project is a degreasing room adjacent to the garage where maintenance personnel can clean engine parts before working on them. CITRAN has found that the degreasing operation helps speed up maintenance operations and increases accuracy in spotting and repairing leaks. Another advantage resulting from the project is that CITRAN now can lubricate a vehicle while it is being refueled.

The Dallas Transit System also recently dedicated a new maintenance and service center, completing its nine-year modernization and expansion program. The 88,000-square foot split-level structure, which cost $2.9 million, houses shops for heavy overhaul, light unit overhaul, paint and body work, sign work, upholstery, and printing, as well as a building maintenance department, storeroom, offices, and a recreation room. It also features 29 bus bays, a dynamometer room where exhaust emissions are tested and evaluated, and a steam cleaning room.

Where existing facilities do not lend themselves to remodeling or expansion, new construction may be required. Denver's Regional Transportation District (RTD) expects to complete construction of a new 256,000-square foot bus storage and maintenance facility by late 1976. RTD expects that a highly efficient bus repair system--one permitting routine maintenance operations to be performed at the same time as specialized repair work--will result. Repair areas are being designed to include a stock of parts so that mechanics will not need to waste productive time traveling to and from a stock room. Other RTD garage features include wash and fueling lanes, paint and body shops, and an indoor brake test system. The garage will be designed to accept a solar heating system. The cost of the facility is estimated at $6.6 million for construction and $1.2 million for equipment.

Maintenance as a Marketing Aid

Vehicle cleanliness, the repair of torn seats, replacement of broken windows, removal of graffiti, and upkeep of on-board advertisements are also among the actions warranting attention from maintenance crews, since they can significantly enhance the image of the transit operation.

Many transit properties have adopted formal policies on the frequency and extent of bus cleaning, while others schedule bus cleaning on an informal basis. For instance, transit properties such as those in Atlanta, Baltimore, Pittsburgh, Toronto, and Chicago wash their vehicles each day as a matter of policy (weather permitting). The Chicago Transit Authority's daily washing task is accomplished in less than three minutes per bus as the result of its newly installed bus washer. The specially designed machinery is capable of washing the top, sides, front, back, and wheels of two buses at one time.

By contrast, the Washington, DC, Metropolitan Area Transit Authority (WMATA) uses an informal bus cleaning policy. WMATA services its fleet in eight maintenance garages, each of which sets its own cleaning schedule. Interior vacuuming is performed more regularly, usually on a daily basis. The schedule for the thorough scrubbing of vehicle interiors varies from once each month to once every four months. Exterminating is performed approximately once a month by an outside contractor.

EVALUATION OF SYSTEM PERFORMANCE

The degree of internal efficiency that a transit system demonstrates is largely dependent upon the type of control management exercises over the financial and operational aspects of the system's performance. Heretofore, little assistance on these vital matters has been available to transit managers on an industrywide basis.

Cost accounting practices have developed within individual operations to satisfy local requirements and, as a result, are based on a wide variety of accounting categories. Although these practices usually are satisfactory for the individual operation, the lack of a standardized set of accounts for the industry has prevented collection of industrywide statistics to use as an external measure of one system's financial performance relative to another system's financial performance.

Industry reports on operating data have similarly suffered from a lack of standard reporting categories. The American Public Transit Association (APTA)*, the main source for financial and operating statistics within the transit industry, uses two data collecting systems. Acquisition of data by APTA, however, depends upon the voluntary submission of information by its members, and only 10-15 percent file reports. In addition, APTA accepts financial data based on either the APTA Accountant's Association or the Interstate Commerce Commissions' chart of accounts. Substantial differences in the accounting categories of the two systems prevent the consolidation of financial data to adequately measure the industry's aggregate financial performance.

*Formed by the merger of the American Transit Association (ATA) and the Institute for Rapid Transit (IRT).

Contrary to the financial reporting system, the APTA Transit Pars Data Interchange, devised in an attempt to characterize the industry's operating performance, uses standard definitions for reporting categories. In the Pars system, acquired data is arrayed in such a way as to permit comparisons of operating performance among transit systems by establishing a "par" for each expense reporting category. "Par" for each category represents the percentage of operating revenues that, if designated for the category, will result in a 10 percent net operating profit.

Project FARE

The major shift in the transit industry from private to public ownership intensified the need for an industrywide information base. As a result, in 1971 UMTA, ATA, and the Institute for Rapid Transit jointly developed a program to devise an improved system. The outcome was initiation of Project FARE (Uniform Financial Accounting and Reporting Elements), the projected database of which is designed to serve:

- Federal, state, and local government agencies for transit industry analysis and for financial program administration.
- Transit industry associations for monitoring industry performance.
- Individual transit systems for comparing their performance with other similar operations.

Implementation of the FARE system will partially satisfy the reporting requirement of Section 15(a) of the Urban Mass Transportation Act of 1964, as amended. Also, FARE data must be furnished by transit properties after July 1, 1978 in order to qualify for UMTA Section 5 assistance.

FARE Reporting Categories

FARE data will be collected according to standard reporting category definitions, each category being defined at the highest level of detail to satisfy the needs of potential users. FARE's reporting structure comprises the following four elements:

- Expenses, including detailed subsidiary schedules and auxiliary data relating to expenses.
- Balance sheet information, including detailed subsidiary schedules for reporting tangible property used in transit operations.
- Revenue and passenger statistics.
- Nonfinancial operating data.

Codification of the reporting categories is currently in process, the planned completion date for Project FARE being January 1977.

Implementation of the FARE system will provide transit managers with powerful tools for monitoring, controlling, and evaluating their operations. FARE information can be enhanced and/or supplemented by computer projects that have been developed to improve internal transit efficiency. Specifically, the three components of the TOMS (Transit Operations and Management Systems) program--RUCUS (Run Cutting and Scheduling), SIMS (Service, Inventory, and Maintenance System), and MPS (Maintenance Planning and System for rail rapid transit)--complement FARE by enhancing the industry's ability to furnish FARE data.

APPENDICES

APPENDIX A

SELECTED ANNOTATED BIBLIOGRAPHY

GENERAL LITERATURE SURVEYS

Alan M. Voorhees and Associates, Inc. Guidelines to Reduce Energy Consumption through Transportation Actions. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration, May 1974.

Discusses various low-cost, short-term transportation actions and estimates their potential for reducing energy consumption. The transportation actions evaluated in this document may reduce energy consumption in one or more of the following ways: improving the efficiency of vehicle operation; causing a shift from low-occupancy travel modes to high-occupancy travel modes; and reducing travel demand.

INTERPLAN Corporation. Joint Strategies for Urban Transportation, Air Quality and Energy Conservation. Vol. 1: Joint Action Programs (PB 244 473). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration; the U.S. Environmental Protection Agency; and the U.S. Federal Energy Administration. Springfield, VA: NTIS, January 1975.

Fifty-four transportation actions that might jointly serve to further UMTA, EPA, and FEA goals are comprehensively surveyed. The interrelated impacts of potential joint implementation are analyzed and the results utilized to formulate synergic programs.

R. H. Pratt Associates, Inc. Low Cost Urban Transportation Alternatives: A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities. Vol. I: Results of a Survey and Analysis of Twenty-One Low Cost Techniques. Prepared for the U.S. Department of Transportation, Assistant Secretary for Policy, Plans, and International Affairs, January 1973.

Twenty-one low cost transportation alternatives are surveyed. It is concluded that the "most promising" transportation alternatives are exclusive bus lanes on urban arterials, reserved lanes on freeways, busways on specially constructed rights-of-way, work schedule changes, and highway traffic engineering system improvements.

IMPROVED VEHICULAR FLOW

Highway Research Board. Highway Capacity Manual--1965. Highway Research Board Special Report 87. Washington DC, March 1966.

A condensed and authoritative source on the present empirical and theoretical information on highway capacity. The document functions as a guide for determining the capacity, service volume, or level of service that will be provided by either a new highway design or an existing highway.

Institute of Traffic Engineers. Transportation and Traffic Engineering Handbook. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1976.

Focuses on the major elements of total transportation planning, particularly as they relate to traffic engineering.

Improvements in Signalized Intersections

U.S. Department of Transportation, Federal Highway Administration. Manual on Uniform Traffic Control Devices for Streets and Highways. 1971, pp. 234-240.

Presents traffic control device standards (warrants) for all streets and highways. The following eight parameters are presented as factors for analysis during investigation of the need for traffic signal control: minimum vehicular volume, interruption of continuous traffic, minimum pedestrian volume, school crossings, progressive movement, accident experience, systems, combination of warrants.

Canada, Ministry of Transport; Ontario Ministry of Transportation; and the Corporation of Metropolitan Toronto. Improved Operation of Urban Transportation Systems. Vol. 1: Traffic Signal Control Strategies: A State-of-the-Art. Downsview, Ontario, Canada, March 1974.

Describes numerous computerized signal timing techniques.

Wagner, Frederick A., Jr.; Frank C. Barnes; and Daniel L. Gerlough (Alan M. Voorhees & Associates). Improved Criteria for Traffic Signal Systems in Urban Networks. National Cooperative Highway Research Program Report 124. Washington, DC: Highway Research Board, 1971.

Explores ways of improving traffic operations through simple modifications of fixed-time signal settings. Through field studies, the study sought to verify the ability of computer simulation methods to predict accurately the effects of signal timing modifications.

Freeway Ramp Metering

Newman, Leonard; Alex M. Dunnet; and Gerald J. Meis. "An Evaluation of Ramp Control on the Harbor Freeway in Los Angeles." Freeway Operations, Surveillance, and Communications. Highway Research Record 303. Washington, DC: Highway Research Board, 1970, pp. 44-55.

Presents an evaluation of conditions on the Los Angeles Harbor Freeway before and after ramp control. The results showed that freeway congestion and delay were decreased substantially.

One-Way Streets, Reversible Lanes, and Traffic Channelization

American Association of State Highway Officials. A Policy on Design of Urban Highways and Arterial Streets: 1973. Washington, DC, 1973.

An analysis of channelization, one-way streets, and reversible lanes is provided in Part III, Chapter K of this source.

Highway Research Board. Channelization: The Design of Highway Intersections at Grade. Highway Research Board Special Report 74. Washington, DC, 1962.

Includes numerous design examples of channelization to illustrate present design practice. A critical analysis of the channelization examples is presented.

Removal of On-Street Parking

Stout, R. W. A Report on CBD Parking. Highway Planning Technical Report 23. U.S. Department of Transportation, Federal Highway Administration, December 1973.

Describes CBD parking characteristics in urban areas of various sizes.

Off-Street Loading

Battelle, Columbus Laboratories. Urban Goods Movement Program Design. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration, June 1972.

Presents a detailed examination of urban goods movement characteristics in the United States. Nine options that appear to be promising candidates for alleviating problems relating to the urban goods movement are identified and developed. Spatial and temporal separation of goods and people movements, required off-street loading and unloading facilities, and urban fringe terminal systems are among the options surveyed.

Wilbur Smith and Associates. Urban Transportation Concepts: Center City Transportation Project (PB 198 603). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, September 1970, pp. 165-171.

Describes the characteristics of the urban goods movement and suggests a strategy for improvement that includes regulatory controls on truck routes and loading periods, traffic operational improvements, modifications of zoning ordinances, consolidation of goods movement, and construction of special truck ways and tunnels.

PREFERENTIAL TREATMENT OF HIGH-OCCUPANCY VEHICLES

Levinson, Herbert S.; Crosby L. Adams; and William F. Hoey (Wilbur Smith and Associates). Bus Use of Highways: Planning and Design Guidelines. National Cooperative Highway Research Program Report 155. Washington, DC: Transportation Research Board, 1975.

Provides planning and design guidelines for the efficient use of highway facilities, arterials, and terminals. The report details basic planning parameters and warrants for various bus priority measures.

U.S. Department of Transportation, Transportation Systems Center. Priority Techniques for High Occupancy Vehicles: State-of-the-Art Overview. Working draft. Prepared for the U.S. Department of Transportation, Office of the Secretary, Urban Mass Transportation Administration, and the Federal Highway Administration, February 1975.

Presents an overview of priority techniques for high-occupancy vehicles, a set of transportation improvements that make more efficient use of existing vehicle and highway capacities. The priority techniques are discussed in light of operational experience, implementation guidelines, and decision-making criteria.

Freeway Bus and Carpool Lanes and Access Ramps

California, Business and Transportation Agency, Department of Transportation. Freeway Lanes for High-Occupancy Vehicles: Third Annual Progress Report. Sacramento, CA, December 1973.

Surveys the operational characteristics of California's busway, preferential toll collection provisions, and contra-flow and with-flow bus and/or carpool lanes. Examines bus and carpool bypass lanes on metered ramps and carpool motivation techniques.

Bus and Carpool Lanes on City Streets and Urban Arterials

Wilbur Smith and Associates, and Sverdrup and Parcel and Associates, Inc. Bus Rapid Transit Options for Densely Developed Areas. Prepared for the U.S. Department of Transportation, Office of the Secretary, Federal Highway Administration, and the Urban Mass Transportation Administration, February 1975.

Gives guidelines for providing bus rapid transit in densely developed areas without freeways. The effectiveness of on-street means of improving passenger flow is ranked as follows (in order of decreasing effectiveness): bus streets, median bus lanes, contra-flow curb bus lanes, and with-flow curb bus lanes.

Bus Preemption of Traffic Signals

Evans, Henry K., and Gerald W. Skiles. "Improving Public Transit through Bus Preemption of Traffic Signals." Traffic Quarterly 24 (1970):531-543.

Describes the 1967 Los Angeles bus preemption of traffic signals experiment.

Kay, J. L.; J. C. Allen; and J. M. Bruggeman (JHK and Associates, and Peat, Marwick, Mitchell and Co.). Evaluation of the First Generation UTCS/BPS Control Strategy. Executive Summary (PB 244 110). Prepared for the U.S. Department of Transportation, Federal Highway Administration. Springfield, VA: NTIS, March 1975.

Evaluates the performance of five UTCS/BPS control alternatives tested in Washington, DC.

U.S. Department of Transportation, Urban Mass Transportation Administration. "Bus Priority System (BPS)." In Innovation in Public Transportation: A Directory of Research, Development and Demonstration Projects, pp. 16-18, June 1974.

Briefly describes Washington, DC's bus priority system and gives an extensive list of reports on bus priority and urban traffic control systems.

Toll Policies

Garcia, J. M. "Exclusive Bus and Carpool Lanes Installed and Operated by the State of California." Paper presented at the Technology Sharing Workshop on Priority Techniques for High-Occupancy Vehicles, 5-6 February 1975, San Francisco, CA.

The San Francisco-Oakland Bay Bridge nonstop provision for buses and carpool vehicles at the toll collection center is defined in the course of this survey of high-occupancy preferential treatments employed in the state of California.

REDUCED PEAK-PERIOD TRAVEL

Remak, Roberta, and Sandra Rosenbloom. Peak Period Traffic Congestion. 2 vols. Draft. Prepared for the Transportation Research Board, National Cooperative Highway Research Program. Santa Barbara, CA, and Austin, TX, December 1974.

Volume I identifies eleven major techniques for reducing traffic congestion in urban areas. Volume II presents the results of a nine-month study of solutions to reduce that congestion. Volume II also describes and evaluates eight packages of mutually-supportive approaches to alleviating peak-period congestion.

Work Rescheduling

Desimone, Vincent R. "Four-Day Work Week and Transportation." Transportation Engineering Journal 98 (1972): 705-714.

Surveys the prospects for four-day workweek implementation and concludes that the action can measurably improve mobility and reduce transportation congestion problems. Contends that potential transportation impacts that must be dealt with are total travel, peak-period travel, and safety considerations.

O'Malley, Brendan W. "Work Schedule Changes to Reduce Peak Transportation Demand." Better Use of Existing Transportation Facilities. Transportation Research Board Special Report 153. Washington, DC, 1975, pp. 166-182.

A comprehensive survey of New York's experience with rescheduled work hours. Includes examples of questionnaires and study results used to determine the feasibility of work schedule adjustments and provides program planning and implementation considerations.

Owens, Robert D., and Glen J. VanWormer. "The Effects of Staggered Working Hours on Traffic Volumes at a Large Industrial Complex." Traffic Engineering, August 1973, pp. 61-64, 81.

Reviews the impact of 3M Company staggered work hours on traffic volumes on nearby roads. Concluded that staggered work hours have been highly successful in reducing morning and evening peak-period traffic volumes in the vicinity of the company.

Congestion Pricing

Bhatt, Kiran U. Road Pricing Technologies: A Survey (1212-11). Washington, DC: The Urban Institute, August 1974.

Surveys various roadway usage pricing policies. The focus is on four of the most promising technologies: manual or automated toll booths, supplementary licenses, automatic vehicle identification systems, and on-vehicle meters. Also summarizes the likely administrative and enforcement procedures, associated problems, and costs of the four technologies.

Geok, Lim Leong. "Singapore." In Proceedings of the O.E.C.D. Conference on Better Towns with Less Traffic. pp. 97-126, Paris, France: Organization for Economic Co-operation and Development, 1975.

Provides a detailed examination of Singapore's proposed vehicle restraint measures. Increased parking fees and auto licensing within a center city restricted zone were determined to be the most feasible means of decreasing the city's traffic congestion.

Transportation Research Board. Problems in Implementing Roadway Pricing. Transportation Research Record 494. Washington, DC, 1974.

A collection of research papers examining the problems related to roadway pricing, particularly legal issues, collection problems, and parking taxes.

Watson, Peter L., and Edward P. Holland. "Congestion Pricing--the Example of Singapore." Finance & Development, March 1976, pp. 20-23.

Provides the most recent information on Singapore's experience with congestion pricing. Indications are that the pricing scheme has been very successful in reducing traffic congestion in the restricted zone during the hours of restriction.

Peak-Period Truck Restrictions

Battelle, Columbus Laboratories. Urban Goods Movement Program Design. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration, June 1972.

Assesses a series of program plans and projects directed toward resolving the problems of transporting commodities within urban areas and defines these plans in terms of the effects upon the shipper, the carriers, consignees, and the general public.

Wilbur Smith and Associates. *Motor Trucks in the Metropolis.* Detroit, MI: Automobile Manufacturers Association, August 1969.

Presents the results of an in-depth study of the operation of the motor truck in urban areas. The focus is on the use of trucks; that is, truck movements, truck use in relation to land use, and other facts about trucks and their operations as a part of the total urban transport system.

PARKING MANAGEMENT

London Transport Executive. *Action Plan for Improvements in Transportation Systems in Large U.S. Metropolitan Areas: A Generalized Automobile Parking Policy to Encourage Increased Use of Public Transit by Commuters.* Prepared for the U.S. Department of Transportation, Office of the Secretary, July 1972.

Identifies the development of parking policies as a method for increasing transit ridership and reducing automobile use in the congested downtown areas of large U.S. cities. Suggests several approaches that could serve as the basis for an auto parking policy in large cities.

Parking Regulations

Delaware Valley Regional Planning Commission. *Philadelphia Central Business District Parking Rate Experiment* (PB 238 168). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, September 1974.

The Philadelphia CBD parking rate experiment determined that rate changes have an effect on parkers, related revenues, and turnover rates. As the result of rates favoring short-term parking, there was a decrease in the number of long-term users. However, the decrease was filled by a greater number of short-term parkers.

Kulash, Damian. *Parking Taxes as Roadway Prices: A Case Study of the San Francisco Experience* (1212-9). Washington, DC: The Urban Institute, March 1974.

A detailed explanation of San Francisco's experience with a 25 percent parking tax. Parking was reduced throughout the taxed area in response to the increased parking charges.

Park-and-Ride Facilities

Gatens, Daniel M. (University of Washington, Seattle). Locating and Operating Bus Rapid Transit Park-Ride Lots: A Synthesis of Experience and Some Preliminary Planning Guidelines (PB 236 010). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, August 1973.

Reviews and synthesizes previous experiences with locating and operating park-and-ride lots throughout the country. As the result of experience in seven municipalities, a set of general planning guidelines relevant to the location and size of a park-and-ride facility in an urban transportation corridor was developed.

PROMOTION OF NON-AUTO OR HIGH-OCCUPANCY AUTO USE

Ridesharing

Bush, Leon R., and George J. Todd. "Vanpool Implementation in Los Angeles." In Proceedings of the 4th Annual Los Angeles Council of Engineers and Scientists Symposium: Transpo LA--Economic Leverage for Tomorrow, edited by A. D. Emerson, pp. 55-70. Los Angeles, CA: American Institute of Aeronautics and Astronautics, 1975.

Documents Aerospace Corporation's successful vanpool program in El Segundo, CA. Detailed guidelines are presented on program organization, costs, database requirements, and operating procedures.

Owens, Robert D., and Helen L. Sever. The 3M Commute-A-Van Program: Status Report. St. Paul, MN: 3M Company, May 1974.

Details 3M's company-run vanpool program. Through the use of economic incentives, 3M has utilized its vanpool system to reduce congestion, parking demand, and capital expenditures for auto-related facilities.

Pratsch, Lew. Carpool and Buspool Matching Guide. 4th ed. U.S. Department of Transportation, Federal Highway Administration. January 1975.

Describes and reviews the operational experience with 19 carpooling incentives, particularly with regard to implementation considerations, applicability, institutional-legal barriers, public acceptability, and effects on travel behavior and energy consumption.

De Leuw, Cather & Company. User Manual. 2 vols. Draft. Prepared for the U.S. Department of Transportation, Federal Highway Administration. September 1975.

Volume I, Bicycle Facility Design Criteria, provides bikeway design guidelines and implementation considerations. Volume II, Bicycle Facility Location Criteria, outlines the planning process and locational criteria necessary for developing a comprehensive bicycle plan.

English, John W.; Craig W. Conrath; and Michael L. Gallavan. Bicycling Laws in the United States Traffic Laws Commentary, Vol. 3, No. 2. U.S. Department of Transportation, National Highway Traffic Safety Administration, September 1974.

Reviews bicycling laws of the 50 states and of 50 cities selected at random.

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Reviews pedestrian laws of the 50 states and of 50 cities selected at random.

Fruin, John J. Pedestrian Planning and Design. New York: Metropolitan Association of Urban Designers and Environmental Planners, Inc., 1971.

Explores the components of pedestrian planning and design considerations for pedestrian-oriented environments. Identifies eight planned pedestrian environments and describes reasons for their success.

Hamill, James P., and Peter L. Wise (Pan-Technology Consulting Corporation). Planning for the Bicycle as a Form of Transportation (PB 234 664). Prepared for the U.S. Department of Transportation, Office of the Secreatry. Springfield, VA: NTIS, July 1974.

Manual designed to assist local governments and cycling groups in planning for the development of safe, functional, and economical bikeway facilities.

Ohrn, Carl E., and Richard C. Podolske. A Framework for Investing in Urban Bicycle Facilities. Minneapolis, MN: Barton-Aschman Associates, Inc., 1974.

A detailed examination of considerations for urban bicycle facilities. Examines the operational and applicability characteristics of bicycle routes, lanes, and paths.

Peat, Marwick, Mitchel & Co., and RTKL Associates, Inc. A Manual for Planning Pedestrian Facilities (PB 241 053). Prepared for the U.S. Department of Transportation, Federal Highway Administration. Springfield, VA: NTIS, June 1974.

Provides basic considerations necessary to plan pedestrian facilities or systems of facilities. Includes the basic concepts in pedestrian trip generation and movement and the types of facilities available to the planner. Provides a general approach to determining the economic costs of pedestrian facilities.

Seattle, Engineering Department, Traffic and Transportation Division. Bikeway System Planning and Design Manual. Prepared for the Washington Traffic Safety Commission. Seattle, WA, August 1975.

Examines the bikeway planning process and identifies the techniques that aid in bikeway system formulation, implementation, and evaluation.

Auto-Restricted Zones

Barton-Aschman Associates, Inc. Action Plan for Improvements in Transportation Systems in Large U.S. Metropolitan Areas. Auto-Free Zones: A Methodology for their Planning and Implementation. Prepared for the U.S. Department of Transportation, Office of the Secretary, July 1972.

Analyzes the concept of auto-free zones, with emphasis on factors leading to proposals for such zones. Discusses various types of auto-free zones and settings for their development and provides planning techniques and the framework for an evaluation system.

Breines, Simon, and William J. Dean. The Pedestrian Revolution: Streets Without Cars. New York: Random House, Vintage Books, 1974.

Describes an array of pedestrian-oriented facilities in use throughout the world. Special attention is focused on pedestrian islands and pedestrian districts as ways to recapture urban open spaces for human use.

Carlson, David, and Mary R. S. Carlson. "The Pedestrian Mall: It's Role in Revitalization of Downtown Areas." Urban Land, May 1974, pp. 3-9.

Details the United States experience with pedestrian malls and examines conditions that contribute to their success. Determines that malls warrant serious consideration in medium-sized or small cities where CBD revitalization is sought.

Organisation for Economic Co-operation and Development. Streets for People. Paris, France, 1974.

Considers various approaches and techniques for achieving traffic-free environments and provides several site-specific analyses of program implementation.

Orski, C. Kenneth. "Car-Free Zones and Traffic Restraints: Tools of Environmental Management." Pedestrian Protection. Highway Research Board 406. Washington, DC: Highway Research Board, 1972, pp. 37-45.

Details the Bremen, Germany, and Göthenburg, Sweden experiences with traffic cells.

Thomson, J. M. "Traffic Limitation in Towns." Paper presented at the University of California conference, "Transportation Horizons: Rebuilding Urban Environments," 20-25 September 1973, Berkeley, CA.

Considers the advantages and disadvantages of traffic limitation and outlines the basic objectives of a traffic limitation policy. Examines traffic restriction, restraint, and avoidance measures as part of a larger traffic limitation scheme.

TRANSIT AND PARATRANSIT SERVICE IMPROVEMENTS

Merritt, John C. (Purdue University, West Lafayette, IN). The Effect of Improved Services on the Bus Transit Ridership in the Greater Lafayette Area (PB 238 939). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, December 1973.

Details a research project that was performed to study the effects of new transit equipment and improved routing on riders and their attitudes toward the local transit system. Daily ridership more than doubled as the result of improved service, and riders expressed more positive attitudes toward system performance.

Transit Marketing

Grey Advertising, Inc., and Lesko Associates. Transit Marketing Management Handbook: Marketing Plan. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration, April 1976.

Focuses on transit marketing program planning, particularly objectives, strategies, budgeting, and the development of a marketing action plan. Part III of the report provides a sample marketing program plan for a hypothetical transit system as a planning aid.

London Transport Executive, and Barton-Aschman Associates, Inc. Action Plan for Improvements in Transportation Systems in Large U.S. Metropolitan Areas: A Generalized Public Transit Marketing Policy (DOT-OS-10192). Prepared for the U.S. Department of Transportation, Office of the Secretary, July 1972.

Examines an action plan for improvements to transportation systems in Washington, DC. Discusses the need for a community relations department and the provision of information to management on public attitudes and trends.

National Urban League, and Mark Battle Associates, Inc. Marketing Techniques and the Mass Transit System (PB 233 735). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, July 1973.

Identifies marketing and information techniques being used by mass transit systems to increase patronage and make transit more responsive to public needs. Also develops a model for evaluating transit information and marketing systems.

Security Measures

American Transit Association. Vandalism and Passenger Security: A Study of Crime and Vandalism on Urban Mass Transit Systems in the United States and Canada. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration, September 1973.

Analyzes the extent and seriousness of crime and vandalism on urban mass transit systems and discusses various approaches used in dealing with the problem.

Metropolitan Washington Council of Governments, Department of Public Safety. Citizen Safety and Bus Transit: A Study of the Relationship between Personal Safety and Bus Transit Usage in the Metropolitan Washington Area (PB 237 740). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, June 1974.

Investigates the major factors that affect the relationships between bus transit and crime and the citizen in the Washington, DC, area. The report focuses on actual reported on-bus incidents, reported incidents that occur at local bus stop intersections and bus stop approaches, and incidents observed by bus riders. Concludes that personal safety is a low-priority concern among bus riders and nonriders.

Transit Shelters and Terminals

Levison, Herbert S.; Crosby L. Adams; and William F. Hoey (Wilbur Smith and Associates). Bus Use of Highways: Planning and Design Guidelines. National Cooperative Highway Research Program Report 155. Washington, DC, Transportation Research Board, 1975, pp. 130-155.

Provides design and location guidelines, cost information, and planning considerations for the provision of passenger shelters, central terminals, and outlying terminal facilities.

U.S. Department of Transportation, Federal Highway Administration. Bus Shelters. February 1973.

Provides information on the desirable characteristics of bus shelters, analyzes state highway agencies' experiences with bus shelters, and details local public and private transit companies' experiences with providing bus shelters. Includes illustrations on the types of shelters commonly used, materials used, size of the structures, and design considerations.

Transit Fare Policies and Fare Collection Techniques

"Fare Collection Systems: A Review and Prognosis." Metropolitan. November/December 1975, pp. 14-28.

Examines the state of the art of fare collection and details the latest innovations in fare collection systems.

Grey Advertising, Inc., and Chase, Rosen & Wallace, Inc. Transit Marketing Management Handbook: Pricing. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration, April 1975.

Briefly discusses the raising and lowering of fare levels. Part III of this document examines fare structure and fare collection techniques. Summarizes the characteristics of several prepaid fare systems.

Hershey, William R. et al. Transit Fare Prepayment. Prepared for the U.S. Department of Transportation, Transportation Systems Center. Ann Arbor, MI: The Huron River Group, Inc., February 1976.

Surveys the experience, problems, and public response to various prepaid transit fare programs and assesses the cost effectiveness, advantages, and market potential of prepaid fares. The report identifies the best applications and implementation structures for prepaid fare systems.

Holland, Dempster K. (St. Louis University, Center for Urban Programs). A Review of Reports Relating to the Effect of Fare and Service Changes in Metropolitan Public Transportation Systems (PB 234 069). Prepared for the U.S. Department of Transportation, Federal Highway Administration. Springfield, VA: NTIS, June 1974.

Reviews articles and reports developed in the past 10 years, which relate to demand elasticities for public ground intracity transportation.

Leicester, Edward Hall, and F. Houston Wynn (London Transport Executive and Wilbur Smith and Associates). Transit Technical Studies: Analysis of Alternative Bus Fare Structures (PB 237 244). Prepared for the Washington Metropolitan Area Transit Authority. Springfield, VA: NTIS, July 1974.

Examines the likely effects of alternative fare policies on bus patronage and annual fare revenues of the Washington, DC, Metropolitan Area Transit Authority.

Nelson, Gary. "Fairtran: Operation of a Credit Card Transit Fare System." Draft. Latham, NY: RRC International, Inc., August 1975.

Details the operational characteristics of the credit card transit fare system currently in operation in Derby, CT. Analyzes the advantages and disadvantages that have become apparent since ths system was instituted in March 1973.

Extension of Transit with Paratransit Services

INTERPLAN Corporation. Potential for Flexicab Services: Innovative Uses of Taxis and Jitneys for Public Transportation (PB 248 783). Prepared for the U.S. Department of Transportation, Office of the Secretary. Springfield, VA: NTIS, December 1975.

Discusses the innovative uses of taxis and jitneys in providing public transportation services. Concludes that such modes can (1) offer mobility in low-density areas where mass transit is infeasible, (2) economically supplement mass transit to improve the overall level of service, and (3) promote ridership of regional commuter rail and rapid rail systems and express bus services in order to reduce the use of private automobiles.

Kirby, Ronald F. et al. (The Urban Institute). Para-Transit: Neglected Options for Urban Mobility. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration and the Federal Highway Administration, June 1974.

Investigates urban transportation modes referred to collectively as paratransit. Reviews and assesses experience to date with paratransit and the potential roles of these services in urban transportation systems. Provides recommendations for overcoming obstacles to the application of these modes.

Integration of Transportation Services

Homburger, Wolfgang S., and Vukan R. Vuchic. "Federation of Transit Agencies as a Solution for Service Integration." Traffic Quarterly 24 (1970):373-391.

Provides a brief analysis of the many problems associated with integrating urban public transport services. Hamburg, Germany's federation of transit organization (HVV) is cited as an organization successful in dealing with these problems, and the HVV solution is examined in detail. The HVV formula for revenue distribution is also included in the text.

INTERPLAN Corporation. Integration of Transit Systems (PB 241 270, 241 271, 241 272, 241 273). 4 vols. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, May, June, and October 1973.

Defines the basic categories of transit integration and assesses the potential for interagency and intermodal integration of transit system operations in U.S. urban areas, drawing on an analysis of the successful experience of European transit systems.

TRANSIT MANAGEMENT EFFICIENCY MEASURES

Route Evaluation

Alan M. Voorhees & Associates, Inc. A Systems Analysis of Transit Routes and Schedules. Prepared for the Washington Metropolitan Area Transit Commission. McLean, VA, November 1969.

Details a U.S. Department of Housing and Urban Development demonstration of a transit planning computer program package for use in improving transit routing and scheduling. The program was demonstrated by the D.C. Transit Company in Washington, DC, and resulted in a revised operating plan that would improve transit operations.

Roberts, Kenneth R. (The Mitre Corporation). Vehicle Scheduling and Driver Run Cutting: RUCUS Package Overview (PB 241 501). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, November 1973.

This report describes the Run Cutting and Scheduling (RUCUS) package, a set of computer programs designed to assist in developing optimal time intervals between vehicles and allocating vehicles and drivers more efficiently. Further information on RUCUS can be obtained from the Urban Mass Transportation Administration, Office of Transit Management, Washington, DC, 20590.

Vehicle Communication and Monitoring Technologies

Lukes, Martin, and Raymond Shea (Chicago Transit Authority). Monitor-CTA (PB 223 878). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springgield, VA: NTIS, May 1973.

Details the Chicago Transit Authority's experience with an automatic vehicle monitoring demonstration project. Determines that there is excellent potential for increased management information from the use of a monitoring system.

Port Authority of New York and New Jersey, Tunnels and Bridges Research Division. Urban Corridor Demonstration Program, Manhattan CBD-New Jersey Corridor: Automatic Bus Identification (PB 235 061). Prepared for the U.S. Department of Transportation Administration, Federal Highway Administration, Urban Mass Transportation Administration, and Office of the Secretary. Springfield, VA: NTIS, June 1974.

Describes the experimental use of automatic bus identification systems in a Manhattan-New Jersey Urban Corridor Demonstration Program. The AVI test programs showed that the systems tested were accurate and reliable. As the result of this study, the following conclusions were drawn: low power radio frequency technology is ready to implement AVI applications, a standard AVI equipment specification is essential to ensure future compatibility, early implementation of AVI applications should be encouraged, and an operational bus AVI system should be implemented under federal sponsorship.

Maintenance Policies

Bakr, M. M., and S. L. Kretschmer (Marquette University, Milwaukee). Optimal Scheduling of Bus Maintenance (PB 238 575). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, March 1974.

Proposes a formal approach toward the determination of bus maintenance schedules, based on the total cost of periodic preventive maintenance and the cost of unscheduled repairs. The total cost is expressed in terms of various cost elements and the probabilities of failure for different systems in the bus. A computer program is used to derive the least-cost maintenance schedule.

Thurlow, Virgil S. (The Mitre Corporation). SIMS Overivew: Service, Intentory, and Maintenance System (PB 241 495). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, October 1973.

Provides a brief overview of the three SIMS modules and how they can assist transit properties in managing their servicing and maintenance activities.

Thurlow, Virgil S.; John Bachman; and C. Denver Lovett (The Mitre Corporation). Bus Maintenance Facilities: A Transit Management Handbook. Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Washington, DC: November 1975.

Addresses the question of bus maintenance facility capacities necessary to support particular fleet sizes. Provides standards and guidelines for buildings, service facilities, garages, plant layouts, and support equipment. Includes measures of efficiency in facility use by which properties may reorganize space, change traffic patterns, or otherwise modernize their maintenance building(s).

Evaluation of System Performance

Harvey, David L. et al. (Arthur Andersen & Co.). Project FARE Task IV Report: Urban Mass Transportation Industry Financial and Operating Data Reporting System. Vol. I: Task and Project Summary (PB 226 354). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration. Springfield, VA: NTIS, November 1973.

Details the Task IV component of Project FARE and provides a summary of the entire project. Recommends that the FARE reporting system be implemented in conjunction with a nationwide program of assistance to coordinate and upgrade the internal information systems of individual transit properties. Additional information on FARE is available from the Urban Mass Transportation Administration, Office of Transit Management, Washington, DC, 20590.

APPENDIX B

SOURCES OF INFORMATION FOR DATA CONTAINED IN TABLES AND FIGURES

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4.	R. H. Pratt Associates, Inc. Low Cost Urban Transportation Alternatives: A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities. Vol. I: Results of a Survey and Analysis of Twenty-One Low Cost Techniques. Prepared for the U.S. Department of Transportation, Assistant Secretary for Policy, Plans, and International Affairs, January 1973, p. 104.
5.	Wilbur Smith and Associates. Motor Trucks in the Metropolis. Detroit, MI: Automobile Manufacturers Association, August 1969, p. 105.
6.	Levinson, Herbert S.; Crosby L. Adams; and William F. Hoey (Wilbur Smith and Associates). Bus Use of Highways: Planning and Design Guidelines. National Cooperative Highway Research Program Report No. 155. Washington, DC: Transportation Research Board, 1975, p. 13.
7.	INTERPLAN Corporation. Joint Strategies for Urban Transportation, Air Quality and Energy Conservation. Vol. 1: Joint Action Programs (PB 244 473). Prepared for the U.S. Department of Transportation, Urban Mass Transportation Administration; the U.S. Environmental Protection Agency; and the U.S. Federal Energy Administration. Springfield, VA: NTIS, January 1975, pp. 2-34, 2-35.
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9.	Levinson, Herbert S. et al. (Wilbur Smith and Associates). Bus Use of Highways: State of the Art. National Cooperative Highway Research Program Report No. 143. Washington, DC: Highway Research Board, 1973, p. 14.
10.	Crain, John L.; Peter G. Fitzgerald; and Sydwell Flynn (Bigelow-Crain Associates). Golden State Corridor Bus Priority System. Prepared for the Transportation Systems Center. May 1975.
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	Orski, C. Kenneth. Bus Priority Programs and Policies in the United States. Prepared for the OECD Conference on Better Towns with Less Traffic, 14-16 April 1975, Paris, France.
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