NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 69

# BUS ROUTE AND SCHEDULE PLANNING GUIDELINES

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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# BUS ROUTE AND SCHEDULE PLANNING GUIDELINES

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:

PLANNING
FORECASTING
OPERATIONS AND TRAFFIC CONTROL
(PUBLIC TRANSIT)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. MAY 1980

## NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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## PREFACE

There exists a vast storehouse of information relating to nearly every subject of concern to highway administrators and engineers. Much of it resulted from research and much from successful application of the engineering ideas of men faced with problems in their day-to-day work. Because there has been a lack of systematic means for bringing such useful information together and making it available to the entire highway fraternity, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize the useful knowledge from all possible sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series attempts to report on the various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which they are utilized in this fashion will quite logically be tempered by the breadth of the user's knowledge in the particular problem area.

## FOREWORD

*By Staff*
*Transportation*
*Research Board*

This synthesis will be of interest to urban planners, transportation managers, and route planners who must establish, budget, and adjust bus transit routes. The synthesis contains specific guidelines to achieve the best route and service policies and plans.

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Administrators, engineers, and researchers are faced continually with many highway problems on which much information already exists either in documented form or in terms of undocumented experience and practice. Unfortunately, this information often is fragmented, scattered, and unevaluated. As a consequence, full information on what has been learned about a problem frequently is not assembled in seeking a solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of synthesizing and reporting on common highway problems. Syntheses from this endeavor constitute an NCHRP report series that collects and assembles the various forms of information into single concise documents pertaining to specific highway problems or sets of closely related problems.

Establishing the best bus routes and services for a given urban area entails an examination of past systems, the current system, and potential needs for future service. Once these have been identified, the goals and objectives of that area's bus transit must be stated. Then, when routes and schedules have been implemented, service levels must be carefully monitored for improvement, although changes should be made only with great care and consideration.

This report of the Transportation Research Board presents numerous aspects of bus route and service planning, from route structure, coverage, and length to passenger comfort and safety. It should prove useful as a tool for urban bus transit planners in upgrading or expanding bus service and in coordinating bus and rail service.

The report strongly recommends that uniform standards for interstate over-limit travel be sought. Enforcement efforts and permit procedures also need to be coordinated.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

## CONTENTS

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W. Campbell Graeub, Engineer of Public Transportation, Transportation Research Board, assisted the Special Projects Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

# BUS ROUTE AND SCHEDULE PLANNING GUIDELINES


## SUMMARY

Bus transit service planning in most urban areas is largely an outgrowth of historic and geographic circumstances. Planning should reflect the specific needs and operating requirements of each urban area. Relevant planning factors include: past operating practices and procedures; the current operating authority and system extent; revenue requirements (i.e., reliance on fares); land-use, population density, and employment features; street patterns; and the availability of off-street rail transit. These factors, singly and in combination, influence the pattern of bus services and the opportunities for change and expansion.

The best possible service should be provided to the greatest number of people within the governing economic constraints. Planning must balance the amount and type of services provided with the net costs of providing the service. This trade-off underlies all service planning decisions.

Bus services should be carefully related to existing and potential markets and concentrated in heavy travel corridors with the greatest service frequency and route coverage in the approaches to the city center. Route structure should be clear and understandable, and service duplication should be avoided. Changes in transit service must be coordinated with planning and traffic agencies to expedite bus flow and to assure that streets in nearby developing suburban areas are able to accommodate buses. These changes in service should minimize disruption of existing riding patterns.

The greatest opportunities for major modifications to services or routes accompany (a) expansion of transit services from urban and regional carriers into integrated systems and (b) provision of new service to growing suburban areas. However, the alterations in service patterns usually represent small-scale, fine-grained adjustments. Such adjustments reflect changes in actual ridership due to population growth or decline; provision of service to new employment centers, schools, or residential areas; ability to operate on new streets or expressways; and "restructured" or reduced service to bring costs and revenues in better balance. In almost every case, the amount of financial support beyond fare-box revenues influences the amount and type of service.


### GUIDELINES

The following service planning guidelines reflect current practice in the United States and Canada.

- *Service Criteria.* Bus service should be provided where (a) population density exceeds 2000/mile$^2$ (770/km$^2$) and (b) ridership exceeds 20 to 25 pas-

sengers per bus hour on weekdays, 15 on Saturdays, and 10 on Sundays. Route continuity and transfer requirements may lower these factors.

- *Service Area.* The service area is normally defined by legislation. Where population density within this area exceeds 4000/mile$^2$ (1500/km$^2$), or three dwelling units per acre (7.4/hm$^2$), 90 percent of the residences should be within 0.25 mile (400 m) of a bus line. Where population density ranges from 2000 to 4000/mile$^2$ (770 to 1500/km$^2$), 50 to 75 percent of the population should be within 0.5 mile (800 m) of a bus line.

- *Route Structure and Spacing.* Bus routes should fit major street patterns. Basic grid systems are appropriate where streets are in a grid pattern; radial or radial-circumferential systems are applicable where radial or irregular street patterns exist. The transit center (timed-transfer concept) may be used to concentrate bus lines in suburban centers. Bus routes should be spaced at approximately 0.5 mile (800 m) in urban areas and 1 mile (1600 m) in low-density suburban areas. Closer spacing should be provided where terrain inhibits walking.

- *Route Directness and Length.* Circuitous routings should be avoided: a route not more than 20 percent longer than the comparable trip by car is desirable. Route deviation should not exceed 8 min per round trip (based on at least 10 customers per round trip). There should usually not be more than two branches per trunk-line route, and never more than four.

Routes should be as short as possible to serve their markets, and generally should not exceed 25 miles (40 km) or 2 hr per round trip. Where long routes are required, travel times should be increased because of the difficulty in maintaining schedules. Through routes, which can save costs and reduce congestion in the central business district (CBD), should be provided wherever possible.

- *Route Duplication.* There should be one route per arterial except on approaches to the CBD or major transit terminal. A maximum of two routes per street (or two branches per route) is desirable. Express service should utilize freeways or expressways to the maximum extent possible. Express and local services should be provided on separate roadways, except where frequent local service is provided.

- *Service Period.* Regular service should be provided on weekdays from about 6 a.m. to 11 p.m. Suburban feeder service should be provided on weekdays from 6 a.m. to 7 p.m., or only during the morning and afternoon rush periods. In larger cities, 24-hr service should be provided on selected routes. Saturday and Sunday service should be provided on principal routes; however, Sunday service may be optional in smaller communities.

- *Service Frequency.* Bus service frequency should not be less than that determined by (a) policy headways or (b) desirable loading standards, whichever is appropriate. Desirable minimum service frequencies are: peak—20 min urban, 20 to 30 min suburban; midday—20 min urban, 30 min suburban; evening—30 min urban, 60 min suburban; owl—60 min.

- *Loading Standards.* Desirable loading standards are: peak 30 min—150 percent; peak hour—125-150 percent; transition period—100-125 percent; midday/evening—75-100 percent; express—100-125 percent; suburban—100 percent. Policy headways may result in lower loading standards.

- *Bus Stops.* Bus stop frequency should be approximately 10 to 12/mile (6 to 7/km) in central areas, 6 to 8/mile (4 to 5/km) in urban areas, and 2 to 5/mile (1 to 3/km) in suburban areas. Express service stop frequency should be 2 to

4/mile (1 to 2/km) in suburban pickup areas. Energy conservation may call for longer spacing between stops.

Bus stop lengths per 40-ft (12-m) bus should not be less than 105 ft (30 m) near side, 140 ft (43 m) midblock, and 80 ft (24 m) far side (140 ft after a right turn). An additional 45 ft (14 m) should be added for each additional 40-ft bus expected to stop simultaneously. For 60-ft (18-m) articulated buses, 20 ft (6 m) should be added.

- *Service Changes.* Major service changes should be instituted not more than 2 or 3 times each year. A minimum 6-month period should be established for experimental service.
- *Route Planning Procedures.* Key steps in planning route changes include: (a) a review of characteristics of the service area, including physical feasibility for bus operations; (b) an estimate of ridership (often by comparison with similar areas); (c) an estimate of revenues; (d) a simulation of travel times by car, considering bus requirements; (e) schedule preparation; (f) an estimate of costs; and (g) an assessment of economic performance.

## RESEARCH NEEDS

Significant research needs include:

- Improved methods for estimating ridership and results of service changes.
- Assessment of the effects of operating policies on energy requirements.
- Equipment design, including door arrangements and seating configurations.
- Fare collection methods, policies, and equipment.
- Transit management tools, including computerized schedule preparation.
- Service to low-density areas.
- Information and marketing.
- Improved bus speeds and dependability.

CHAPTER ONE

# INTRODUCTION

Bus transportation is the dominant form of public transport in American cities today. Buses carry almost 70 percent of the 7.9 billion annual passenger trips in the United States and account for more than 55 percent of the 35.8 billion annual passenger miles (57.6 billion km). They serve cities of all sizes. As of January 1, 1978, there were 1004 bus systems in the United States, more than a quarter of which were in urbanized areas of fewer than 50 000 people (*1*).

Urban bus and rail transit systems are now viewed as essential public services whose many benefits to mobility, environmental quality, and energy conservation have brought increased local, state, and federal support to help upgrade and modernize service. These systems provide mobility to all residents, increase capacity in heavily traveled corridors, reduce reliance on car trips, shape urban development, and permit city centers to be compact and intensively developed.

Because of these benefits, existing bus services are being upgraded and expanded and new service is being initiated in communities where none existed before. However, the expansion of planning efforts has not been accompanied by a corresponding evaluation of the methods and techniques of bus service planning.

## PURPOSE AND SCOPE

For each urban area the process of planning bus transit services—establishing and revising routes, schedules, and hours of operation—has developed largely from the original transport policies and patterns of that area.

- Many current routes and systems are carryovers from old streetcar operations.
- Administrative and financial conditions, including the sources and levels of subsidy, play an important role in the location and level of service.
- Most transit operators plan routes on an intuitive basis by drawing on their experience and their knowledge of existing land-use, ridership, and schedule requirements. Considering that this is not usually an analytical procedure, such route selection is known to have a fair degree of success.
- Within the context of financial, service, operational, and aesthetic goals, factors to be considered include service criteria, convenience, transfers, speeds, cost of service (farebox returns and subsidies), geographic conditions (including street conditions), and service to special groups (elderly, handicapped).
- User input is considered and public hearings are held to assist in route planning.

There is need to clearly identify, assess, systematize, and formalize the current practices, methods, and criteria that have general applicability. Accordingly, this synthesis brings together the best contemporary practice in the United States and Canada into a set of service planning guidelines. It looks into urban areas of various sizes that both have and lack rapid transit; it identifies goals, criteria, standards, and emerging planning guidelines. These guidelines emphasize practice rather than theory and short-range rather than long-range planning.

The guidelines are based on interviews with transit agencies over a broad spectrum of U.S. and Canadian cities such as Akron, Chicago, Cleveland, Knoxville, Milwaukee, Nashville, Oakland, Pittsburgh, Toronto, and Washington, D.C. Pertinent reports and service standards from other cities were also collated and reviewed.

This synthesis also investigates various aspects of planning for both conventional motor coaches operating in urban areas and some trolley bus and streetcar (light-rail) operations. The primary focus is on bus service planning, often referred to as operations planning by transit agencies, and on planning routes and schedules, accelerating bus flow, and monitoring service. Many other factors, such as finance, marketing, and management are briefly discussed in terms of their effects on service decisions.

Terms used in this synthesis conform, insofar as possible, to the definitions in Transportation Research Board Special Report 179, "Glossary of Urban Public Transportation Terms."

## USE OF SYNTHESIS

The synthesis is mainly directed toward transit planners and officials who control routes and services and toward metropolitan planning agencies who influence development and long-range transit actions. It will help the rapidly expanding group of transit managers and planners, as well as those concerned with existing services and systems. The guidelines will be useful in

- Upgrading existing services,
- Expanding service to suburban areas,
- Restructuring service to take advantage of changes in operating territories and new administrative arrangements (i.e., regional transportation authorities),
- Planning new rail transit lines or street systems, and
- Gaining ridership and improving performance.

Application, which will vary among transit systems, reflects individual differences in precedents, physical conditions, system size, needs, and resources. Service patterns,

route types, and scheduling requirements will be vastly simplified for small transit properties.

### ORGANIZATION

The synthesis contains general guidelines and illustrative examples drawn from bus systems of varying size and complexity (Appendixes A and C). The following chapters set forth bus service guidelines pertaining to:

- Planning factors and context,
- Goals and objectives,
- Route and service planning,
- Service levels,
- New routes and service changes,
- Monitoring and scheduling service, and
- Improving bus flow.

A final chapter summarizes current and future research, and the appendixes contain detailed case studies.

CHAPTER TWO

# CONTEXT AND OVERVIEW

Bus service planning should reflect the specific needs and patterns of each urban area. Planners should carefully consider past operating practices and procedures; the current operating authority and extent of the system; revenue requirements (i.e., reliance on user fares); land use, population density, and employment features; street patterns; the availability of off-street rail transit; and usage potentials.

The best times to make major changes in services or routes are when urban and regional carriers are being integrated into one system and when new service is being provided to growing suburban areas. For most transit agencies, however, such changes in service patterns are usually only small-scale, fine-grained adjustments that reflect actual ridership changes caused by population growth or decline; service to new employment centers, schools, or residential areas; operations on new streets or expressways; and restructured or reduced service to bring costs and revenues into better balance. In almost every case, the amount of financial support beyond farebox revenues influences the amount and type of service.

### PAST PRACTICES

Most urban bus systems have grown naturally from historic and geographic patterns such as the route structure, operating practices, and administrative constraints that characterized early street railway operations. Because transit-dependent people concentrate in established transit corridors, it is difficult to change basic routings. For example, in the Washington, D.C., area, before the rail line opened in 1976, the Virginia and Maryland bus lines' service patterns largely reflected those of former operations under private ownership. Within D.C. the service pattern was largely that of the streetcar and bus lines once operated by the Capital Transit Company. However, routes are now being restructured to feeders as each new section of the rail system is opened, although full integration of services is inhibited by different revenue requirements within each of the eight jurisdictions. Also, in New York City, rail and bus lines continue to resemble their separate origins and to operate without coordinating their services.

The effects of history are being progressively reduced as regional transit agencies increasingly extend their scope of operations. Denver, Portland, and Los Angeles can provide good examples. But historic factors remain a planning consideration.

### EXTENT OF OPERATING AUTHORITY

Ideally, an entire urbanized area should be served by transit. A publicly owned transit agency should cover as large an area as is economically feasible. Private companies often find it unprofitable to serve lower-density, outlying regions and can be expected to serve these areas only if financial aid is available (*2*).

A key factor in bus service planning, therefore, is the geographic extent of operation, i.e., whether the service is confined to the central city and sometimes its adjacent suburbs or whether it extends across the entire metropolitan area.

Most street railway and bus systems were originally operated within city limits that continue to dominate many systems. This operating pattern resulted in a system of short, high-density lines; a large number of passengers carried per bus mile operated; and a relatively small number of low-density lines. The suburban services by other carriers, often with longer headways and lines, are still being provided in the New York City, San Francisco, and Detroit systems.

Systems in many metropolitan areas whose boundaries between city and suburb are blurred provide both types of services. Regional transit agencies such as those in Atlanta, Boston, Cleveland, Denver, Houston, Los Angeles, Miami, and Oakland provide a great variety of service frequencies

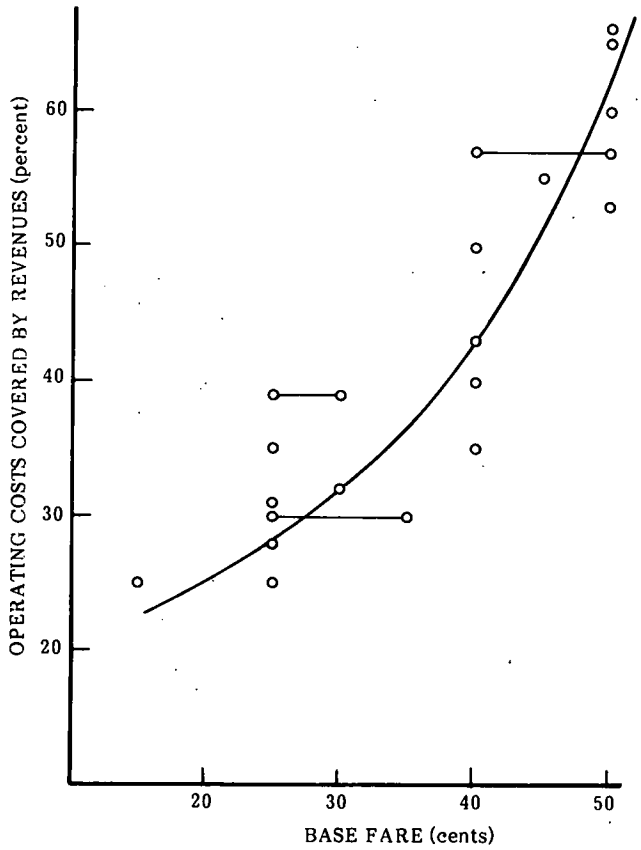



*Figure 1. Transit fare in relation to expenses covered (1977) (based on data from Table 1).*

and types. They operate many low-density suburban lines, in an attempt to provide unified regional services—usually as a single operating entity.

An important alternative to extending the agency's operations in low-density areas is to contract for services with private carriers. Under New York's Metropolitan Transportation Authority (MTA) and Chicago's Regional Transportation Authority, it is the regional agency that establishes financial and service policies, including purchase of service agreements with suburban and private carriers. The principal carrier is operated and managed through the long-established transit operator under the financial guidelines of the regional agency.

Geographic boundaries, especially state lines, limit operating authorities and inhibit integration of system operations. Thus, although the Southeastern Pennsylvania Transportation Authority (SEPTA) has effectively integrated city and suburban lines, the Port Authority Transit Corporation (PATCO) Lindenwold line (Philadelphia) and New Jersey bus lines remain separate entities. A similar situation has arisen in the San Francisco area, where the city-owned Muni system and Alameda-Contra Costa (AC) Transit serve the city and East Bay respectively, whereas the Bay Area Rapid Transit (BART) system overlaps both carriers. In contrast, the Bi-State system (St. Louis) extends into Illinois areas as well.

## REVENUE REQUIREMENTS AND PUBLIC POLICY

Public transport services are influenced by policy decisions on required revenue from the farebox and other sources. Current financial problems are one aspect of the general urban problems of rising costs, declining revenues, and reduced services.

During its formative years, transit was viewed as a monopoly to be regulated in the public interest. Today, it is viewed as an essential public service to be financially supported if it is to operate at reasonable fares. Energy and air quality concerns further underscore the importance of good transit service.

Community support of operating costs beyond farebox revenues is now a reality in most American cities. Table 1 shows that fares currently cover between 25 and 65 percent of total operating costs. Figure 1 shows how the proportion of costs borne by fares increases as fares rise. California, for example, finances about one-third of its transit service costs from the farebox. Special metropolitan funding arrangements, such as those found in Atlanta, Denver, and San Diego, permit low systemwide fares.

Figure 2 shows the generalized relations among drivers' wage rates, fares, and subsidies. These relations are generally valid over time, although precise values may vary. The break-even fares (inclined line) roughly equal 10 percent of the wage rate. Thus, a $2.50/hr wage rate calls for a $0.25 fare to break even, and an $8.00/hr wage calls for an $0.80 fare. Thus, a $0.50 fare and an $8.00/hr wage rate would involve a $0.30 subsidy per passenger. The subsidy per rider can be approximated by the following formula:

$$\text{Subsidy} = \frac{\text{Wage rate}}{10} - \text{fare}.$$

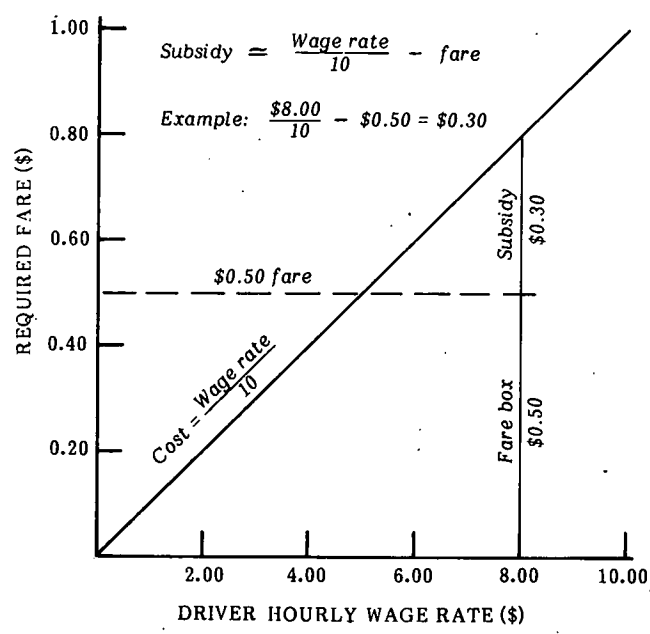



*Figure 2. Approximate relations among fares, drivers' hourly wage rates, and subsidy.*

TABLE 1

TRANSIT FARES, SUBSIDIES, AND TAXES IN MAJOR U.S. METROPOLITAN AREAS (1977) (3)

| Metropolitan Area | Base Fare In Cents | Average Fare in Cents (reflects fares of transfer and discount riders) | Transfer and Zone Charges | % of Operating Expenses Covered by Fare Box and Other Transit Revenue | Tax Funds Committed Specifically to Transit |
|---|---|---|---|---|---|
| **Atlanta** | 15 | 14.9 | Free transfer in main service area 4 zones - Max $1 | 25 | 1% sales tax. Split 50-50 between operating and capital |
| Baltimore | 40 peak<br>35 off-peak | N/A | $.05 transfer<br>10 zones - Max $1 | N/A | 1) $.09 per gallon gasoline tax<br>2) Motor Vehicle registration fees<br>3) Motor Vehicle excise tax of 4% on any transfer of titles<br>4) Corporate income tax of 0.75%<br>(Tax revenues go into a common transportation fund) |
| **Boston** | 25 | 36.5 | No free or reduced rate transfer 13 zones - Max. $1 | 25 | 1) Property tax<br>2) Cigarette tax - $.04 a pack |
| Chicago | 50 | 49.7 | $.10 transfer<br>3 zones - Max. $.90 | 65 | 1) 3/32 of sales tax collected in region<br>2) $14 of each motor-vehicle registration fee collected in Chicago<br>3) $5-million mandated appropriation from Cook County or Chicago<br>4) Up to 5% gasoline tax (collected at 5% as of Oct. 1, 1977)<br>5) Parking tax (not collected at this time) |
| **Cleveland** | 25<br>35 rap. trans. | 30.2 | Free transfer<br>No zones | 30 | 1% sales tax |
| Detroit | 40 | N/A | $.05 transfer<br>11 zones - Max. $1.05 | 43 | State general transportation fund from 0.5¢/gal. gasoline tax |
| **Houston** | 40 | 32.5 | Free transfer<br>3 zones - Max $.60 | 50 | None |
| Kansas City | 40 | 25.6 | Free transfer<br>8 zones - Max $1 | 35 | 0.5% sales tax, of which 85% may be used for operating expenses |
| **Los Angeles** | 40 | 32 (est.) | $.10 transfer<br>6 zones - Max $1.60 | 40 (est.) | 0.25% sales tax |
| Milwaukee | 50 | 37 | Free transfer<br>3 zones - Max. $.65 | 66 | County property tax |
| **New York** | *50 | *47.1 | *$.25 transfer - bus to bus; subway to subway generally free | *60 (est.) | *0.5% mortgage tax. Funding from Triborough Bridge and and Tunnel Authority tolls |
| Philadelphia City Trans. Div. | 45 | 43.8 | $.05 transfer<br>4 zones - Max $1.80 | 55 | None |
| **Pittsburgh** | 50 | 37.3 | $.10 transfer<br>13 zones - Max. $1.80 | 53 | None |
| St. Louis | 25 | 27 | $.10 transfer<br>7 zones - Max. $.95 | 31 | 1) 0.5% sales tax from St. Louis City and County, of which 85% may be used for operating expenses<br>2) 2/32 of the sales tax collected in the 3-county Illinois service area |
| **San Francisco** | | | | | |
| **AC Transit** | 25 local<br>60 trans-bay | 26.5 | None | 35 | 1) 45.9¢ per $100 property tax<br>2) Portion of 0.25% gasoline tax |
| BART | 25 CBD<br>30 suburbs | 67.4 | Graduated fare structure<br>Max. - $1.45 | 39 | 1) $.05/$100 property tax (operating)<br>2) 0.5% sales tax (operating)<br>3) 0.25% sales tax (capital)<br>4) Portion of 0.25% gasoline tax |
| **Municipal Railway** | 25 | 21.1 | None | *28 | 1) Portion of 0.25% gasoline tax<br>2) Operating deficits met by various city/county taxes |
| Seattle | 30 | 28 | Free transfer<br>$.20 zone - Max $.50 | 32 | 1) 0.33% sales tax<br>2) 1% auto excise tax |
| **Washington** | Bus<br>50 peak<br>40 off-peak | 53 (est.) | Free transfer, bus to bus; 4 zones - Max. $1.50. No free or reduced rate transfer from bus to rail | 57 (est.) | None |
| | Rail<br>40-65 peak<br>40-55 off peak | 45 (est.) | Graduated fare structure - Max. $.65 | 48 (est.) | |
| SURVEY AVERAGE | 37.2 peak | 36.4 | | 43 | |

*Data from non-transit-authority source

## FARES AND TRANSFERS

Fare and transfer policies relate to and influence system designs. Pricing public transport services calls for achieving fares that encourage ridership but provide reasonable operating revenues. Convenience to passengers and ease of fare collection are also desirable objectives. Single-ride fares, tokens, passes, and transfer arrangements normally reflect these requirements.

### Fare Structures

Exact fares are usually required for most single-vehicle rides—a practice that speeds fare collection and increases security. Most agencies have a basic flat-fare zone and then some zone fares for suburban or longer trips. The growing array of special conditions—e.g., suburb-city fares; discounts for weekend travel, school children, and the elderly; and premium express service—causes a growing array of fares. Honor fare systems, such as found in Europe, have not been tried in the United States. Free transit service, usually part of a pay-as-you-enter inbound and pay-as-you-leave outbound system, is limited to a few city centers such as Seattle.

### Transfers

Transfer costs and practices vary. Free transfers appear to be essential in grid systems where many passengers must use more than one vehicle; they are desirable, although perhaps less important, in radial route systems. Milwaukee and Toronto have free transfers; Chicago charegs $0.10.

In 1974, the Chicago Transit Authority (CTA) implemented a liberalized transfer system that permits unlimited rides for the first 60 min after payment of fare. The transfer allows riding in any direction on any bus or rapid transit line for the 60-min period. This eliminates time-stamping rail-to-bus transfers and increases ride flexibility. In contrast, the New York City Transit System has very limited transfer privileges, and the Massachusetts Bay Transportation Authority (MBTA) system generally has no free transfers among bus or bus-rail services.

### Promotional Fares

As part of system marketing efforts, fares are often keyed to special or promotional services. Premium fares for express services, discount fares for shoppers' shuttle routes, weekend discounts, and free or no-fare zones are common examples. These promotional fares are an integral part of most systems' marketing activities.

The Port Authority of Allegheny County's promotional service activities, for instance, include tokens, given with store purchases in several outlying communities, that are good for a $0.05 fare discount; a Tuesday fare discount of $0.15 except for peak hours; the "wild-card" bus, one bus on the entire system during the morning peak for which there is no fare; and the $1.25 special that allows four people (but not more than two adults) unlimited rides from 10:00 a.m. on Saturday to 4:00 a.m. on Monday. The fringe parking lots near the Golden Triangle sell a $0.05 reduced fare ticket for the downtown zone.

The Greater Cleveland Regional Transit Authority offers a free ticket, printed in the paper, that is good on Sundays, park and ride, and stop and shop. Nashville offers "nickel day" several times a year and on Easter Sunday. Milwaukee provides a weekly bus pass.

The MBTA has a unique pass program that could set a pattern for other systems. Working with employees, MBTA offers a payroll-deductible monthly pass available in six different options offering a month's worth of unlimited travel for the price of 18 round trips.

## DEVELOPMENT AND STREET PATTERNS

Service planners should recognize city type, its basic physical and economic structure, the strength and character of its city center, and the locations of its residences, shops, schools, and employment areas. All these, coupled with the ease or difficulty of driving and parking, will form the riding habits and the locations and amount of service. High densities, concentrated travel corridors, topographic barriers, a growing economy, and strong central areas make for a good transit city. Conversely, low densities, dispersed development, and weak central areas limit ridership.

Street patterns influence service in general ways. First, the presence or absence of suitable streets limits where and if buses can travel. Cities with radially developed street patterns have bus service with no or limited crosstown routes. Even the large Boston metropolitan area has relatively few crosstown (circumferential) routes because of the restricted street patterns. Conversely, systems, such as those in Chicago, Toronto, and Milwaukee, that have grid street patterns develop many crosstown bus routes, and passenger transfer becomes an important part of the bus system. Obviously, as an urban area loses population, the opportunities for non-CBD-oriented routes are reduced even if there is a grid system. Second, the old, established transit routes are often the locations of apartments and retail areas that developed in a ribbon along these streets. Moreover, traffic engineering improvements are usually concentrated along arterial streets and make them better suited for bus operation.

These patterns may reinforce ridership and limit shifting of bus lines to other streets. Many agencies find it desirable to concentrate on group lines in older transit corridors to improve service frequency and visibility (for example, AC Transit).

## RAPID TRANSIT

Rail transit lines operating on exclusive (or semiexclusive) rights of way also influence service patterns. The line-haul part of the trip to the city center should be by rail, but bus routes should complement rail lines to the maximum extent possible. This limits the number of radial bus lines and, in some cases, the amount of express bus service. It has the advantages of providing faster rides for CBD-based travelers, reducing service duplication, maintaining schedule reliability, and minimizing operating costs. Cities without rail transit must provide radial line-haul local and express buses. This usually leads to a radial bus pattern, even with a grid street system.

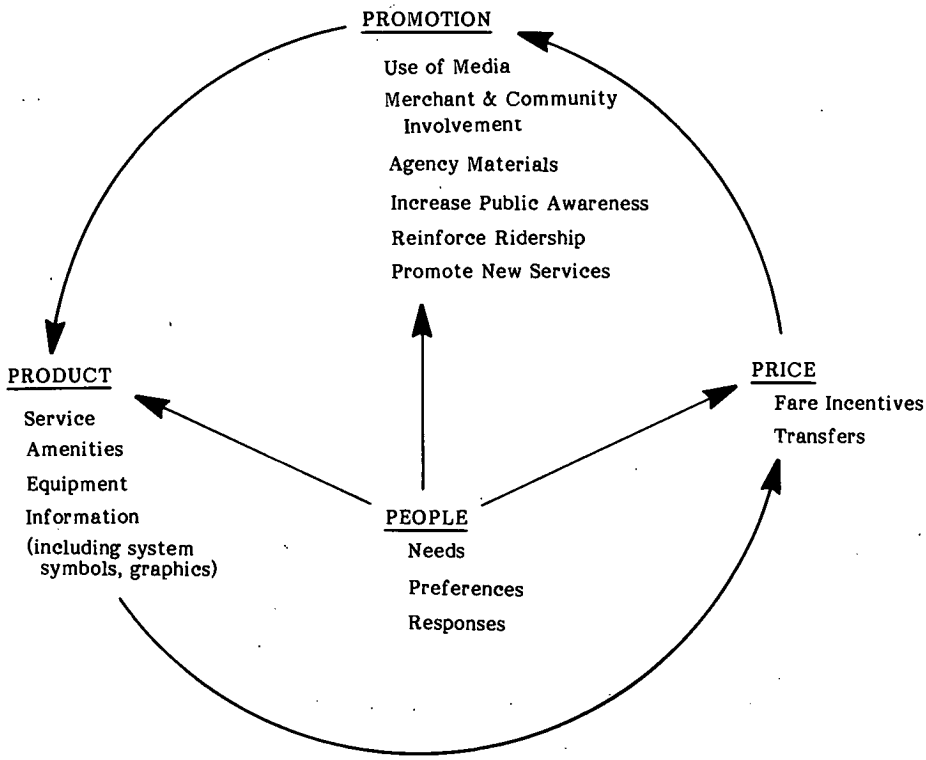



*Figure 3. Transit marketing cycle.*

## TRANSIT RIDERSHIP

Rider demands also influence route structure and service frequency. Family income, car ownership, and residential and employment density have important bearing on line and system patronage; these socioeconomic and land-use variables are normally outside the control of the transit operator. Fare structure, system speed and reliability, and the actual service provided, which also affect ridership, can in turn be influenced by operating policy and service planning. In most cities, about two-thirds to three-quarters of all bus trips are made by people without drivers' licenses. However, the proportions of "choice" and "captive" (transit dependent) riders vary widely by city, route, and time of day.

It is necessary, therefore, to know the types of riders along any route or group of routes. This means identifying the mix of riders by trip purpose (work, shop, school, medical, dental, other), time of day (peak, off-peak), and age group (young, school children, adult, elderly). Special travel pattern surveys such as home interviews usually are needed before new systems or major route changes are initiated; schedule, ridership, and transfer data can be augmented by on-vehicle surveys for existing bus lines.

## SERVICE PLANNING AND TRANSIT MARKETING

The marketing of public transport has several basic objectives: to promote transit services; to improve the image and identity of the service; to inform the public; to increase ridership; and to provide service where it best benefits operator, passengers, and the community.

The emphasis on these objectives and the emergent marketing programs vary among cities. What is sensible for a fleet of several thousand vehicles may be impractical for a smaller concern. Moreover, specific urban economic and community characteristics will also influence the marketing program. [Details on transit marketing programs have been given previously (*2, 4-13*).]

*The best way to market the transit system is to provide good service and inform the public about it.* Little is gained by developing extensive marketing programs where service is infrequent, unreliable, or unavailable. The Milwaukee County Transit System indicates that having polite drivers run clean, well-maintained buses on time represents 90 percent of its marketing effort; promotion takes approximately 10 percent.

Communities that have maintained low fares, that have expanded service into growing areas, and that are not beset by social or economic problems often report major ridership gains. Of seven cities that reported 40 to 400 percent ridership gains during the 1971-1975 period, five had not changed their basic adult fare and two had lowered it (*14*). All seven had increased their annual bus miles between 27 and 261 percent.

Transit marketing programs should therefore include a total package of related actions that

- Identify user needs.
- Provide services and amenities to meet these needs.
- Promote services.

Developing programs becomes an interactive, people-centered process that includes product, promotion, and price (Figure 3).

Typical marketing efforts involve

- Consumer and market research including market segmentation;
- Service changes, adjustments, innovations, and promotions;
- Improved passenger amenities and equipment;
- Passenger information on vehicles, at stops, and in information centers;
- Special graphic images, logotypes, and color schemes;
- Advertising by radio or television;
- Merchant and community promotion schemes;
- Special fare and price incentives;
- Complaint procedures; and
- Improved driver attitudes.

CHAPTER THREE

# GOALS, OBJECTIVES, AND GUIDELINES

Goals and policy guidelines enable transit agencies to plan services and allocate available resources in a consistent, rational, and systematic manner. They also provide a context for developing detailed service standards and planning criteria, and for establishing performance measures. When service policies conflict with economic limitations brought about by fare policies and available public funding, resources should be administered in the most cost-effective manner.

## GOALS

The public transport system should provide the best possible service to the greatest number of people at the least total cost. Basic community goals are the following:

- To establish and maintain a network of high-quality urban transit services for residents and visitors.
- To provide access to places of residence, work, school, personal business, shopping, and recreation with the amount and type of service appropriate to each. This implies a minimum level of service on routes where minimum acceptable levels of ridership and revenues cannot be realized.
- To decrease auto use by attracting new customers (i.e., choice riders), thereby helping to reduce traffic congestion, air pollution, and energy consumption.
- To provide and ensure reasonable service for elderly, handicapped, young, and low-income people.
- To operate buses in a safe and comfortable manner.

Corollary goals call for (a) achieving a specified increase in annual ridership by a certain date, with approximately the same or fewer employees (*15*), (b) helping conserve natural resources (*15*); (c) maximizing benefits to the regional economy (*16*); and (d) contributing to an improved urban environment (*17*).

## SERVICE OBJECTIVES

The bus system should be designed, managed, operated, and maintained so that it will be attractive enough to patrons to ensure its continued use. Its route structure and service pattern should provide access to major trip generators, be simple and clear, and be economically efficient. Service can be improved by having

1. An up-to-date route system consistent with current demands and understandable to riders,
2. Convenient schedules,
3. Reliable services,
4. Coordinated transfer opportunities,
5. Effective integration with rapid transit systems and other public transportation services where provided,
6. Amenities at bus stops,
7. Reasonable fares, and
8. Park-and-ride facilities.

The objectives that apply to planning new services or adjusting existing ones include accessibility, route and system coordination, coordination with regional development, convenience and speed, safety, equipment, and personnel considerations, efficiency, and service monitoring and responsiveness. These service objectives reflect

- The needs and desires of both the people who now use the system and those who can be induced to use it;
- The services offered in terms of route configuration, frequency of service, on-time performance, spacing of stops, etc.;
- The vehicles used to perform the services, such as urban transit buses;
- The facilities on which the service operates, i.e., the streets and highways; and
- The performances of the people who operate and maintain the system.

### Service Accessibility

Regular route bus service should meet the travel needs of most residents in the service area. Service should be

placed to provide all segments of the population with access to areas of employment and to essential services. This should apply especially to low- and middle-income families, the elderly and handicapped, and others who do not or cannot operate an automobile.

System design should emphasize transit service to vital land uses and major trip generators, such as employment, shopping, medical, education, and recreation centers. Special concern should be directed to providing service to those groups who depend on transit to satisfy their urban transportation needs.

#### Route and System Coordination

Routes and services should be as simple and direct as possible. Transfers, duplication of services, and indirect routings should be avoided. Bus lines should complement rather than compete with rail lines so that each mode is used to its best advantage. Where rail lines exist, they should provide the line-haul function and through bus service should be replaced by feeder service. In areas without rail transit, buses should continue to perform both line-haul transit functions and feeder services. Park-and-ride lots may be appropriate to reinforce ridership, especially at suburban rapid transit stations.

#### Coordination with Regional Development

Existing and proposed services should be coordinated with the system's development goals and should be compatible with growth policies and development plans of the jurisdiction serviced.

Service planning should permit expansion of transit service, as warranted, into newly developing areas. This calls for continued surveillance of (a) new residential, industrial, commercial, and institutional development; (b) new road alignments and designs; and (c) traffic control measures and devices. This allows ongoing adjustments to designs and measures so that public transport service is not difficult or unduly expensive. Service expansion should disrupt existing services as little as possible.

#### Convenience and Speed

Bus service should be perceived as convenient and should be competitive with the automobile in overall travel time. For local bus service, door-to-door travel time should be less than 2.5 or 3 times that by car.

If door-to-door travel times for present and potential riders are to be minimized, the highest quality facility available must be used. Better routings between principal passenger origins and destinations and efficient spacing of routes and stops should minimize transfers, walking distances, and service changes. Timed transfers may be appropriate where long-headway lines meet.

Easily remembered schedules can be provided where bus headways exceed 10 min (for example, "clockface" schedules). Passenger shelters should be provided at major boarding and transfer points and at key locations where service is infrequent.

#### Safety

Public transport service should continue to be safer than other urban transport modes and should be located, designed, and operated to promote the safety of transit passengers, transit employees, and the general public. All elements of the system should be designed to minimize accident exposure.

#### Equipment

New concepts and improvements in bus designs should be used within the limits of financial policy. Vehicles should be mechanically reliable, smooth-riding, climate-controlled, quiet, easy to get in and out of, well-lighted, attractive and appealing to passengers, and thoroughly cleaned on a regular basis.

Bus service should minimize air and noise pollution by establishing rigid maintenance standards.

#### Personnel

Personnel policies encourage safe, dependable, and comfortable bus service. Consistent improvements in methods of recruiting and training operating personnel ensure safe, efficient operations by helpful, competent, courteous, and neat operators. Street supervisors should monitor schedule performance and control emergency situations, especially in large agencies.

#### Service Efficiency

Rush-hour and off-peak service should optimize use of manpower, vehicles, and other resources and encourage maximum use of the entire public transport system. Underused services drain resources. Service efficiency can also be increased by (a) maximizing average operating speeds, (b) minimizing ratio of recovery time to revenue-producing time, and (c) minimizing operation of redundant or competitive services.

#### Service Monitoring and Responsiveness

Operations planning and research staffs continually monitoring services for opportunities to increase ridership and efficiency can adjust services to reflect changes in travel patterns and (especially in large cities) make transit competitive with the car. Ongoing efforts will shorten journey times, enhance passenger comfort and convenience, and maintain fares perceived to be comparable to private car costs. Service changes should be developed cooperatively with the communities and neighborhoods involved.

#### Service Planning Guidelines

The preceding goals and objectives are increasingly translated into service standards and guidelines. The suggested bus service planning guidelines set forth in Table 2 reflect current practice. Guidelines for specific properties are presented in Appendix C. Additional details are contained in subsequent chapters.

TABLE 2

SUGGESTED SERVICE PLANNING GUIDELINES

1. SERVICE PATTERN
   - 1.1 Service Area and Route Coverage
     - a. Service area is defined by operating authority or agency.
     - b. Provide 1/4-mi coverage where population density exceeds 4,000 persons per sq mi or 3 dwelling units per acre. Service at least 90 percent of residents.
     - c. Provide 1/2-mi coverage where population density ranges from 2,000 to 4,000 persons per mi (less than 3 dwelling units per acre). Serve 50 to 75 percent of the population.
     - d. Serve major employment concentrations, schools, hospitals.
     - e. Two-mi radius from park-and-ride lot.
   - 1.2 Route Structure and Spacing
     - a. Fit routes to major street and land use patterns. Provide basic grid system where streets form grid; provide radial or radial-circumferential system where irregular or radial street patterns exist.
     - b. Space routes at about 1/2 mi in urban areas, 1 mi in low-density suburban areas, and closer where terrain inhibits walking.
   - 1.3 Route Directness—Simplicity
     - a. Routes should be direct and avoid circuitous routings. Routes should be not more than 20 percent longer in distance than comparative trips by car.
     - b. Route deviation shall not exceed 8 min per round trip, based on at least 10 customers per round trip.
     - c. Generally, there should be not more than two branches per trunk-line route.
   - 1.4 Route Length
     - a. Routes should be as short as possible to serve their markets; excessively long routes should be avoided. Long routes require more liberal travel times because of the difficulty in maintaining reliable schedules.
     - b. Route length generally shall not exceed 25 mi round-trip or 2 hr.
     - c. Two routes with a common terminal may become a through route if they have more than 20 percent transfers and similar service requirements, subject to (b). This usually results in substantial cost savings and reduces bus movements in the central business district.
   - 1.5 Route Duplication
     - a. There should be one route per arterial except on approaches to the CBD or a major transit terminal. A maximum of two routes per street (or two branches per route) is desirable.
     - b. Express service should utilize freeways or expressways to the maximum extent possible.
     - c. Express and local services should be provided on separate roadways, except where frequent local service is provided.

2. SERVICE LEVELS
   - 2.1 Service Period
     - a. Regular service: 6 a.m. to 11 p.m./midnight, Mon.-Fri.
       Priorities: weekday commuter, 6-10 a.m. and 3-7 p.m.; weekday, 6 a.m.-7 p.m.; Saturday, 7 a.m.-7 p.m.; Evenings, 7 p.m.-midnight; Sundays, 9:00 a.m.-7:00 p.m.
     - b. Owl service: selected routes, large cities—24 hr.
     - c. Suburban feeder service: weekdays, 6-9 a.m., 4-7 p.m.
       (Some services 6 a.m. to 7 p.m.)
     - d. Provide Saturday and Sunday service over principal routes except in smaller communities, where Sunday service is optional.
   - 2.2 Policy Headways Desirable—Minimum Service Frequency
     - a. Peak: 20 min—urban; 20-30 min—suburban.
     - b. Midday: 20 min—urban; 30 min—suburban.
     - c. Evening: 30 min—urban; 60 min—suburban.
     - d. Owl: 60 min.
   - 2.3 Loading Standards
     - a. Peak 30 min: 150 percent.
     - b. Peak hr: 125-150 percent.
     - c. Transition period: 100-125 percent.
     - d. Midday/evening: 75-100 percent.
     - e. Express: 100-125 percent.
     - f. Suburban: 100 percent.

     Note: Policy headways may result in considerably lower load factors.
   - 2.4 Bus Stops
     - a. Stop frequency: central areas, 10-12 stops/mi; urban area, major signalized intersections, 6-8 stops/mi; suburban areas, 2-5 stops/mi; express or suburban service, 2-4 stops/mi in pickup zone.
     - b. Stop location: depends upon convenience and safety; no parking in curb lane all day or peak-hrs, far side; parking in curb lane, near side (except where conflicting with right turns).
     - c. Stop length (one 40-ft bus): near side, 105-150 ft; midblock, 140-160 ft; far side, 80-100 ft; straight approach, 140 ft after right turn; add 20 ft for 60-ft articulated bus; add 45 ft for each additional 40-ft bus expected to stop simultaneously.
   - 2.5 Route Speeds
     - a. Central area: 6-8 mph.
     - b. Urban: 10-12 mph.
     - c. Suburban: 14-20 mph.
   - 2.6 Passenger Access Criteria (Optional)

$$T_t = P_i t_i + h$$

where $T_t$ = total passenger access time (min)

$P_i$ = population in strata i

$t_i$ = distance of strata i divided by 270 (min)

$h$ = headway (min)

   - 2.7 Service Reliability
     - a. Peak: 80 percent of buses 0 to 3 min late.
     - b. Off-peak: 90-95 percent of buses 0 to 3 min late.

*continued on next page*

TABLE 2 (*continued*)

3. NEW ROUTES
   - 3.1 Service Evaluation
     - a. Examine physical constraints/street patterns for reliability.
     - b. Estimate ridership and costs.
     - c. Compare with existing route performance.
   - 3.2 Service Criteria
     - a. Minimum density of 2,000 persons/sq mi.
     - b. Twenty to 25 passengers/bus hour weekdays; 15 Saturday; 10 Sundays and holidays. Less riders if route impairs continuity or transfers.
     - c. Fares should cover 40 to 50 percent of direct costs of service.
   - 3.3 Frequency of Change
     - a. Major changes not more than 2 or 3 times per year. Other changes may be at other times.
   - 3.4 Length of Trial Period
     - a. Minimum 6 months experimental service.

4. PASSENGER COMFORT AND SAFETY
   - 4.1 Passenger Shelters
     - a. Provide at all downtown stops.
     - b. Provide at major inbound stops in residential neighborhoods.
     - c. At stops that serve 200 to 300 or more boarding and transferring passengers daily.
   - 4.2 Bus Maintenance
     - a. Spares should not exceed 10 to 12 percent of scheduled fleet.
     - b. Five thousand-mi preventative maintenance inspection.
   - 4.3 Bus Route and Destination Signs
     - a. Provide front and side mounted signs.
     - b. Front sign should give at least route number and general destination; side sign should give route number and name (front sign may give all three types of information).
   - 4.4 Passenger Information Service
     - a. Provide telephone information service for period that system operates.
     - b. Ninety-five percent of all calls should be answered in 5 min.
   - 4.5 Route Maps and Schedules
     - a. Provide dated route maps annually.
     - b. Provide printed schedules on a quarterly basis or when service is changed.
     - c. Schedules should provide route map (for line).
   - 4.6 Driver Courtesy, Efficiency, Appearance
     - a. Carefully select, train, supervise, and discipline drivers.
     - b. Avoid extremes in personal appearances.
     - c. Provide driver incentive programs.
   - 4.7 Passenger and Revenue Security System
     - a. Exact fare procedures—generally usable.
     - b. Provide radio communication for driver with secret emergency alarm.
     - c. Provide transit police (large properties).

CHAPTER FOUR

# ROUTES AND SERVICES

Providing the best possible service to the greatest number of people calls for carefully relating service to existing and potential markets. Concentrating service in heavy travel corridors entails greatest route coverage and service frequency on the approaches to the city center and a thinner service in suburban areas.

Principal services generally should be radial; crosstown (or circumferential) lines normally should be limited to larger cities; and feeder lines will be in medium-sized communities. Express bus service should be provided to the city center in a way that complements local bus routes and other public transport services. The route structure should be clear and simple, and several varieties of service on a single street should be avoided. Reverse commuting services should be scheduled to major outlying employment centers.

## SERVICE AREA AND ROUTE COVERAGE

A service area is usually defined by charter, legislation, or ordinance. Within this area, the delineation of areas served provides a measure of transit accessibility and a method by which to judge duplicate service. Area coverage expresses how many people live within a reasonable walking distance. The area within a 5-min walking distance from bus stops is traditionally considered the primary service area, and those between 5 and 20 min are secondary service areas. For park-and-ride facilities, where passengers come to stops by car, longer distances are acceptable.

Bus service coverage and frequency relate to density of the street system and density of population. This generalized relation has long been recognized. Figure 4 shows that the best bus coverage and most bus miles per 1000 residents are found in the central city (New Haven), followed by the three contiguous "streetcar" suburbs (*18*).

As a general guide, in areas of high population density and low automobile ownership, parallel or adjacent routes should be spaced so that potential bus riders are no more than 0.25 to 0.375 of a mile (0.4 to 0.6 km) from service. Some unavoidable pockets of population will live beyond this distance because of the layout or discontinuity of the street pattern, but the aim is to have most users within a 5-min walk, at normal walking speeds, from a bus stop. For example, 99 percent of Chicago's population lives 0.375 mile (0.6 km) from a bus route.

For less densely built-up areas, or where there are scattered pockets of population, particularly where car ownership is high, a 10-min walk, or a 1-mile (1.6-km) spacing between bus routes, is acceptable. In outer areas of low population density, the service coverage should be individually determined.

These criteria translate into parallel bus routes every 0.5 mile (0.8 km) in urban areas and 1 mile (1.6 km) in suburban areas. The following general guidelines are suggested:

- One-quarter-mile (0.4-km) local bus service coverage where population density exceeds 4000/mile$^2$ (1500/km$^2$) so that at least 90 percent of the residents are reached.
- One-half-mile (0.8-km) local bus service coverage where population density ranges from 2000 to 4000/mile$^2$ (800 to 1500/km$^2$) so that 50 to 75 percent of the population is served.
- One-half-mile (0.8-km) arterial street express bus service (Milwaukee's standard).
- Two-mile (3.2-km) radius from a park-and-ride facility.

The rationale underlying these criteria is further described below in relation to route structure and spacing.

The effect of grades should be considered in evaluating route coverage and providing service. A 5-min walk on a level grade, based on 3 mph (5 km/hr), results in a 0.25-mile (400-m) walking distance. This distance drops to 1200 ft (370 m) for an 8 percent grade and 900 ft (270 m) for a 14 percent grade (*19*).

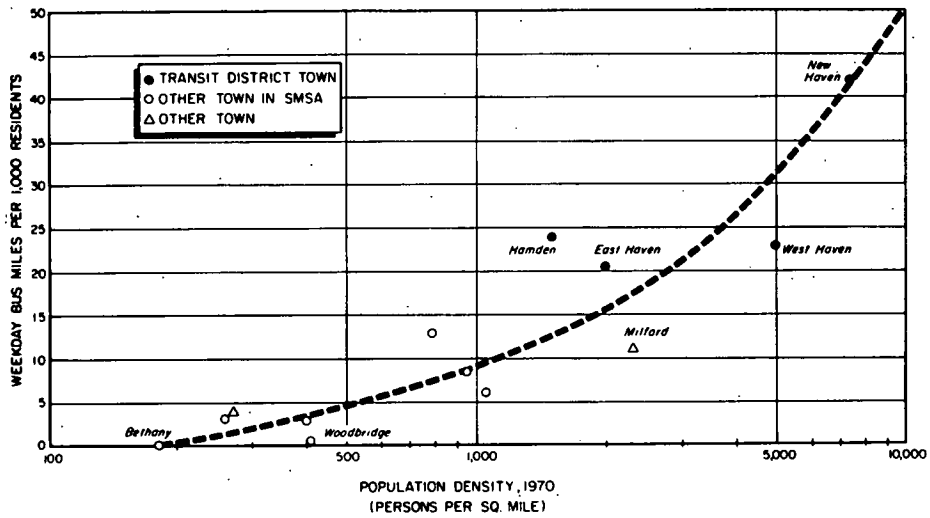
## ROUTE STRUCTURE AND SPACING

Bus route structure and spacing should fit the arterial street and expressway pattern and urban development density. Bus service should be provided on major urban arterial streets and in suburban areas where traffic density warrants, where the route pattern is directed toward the CBD and other major activity centers. However, where rapid transit is available, the routes should feed the major stations. Good bus route spacing provides desired coverage and capacity and minimizes service duplication.

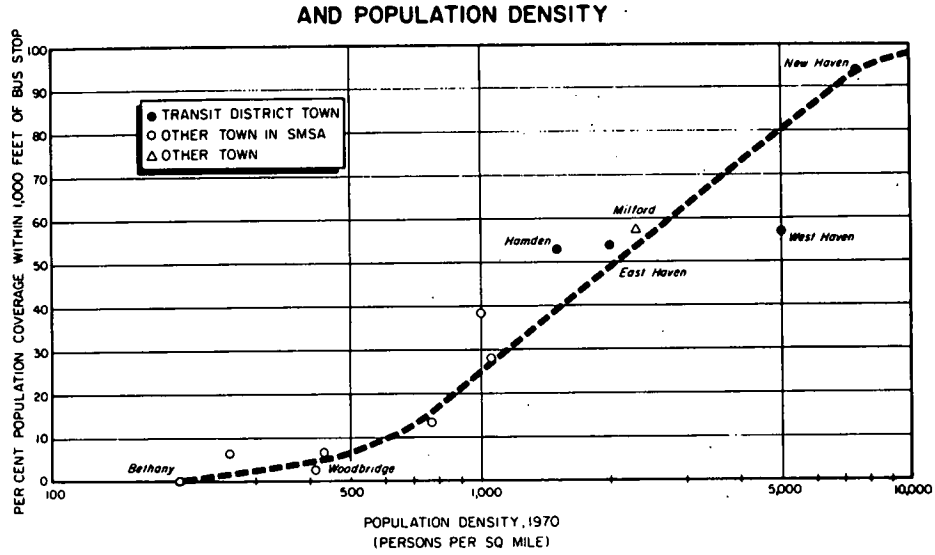
### System Patterns

Transit routes in smaller communities normally include a few radial lines that meet in the city center. As the size of the service area increases, there is a corresponding increase in the number of routes and complexity of the route structure.

Transit systems, particularly large systems, include a combination of radial, circumferential, and grid route structures. Sometimes, as in Pittsburgh, complex or irregular systems emerge because of topographic barriers or irregular street networks. The route structure should always rationally connect activity centers with residential areas by the street network. Passenger convenience and operating efficiency are the underlying objectives. "Theoretical" route configurations should be avoided. Figures 5 through 8 show the various types of route patterns found in U.S. and Canadian cities.




SERVICE QUANTITY
AND POPULATION DENSITY




SERVICE COVERAGE
AND POPULATION DENSITY

*Figure 4. Bus service in relation to population density (New Haven) (18).*

*Radial Systems*

Radial networks such as those in Boston, Washington, D.C., and Pittsburgh are the most common type of route pattern. Radial bus routes are appropriate in cities with radial, radial-circumferential, or irregular street patterns. In larger cities, some circumferential or crosstown sevice may be superimposed on the radial pattern (e.g., Boston), but this type of service is difficult to provide in smaller urban areas (e.g., New Haven).

The radial system radiates from the city center and provides direct service to it from outlying places. Service to many non-CBD destinations is sometimes difficult and circuitous, especially where secondary centers have increased in importance.

Radial routes generally serve major travel corridors, often with several branches in their outlying sections. In planning branches, care must be exercised to maintain uniform intervals (headways) on the common sections of route and avoid bunching of buses. This problem can become acute where service frequencies on the branches vary, especially where there are more than two branches.

*Grid Systems*

Cities with grid or section-line street networks and with few geographic or topographic barriers (e.g., Chicago, Milwaukee, Toronto) should provide a grid or modified grid of bus routes. This basic grid can then be complemented with radial local and express routes, either via the grid (fol-

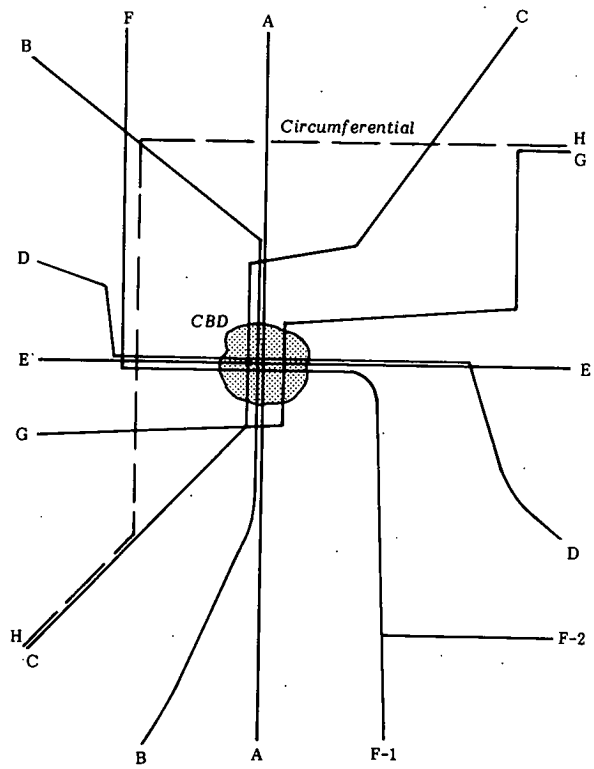



*Figure 5. Radial bus routes.*

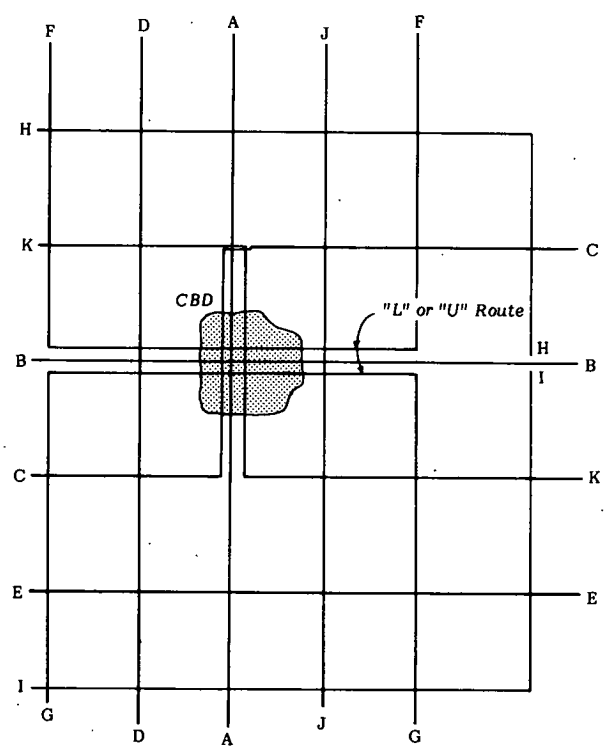



*Figure 6. Grid system complemented with L and U routes.*

lowing L or U routings) or over diagonals—except in corridors served by rail transit. The Toronto Transit Commission (TTC), for example, indicates that "the current policy for the system configuration is to provide a grid system of routes on major arterials throughout the metropolitan area thereby supplying convenient service for the majority of origins and destinations. However, the introduction of a subway or light rail line can alter this pattern such that the surface routes will be coordinated with these high-speed transit services" (*20*).

The grid route system (like a grid roadway or freeway system) avoids the problems of route convergence and over-concentration of bus routes on a single street. The grid has a high degree of "connectivity." It enables passengers to reach many destinations without traveling to the city center. It is also relatively simple to understand.

Because bus lines do not always closely follow the same major radial road that travelers desire, transfers are commonly required. This in turn means relatively short head-

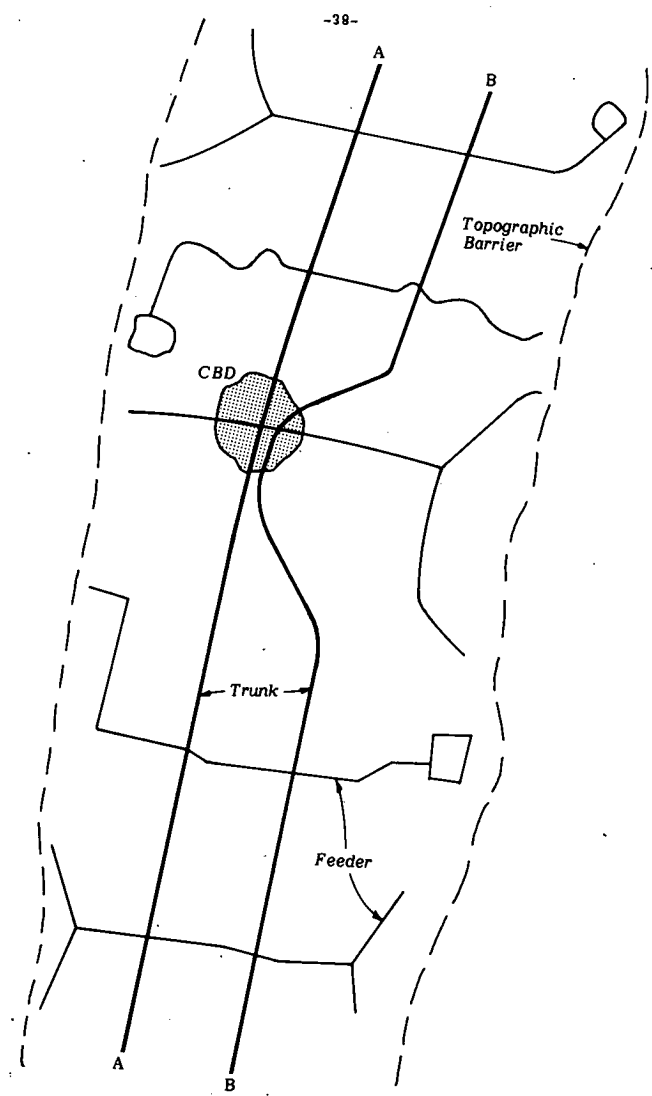



*Figure 7. Trunk line system with feeders.*

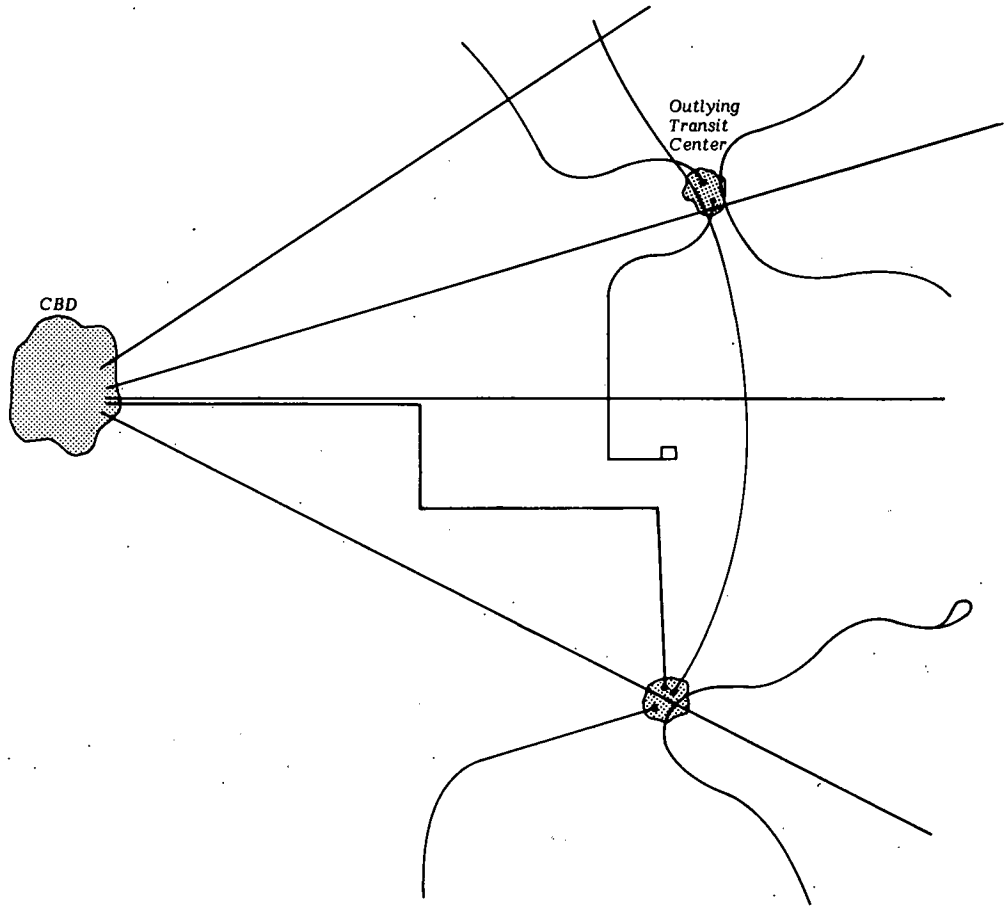



*Figure 8. Timed-transfer system with transit centers.*

ways or careful scheduling to minimize passenger waiting times. Midday (base) headways of 15 min or less are normal for convenient transfer connections. If population density or ridership is too low to support frequent headways, a grid system may not be appropriate.

*Trunk Line with Feeders*

The trunk-line-with-feeder system is based on a strong major bus or rail artery serving a major travel corridor (*21*). Because of topographic or geographic barriers and street arrangements and development patterns, it is better to provide feeder service to major trunk lines than to run all buses to major destinations. This allows a higher level of through service than could be supported only by passengers walking to stops; however, passenger transfers are required (*21*).

AC Transit Transbay, express, and local buses and the BART in the East Bay area of San Francisco provide the clearest example. However, the feeder service to rail transit in Cleveland and other cities also reflects this concept.

*Timed-Transfer Systems*

The timed-transfer network allows buses to "meet" at specific transfer points, such as a regional shopping center or major activity center, on a pretimed basis. Buses operate on the same midday frequency—usually a 30-min headway—and are scheduled to arrive at the same time and leave at the same time, after as much as 5 min are allowed for passengers to change buses. The transfer can be made on-street in loading areas or in specially constructed off-street transit centers. During peak periods when service operates every 15 min or less, random transfers can be provided.

Timed-transfer networks have helped to increase ridership in Edmonton, Portland, and Denver. They substantially improve transfer conditions for passengers and are best applied in suburban areas that have low service frequency. They require careful designing and scheduling, and the number of such points in any given system is limited. To be cost-effective, the cycle time on all connecting routes must be the same. If a route cannot be expanded or cut back so its round-trip travel time is an even multiple of the cycle time, then extended layovers will be required (*22*). Planning, therefore, must consider and resolve

- Possible differences in running times between several routes operating between the same pair of interchange points,
- Length of route (round-trip cycle time) in relation to

desired service frequency (to minimize wasted bus and driver hours),

- Scheduling conflicts between demands at interchange points and at intermediate points,
- Effects of traffic congestion on schedule reliability and running times, and
- Effects of variations in passenger volumes by time of day on specific routes, which may call for more frequent service.

#### Bus Route Examples

Figures 9 through 13 show how city bus routing patterns vary with terrain, street systems, and rail transit lines.

*Toronto*

The service pattern for Toronto (Figure 9) shows a basic grid system with routes focused on subway stations. It is significant in that bus lines are not only broken where they meet the subway, but that they are sometimes diverted from their former routes.

*Nashville*

The Nashville system (Figure 10) shows how local and express bus routes converge as they approach the city center.

*AC Transit*

AC Transit (Oakland, California) (Figure 11) has two main focal points, downtown Oakland and San Francisco (across the Bay Bridge), and many satellite focal points for each major city center.

*Tri-Met*

Tri-Met (Portland, Oregon) (Figure 12) has focused its westside lines into two major transit centers.

*Westport*

Westport, Connecticut's "minnybuses" operate separate service patterns for commuters and shoppers (Figure 13). The commuter services are keyed to the commuter rail stations, whereas the midday shopper services focus on the town center. The system also operates a "maxytaxi" system.

#### Residential Areas

Typical bus route spacing guidelines for residential areas are shown in Figure 14. The distance between parallel routes reflects a compromise among the frequency of service that can be provided, the walking distance, and the travel demand.

- Bus routes in built-up residential areas should be at 0.5-mile (0.8-km) intervals to provide service within a 0.25-mile (0.4-km) distance of residences. Bus routes at 0.5-mile intervals generally serve major arterial streets but do not overlap routes or duplicate service. Half-mile bus grids in both directions further increase transit access without duplicating service.
- In areas of high transit use, on CBD approaches, and on radial street systems where routes converge, overlapping or routes that otherwise would be considered redundant may be justified by riding demand and capacity requirements.
- In suburban areas, spacing of bus routes at 1-mile (1.6-km) intervals will bring half the residents to within a 5-min walk, and all the population within a 10-min walk.

These desired bus route spacings are not always possible because of the configuration of the street system, the interposition of physical barriers, and the occasional need to reach closer points of heavy passenger travel demand. The spacing standards for any given transit system are subject to modification where physical barriers such as unbridged rivers, extreme changes in elevation, or lack of cross-streets prevent access. Where there are no cross-streets, efforts should be made to open streets, because the transit system should not have to bear the cost of accommodating inadequate design. Bus route spacing should, of course, be closer where terrain inhibits walking.

In general, few lines with frequent service are preferable to many lines with infrequent service. Operation of similar lines parallel to each other at short distances is a duplication of service and lowers the quality of service. However, in areas of very low demand, it is preferable to reduce the frequency rather than increase separation of lines farther than 1 mile (1.6 km) to avoid poor area coverage. Moreover, if service is infrequent, riders rely on schedules.

The MBTA route spacing criteria for feeder and crosstown services based on population density are shown in Table 3. Spacing of feeder lines ranges from 0.4 mile (0.6 km) where density exceeds 12 000 people/mile$^2$

TABLE 3

MBTA ROUTE SPACING CRITERIA

| Population per sq mi (thousands) | Average Spacing (miles) Feeder | Crosstown | Route Miles per Square Mile |
|---|---|---|---|
| >12 | 0.40 | 0.60 | 4.00 |
| 10 to 12 | 0.50 | 0.75 | 3.33 |
| 8 to 10 | 0.60 | 0.90 | 2.67 |
| 6 to 8 | 0.80 | 1.20 | 2.00 |
| 4 to 6 | 1.00 | 1.50 | 1.67 |
| 2 to 4 | 1.00 | -- | 1.00 |
| <2 | 2.00 | -- | 0.50 |

Note: Closer spacing provided where terrain hampers walking.

*1000 people per sq mi = 386/km$^2$*
*1 mile = 1.609 km*
*1 mile per sq mi = 0.62 km/km$^2$*


*Figure 9. Toronto grid system in areas of flat terrain. Note breaking of east-west lines at Yonge Street subway.*

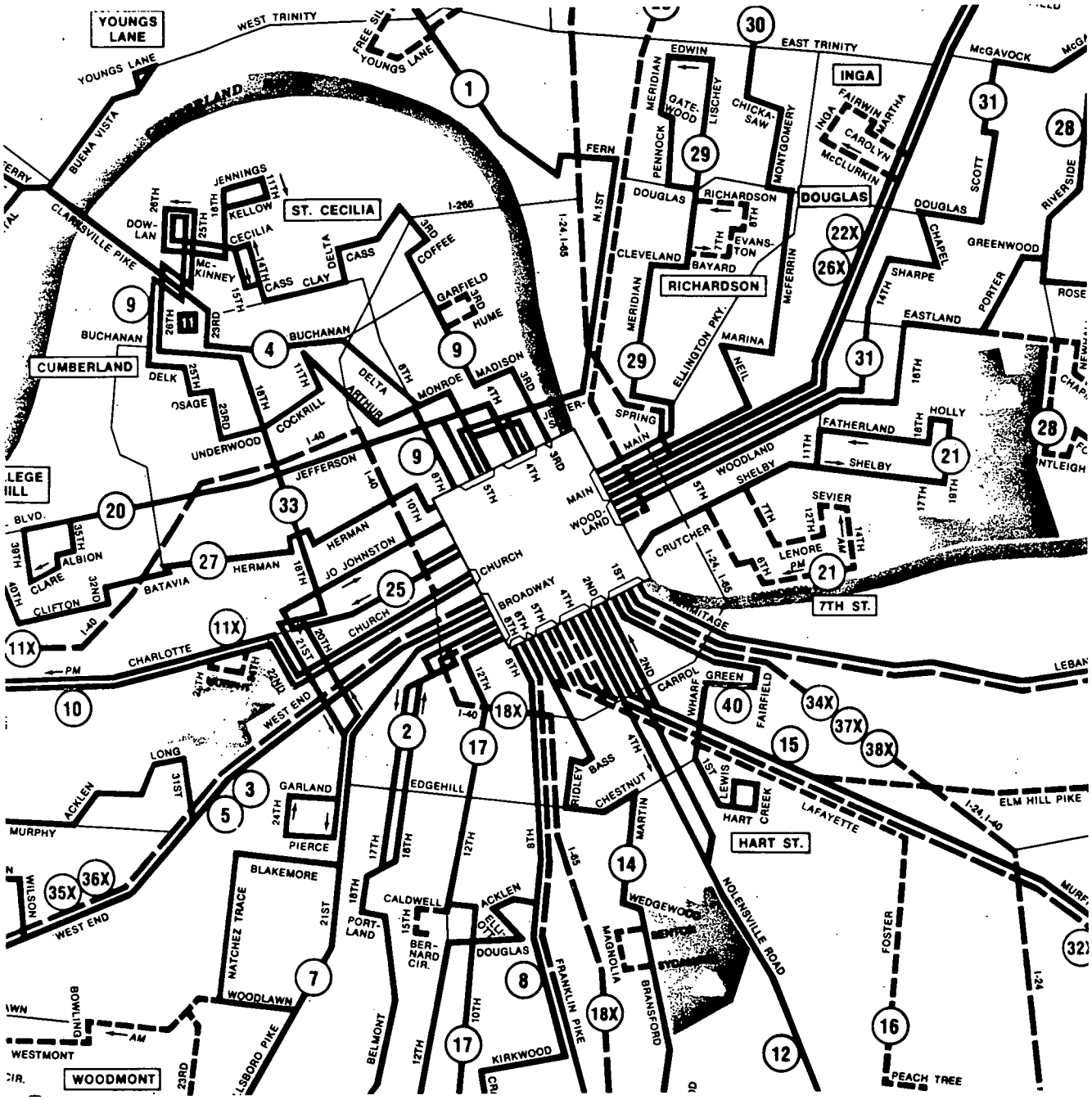



*Figure 10. Nashville all-bus system.*

(4600 km²) to 1.0 mile (1.6 km) for densities of 2000 to 6000 people/mile² (770 to 2300/km²). Spacing of crosstown lines ranges from 0.6 mile (1.0 km) for densities of over 12 000 people/mile² to 1.5 miles (2.4 km) for densities between 4000 and 6000 people/mile² (1500 to 2300/km²). Four thousand people per square mile is the minimum density for crosstown service.

Spacing criteria also can be based on car ownership and population density. A transit route spacing guide proposed for the Washington (D.C.) Metropolitan Area Transit Authority (WMATA) suggests 0.5-mile (0.8-km) spacing for bus lines in areas of medium population density and car ownership (*17*). Spacing is increased as car ownership rises and density decreases, and vice versa.

Of course specific land-use factors, such as residential concentrations, schools, social service facilities, and medical care facilities, should be considered in route network design. Every effort should be made to connect as many residential, employment, and shopping concentrations as possible within each route's service area, with the closest

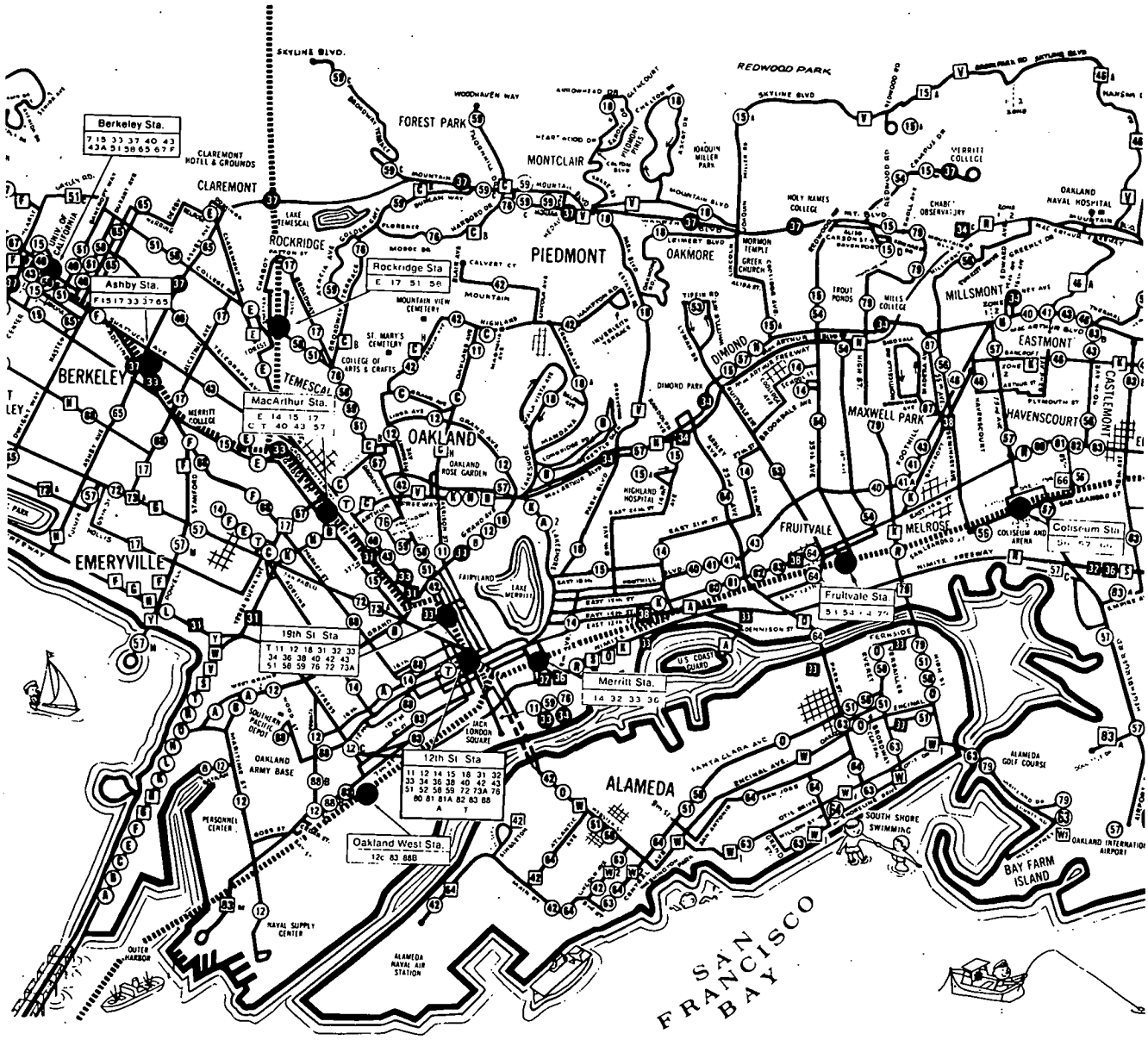



*Figure 11. AC Transit route (Oakland). Settlement patterns and terrain create a long, narrow, multicentered corridor with trunk and feeder lines.*

spacing practicable. In establishing route structure and spacing, the special service needs of those areas where a substantial percentage of the population is handicapped or elderly ought to be considered.

Bus routes operate best where streets have at least one 10-ft (3-m) lane each way, where structural conditions permit bus service, and where intersection geometry can accommodate bus turns.

### Central Business District

Planning downtown bus routes and spacing includes consideration of street pattern, major entry points, terrain, employment locations, and service frequency. Routes concentrated on key streets will give riders a sense of "transit identity" and a clear idea of the service and will put enough buses there to make a priority treatment feasible. Accordingly, depending on the size of the business district, as many routes as possible should operate on the same street or same few streets. Unless prevented by a one-way street pattern, or by looping requirements, buses should operate in both directions on the same street to simplify routes, improve passenger understanding, and minimize excess bus travel. These factors underscore the desirability of downtown bus malls.

Dispersed routing patterns may be necessary in larger city centers because of dispersed employment areas or capacity limitations on the curb bus lanes. Los Angeles,

Washington, D.C., and Manhattan are obvious examples; however, similar conditions exist on a smaller scale in other city centers.

Bus routes entering the city center should be spaced to traverse the center of the area within three city blocks [900 to 1200 ft (270 to 370 m)]. The goal is to bring major downtown employment and shopping concentrations to within 600 to 800 ft (180 to 240 m) of a bus stop. Routes generally should cross the entire central area to provide convenient passenger delivery to all points and to minimize bus turns on congested downtown streets. Through routing is often desirable, but buses that must terminate and layover downtown should pass through the CBD (central business district) so that their curb layovers are in less congested areas.

Passengers leaving major employment centers should be able to board and alight from buses without having to cross major traffic flows. The maximum waiting times along major downtown streets served by a number of bus routes connecting major activity centers should not usually exceed 5 min during normal operating hours; the average waiting time should not exceed 3 min. Headways on individual routes may be longer, depending on the number of routes combined.

### Outlying Employment, Shopping, and Institutional Complexes

Routes serving outlying (non-CBD) shopping and office complexes, factories, and institutions should provide streetside bus stops at major entrance points and, in some cases, should enter the grounds for closer and safer delivery of passengers. This will vary with the size of the complex and the walking distances, the availability of safe and operable roadways and stopping places within the complex, the difficulty of returning to the main traffic flow, and the degree of route diversion involved. Large regional shopping centers (such as Roosevelt Field, Long Island) are often the logical choice for bus terminals. Bus schedules should be keyed to shift changes at outlying industrial plants (or schools) to facilitate reverse commuting.

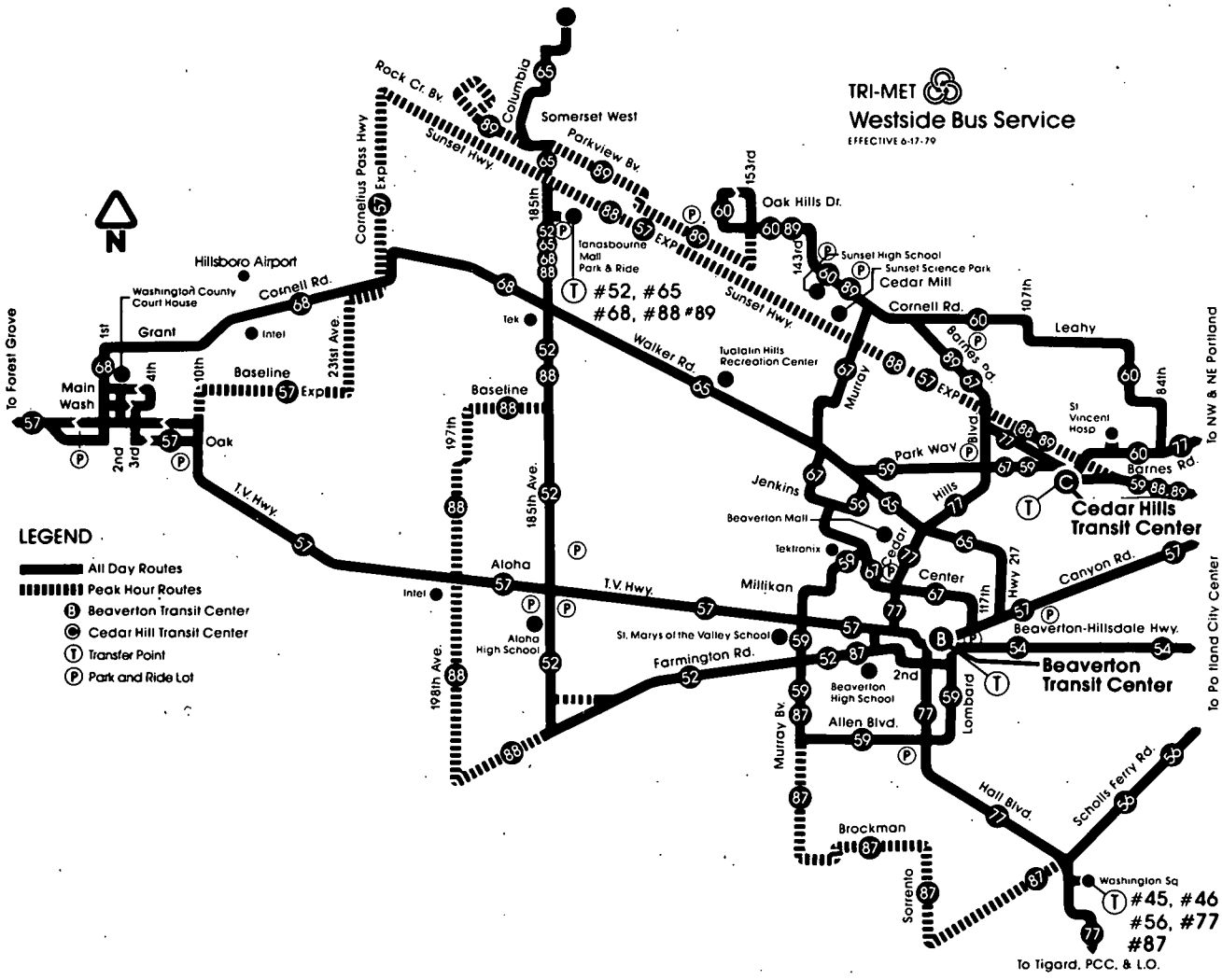



*Figure 12. Tri-Met westside bus service (Portland, Oregon). Note the two timed-transfer points (transit centers).*

## ROUTE DESIGN GUIDELINES

The following bus route design principles reflect different practices that appear to have been successful.

### Route Directness and Diversion

Routes should be direct and clear. Circuitous routings are to be avoided, because simple routes are shorter, more economical to operate, easier for passengers to use. Routes should not be more than 20 percent longer in distance than the comparable trip by car.

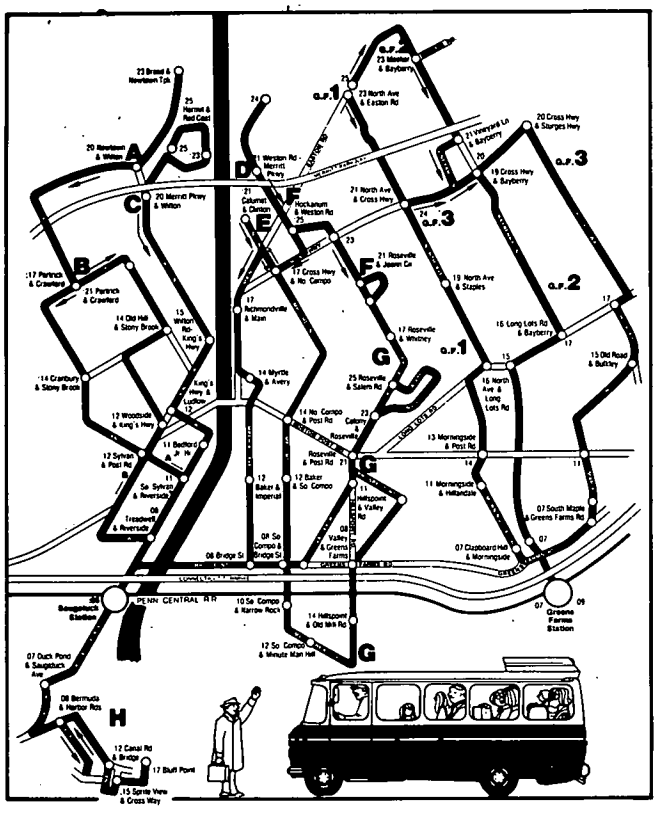
The MBTA criterion states that "No more than 25% of those customers only using surface vehicles should require more than one vehicle to complete their trip by surface transit." Such a criterion, however, is not applicable in grid systems (e.g., Toronto and Chicago) where passenger transfer plays an integral part.

Routes should serve major traffic generators. Directness of route for the entire bus system can best be achieved by connecting large traffic generators and placing routes along the most concentrated, travel-dense lines, while serving populated areas between them as well as possible. The object, as expressed by WMATA, is "to provide the closest route spacing practicable while avoiding circuitous routings which would deter riders and increase costs. Routes will have as direct an alignment and as little turning back as the street pattern and requirement of service coverage will permit" (*17*).

In practice, a delicate balance should be maintained between keeping a route direct and providing service to places with high demand. The decision to divert a route should depend on such factors as expected patronage, length of diversion in time and distance, and number of other deviations already made by the route. Branch or separate routes are often preferred to route deviations.

Circuitous or "off-route" routing may improve convenience for some passengers, but it generally tends to lengthen the trip time for most riders. This seriously detracts from the quality of service and adversely affects total riding. In addition, circuitous routing complicates passenger understanding of the transit route system, a critical factor in the attraction or retention of passengers (*16*). Consequently, bus route diversions generally should be restricted to the outer ends of the lines.

Although there may be special circumstances that warrant diverting a bus route off a main route to serve a heavy traffic generator, these should be evaluated in light of the general system configuration and their impact on patron-

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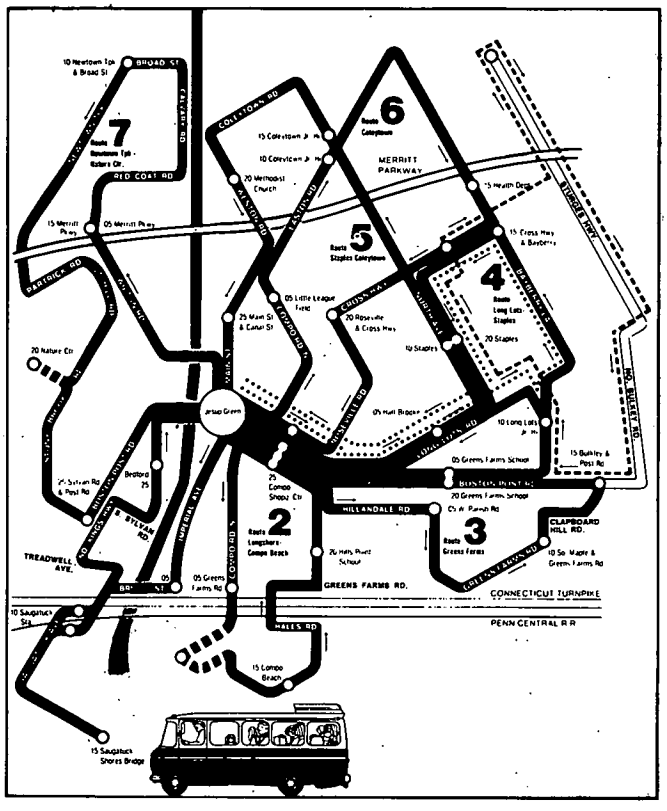



B-SHOPPERS

*Figure 13. Minnybus system (Westport, Connecticut). Routes vary by time of day.*

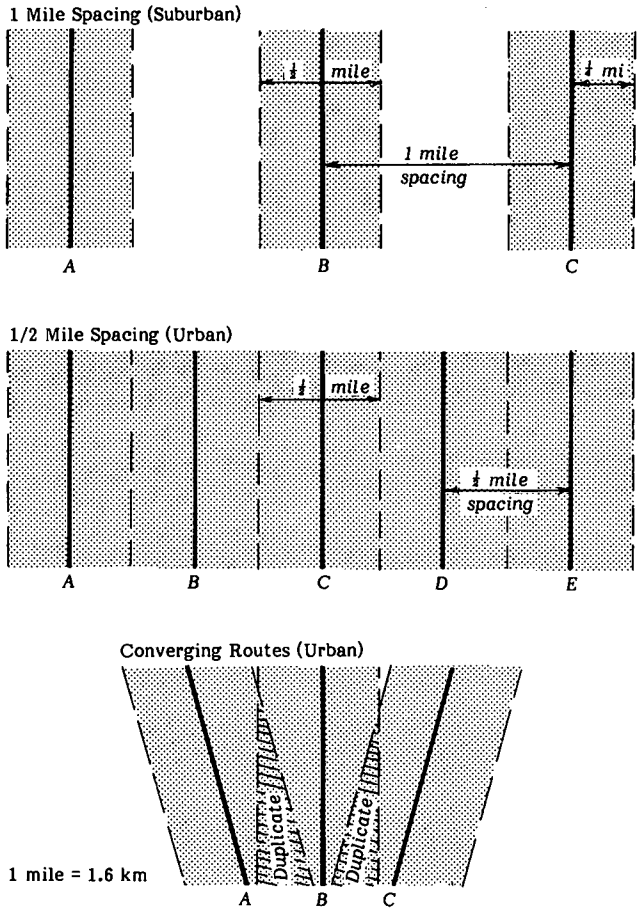



*Figure 14. Typical bus route spacing and coverage in residential areas (after 2).*

age. The MBTA criterion for route deviation provides a general guide for other properties. "Route deviation shall not exceed 8 minutes per covered trip based upon at least 10 customers per round trip" (*15*).

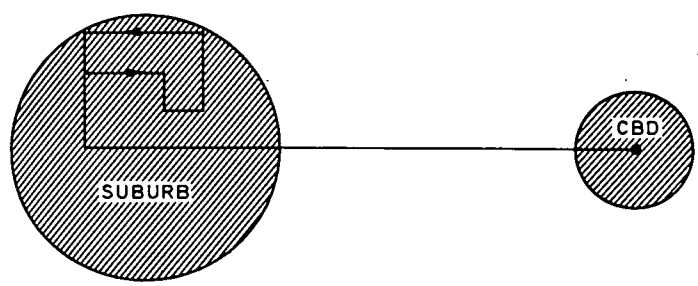
Although directness is a desired goal, it often conflicts with maximizing area coverage. Where demand for bus service is high, direct, closely spaced routes give the best coverage (e.g., Chicago and Toronto). However, in suburban areas of low demand, service is infrequent if only direct routes are used. In these cases, circuitous or loop routes may be appropriate or necessary, but the greatest circuitousness should occur on outlying sections of the route so that the fewest riders are delayed. Figure 15 shows how circuitous routing can be applied in a residential suburb to improve coverage; it also shows an example of a poor route that would be justifiable only under special circumstances.

Bus routes should follow main streets that are direct and continuous and of adequate geometry. Traffic signals and parking controls along these streets often expedite movement. Moreover, such roadways are often the focus of apartment and commercial developments, especially in older cities. Bus routes should follow minor streets only in outlying sections of a route.

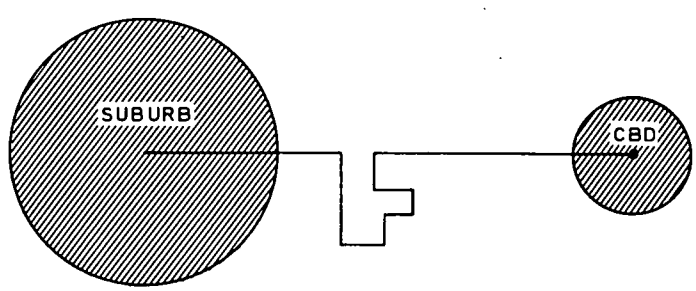
The MBTA, for example, says it will operate service only over asphalt or concrete paved streets of at least 10-ft (3-m) lanes. Streets with steep grades, poorly plowed or sanded roadways, or streets with illegal parking habitually reducing passageways to less than 10 ft are to be avoided. "Safety considerations will prevail in the final determination" (*15*).

Bus loops are necessary where off-street turnarounds are not provided at ends of lines, and in outlying suburban areas where additional coverage is desired. The loops should be as short as possible and should normally operate in one direction. However, in some cases, alternate trips may travel in alternate directions such as in one direction in the morning peak and in the opposite direction in the evening peak. However, this practice is limited chiefly to large loops where a major employment center lies near the junction with the main line.

Routes should operate two ways on the same street. However, one-way street patterns or street grades may require splitting bus routes onto roughly parallel inbound and outbound streets. In these cases, the routes should never be separated by more than two blocks [i.e., up to 0.25 mile (400 m)]. Greater separation reduces service coverage, greatly increases walking distances, and destroys the clarity of the route. As on midtown Manhattan's one-way avenues, split routes may limit short-haul ridership.




a. Circuitous routing at end of route: acceptable.




b. Circuitous routing at mid-route: undesirable.

*Figure 15. Examples of circuitous routing in bus operations (1).*

In some suburban areas, it may be necessary to provide two different routing patterns—one for commuters and one for off-peak business shoppers and students (Figure 16).

### Route Length

Routes should be as short as possible in serving their markets because of the difficulty in maintaining schedules for long routes. The differing traffic requirements along routes may further complicate scheduling, even with "turnback" service. For these reasons, large transit agencies such as those in Chicago, Los Angeles, Toronto, and Boston have broken longer routes into two or more shorter ones, either at rapid transit stations or in the CBD. Breaking a long route into sections allows each section to have headways more closely matched to its demand, and connections between sections can be timed when service is infrequent.

CTA indicates that "at a practical average speed of 12 mph including stops, it would have routes with very long journey times if they were to operate from one end of town to the other or from an outlying extremity to downtown and back" (*23*). CTA says such long trips cause bus operators to tire enough to diminish work output. Chicago's longest route, Ashland Avenue, is 16 miles (26 km).

Ideally, route length should not exceed 25 miles (40 km) per round trip or a 2-hr travel time. The maximum round trip should never exceed 35 miles (55 km) or 3 hr.

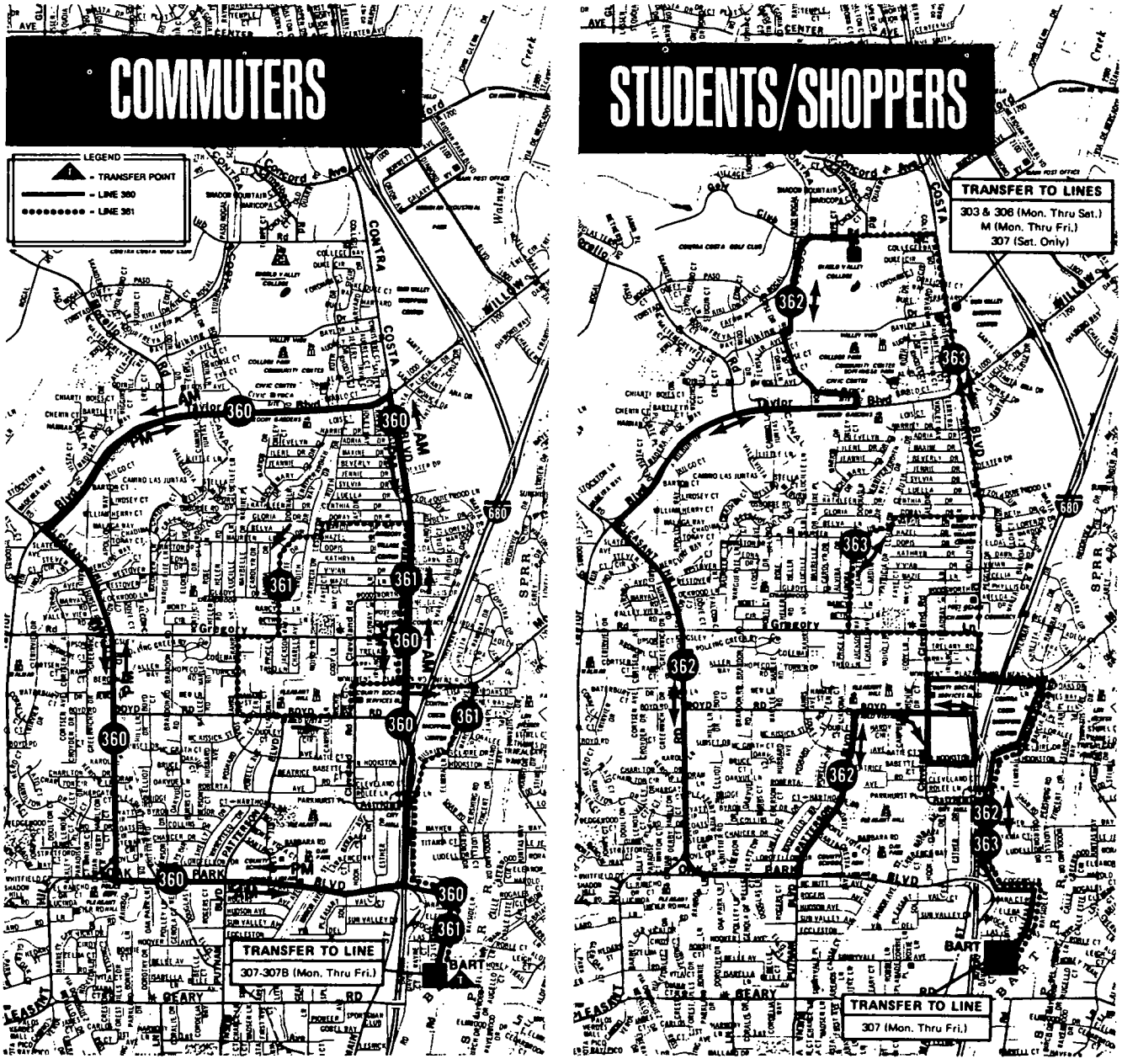



*Figure 16. Commuter and student bus services (AC Transit, Pleasant Hill).*

### Through Routing

Through bus routes often achieve better ridership patterns, reduce transfers, reduce bus miles and turning movements in the city center, and are cost effective to the transit operator. This suggests that bus lines be linked (connected) to form through routes wherever operating conditions permit. Routes that are connected should be balanced in terms of lengths, running times, and service frequencies. Interconnecting short routes should be given priority because through routing of longer routes complicates scheduling and reduces service reliability. Sufficient schedule recovery or "slack time" will maintain on-time operation.

Two separate routes with common terminals may become a through route if they have more than 20 percent transfers and similar traffic requirements. The following additional guidelines, based on MBTA criteria, apply:

- Two routes should serve travel corridors located on approximately opposite sides of a terminal.
- Service frequencies and hours of operation should be closely matched.
- Two routes should be stable and well established, because once they are linked, service on one cannot be modified without affecting the other.
- The combined round-trip running time of the two routes should not exceed 3.5 to 5 hr.
- The linking should have turnback points, operator relief points, and work schedules that ensure that the runs may be compiled with a reasonable ratio of revenue-producing hours to pay hours.
- Infrequent rather than frequent services are those that ought to be linked.

Systems in smaller urban areas such as Akron, Nashville, and New Haven through route most of their lines. Route length and schedule reliability considerations limit the amount of through routing by the larger agencies. Differing revenue and scheduling limit the amount of through routing in Washington, D.C.

Chicago, for example, has through north-south crosstown routes but breaks routes in the Loop to avoid unduly long lines. The Cleveland Transit Authority believes that through routes, especially long ones, are too difficult to schedule. Their maximum route length is 21 miles (34 km); the average is 10 to 12 miles (16 to 19 km).

### Route Branching and Duplication

Ideally, there should be only one route per arterial street, except on approaches to the CBD, at major transfer terminals, or in cities with unusual street patterns. The TTC, for example, states that "in a number of instances it is impossible to avoid the duplication of routes entirely; however, the normal practice will be to provide a single route per major arterial" (*20*). The goals of achieving consistent headways and maximizing passenger understanding of the system are best achieved with a single route per street, two at the very most.

There should be no more than two branches per trunk line route, four at the absolute maximum, and then only in special cases. Branches should have the same headways and running times. Generally, the more frequent the headway, the more desirable branching becomes as a substitute for loops at outer ends of lines.

Route duplication tends to unnecessarily increase operating expenses, complicate headways, and add to passenger confusion. Thus, although sometimes it may enhance passenger convenience, it does so only at unacceptable cost or with undesirable operating features.

The MBTA policy states that "operation of competitive, overlapping, or redundant regular-route services will be avoided except in thoroughfares where additional service is warranted or where confluences of routes must occur to serve a major activity center such as a rapid transit station or business district" (*15*).

Express and local services generally should have separate roads, except where service frequency is high. Where buses operate every 15 to 20 min in the base and peak periods, express buses should *not* operate on the same street as local buses. In this case, the object is to avoid having express buses pass by passengers waiting for local buses.

### Route Termination and Turnbacks (Short Turns)

The decision on where to terminate the outer end of a bus route depends on (a) desired area coverage, (b) service warrants and ridership, (c) existence of suitable street locations for loops and layovers, and (d) round-trip travel times when clock headways apply.

When clock headways are used, the round-trip running time is increased to the next highest figure divisible by the headway (e.g., from 25 to 30 min for a 15-min headway). When this causes substantial layover time at one or both ends of the route, the route can be extended to consume part of this layover time, thereby providing better coverage than normal standards dictate. In other cases, headways can be adjusted to fit round-trip times.

A rail transit station, timed-transfer point, or regional shopping center is a logical place to terminate bus lines and to break long routes. If there are major traffic generators on both ends of a bus line, ridership improves and one will see reverse riding in the peak.

Passenger demand along typical CBD-oriented bus lines gradually builds up toward the inner portion of the route. During peak periods, it is especially desirable to balance capacity with demand by turning back or "short turning" a portion of the service.

The planner should gauge demand by population distribution or riding counts and design turnbacks at one or more points along the route. These runs, called "trippers" or "extras," may be scheduled or may be extra rush-hour service and are the first to be dropped when there is a shortage of drivers or equipment (*24*).

Where short turns are regularly scheduled, trips on the full route can operate express up to the short-turn point and stop only in the CBD and at transfer points with connecting routes. Where all buses make the same stops, it may be desirable to schedule the short turn ahead of the regular run to better distribute riders among buses.

### Route Permanence

Routes should seem permanent to the public. Once a route has been initiated, it should not be changed continually or unnecessarily. The goal is to maintain rider familiarity with the service—its routes, schedules, and stopping places. Unless major service deficiencies are revealed, a route should not be changed more than once or twice a year (*25*).

## EXPRESS SERVICE GUIDELINES

Express bus service, provided to a growing number of communities throughout the United States, is designed to reduce travel times, especially from suburban areas, and to provide service that is competitive with automobile travel. It may serve as an alternative to, or forerunner of, rail transit.

### Overview of Current Practice

Methods of operation and service patterns vary widely among cities according to population distribution, street pattern, and availability of radial freeways and rail transit.

In cities with rail transit (Boston, Chicago, Cleveland, New York, Philadelphia, San Francisco, and Washington, D.C.), express buses serve areas not reached by rail transit. Examples are Staten Island and metropolitan New Jersey (New York), Lake Shore Drive and Archer Avenue (Chicago), Memorial Shoreway (Cleveland), and the Shirley Highway corridor (Washington, D.C.).

In cities without rail rapid transit (Denver, Hartford, Miami, Milwaukee, Minneapolis, and Seattle), express bus service usually operates on freeways. In some cases, such as St. Louis, extensive express service is provided over arterial streets. In Pittsburgh the Port Authority of Allegheny County Transit (PATransit) has South PATway and East PATway (under construction) special bus-only roads designed to improve express flow.

Express buses operate mainly in mixed traffic, but priority treatments often help reduce their journey times and improve their service reliability. Park-and-ride lots also complement many express bus services. One example is Milwaukee's Freeway Flyers, which operate to and from regional shopping centers.

Express services are provided by the regular transit operations in most cities. Significant exceptions are San Francisco where Golden Gate Transit and AC Transit provide express service outside the city and the New York area where service is provided by the New York City Transit Authority (NYCTA) and by private carriers operating in the city. The New York services are unique in that several lines in the Bronx operate competitive services on the same street as subway and elevated lines. All express services focus on the city center except for express buses in Chicago and Toronto that connect the international airports with outlying rapid transit terminals. Toronto is the only city surveyed that does *not* operate express buses into the downtown area.

### Planning Guidelines

Planning guidelines for express bus service are given in Table 4. Although most cities of more than 25 000 people can sustain some sort of local bus service, express service generally requires a population of more than 250 000. Express service has greatest potential in metropolitan areas larger than 1 million, where it may account for 25 to 30 percent of the total route mileage (*26*). Where local routes go beyond 3 miles (5 km) of the CBD and passenger volumes are great enough (especially for longer trips), express or limited-stop service may complement local service (*27*).

- The CBD is generally the primary area that can be served successfully by express buses. CBD employment should exceed 30 000. Occasionally a major airport or outlying commercial center can be served, as can special events at stadiums or sports arenas.
- The journeys to and from work usually represent the greatest proportion of express trips, and the system should be designed to meet these demands.
- In cities with rail transit, express buses should not serve the same corridors as the rail lines.
- It is usually easier to draw patronage for a new express bus service from local buses than to get people to shift from automobiles. However, where service is competitive with automobile travel, some diversion of motorists can be expected.
- Residential population densities must be high enough to generate a full or nearly full bus load with as few local service stops as possible. Unless a strong CBD orientation has been fostered by using express bus (or rail) service in promoting an area's development, a gross density of about 7000 to 10 000 people/mile$^2$ (2700 to 3900/km$^2$) is usually necessary to support direct express bus service. This density is common in older, small-lot, single-family developments and is found in recent garden apartment and townhouse developments. At least 30 potential peak-hour CBD passengers per mile (19/km) of route appear necessary for direct express bus service to a residential area.
- Park-and-ride lots, needed in suburban areas where densities are too low to generate walk-on traffic, enable express buses to attract riders who might otherwise drive. These lots should be located where off-peak service is provided so that patrons can reach their cars, for example, in case of emergency.
- Buses should operate at or near free-flow traffic conditions for all or most of their trips. The best routes are along busways, freeways, or other roadways where buses can travel quickly without congestion once satisfactory passenger loads are achieved. Express bus service along arterial streets may be desirable where employment and population are clustered at major intersections and there is no freeway in the corridor.
- Express bus service on freeways should be offered in peak periods only, except in very large cities or under unusual circumstances. Express bus service on arterials can be provided during both base and peak periods, although base (midday) service will depend on traffic density.

TABLE 4

EXPRESS BUS SERVICE PLANNING GUIDELINES (AFTER *28* AND *29*)

| | ITEM | GUIDELINE |
|---|---|---|
| 1. | Minimum urban area population | 250,000 - 300,000 |
| 2. | Minimum CBD employment | 20,000 - 30,000 |
| 3. | Minimum peak-hour peak direction passengers per route mile | 30-50 for local service on surface street segment |
| 4. | User characteristics | Choice and mode-dependent white collar CBD employees, some professionals |
| 5. | Service objectives | Rapid peak period access to CBD, with emphasis on home-to-work trips |
| 6. | Route length (typical) | Five to ten miles. Express service for 3 or more miles |
| 7. | Route coverage | 1/4 to 1/2 mile in local service areas |
| 8. | Access to bus stop | Pedestrian, feeder bus, auto |
| 9. | Stop frequency | 1/4 to 1 mile for intervals where stops are made in express zone |
| 10. | Maximum desired headways | |
| | Peak | 20 minutes or less |
| | Off-peak | May not operate |
| 11. | Overall running speed | 15 to 30 miles per hour |
| | Express only, on freeways | 35 to 40 miles per hour |
| | Express only, on arterials | 15 to 25 miles per hour |
| 12. | Maximum door-to-door travel time (including transfers) | 45 minutes |
| 13. | Maximum accountable time difference by which bus can exceed car for door-to-door journey to attract choice trips | 10 minutes |
| 14. | Minimum time advantage over local bus excluding waiting and transfers | 5 minutes |

*1 mile = 1.609 km*

- Service may operate nonstop in the express zone (typical freeway "closed-door" operations) or limited stop (typical "open door" arterial operations). Where limited-stop service is provided, buses should stop at major transfer points and cross streets but not more often than every 0.5 mile (0.8 km).
- An attempt should be made to give every passenger a seat, even during the peak 20-min periods. This is especially important where long [more than 5-mile (8-km)] nonstop runs operate at relatively high speeds.
- Express and local bus service may be mixed effectively in high-volume corridors (Archer Avenue, Chicago, is one such example; Geary Street, San Francisco, is another). Where the two services operate on the same street or in the same corridor, the express service should provide a means of obtaining better overall passenger distribution and load control in the corridor.
- Express service at spacings closer than 0.5- to 1.0-mile (0.8- to 1.6-km) intervals should be discouraged to minimize service duplication.
- Express buses should save at least 5 min over local bus travel. This calls for a minimum 3-mile (4.8-km) express bus run from the CBD. The time saved by express buses compared to local buses operating on the same streets is usually 1 to 2 min/mile (0.6 to 1.2 min/km) (see Figure 17). Where buses enter the downtown area, every effort should be made to give them preferential treatment to reduce delays and improve service dependability.

The extent to which express runs can draw substantial patronage depends on (a) the size and compactness of the group of transit patrons or potential transit patrons with CBD destinations to be served; (b) the availability of a busway, freeway, other type of limited access highway, or

multilane arterial street; (c) a reasonably free flow of traffic on that highway during weekday rush hours; (d) extensive congestion in the area to be bypassed, which makes it rewarding to avoid the surface streets; and (e) the practicality of bypassing a 3-mile (4.8-km) annular ring around the CBD without creating demand for uneconomical duplication of bus services and without eroding existing local bus patronage.

## SERVICE COORDINATION

Service coordination implies (a) traveler's ability to transfer freely and conveniently between modes; (b) distinct service areas for each mode, thereby minimizing duplication; (c) adjustments and interrelationships of schedules (especially during midday and evening hours); and (d) joint fare structures. Coordination may take place between urban and suburban carriers, rail and bus transit, or bus and car; it may involve routes and schedules within a single bus system or bus and paratransit services. It implies adequate park-and-ride facilities at express transit stations and the use of express bus or rail for long line-haul trips.

Effective coordination of public transport services depends on the extent, layout, and complexity of the system and the number of carriers involved. Historical circumstances are also important, because coordination is most effective where a single transit agency (such as MBTA and its predecessor MTA) has been the dominant carrier for a long time.

Emergence of urban transit authorities in the 1950s and regional transit authorities in the 1970s has resulted in increased service coordination throughout the urbanized area. The CTA, for example, progressively coordinated the three systems it acquired into a unified, citywide system; now the Regional Transit Authority is further coordinating bus and commuter-rail services.

The needs for coordination are greatest where transit agencies are the outgrowth of, or remain, separate or competing systems. Needs are most apparent in the very large, multimodal systems, especially those that cross state lines.

Coordination is a relatively simple task in Akron or Nashville, where a single carrier operates the entire urban bus fleet but is far more complex in New York, with its vast array of bus, rapid transit, and commuter rail services; a long tradition of operating rail and bus systems with the NYCTA as separate entities; and initial development of subways as three separate systems.

Toronto has an excellent example of service coordination. Its bus lines feed subway lines, and transfers are free and often allow direct passage from bus to train. Bus lines are frequently "broken" at subway stations, thereby reducing route length and allowing for differing headways on both legs (see Figure 18).

Rail-bus service is also effectively coordinated in Chicago, Philadelphia, Boston, Cleveland, and Washington, D.C. Service coordination exists between rail lines in New York City, but rail-bus coordination and transfer were limited as of mid-1979.

Issues of revenue accountability in relation to operating subsidy appear to limit coordination of Washington, D.C., and Northern Virginia bus lines. This results in heavily overlapping bus volumes in the downtown area.

Effective coordination means curtailment or elimination of redundant services. The case is clearest when one looks at large agencies that operate both rail and bus lines. In these cases, the goal should be to eliminate lightly used rapid transit stations *or* parallel, overlapping bus lines.

Chicago, for example, restructured its rapid transit lines to minimize service competition with bus lines almost 30 years ago. Closely spaced, lightly used, rapid transit stations (generally with fewer than 1000 passengers/day) were closed on the assumption that parallel bus lines would

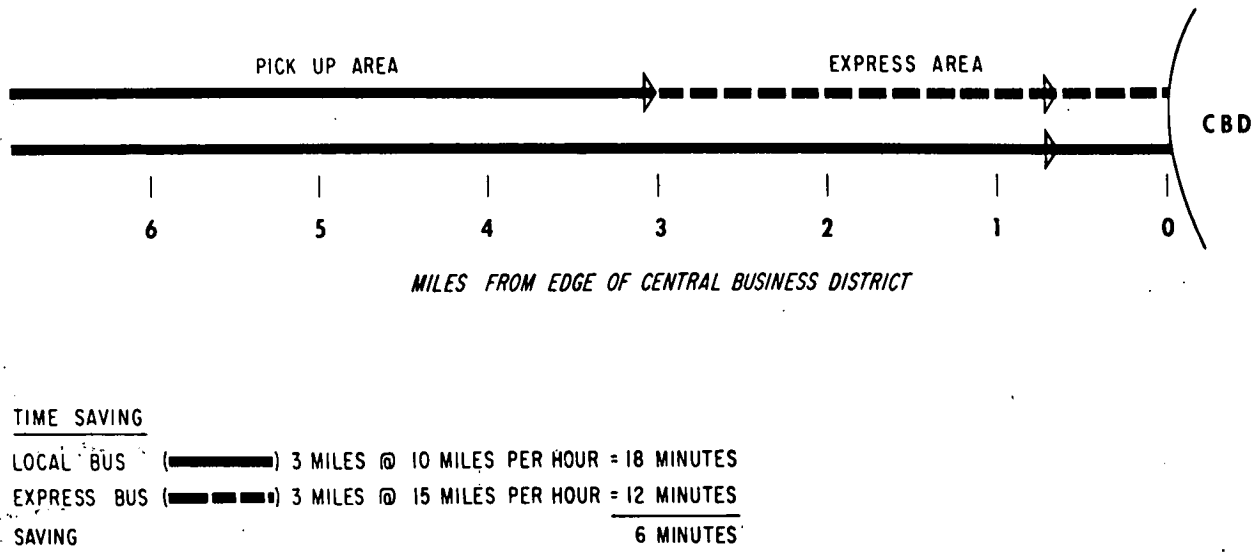



*Figure 17. Potential express bus time savings on arterial street (28). Savings on a freeway would be even greater.*

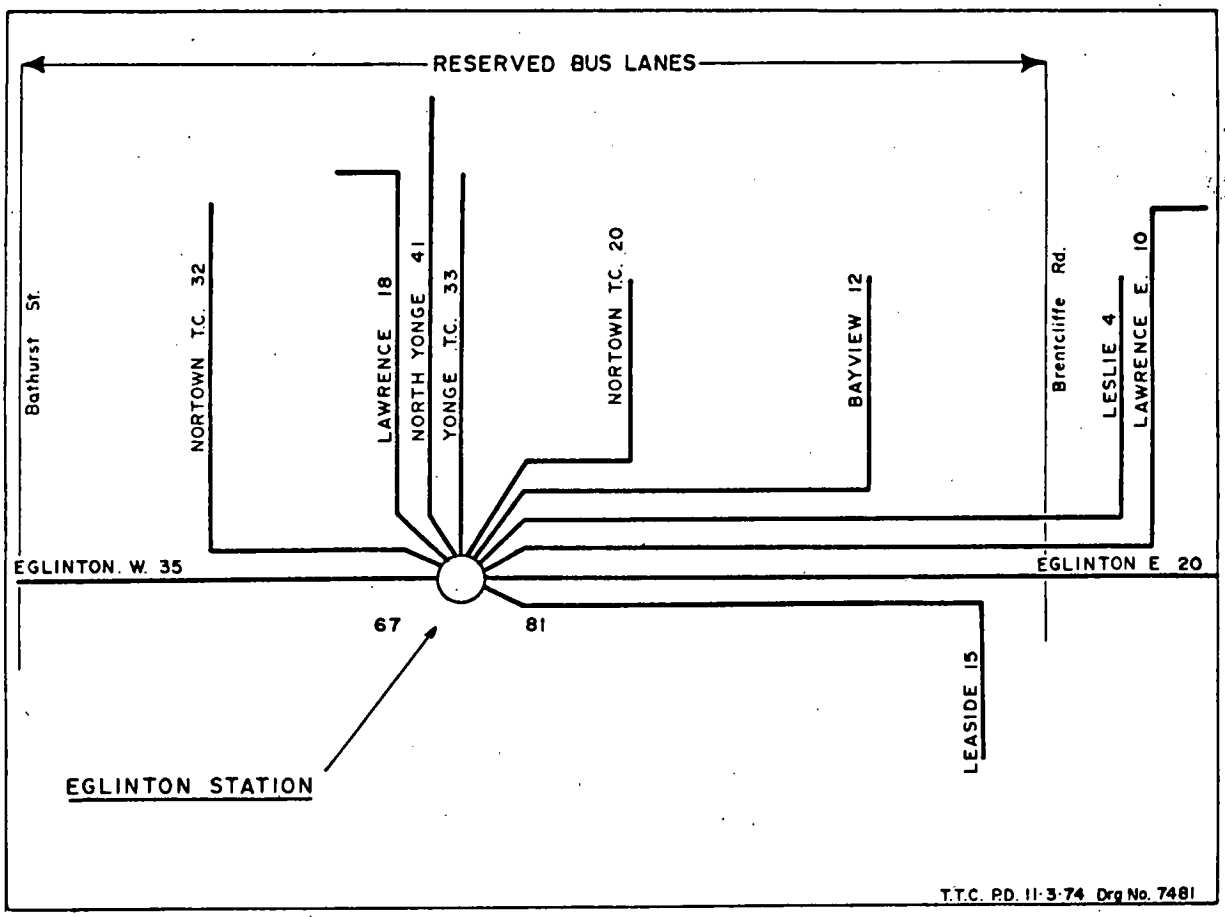



*Figure 18. Bus routes using Eglinton Avenue (Toronto) (1974) (30).*

provide local service. Since then, many bus lines have been altered to feed rapid transit lines and to minimize service duplication.

Many times services appear to overlap but duplication does not actually exist. For example, buses along the Grand Concourse in the Bronx are oriented to the 149th Street hub, whereas subway trains serve the Manhattan market.

"Transit centers," timed transfer points with restructured routes, underlie current planning efforts in bus-only systems such as those in Denver, Portland, and Vancouver, as well as in traditional rail-bus systems.

#### Passenger Transfer and Interchange

Transfers between routes and services should be convenient and easy. Passengers normally prefer riding in one vehicle to transferring. Their reluctance to changing vehicles, however, largely depends on the conditions under which the transfer takes place. Neglect of transfer facilities during the last two or three decades has led to a belief among many planners and operators that a transfer is a major obstacle to use of transit. Experiences of cities that have developed excellent transfer facilities between routes and among different modes (Toronto, Lindenwold Line in Philadelphia, Cleveland, Chicago, Edmonton, Munich) clearly show (*2*) the following:

- A network of routes can operate much more economically and offer higher frequency of service if transfers are given than if attempts are made to avoid them at all costs.
- Transfer stations can be very efficiently integrated with such facilities as long-distance terminals, shopping centers, administrative complexes, etc.
- When transfers are well-designed and operated, passenger objections to transferring are diminished. Timed transfers are increasingly popular.
- Transfers simplify service patterns, especially in a grid system.

The following basic amenities should be provided at major transfer points:

- Convenience such as short walking distances, escalators, and full weather protection;
- Cleanliness, comfort, and safety;
- Excellent information about directions, routes, and schedules;
- Short waiting times; and
- Availability of telephones, minor food shops, drug store, etc.

*Figure 19. Bus-rail interchange (Washington, D.C.).*

As a general rule, transit routes that cross or branch should have transfer areas at points of intersection. This increases the connectedness of the system and hence its convenience. An exception might be made for an express operation (such as a rapid transit line or an express bus), which cannot be expected to stop at every point of intersection with local bus lines (*25*).

In grid systems, natural transfer points occur wherever the two routes cross. In radial systems, transfers should be allowed at the central point of the system, at the points where crosstown routes intersect radials, and at the first point at which two routes merge or diverge. This last condition might be modified where the point of branching of two routes becomes overloaded with transferring passengers. In these situations, other bus stops along the section of the network traveled jointly by both routes can be established as transfer points.

### *Route Diversion*

Whether a bus is diverted from its route to connect with a nearby line is decided by considering such factors as the configuration of the transit network, the length of the proposed diversion, the relative importance of each route involved (in terms of frequency of service and passengers carried), major passenger travel patterns, and the resulting service that is provided. Route restructuring rather than diversion is generally more feasible where a bus-rail interchange is involved.

In the case of a bus-bus interchange, major bus routes may be diverted short distances (two or three blocks) if an interchange with another route can be made at an important activity center. In this way, service is given to the center, while connection to other bus routes is provided. The diversion of one relatively minor bus route to intersect with another is not usually justified unless the point of intersection is at a major center of activity, the point of intersection is at the terminal of one or both lines, or the diversion of the route allows it to cover another area well.

In all cases, route clarity and travel directness must be balanced with system connectedness and passenger convenience. Decisions on diversion must therefore be made carefully.

### *Bus-Rail Interchange*

Bus-rail transit interchange should minimize walking for transferring passengers. Across-the-platform transferring is convenient in those situations where bus roads can be constructed on the same level (e.g., Boston) and parallel to the rapid transit tracks, but this depends on land availability. Grade-separated interchanges are, therefore, more common, and the buses operate from their own off-street loading areas (Figure 19). In high-density and congested districts, a regular curb-side bus stop is provided near the rapid transit station entrance.

Whenever a change in level is required for transferring, at least one escalator (more if pedestrian volumes are large) should supplement stairs. When the distance between the rapid transit and bus platforms is great, passageways should be as pleasant and safe, well lit, and well designed as possible. Buses should have priority access to stations at major park-and-ride locations.

### *Bus-Bus Interchange*

Bus-bus interchange may be bus stops that are adjacent, a common stopping area where two routes merge, or an off-street terminal, all places of major interchange. Stops should be located to minimize walking distance for the greatest number of transferring passengers, but other fac-

tors (such as the design of the roadway or intersection, the presence or absence of sidewalks, and the character of adjacent land uses) must also be considered.

Bus stops at busy transfer points should be equipped with shelters or benches and canopies. Transfer areas handling very large volumes of people and vehicles should be located off-street wherever possible and can be treated as rapid transit stations.

*Timed Transfers*

Transfers between lines with short (5- to 10-min) headways never present waiting problems, but transfers to long-headway lines usually involve considerable waiting. Consequently, it is desirable to coordinate schedules on intersecting routes when headways are fairly long (longer than 15 min in the base period). Because this will be difficult to arrange for all points of intersection and all directions, schedule coordination should be limited to major transfer points. Moreover, the desire to coordinate schedules should be balanced against the desire to start trips from terminals at even intervals of time (such as on the hour, half past the hour, etc.).

Several properties have organized transfers among routes (usually suburban) that have long headways through the timed-transfer focal point system. Edmonton, Portland (Oregon), and Vancouver are examples. These systems use selected points at key locations such as suburban towns and shopping centers for transfers. In Edmonton, vehicles from various routes and on 30-min headways are scheduled to arrive simultaneously and spend at least a 5-min terminal time before returning to their routes. This time ensures some overlap in standing times among routes, thus allowing two-way passenger exchange among all routes. However, it may not be applicable to larger systems because of complex schedule and interface requirements. In Portland, routes on the west side of the city were restructured to serve a major outlying center, and a timed-transfer system was simultaneously initiated.

*Passenger Shelter Guidelines*

Transit systems are providing more and more passenger shelters at bus stops and transfer points to improve amenities and enhance the system's image. Shelters should be built at major passenger terminals or passenger interchange points where bus boarding volumes are heavy, waiting is likely to occur, physical conditions allow their development, and vandalism is not a problem. Shelters also should be provided near hospitals and residences for the aged. Preference should normally be given to inbound stops along radial routes, because these locations are likely to generate the heaviest boarding volumes and passenger delays.

High passenger demand and low service frequency locations should be given priority, which will vary, however, with specific programs. The MBTA gives priority to locations with more than 500 weekday riders (Table 5), whereas WMATA uses 100 riders as a guideline.

In general, shelters should be provided at (a) all downtown stops, (b) inbound stops only in residential neighborhoods, and (c) stops that serve 200 to 300 or more boarding, alighting, and transferring passengers daily. Shelters should be placed a minimum of 3 ft (0.9 m) back from the curb line and within 40 ft (12 m) of any bus stop.

Bus shelters should be constructed of highly durable, weather- and vandal-resistant materials. They should have a pleasing appearance, afford ample weather protection, and give high visibility. They should cost little to install and maintain. "Flow-through" shelter designs that allow passengers to walk from the sidewalk through the shelter onto the bus are desirable (WMATA uses such a design).

The following should be located on, within, or near the shelter:

- Logotype,
- Benches (especially on long-headway routes), and
- Routes served and schedules as appropriate.

It is a good idea to put system and route maps and timetables at passenger boarding points where several lines use the same street or stop. Such locations generally are limited to downtown areas or major transfer points. Cost, space, and maintenance considerations will limit the placement of maps at all shelters.

TABLE 5

MBTA PRIORITY GUIDE FOR BUS SHELTERS

| Riders/Weekday | Average Peak Period Frequency ≥15 min | 5-15 min | ≤5 min |
|---|---|---|---|
| ≥500 | 1 | 1 | 1 |
| 450-499 | 2 | 2 | 3 |
| 400-449 | 2 | 2 | 3 |
| 350-399 | 2 | 3 | 4 |
| 300-349 | 3 | 3 | 4 |

1 = highest priority; 4 = lowest priority

**Service Coordination Examples**

*Chicago*

Chicago's recent rail-bus coordination efforts include the 95th-Dan Ryan and Jefferson Park bus terminals (*31*). When the two expressway-median rapid transit lines opened, these terminals became large-scale intermodal transfer points. Bus routes that formerly continued downtown were terminated at the rapid transit terminals; other routes were diverted to and through the new transit centers. This reduced the number of bus trips into the already congested CBD.

The 95th-Dan Ryan terminal is now a major transfer facility serving residents on Chicago's far south and southwest sides and nearby suburbs. Since its opening in late 1969, it has developed into the busiest of CTA's 140 rapid transit stations. About 50 000 passengers use this terminal each day, and most transfer to and from nine CTA bus

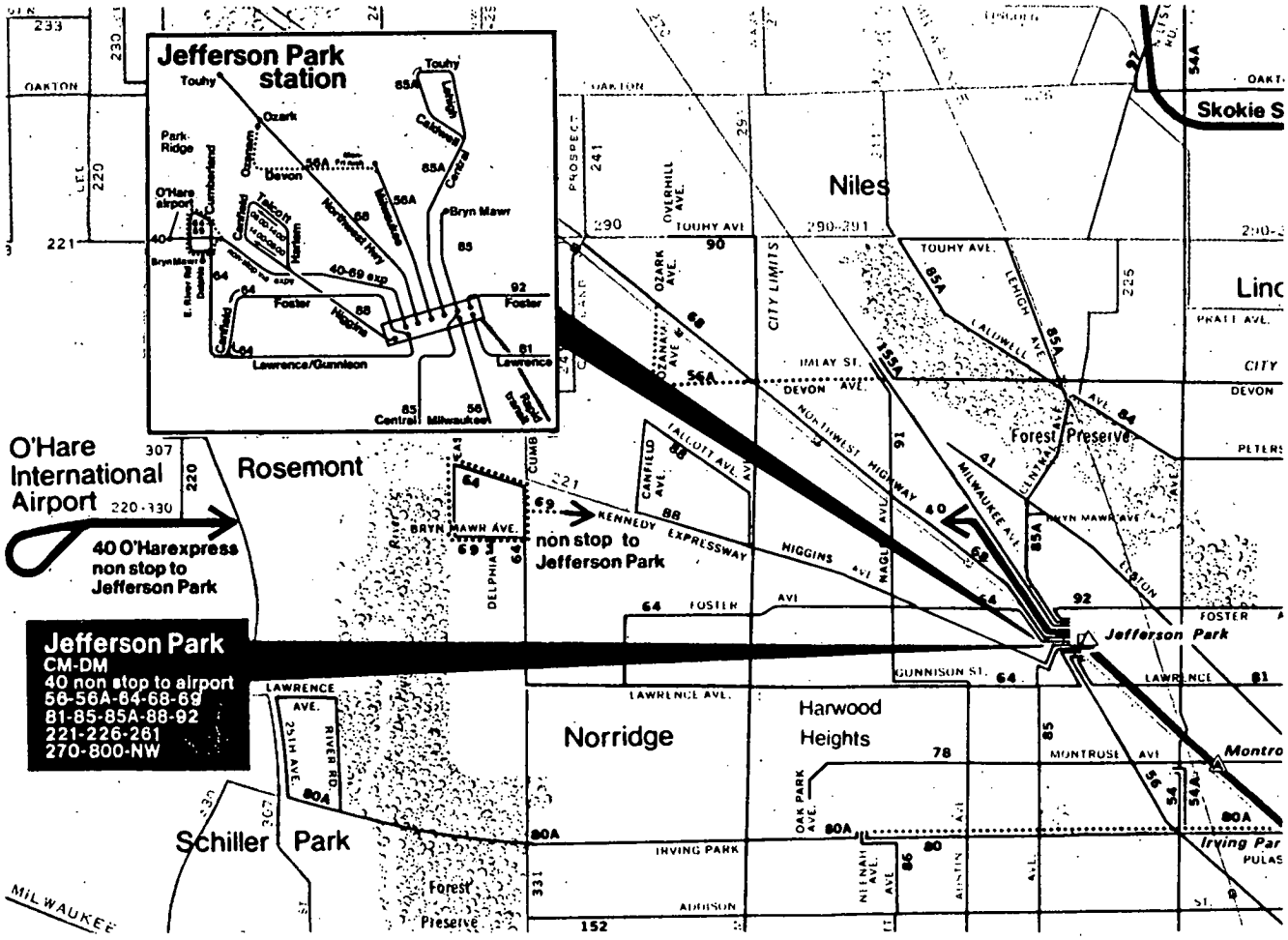



*Figure 20. Jefferson Park terminal (Chicago). Note concentration and breaking of bus lines.*

routes and buses of South Suburban Safeway and the Suburban Transit System. Greyhound Bus Lines also serves this location.

The Jefferson Park Terminal on the CTA west-northwest transit line, opened in 1970, serves passengers from the rapid transit system, 10 CTA bus routes, 4 Nortran suburban bus routes, the Chicago and North Western commuter railroad, and the Greyhound Bus Lines. Few kiss-and-ride facilities are provided. About 14 000 of the 29 000 passengers at this station are bus riders. CTA routes were restructured to serve the station, and long routes were broken to provide better service reliability (Figure 20).

*Toronto*

TTC operates 111 surface routes with buses, trolley coaches, and streetcars. The routes make 131 connections with the subway system; some routes make as many as three connections. Passenger interchange facilities between subway and bus have been improved over the years (*31*).

Studies conducted at the terminal stations show that between 45 000 and 60 000 passengers daily use the west and north terminals. Of this number, about 80 percent arrive and depart by bus and about 12 percent at each location use kiss-and-ride or park-and-ride facilities. The rest of the passengers are classified as walk-in patrons. At the east terminal, bus passengers represent 86 percent of the total station use, and there is about the same 12 percent split for kiss-and-ride and park-and-ride as experienced at the north and west terminals.

Figure 21 shows the relationship of the Finch Subway Terminal on the Yonge Street Subway Extension to local and regional bus lines, commuter parking facilities, and kiss-and-ride.

*Portland*

Tri-Met coordinated west side services instituted in Portland, Oregon, by restructuring bus lines to serve local transit centers. Radial trunk services were concentrated on a few routes and complemented by increased local and crosstown services with timed transfer. In many respects, the local transit centers function similarly to bus-rail interchange points in larger cities.

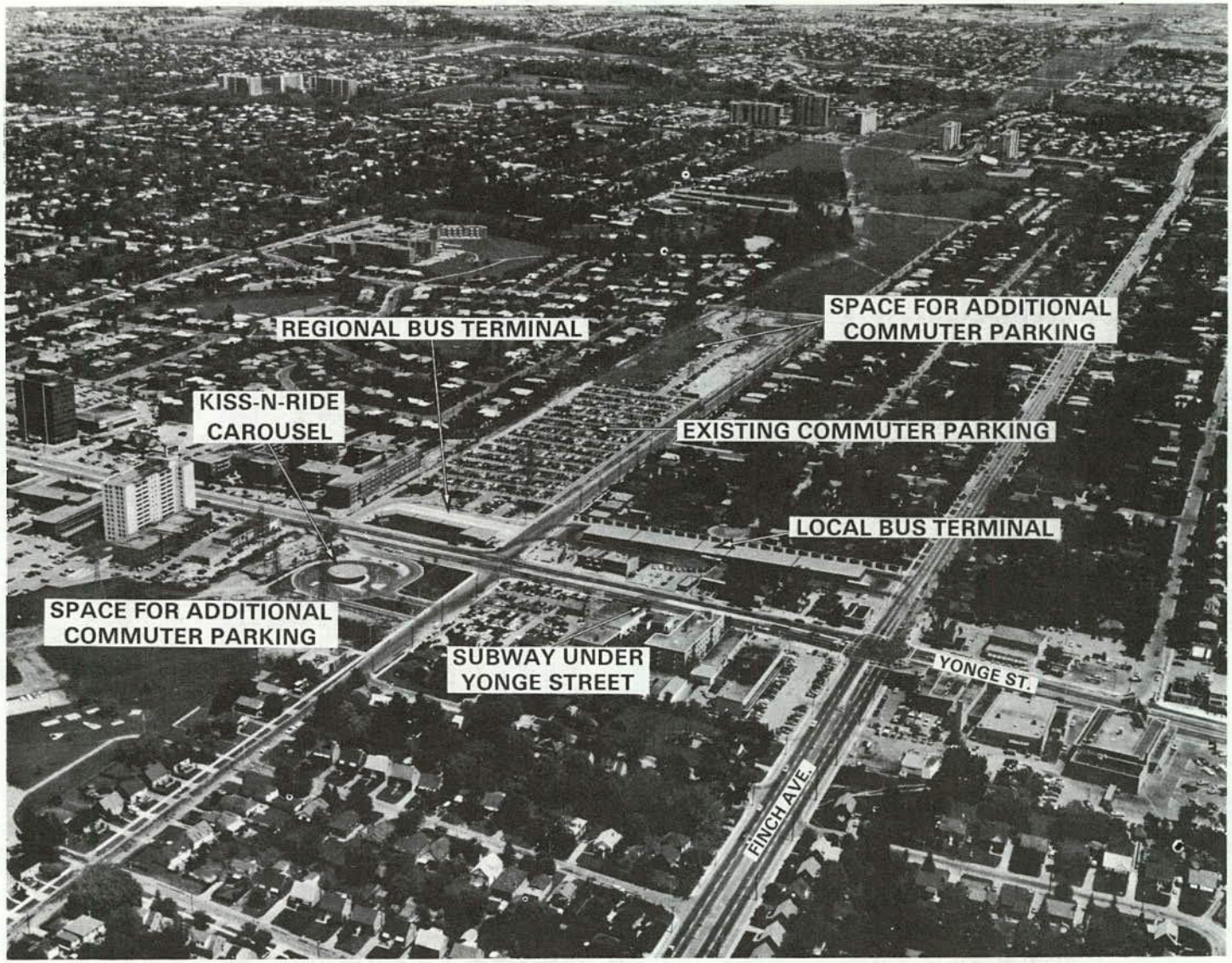



*Figure 21. Finch subway terminal showing layout of facilities (Toronto).*

TABLE 6

SPECIAL TRANSIT SERVICES (AFTER *24*)

| ROUTE AND DESCRIPTION | |
|---|---|
| 1. School Service.<br>2. University Service.<br>3. Shopper Service.<br>4. Industrial Service. | Operated on fixed routes and open to all passengers as distinct from charter or private service. |
| 5. Shift Service. Special trips operated to coincide with a plant shift change. | |
| 6. Employee Service. An employee route—often a combination of regular routes, operated before or after normal transit service hours to take bus drivers to and from home. Employee services will often carry revenue passengers and appear on timetables. They are becoming less common as these trips divert to the automobile. | |
| 7. Contract Service. A route provided to an industrial plant or other location under a specific subsidy arrangement. Such routes mav extend outside the operators service area, or may serve facilities where regular transit service cannot be warranted. Where contract routes are restricted to specific riders and are not available to the general public, the buses are said to be "not in revenue service" and the service is then a "charter service." | |
| 8. Recreation Service. Specific routes or extensions of regular routes to recreation facilities such as municipal, regional, or provincial parks; ski areas; and beaches. These routes may extend beyond the normal service area and are usually seasonal. | |
| 9. Special Event Service. Special routes to sporting or entertainment events as distinct from augmented service on regular routes. Special event routes may run express from suburban shopping plazas where arrangements have been made to provide park-and-ride spaces. A premium fare may be charged. Revenue is usually obtained in one direction only and buses rarely can make a second trip. | |
| 10. Downtown Distribution. Special routes distributing passengers through the CBD, particularly if subway, bus or railway stations are not centrally located. This may be a two-way service or a loop operated in only one direction. Special low fares are common. This type of service is sometimes subsidized by the downtown merchants association as a shopper service. | |
| 11. Shuttle Routes. Special routes often equipped with small buses used to distribute passengers through a central area or to connect a special attraction to regular transit routes. Parking lot or interterminal shuttles at airports minimize walking distances. | |
| 12. Airport Service. Regular transit routes serving airports, particularly cargo, maintenance or general aviation sections, to provide service to employees. They may include specific routes for air passengers operating express to a downtown location or rail transit station. (Premium-fare service to downtown hotels is not usually provided by the transit company.) | |
| 13. Park-and-Ride Service. Special peak-hour express service, often at a premium fare, to connect park-and-ride lots not served by regular transit routes with the central business district. | |
| 14. Dial-A-Ride. Many-to-one demand-responsive service, often connecting with other buses at a shopping center or major transfer point. | |
| 15. Charter Service. Charter service provided by the transit company as a means of obtaining extra income. Often operated on weekends. | |

## SPECIAL SERVICES

Many transit systems operate special services, such as express buses or freeway flyers (sometimes with premium fares), downtown shopper shuttles (at discounted or no fare), or promotional services that are keyed to downtown sales, special attractions at museums, football games, or special events. In some respects, these services are modern versions of the streetcar (or rapid transit) services provided to system-owned amusement parks, such as Coney Island (New York) or Glen Echo (Washington, D.C.) 50 years ago. Table 6 summarizes various types of special services provided by many transit systems. Some examples follow:

- PATransit provides a regional system of Red Flyer express routes during rush hours.
- CTA operates a "culture bus" on summer Sundays between the city's seven major museums. A special $0.80 fare allows unlimited riding. An "L"ephant bus connects the Lincoln Park Zoo with the North-South Rapid Transit Line.
- Milwaukee operates a system of freeway flyer express bus routes between the downtown and park-and-ride lots at regional shopping centers.
- Knoxville provides football shuttles and charter services.

CHAPTER FIVE

# SERVICE LEVELS

Bus service levels are usually the result of past practices, ridership requirements, and economic constraints. Peak-hour service frequencies generally reflect ridership levels and capacity needs, whereas base period and evening services often reflect policy headways.

## SERVICE PERIODS

Twenty-four-hour service, 7 days a week, is normally limited to major systems such as those in New York, Chicago, Philadelphia, Pittsburgh, and Washington, D.C. However, many large cities provide no owl (early morning) service. Medium-sized cities provide service 7 days a week, usually about 18 hr per day.

Table 7 shows the progressive reduction in CTA bus services from Saturdays to Sundays and service during owl periods. Some three-quarters of the CTA bus routes operate 24 hr daily. In Washington, D.C., 10 out of 345 basic routes operate 24 hr. In Nashville, service is provided 7 days a week from 5:00 a.m. to 12:30 a.m. Knoxville operates weekdays and Saturdays from 5:30 a.m. to 9:00 p.m., Sundays from 8:00 a.m. to 8:00 p.m., and holidays from 11:00 a.m. to 7:00 p.m.

General guidelines, based on current North American practice, suggest the service periods given in Table 8. In small and medium-sized communities, special weekend service patterns may have buses concentrated on principal routes.

The frequency of bus service is usually determined by (a) policies regarding the minimum level of service (i.e., policy headways), (b) the number of buses needed to handle passenger loads, or (c) some combination of these two. Policy headways are more common for off-peak conditions, whereas passenger loads are given more consideration during the rush (peak) hours.

### Policy Headways

Bus service frequency is established by policy headways, on lightly traveled lines. The usually more frequent service on grid systems reflects the need for transfers. Peak policy headways of 20 min are common except in outlying suburban areas where 30-min headways are acceptable. Midday and evening policy headways should not exceed 30 min except for low-density suburban lines where 60-min headways are acceptable. Headways of more than 10 to 15 min involve long passenger waits and require published bus schedules.

Headways longer than 6 min should have the same departure times each hour so that riders can remember them. This suggests that headways of 7.5, 10, 12, 15, 20, and 30 or 60 min should be used.

On lines with branches, uniform headways should be provided along the common route where all branches carry about the same passenger volumes. This is a desirable objective where several lines operate on the same street, al-

TABLE 7

CTA SERVICE BY TIME PERIOD (1977)

| | Number of Routes Operated | | | Round Trip Route Mileage* | | |
|---|---|---|---|---|---|---|
| Time of Operation | Bus | Rail | All Service | Bus | Rail | All Service |
| Weekday Rush | 137 | 7 | 144 | 2,084 | 205 | 2,289 |
| Weekday Base | 120 | 7 | 127 | 1,858 | 205 | 2,063 |
| Saturday | 109 | 7 | 116 | 1,665 | 183 | 1,848 |
| Sunday | 95 | 5 | 100 | 1,446 | 160 | 1,606 |
| Owl | 66 | 5 | 71 | 985 | 160 | 1,145 |

* Round trip route mileage is the linear miles of route for one round trip between outer terminals. Outer terminals are defined as those terminals farthest apart between which 25 percent or more of all trips operate. If a route consists of a main line with two or more branches with equal service, the mileage is the sum of the main line round trip mileage plus additional round trip mileage on each branch.

*1 mile = 1.609 km*

TABLE 8

GENERAL SERVICE PERIOD GUIDELINES

| ROUTES | TIMES | DAYS |
|---|---|---|
| Local Bus Service | | |
| Principal routes | 5:30 a.m. - 12:30 a.m. approx. | Daily & holidays |
| Selected routes | 24 hours (large cities) | Sun. - Sat. |
| Other routes | 6:00 a.m. - 9:00 p.m. | Mon. - Fri. (or Sat.) |
| Industrial routes | Peak periods | Mon. - Fri. |
| School Routes | 9:00 a.m. - 4:00 p.m. | Mon. - Fri. |
| Express Bus Service | | |
| Major routes | 6:00 a.m. - 7:00 p.m. | Mon. - Fri. (or Sat.) |
| Other routes | Peak periods | Mon. - Fri. |

though complete blending of headways may be difficult in practice with high or highly variable service frequencies. Layover or recovery time at one or both ends of the line should be adjusted as needed to obtain desired headways.

Frequent midday service often can be provided without substantial additional costs, because peak hours determine vehicle and driver requirements and driver work rules limit the number of split shifts. For these reasons, the peak-to-base ratio (ratio of buses operating in peak to buses operating midday) rarely exceeds 2, even though actual variations in ridership would be greater.

#### Loading Standards

Bus loading standards should reflect the type and frequency of service and time of day. They should be highest for short-headway local bus lines, and lowest for freeway express or flyer services. Table 9 gives suggested loading standards at maximum local points, based on a review of contemporary practice.

Express service operating over freeways should not carry standees because of high travel speeds and length of express runs (sometimes 30 min). Express service on arterial streets may carry as many as 33 percent standees in the peak 30 min.

Local buses operating on headways of 10 min or more should have load factors of 100 percent or less, except for the peak 20 to 30 min when load factors may approach 125 percent. When buses are operating on headways of 6 to 9 min, load factors should not exceed 140 percent in

TABLE 9

SUGGESTED MAXIMUM LOADING STANDARDS IN PERCENTAGE OF SEATS (MAXIMUM LOAD POINT)

| TIME PERIOD | TYPE OF SERVICE | | | | |
|---|---|---|---|---|---|
| | Local | | | Express | |
| | ≤ 5 min headway | 6 to 9 min headway* | ≥ 10 min headway | Freeway | Arterial |
| Peak 20 to 30 min | 160 | 140 | 125 | 100 | 133 |
| Peak 60 min | 140 | 120 | 100 | 100 | 120 |
| Transition (before/after peak) | 120 | 110 | 100 | 100 | 110 |
| Midday | 100 | 100 | 80 | 100 | 100 |
| Evening | 100 | 100 | 70 | 80 | 80 |

*Values in this column can be used where headways are not specified.

the peak 20 to 30 min. Local buses operating on headways of 5 min or less should have load factors that do not exceed 160 percent of seats during the peak 20 to 30 min.

The Cleveland transit system, for example, proposed the bus loading standards for various times of day given in Table 10.

TABLE 10

PROPOSED LOADING STANDARDS FOR CLEVELAND (1975)

| TIME PERIOD | PERCENT OF SEATING CAPACITY* AT MAXIMUM LOAD POINTS |
|---|---|
| 5:00 a.m. to 6:00 a.m. | 80 |
| 6:00 a.m. to 7:00 a.m. | 100 |
| 7:00 a.m. to 9:00 a.m. | 125 |
| 9:00 a.m. to 10:00 a.m. | 100 |
| 10:00 a.m. to 2:30 p.m. | 80 |
| 2:30 p.m. to 4:00 p.m. | 100 |
| 4:00 p.m. to 6:30 p.m. | 125 |
| 6:30 p.m. to 7:00 p.m. | 100 |
| 7:00 p.m. to 8:00 p.m. | 80 |
| 8:00 p.m. to 5:00 a.m. | 20 |

*Based on 50 seats per vehicle.

#### Schedule Adjustments

Among the circumstances that call for adjusting standards in developing practical schedules are

1. Surge loading for short periods or short distances or both,
2. Scheduled versus actual frequency,
3. Convenient schedule headways that conform to required running times, and
4. The blending of headways where routes share service areas.

### BUS STOPS

Bus stop spacing and location should balance passenger convenience with operating speeds and traffic requirements. Energy constraints may imply longer spacing between stops in years ahead.

#### Spacing

Bus stop spacing ideally reflects ridership density: stops should be close together in the CBD and far apart in outlying suburban areas. Stops should be as far apart as possible without adversely affecting passenger convenience. For these reasons, most major properties limit stop spacing to about 600 ft (180 m). A review of current practice suggests the following general guidelines.

- Buses should stop at major generators, at major signalized intersections, and at all intersecting bus lines.
- CBD spacing should range from 400 to 600 ft (120 to 180 m).
- Stops in urban service areas [densities greater than 5000 people/mile$^2$ (1900/km$^2$)] should average about 660 ft (200 m) with a range from 400 to 750 ft (120 to 230 m).
- Stops in suburban areas may range up to 1200 ft (360 m) for local service and up to 0.5 mile (0.8 km) for express or regional service.

#### Location

The location of curb bus stops—near side of intersection, far side, or midblock—may significantly affect the transit operation itself as well as overall street capacity. The use of near and far-side stops varies among transit agencies, and stopping locations are often carryovers from the time when they were common among streetcar systems. Both stopping patterns will function effectively provided that (a) stops are long enough and (b) locations are reasonably standardized within the community. The significant exception is where stops must be relocated to avoid major conflicts that would otherwise impede bus, car, or pedestrian flows.

The choice of stop depends on availability of curb loading space, location of existing stops, convenience of passenger transfer, and proximity to passenger destinations. Other significant factors include bus routing patterns, directions of intersection streets, the types of traffic signal controls (signal, stop, or yield), traffic volumes and turning movements, and widths of sidewalks or roads.

Far-side stops are preferable where sight distance or signal capacity problems exist, where buses have use of curb lanes during peak travel periods, where right or left turns by general traffic are heavy, and where buses turn left.

Near-side stops are preferable where bus flows and traffic are heavy and parking conditions permit. From the transit operator's point of view, they make it easier to rejoin the traffic stream, particularly where curb parking is permitted in peak periods, and they enable the first bus to be properly lined up at the stop line.

Midblock stops are generally appropriate in downtown areas where multiple routes require long loading areas and where stops might extend an entire block.

The length of bus stops should reflect (a) the number of buses that each stop will accommodate simultaneously in each peak 20- to 30-min period, (b) what maneuvering is required of buses entering and leaving the stop, (c) the type of stop, and (d) the type of bus (i.e., regular, articulated). Effective enforcement of no parking or no standing regulations at stops is essential.

The number of buses that can be handled at a curbside bus stop without causing an unacceptably long queue (and associated waiting line) varies with the service time per bus and, to a lesser degree, with the number of loading positions. Additional loading spaces (or additional length of bus zones) increase the capacity, but at a decreasing rate as the number of spaces increases.

The number of bus loading positions at any given stop, in turn, depends on (a) the rate and nature of bus arrivals, (b) passenger service times, and (c) desired amount of queuing. Bus stop bay capacity requirements based on a Poisson (random) arrival rate and a 95 percent confidence level are summarized in Table 11 (*26*). This table

TABLE 11

BUS STOP BAY CAPACITY REQUIREMENTS (*26*)

| PEAK-HOUR BUS FLOW | CAPACITY REQUIRED (BAYS) WHEN SERVICE TIME AT STOP IS 10 SEC | 20 SEC | 30 SEC | 40 SEC | 60 SEC |
|---|---|---|---|---|---|
| 15 | 1 | 1 | 1 | 1 | 1 |
| 30 | 1 | 1 | 1 | 1 | 2 |
| 45 | 1 | 1 | 2 | 2 | 2 |
| 60 | 1 | 1 | 2 | 2 | 3 |
| 75 | 1 | 2 | 2 | 3 | 3 |
| 90 | 1 | 2 | 2 | 3 | 4 |
| 105 | 1 | 2 | 3 | 3 | 4 |
| 120 | 1 | 2 | 3 | 3 | 5 |
| 150 | 2 | 3 | 3 | 4 | 5 |
| 180 | 2 | 3 | 4 | 5 | 6 |

[a] Random arrivals: 95 percent confidence level. Computed from the cumulative poisson distribution.

gives the number of bus areas that should be provided on street if one wants only a 5 percent chance that the bus bays will overload. Thus, it is a reasonable approximation of the 1965 Highway Capacity Manual (*32*) service level C. Criteria are as follows:

- Passenger service times of 20 sec or less—one bus position per 60 peak-hour buses (this is the typical radial arterial street condition);
- Passenger service times 30 to 40 sec—one bus position per 30 peak-hour buses; and
- Passenger service times greater than 40 sec—one bus position per 20 peak-hour buses.

These results are generally consistent with the guidelines, set forth in the Highway Capacity Manual, that stated that "a bus stop can serve buses arriving at half the average service rate, or trip frequency, with well under 10 percent probability of forming queues beyond the stop."

Transit agencies vary these guidelines in practice. The MBTA, for example, provides multiple stops wherever combined bus headways are 5 min or less. Often, separate loading positions are provided for each principal bus route.

Figure 22 and Table 12 give minimum desirable bus stop lengths for curb bus loading zones, as specified in various publications. These guidelines are based on a 40-ft (12-m) bus; stop lengths should be adjusted for a longer or a shorter length, and 45 ft (14 m) should be added for each additional bus. Suggested guidelines for 60-ft (18-m) articulated buses are also given. Access to lifts for the handicapped should be considered in bus stop design and bus shelter placement.

## ROUTE SPEEDS

Bus route speeds vary according to operating territory and time of day. Typical bus speeds range between 10 and 12 mph (16 and 19 km/hr) for local urban service and between 12 and 15 mph (19 to 24 km/hr) for suburban runs. Express bus speeds are higher, depending on the length of the nonstop runs and operating speeds (with and without bus priorities) on the express runs.

TABLE 13

MBTA GUIDELINES FOR ROUTE SPEED (1975)

| Item | Bus Route Speed: Excluding Recovery Time mph | km/h | Including Recovery Time mph | km/h |
|---|---|---|---|---|
| System average | 13.9 | 22.4 | 11.0 | 17.7 |
| Quartile deviation | 2.3 | 3.7 | 2.4 | 3.9 |
| Goal | 11.6 | 18.7 | 8.6 | 13.8 |

Schedule speeds in Pittsburgh, for example, range between 3 and 18 mph (5 and 29 km/hr) and average 14 mph (23 km/hr) including recovery time. The Red Flyer express bus routes average about 25 mph (40 km/hr). AC Transit speeds range between 6 and 19 mph (10 and 31 km/hr).

The goal MBTA has set by using statistical measures to assess route performance is to have no speed slower than one quartile deviation of the system average. The guidelines in Table 13 were set forth for 1975. MBTA requires

TABLE 12

MINIMUM LENGTHS FOR CURB BUS LOADING ZONES

| Bus Length (ft) | Loading Zone Length (ft): One-Bus Stop, Near Side | Far Side | Mid-block | Two-Bus Stop, Near Side | Far Side | Mid-block |
|---|---|---|---|---|---|---|
| 40 (ITE) | 105 | 80* | 140 | 150 | 120 | 140 |
| 40 (NCHRP 155) | 90-105 | 80-100 | 130-165 | 135-150 | 125-145 | 175-210 |
| 60 (Articulated) | 125 | 100-120 | 150-175 | 175-190 | 165-185 | 180-250 |

*140 feet after right turn

*1 ft = 0.3048 m*

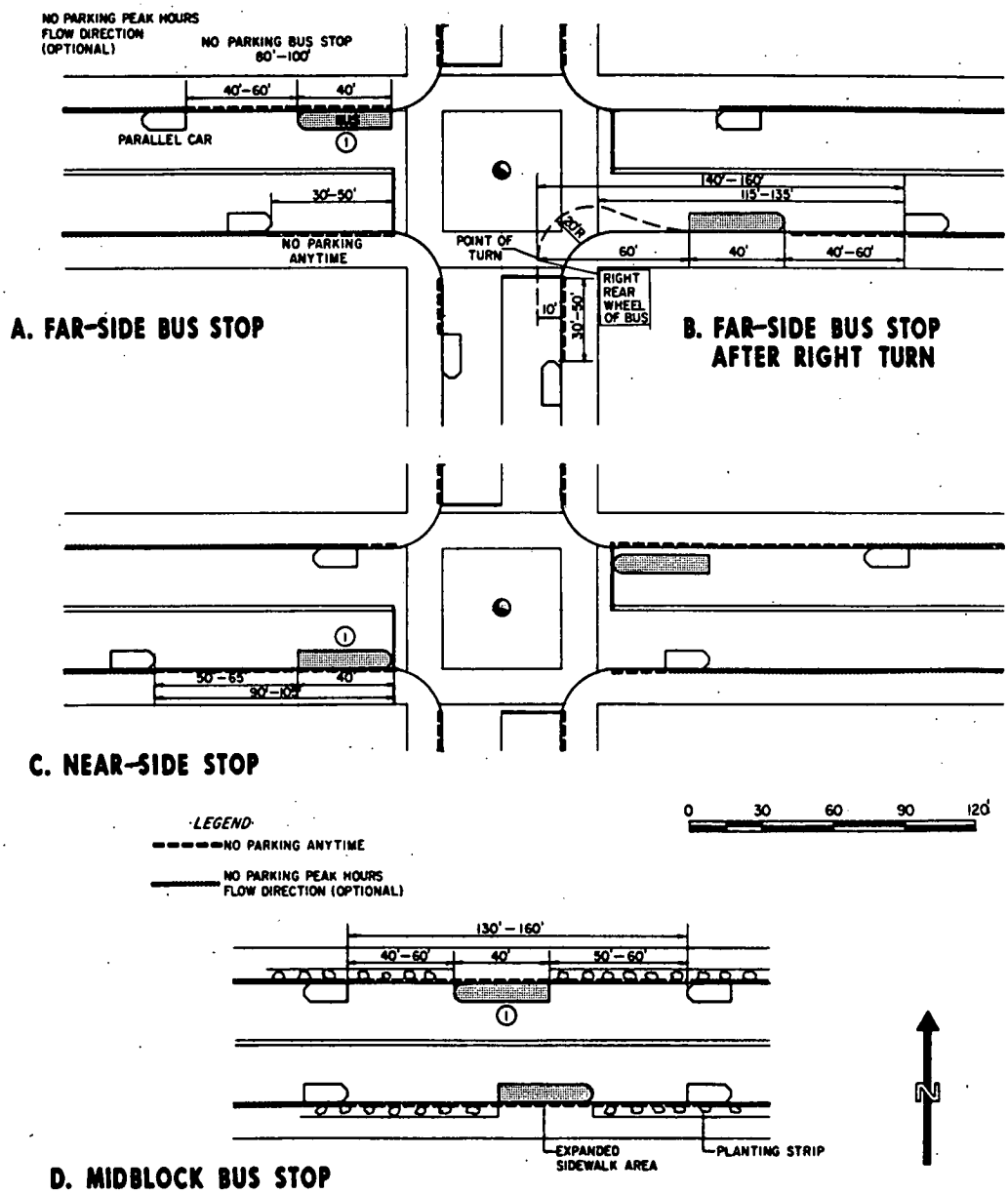



*Figure 22. Bus stop design standards for 40-ft buses (26). Add 20 ft for articulated buses.*

investigation of any service having a layover time to running time ratio greater than 20 percent. No service is allowed to let this ratio exceed 30 percent. (This is perhaps a scheduling problem as well.)

## PASSENGER JOURNEY TIMES

Most transit agencies do not have specific criteria for passenger journey times, although such criteria are sometimes postulated in planned service standards. For example, criteria established for the New Jersey DOT indicate that journey times by local buses should not be more than 3 times longer than those by car.

TTC has derived a passenger access index based on population served, proximity to bus service, and headways. This index is defined as follows:

$$T_t = \Sigma P_i t_i + \sqrt{h},$$

where

$T_t$ = total passenger access time (door-to-door time in person minutes),

$P_i$ = population in strata $i$,

$t_i$ = time of strata $i$ in minutes equals distance of strata $i$ divided by 270 (ft/min), and

$h$ = headway (min).

The square root of the headway is used because under

wide headway conditions passengers take into account the arrival of the bus before walking to the stop. In short headway situations, this method approximates half of the headway or the average waiting time (*20*). The access index is one of the criteria used in the TTC route selection process (see Appendix D).

#### Service Reliability

Most transit agencies specify that 80 to 90 percent of all buses should operate on time—i.e., between about 1 min early and 3 to 5 min late. The following guidelines for on-time percentages are commonplace and should be measured at principal time check points, such as at the maximum load point or CBD:

| | |
|---|---|
| Headways 10 min or less (peak) | 80-85 percent |
| Headways 10 min or less (off-peak) | 85-90 percent |
| Other lines (off-peak) | 90-95 percent |
| Other lines (peak) | 80-90 percent |

TABLE 14

NEW JERSEY MINIMUM PERCENTAGE OF BUSES ON TIME OR NOT MORE THAN 5 MIN LATE

| Headway (minutes) | Local Peak | Local Off-peak | Feeder | Suburban Peak | Suburban Off-peak |
|---|---|---|---|---|---|
| <10 | 75 | 80 | 95 | 85 | 80 |
| 10-30 | 80 | 90 | 95 | 90 | 90 |
| >30 | 90 | 95 | 95 | 95 | 95 |

Suggested guidelines for the state of New Jersey in Table 14 show the reliability requirements by type and frequency of service.

Average speeds for bus routes should be set realistically. Running time checks can be used to adjust speeds as needed where buses operate too fast or too slow.

CHAPTER SIX

# NEW ROUTES AND SERVICE CHANGES

Bus service changes in U.S. and Canadian cities are usually fine-tuned adjustments to established route patterns. They involve service reductions in declining parts of the central city, expansion to new residential areas or outlying shopping centers, or increases in service frequency along specific routes or corridors. The principal exceptions are where service areas expand, where regional transit authorities are established (e.g., Atlanta, Chicago, Cleveland, Denver), or where new rapid transit lines make possible a restructuring (and cutback) of bus services (e.g., Chicago, Toronto, San Francisco-Oakland, Washington, D.C.). In changing routes, care should be exercised to minimize inconvenience to existing passengers.

## INITIATING SERVICE CHANGES

Service changes may be initiated in response to requests from the community, metropolitan planning organization (MPO), or transit agency board, as a result of on-going system evaluation by the transit property, or to reflect major changes in the system's financial requirements. Changes should be evaluated by the transit management, including appropriate boards of the transit agency. The flexibility of bus operations makes it easy for transit systems to experiment with service changes without major capital cost expenditures.

Service experiments should be tried for a sufficiently long time to allow ridership patterns to develop and to give riders a sense of route permanence. Trial periods should be at least 6 months long.

In Akron, one new route has been implemented about every 4 months. When a request is received, the staff studies it and refers it to committees of the metro board—the planning and services committee and the finance committee. If the staff and committees approve the new route or service change, it is then implemented.

In Pittsburgh, requests can be initiated by almost any person, and as many as 10 new routes are implemented each year.

Large properties, such as CTA, make 11 to 20 service changes each year.

Metrobus service changes by WMATA can be implemented within a 26-week period. The critical path for such changes involves 2 weeks of preparation, 13 weeks for public hearing and review, and 11 weeks of staff action before implementation (see Figure 23).

## RELATION TO NEW DEVELOPMENT

Bus service extensions and changes typically follow the population. This contrasts with the practice 50 to 75 years ago when transit lines were developed in advance of population and often served to bring about new industrial and commercial development. There are, however, exceptions: Milwaukee, for instance, provides service to regional shopping centers before they open. The WMATA, when in-

formed of new housing and commercial development, is sometimes able to lead development with service.

Figure 24 shows how access to bus routes can be improved in suburban areas by providing walkways or constructing street links to allow buses to penetrate residential areas. Clustering of activities in new developments is conducive to good bus service. Ideally, each new subdivision or major commercial development should be checked for its transit service as well as its traffic capacity. Zoning should be conditional on provision of suitable transit services.

## STEPS AND PROCEDURES

Bus service planning is a short-range process, usually done on a step-by-step (or route-by-route) basis. Procedures developed for long-range transit planning—such as UMTA's UTPS, and INET, network analysis, modal choice models, and alternatives evaluation—are generally not appropriate for analyzing the impacts of specific route changes.

The same general considerations that govern route development and service frequencies also govern planning service changes. These have already been outlined. Table 15 summarizes the guidelines used by the Port Authority of Allegheny County in planning changes. Planning service changes involves estimates of the costs, revenues, and community benefit associated with new, expanded, or restructured bus routes. The procedures are generally more complex in large properties (e.g., Boston and Toronto) because of the more complex route structures and greater opportunities for new routes and the broader array of service change choices. Key steps include screening, investigation and analysis, review, operation, and evaluation. The general steps followed in establishing and assessing new routes are summarized in Figure 25.

### Review Characteristics of Proposed Service Area

Population, land-use, and ridership factors underlying the route change should be identified, as should the types of developments to be serviced and the prospects for growth and change. New routes and service extensions should consider

- Density and spatial distribution of the population,
- Distribution and concentration of employment,
- Income and age structure of the population,
- Availability and acceptability of fringe parking,
- The nature of the terrain and available street pattern

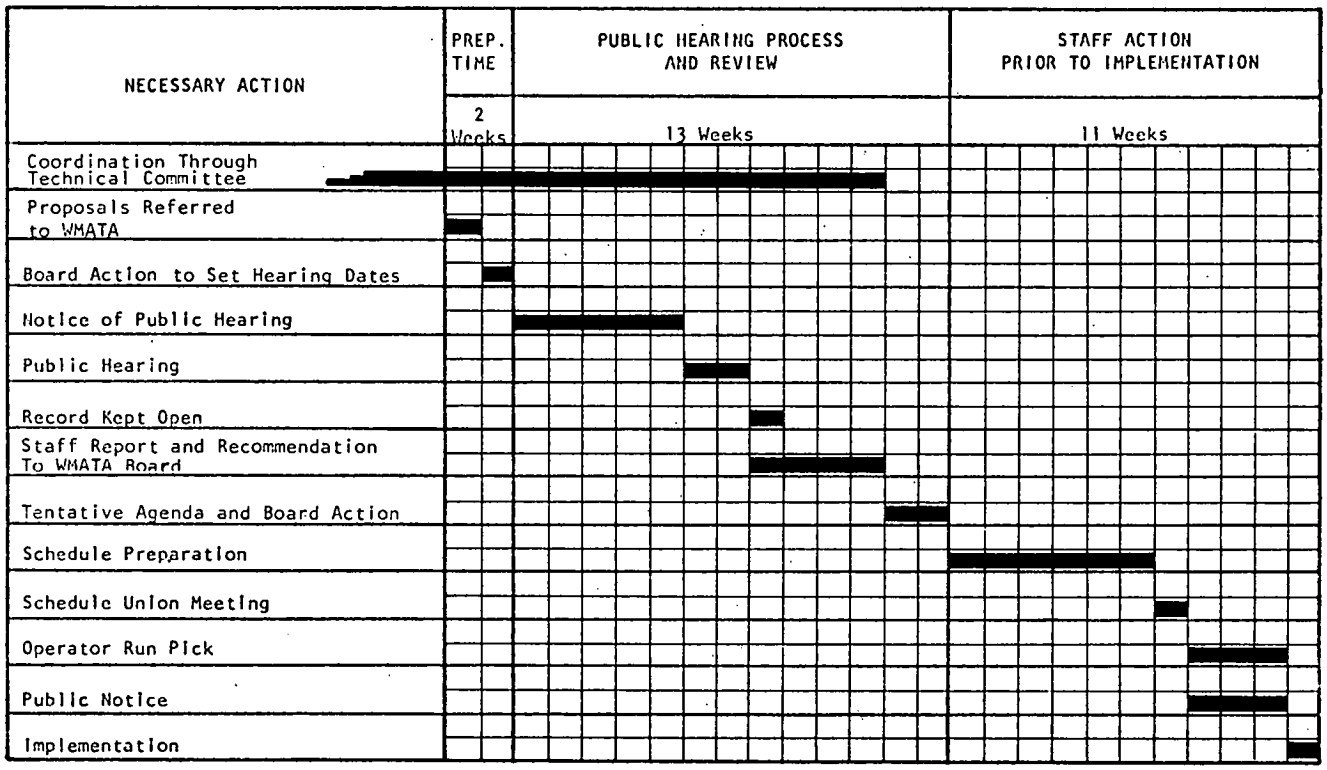



*Figure 23. Critical path for making average service changes in Metrobus (Washington, D.C.) operations when public hearings are required.*

with particular regard for the suitability of a bus operation,

- Siting of retail shopping and service areas,
- Location of medical care centers, welfare and social service facilities, recreational areas, schools, churches, and hospitals, and
- Trip patterns of the population in the service area.

CTA finds aerial surveys are a useful tool for quickly reviewing potential route changes. Photos taken from about a 7000-ft (2100-m) elevation provide a good scale for counting buildings and estimating heights, which in turn provides a base for population and riding estimates (*23*).

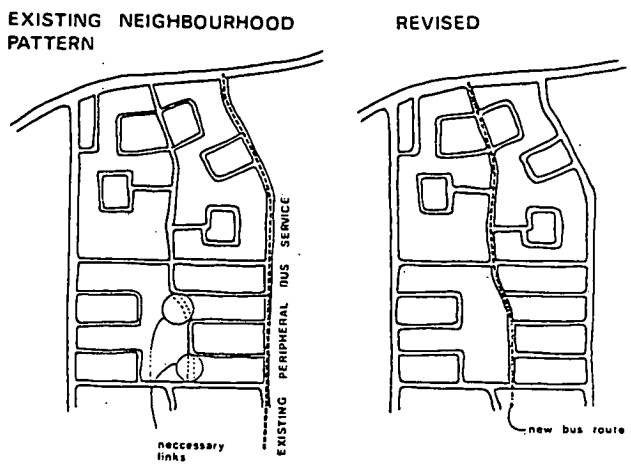
#### Examine Existing Route Structure

The existing route structure in the service area and its ability to serve projected commercial and residential developments should be evaluated. This is essential if one is to avoid establishing new routes that would compete with and draw riders from existing lines. In some cases, deficiencies in the existing route structure can provide the impetus for major route changes.

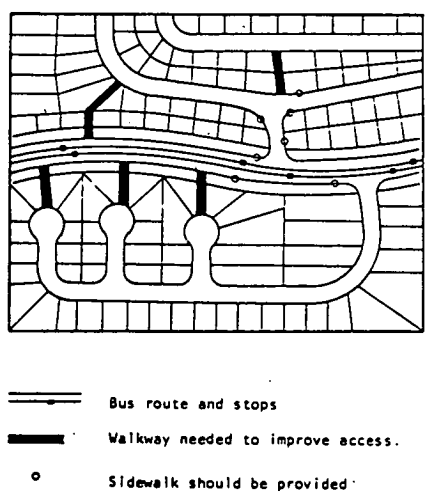
#### Prepare and Field Test Service Concept

A service concept for the proposed route should be prepared and field checked to determine operating conditions and to identify potential problems and constraints. The following factors should be checked:

1. Relation to major passenger generators in the service area;




(A) Suburban street layout may preclude direct bus routing with good coverage. The addition of bus-only or bus-related links during design or at a later date will permit the more desirable routing.




(B) Requirements for improved walking access to transit in typical North American suburban subdivision.

*Figure 24. Adapting suburban streets for bus service (24).*

TABLE 15

PATWAY GUIDELINES FOR SERVICE CHANGES

| | |
|---|---|
| 1. | Providing rush-hour and off-peak services that optimize utilization of manpower, vehicles, and other resources while encouraging maximum use of public transportation services. |
| 2. | Minimizing under-utilized or inefficient services that are a drain on transportation resources without sufficient offsetting benefits. |
| 3. | Offering the best possible level and quality of service for those now using public transportation. |
| 4. | Minimizing the ratio of recovery time to revenue production time. |
| 5. | Maximizing average operating speeds. |
| 6. | Establishing total peak period, mid-day period, and evening period maximum load standards of seating capacity per vehicle. |
| 7. | Maintaining a peak period, off-peak, and transit-dependent passenger per mile average. |
| 8. | Maintaining a route average of at least 25 passengers per vehicle hour during the time being analyzed (peak period). |
| 9. | Addressing the transportation needs of the people who travel locally within and between areas outside the regional core. |
| 10. | Reviewing schedule adjustments that would or would not affect senior citizen and handicapped daily ridership. |
| 11. | Avoiding overlapping of regular route service except where additional service is warranted or where concentration of routes must occur to service a major center such as Allegheny Center. |
| 12. | Not discontinuing a route without determining the social and environmental benefits to the area. (Estimated use by transit dependents.) |

2. Interchange points with other bus and rail lines;
3. Adequacy of street geometry including pavement widths and strengths, turning radii, clearance requirements, and grades;
4. Ability to turn buses at the end of the line; and
5. Opportunities to provide terminal facilities for drivers.

The field test should also simulate bus running times, including passenger stops and layovers. For example, TTC will not evaluate proposed new routes or route extensions in depth if physical constraints are present and cannot be eliminated. A suitable on- or off-street bus loop is essential for any proposed service change.

Provisions for off-street terminals at the end of the line vary among agencies. CTA generally calls for an off-street turnaround complete with passenger waiting area, employee toilet, and phone. If more than one bus route is to share a turnaround, the design must provide an operating lane at the loading point for each route plus a bypass lane to be used by a bus from any route that is to pass any of its leaders. Milwaukee, in contrast, mainly uses on-street bus loops. Shopping centers are logical terminals for routes from the standpoint of affording physical turnaround facilities and generating reverse riding.

In suburban areas, it may be desirable to key bus lines to rail transit stations in peaks and to shopping and school areas at midday (as in Westport, Connecticut).

### Estimate Ridership and Revenues

The traffic potentials of new or substantially restructured routes should be assessed from aerial photographs, review of population and demographic factors, special neighborhood or community surveys in some cases, and interviews with industries, employers, and developers.

Local input is valuable in assessing need and potential ridership, which are often estimated by analogy to similar routes elsewhere in the transit service area. For nonresidential developments, information should be obtained from developers and employers regarding employment levels, hours of employment and shift changes, residence of employees, and parking availability and costs. Telephone surveys of residential areas may also prove valuable.

Where routes are cut back or eliminated, past ridership trends and passenger on and off counts may be used to assess impacts.

Passenger revenues should be estimated by applying established or proposed fare schedules to the estimated weekday, Saturday, and Sunday ridership totals.

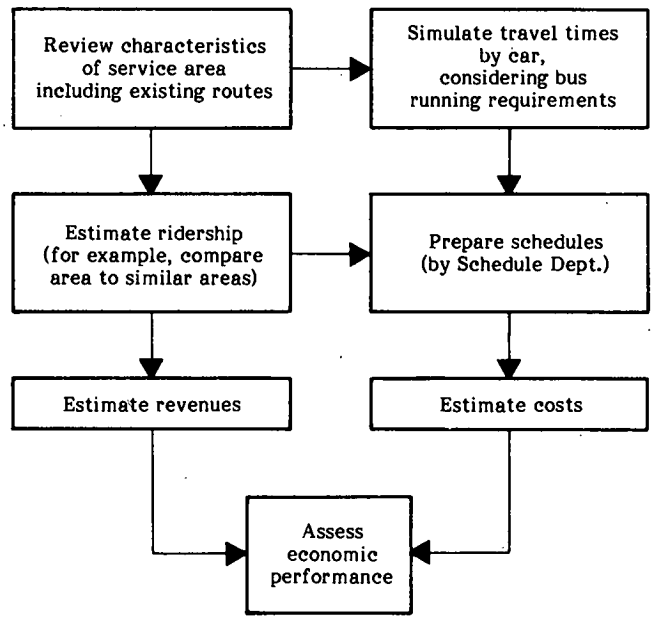



*Figure 25. Generalized procedure for planning new bus routes.*

### Estimate Schedule Requirements and Service Costs

Desired bus service frequencies should be identified. Vehicle and driver requirements should be estimated from detailed schedules that reflect service frequencies, running times, and work rules.

Costs of the service, estimated from the schedules, may be based on bus miles or bus hours or, better yet, on combinations of drivers' wages and bus miles. These may involve direct costs associated with the route or direct plus overhead costs.

### Assess Economic Performance

Costs should be compared with revenues to quantify the financial impacts of the proposed service change. Some agencies consider the social and public service aspects of the change; others rank the proposed route's financial performance according to existing and other new routes to establish priorities, but such a formal process has been the exception rather than the rule.

### Computer-Based Planning Procedures

Several researchers have developed computer-based methods for route planning and analysis, but use of these "interactive graphics" by operating transit agencies is not widespread. The methods use transit network characteristics and travel patterns to produce detailed line ridership characteristics in tabular and graphic form. Figure 26 shows a typical output of such a program (*33, 34*).

## SERVICE WARRANTS

The economic resources available for operating the bus system call for careful allocation to maximize the benefits derived from their use. A service that is not patronized is a disservice to those who must pay for it.

Accordingly, most agencies have established formal or informal warrants that will show service needs. These warrants assure equal and fair treatment of changes throughout the service area and are keyed to levels of expected

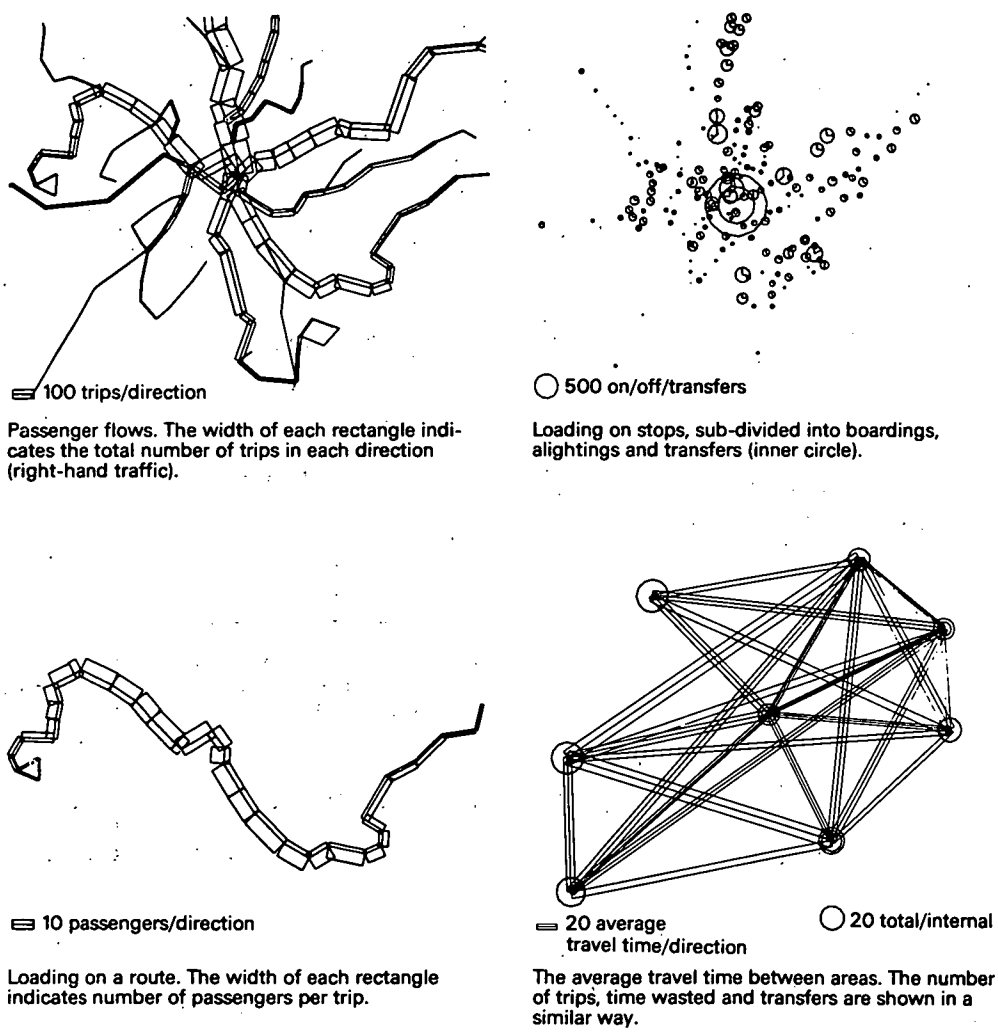



*Figure 26. Typical graphic computer output (33).*

ridership except where the local community is willing to assume all cost responsibility.

WMATA guidelines (*17*) stipulate that

> Any jurisdiction may seek to apply higher standards . . . within its own service area, contingent on the availability of equipment, manpower, and other resources. However, that jurisdiction must assume all the incremental costs that such a policy would entail as dictated by the deficit allocation formula currently in effect.

#### Ridership

Minimum ridership warrants have the advantage of not being keyed to particular cost-fare relations or changes. Typical guidelines are as follows:

| | | |
|---|---|---|
| Passengers/bus hour: | 15 to 25 | weekdays |
| | 10 to 15 | Saturdays |
| | 8 to 10 | Sundays/holidays |
| Passengers/bus mile: | 1.5 to 2.0 | |

Milwaukee uses the base criterion of 2 passengers per bus mile, or 22 passengers per bus-hour for weekday service, which covers about 50 percent of operating costs at 1977-1978 levels. Lower warrants are specified for Saturday, Sunday, and holiday service because the availability of these services enhances total ridership. The passenger base is used rather than revenues, because fares can be changed by public policy.

Generally, acceptable new service involves a progression from minimum (hourly) service during commuter peak hours (6:00 to 10:00 a.m. and 3:00 to 7:00 p.m.) to 6:00 a.m. to 7:00 p.m. weekday service, with possibly improved frequencies; then Saturday service; and, subsequently, night, Sunday, and owl service.

#### Cost-Revenue Relations

Warrants based on cost-revenue usually specify that revenues should cover 30 to 50 percent of costs. These ratios can change substantially if fares remain unchanged when wage rates rise. MBTA provides ranges in these ratios for various types of services.

#### System Continuity Factors

Service may be provided, even if not directly justified by the ridership or cost-revenue warrants, to improve and expand the ability of the system to serve the community. New routes may be appropriate where they improve system continuity or provide essential feeder service.

A bus route can be extended a short distance through a nonproductive riding area to permit a transfer connection with another route or a new route can intersect several other routes to provide a convenient transfer route that improves overall system continuity. Evening or weekend ridership on the end segments of a line may be relatively light, but the service should be provided to maintain a continuity of service.

Conversely, it is essential that new routes do not duplicate existing routes.

#### Route Discontinuance

Service changes may involve cutbacks or discontinuance of routes. For example, between September 1973 and September 1976 CTA discontinued 10 bus routes—about 1.5 percent of its service. Poor ridership and the availability of alternative services should underlie abandonments. However, routes should not be discontinued without determining the social and environmental impacts; PATway (Pittsburgh) identifies the number of transit-dependent riders that would be affected.

WMATA desires to discontinue routes whose revenues cover less than 10 to 20 percent of the net cost of service. It indicates that the minimum acceptable level of patronage on a route should be the point where the cost of providing taxi service falls below that of providing bus service. Routes that consistently fall below these criteria are candidates for reduction in service.

Discontinuing routes is often difficult in view of the adverse public reaction. (The exceptions perhaps are duplicate routes in declining central city neighborhoods.) The numbers of people who testify that they need a route commonly far exceed those who would actually use it.

When a route is discontinued because of substandard economic performance, MBTA will not entertain proposals to continue operation of the service through supplemental financing from groups, firms, or institutions benefiting from the route's existence. They will, however, help find a private transportation enterprise to operate the service under a contractual arrangement with the group, firm, or institution when the service does not violate a service design guideline.

### ROUTE AND SERVICE EVALUATION

Several transit systems have formalized their route evaluation procedures.

#### TTC Service Evaluation and Selection Process

TTC has developed procedures that balance the continuing demand for new and extended services against the limitations on available funds. With these procedures one can compare the relative performance of individual routes in the existing system and forecast ridership and establish priorities for proposed new routes and extensions to the surface system. The six basic factors used are

1. Route economics and service use,
2. Access,
3. Transit dependency,
4. Transit travel time,
5. Land-use planning, and
6. Physical constraints.

Routes that perform poorly by economic standards are analyzed in greater detail.

To further supplement this analysis, the number of reported revenue passengers or fares collected for each route is assessed quarterly. If a route deviates substantially from the average trend for all routes, it is subjected to a more detailed study that includes the completion of appropriate

counts to determine whether or not the service should be adjusted (*20*).

In the service evaluation process for *existing* routes (a) routes are ranked in order of net profit or loss and the lowest 25 percent is analyzed, (b) routes are ranked by the average number of passengers on board between each pair of adjacent stops, (c) routes that have disparate revenue and use are assessed, and (d) the number of revenue passengers is assessed quarterly to review ridership changes. If the number of revenue passengers has changed by more than 10 percent, riders are counted and service adjustments made.

In the service evaluation process for *new* routes (a) physical constraints for practicability are examined, (b) ridership and costs are estimated, and (c) economic viability is evaluated. If the loss is less than $0.50/bus-mile *or* if the access time is 40 000 person minutes or more, the evaluation is continued based on other service standards.

The service selection process allows proposals for new service to be ranked along with existing routes that are poor economic performers and have a low average occupancy. Alternately, if service reductions are contemplated, it allows for determining which poorly performing existing routes might be considered for termination, by taking into account noneconomic evaluation factors such as access.

Appendix D details the two-step selection process that includes information gathering and early filtering and comparative ranking and implementation evaluation.

In the information gathering and early filtering phase, routes that are viable from an economic or access standpoint are identified by giving consideration to revenues, access, travel times, transit dependency, and land use.

In the comparative ranking and implementation evaluation phase, routes are ranked according to net revenue, access change, access and ridership per unit cost, and contribution to transit-dependent or land-use planning goals. This calls for first implementing changes in the routes that rank in the top 10 percent of all factors. Then if resources are available, routes are progressively implemented, starting with those routes that are ranked in the top 10 percent of ridership per unit cost and access, then ridership per unit cost alone, access per unit cost alone, and finally other factors.

All new services selected for implementation are considered experimental for 6 months and are reviewed for service after 90 days to permit adjustments.

### AC Transit

The AC Transit route evaluation was based on six indicators (*35*):

1. During a 30-min interval in the peak period there should be sufficient seats available for the passengers;
2. No lines should have headways greater than 30 min during peak periods of service or 60 min during off-peak periods;
3. A minimum of 33 percent of the district's operating costs should be recovered from the farebox;
4. At least two passengers per bus mile should be carried on trunk lines and one passenger per mile on feeder lines; and
5. Trunk lines should carry at least 28 passengers/hr. Feeder lines should carry at least 14 passengers/hr.

The performance of each route was measured, and a score of −1 given if it was substandard under any indicator. The scores for each route were then totaled with a range of from 0 to −6, and routes were ranked by scores. The lowest ranking one-third was further evaluated for change.

## ESTIMATING BUS RIDERSHIP

Potential new traffic is perhaps the most important criterion for deciding to make a route or service change. A variety of ridership estimation techniques has been developed by transportation planners, researchers, and transit systems to assess the effects of various road and transit system changes. Most of these techniques explicitly or implicitly use such factors as car ownership (or income and residential population density), employment density, and relative travel times and costs by bus and car. But they vary widely in ease of application, treatment of parameters, precision afforded, and responsiveness to fine-grained service changes. From the perspective of most transit operations, the best available estimating techniques are as much art as science, but they can be effectively applied by an experienced transit planner.

Long-range transportation planning studies derive relations based on modal choice models that relate car-bus travel times and costs (i.e., disutilities) to choice and dependent users. The current state of the art involves "logit" modal choice curves, which can be applied on a network basis to travel between zones. These techniques are most applicable to large-scale, long-range changes in system capabilities and are not suited to short-range, small-scale service changes.

Elasticity relations have been used to estimate the effects of fare and service frequency changes on ridership. The change in ridership per unit change in fares (i.e., fare elasticity) has ranged from −0.1 to more than −0.5, depending on market segment and trip purpose. Headway elasticities have been found to range from −0.3 to −0.8, which implies that a 100 percent increase in headways would result in a 30 to 80 percent drop in patronage (*36*). However, energy availability and cost constraints have produced differing results in some properties.

Transit agencies have traditionally estimated ridership by analogy methods that compare a route under consideration with ridership on a "similar route" in terms of service, land-use, and demographic characteristics. Several properties (such as Toronto) are refining this technique.

The analogy method of estimating transit ridership is an outgrowth of the "riding habit" techniques used in developing street railway patronage. The office of the staff engineer for the Capital Transit Company, predecessor of WMATA, superimposed bus routes on spot maps showing houses within the District of Columbia. The number of dwelling units within a three-block walk of the bus line was identified and a riding habit of three rides per dwelling unit was applied to the bus service. Some differentiation

was then made for income, downtown orientation, and related factors. This method, with refinements of riding habits, is still widely used.

Conceptually, the annual rides per capita is a function of distance from bus line for various levels of fare structure and service frequency. Such ridership penetration curves can give each property a reasonable basis for estimating effects of bus service changes. This is an essential first step before a meaningful formula with widespread applicability can be developed. The variables are not only income level, lot size, distance to bus route, and age group; they may include rider attitude as well.

White- and blue-collar neighborhoods, downtown orientation, perceived social norms, perceived personal safety, reaction to antisocial behavior of other riders, perceived necessary levels of convenience standards such as service frequency, cost consciousness or frugality, and energy and environment consciousness are some of the factors that vary from neighborhood to neighborhood and from city to city.

The AC Transit district anticipates about one passenger per mile of service or 1 percent of the population to use the typical suburban bus line. However, these factors vary according to population density and neighborhood type.

#### Basic Steps

Ridership estimation includes the following steps for each route under consideration:

1. Estimate the dwelling units and population within the coverage area, preferably by block. This may include use of census data, mail drops by zip code area, or analysis of aerial photographs.
2. Estimate the nature of the area. This includes median family income, type and age of dwelling units, car ownership.
3. Conduct telephone surveys as needed to identify market and travel attitudes and patterns.
4. Apply the riding habit (daily or annual rides per capita) to the population base to obtain ridership potentials for residential areas served.
5. Identify schools, shopping centers, offices, and industries within the service area. Obtain estimates of enrollment, employment, places of residence, and probable travel modes. Estimate the ridership potential of these activities and add it to the residential ridership identified in step 4.

#### Examples

Transit agencies generally follow the preceding steps in planning and assessing service changes.

*Chicago*

In Chicago, the probable attraction to transit for every housing or working unit is related to its distance from the route under consideration. An estimating basis is provided by the actual calculated riding habits experienced on an existing route in an area of comparable density and economic status.

To further define the potential of a new line, CTA planners ask industries along the route to respond to questionnaires that inventory facts about employees (male, female, skilled, unskilled, white collar, blue collar, etc.), the number of visitors, the availability of parking, and the 1-year anticipated changes in these figures. Suggestions for possible solutions, with indications of order of preference when more than one alternative is presented, are invited from parties requesting change.

When service extension proposals are made as a consequence of a request from outside CTA, typically from an industry that has recently relocated to an outlying area and feels that transit is obligated to follow it, the existence of systematic analysis procedures gives reassurance that the request will receive fair consideration.

*Milwaukee*

Milwaukee's potential ridership estimates before route extensions into new areas are based on a family unit count for residential areas and an employee count in areas that contain employment centers. If shopping centers, schools, or other riding attractions are involved, consideration is given to their ridership potential. Individual homes or other developments within 0.5 mile (0.8 km) of a proposed route extension are indicated on detailed maps, which are further supplemented by aerial surveys of the area to be served. But even with this detailed data it is still necessary to estimate the actual rides that might be taken per day. The data on rides taken in somewhat similar areas are used as rough guides (*40*).

Patronage estimation for Milwaukee's Freeway Flyer illustrates the approach used by many transit agencies. About 14 years ago, as the Milwaukee urban freeway system took shape, transit officials realized they were faced with a new form of competition. The suburb-to-downtown auto trip that previously took 30 min was going to take only 10 to 15 min compared to a 45- to 60-min bus ride.

To meet this competition, the Freeway Flyer service was initiated. Buses traveled nonstop from park-ride lots at outlying shopping centers via the new freeway system to downtown Milwaukee. Many motorists found that the door-to-door travel time was comparable to if not better than their automobile driving time. It was an immediate success in terms of both patronage and finance, and ridership continues to increase on the 12 routes (1978).

The question has often been raised by planning professionals as to how service levels or riding potentials were determined before that first flyer operated. Mayer (*37*) has described it as follows:

> The fact is there was no statistical, objective determination of necessary service levels or riding potentials. There were no market surveys. We had no statistical evidence or calculated reason to know whether anyone would use the service at all.
>
> Of course, we were not completely in the dark. We were very familiar with the suburban area from which the service would originate. We knew from personal knowledge that it was a high downtown employment oriented area. We knew from personal knowledge that downtown office starting times were predominantly 8:00 a.m. with some 8:30 a.m. and 9:00 a.m. and closing hours started at 4:15 p.m.

> We built a route and schedule to fit those known but not documented facts, and after appropriate promotion, the service was inaugurated. A very satisfying 199 rides were taken the first day of operation. Within a few years, over 700 passengers per day were using the Mayfair Freeway Flyer. But, frankly, we had no reason to be surprised if only 20 had used the service that first day. . . .
>
> Of course we learned much from that first freeway flyer. We learned that 80 percent of the riders live within 2 miles of the park-ride lot. We learned that downtown workers like to get to work 15 minutes ahead of time, but are ready to board the bus two minutes after closing. Continuing surveys of existing ridership have been made to apply input to new route development. But even then, the information is used in a generalized application tempered with reason and knowledge. It is seldom applied as a pat formula.

*Nashville*

Potential ridership is estimated through on-board surveys of existing routes and through educated estimates from studying alternative service areas. A nomograph based on behavioral logit models is being prepared.

*Toronto*

A manual method for estimating potential transit ridership has been developed by TTC in association with the Ontario Ministry of Transportation and Communications and the Metropolitan Toronto Planning Department. In essence, the method determines the merits of all the available transit modes within a neighborhood. Then, based on demographics, trip distribution patterns, travel habits, and the observed travel patterns of other similar neighborhoods, an estimate of ridership can be made.

The method for estimating potential transit ridership from a specific area for use in the service standards process involves the following steps (*20*).

1. Define the exact routing and service levels for suggested new routes and route extensions and assess the catchment area involved.
2. Collect all relevant data for the catchment area. These data are examined in association with maps of the area and riding counts on existing routes in the area to determine any peculiarities that may be prevalent.
3. Establish the trip distribution pattern and identify the major attraction or production zones.
4. Estimate the present modal split based on available information.
5. Estimate ridership on the new service based on the characteristics of the area and the attributes of the new service.
6. Where possible, compare an area in which new service is being evaluated with other areas that have similar service to confirm the forecast.

One of the major problems associated with this method involves the supply of relevant data. Understandably, TTC will be required to forecast ridership for areas that have just been or are in the process of developing and where accurate information pertaining to population, employment by category, car ownership, etc., is often incomplete.

To alleviate the information problem, it is proposed that the municipalities that have direct jurisdiction over the neighborhoods and initiate requests for transit service should themselves supply information such as population and employment figures, densities, dwelling units, accesses to arterial roads, school locations, etc., along with their requests.

## EXAMPLES OF SYSTEM CHANGES

Most agencies provide a clear statement of the objectives, features, and benefits of proposed service changes, initially to the system's management and subsequently to passengers. Figure 27 gives a service feasibility report format used by MBTA. Figure 28 is an example of the proposed bus service changes associated with Metrorail in Washington, D.C. Examples of other proposed service changes are contained in Appendix F.

SUBJECT: Short description of the proposed service change (e.g. Direct Bus Service from Quincy Center to U. Mass Harbour Campus).

REF. NO.: A reference number for filing purposes. DATE: _____

UNIT: The unit conducting the feasibility analysis (Service Planning Unit, Plans and Schedules, Operations Analysis Unit).

ANALYST: Name of the person conducting the feasibility analysis and preparing the report.

---

PROPOSED SERVICE PLAN: A concise but complete description of the service plan as finalized with the Advisory Board representative(s) involved. Description will relate to Service Design Guidelines presented in Section 4.1.

ECONOMIC ANALYSIS:

1.) Cost

Direct cost of the proposed service change will be estimated on a daily and annual basis.

2.) Ridership/Revenue

Using available market information daily and annual ridership and revenue will be estimated.

3.) Annual Pro Forma Results

Using the direct cost and revenue information, a projected net cost of service will be calculated. The impact on the assessment(s) of the community(ies) involved will then be determined using the assessment relationships from the most recent fiscal year.

The annual deficit per customer will be calculated.

QUALITATIVE ANALYSIS:

The expected benefits to the users of the proposed service change and the community(ies) involved will be described. Any needed historical perspective or other information pertinent to the evaluation of the proposed service change will be discussed.

*Figure 27. MBTA service feasibility report format.*

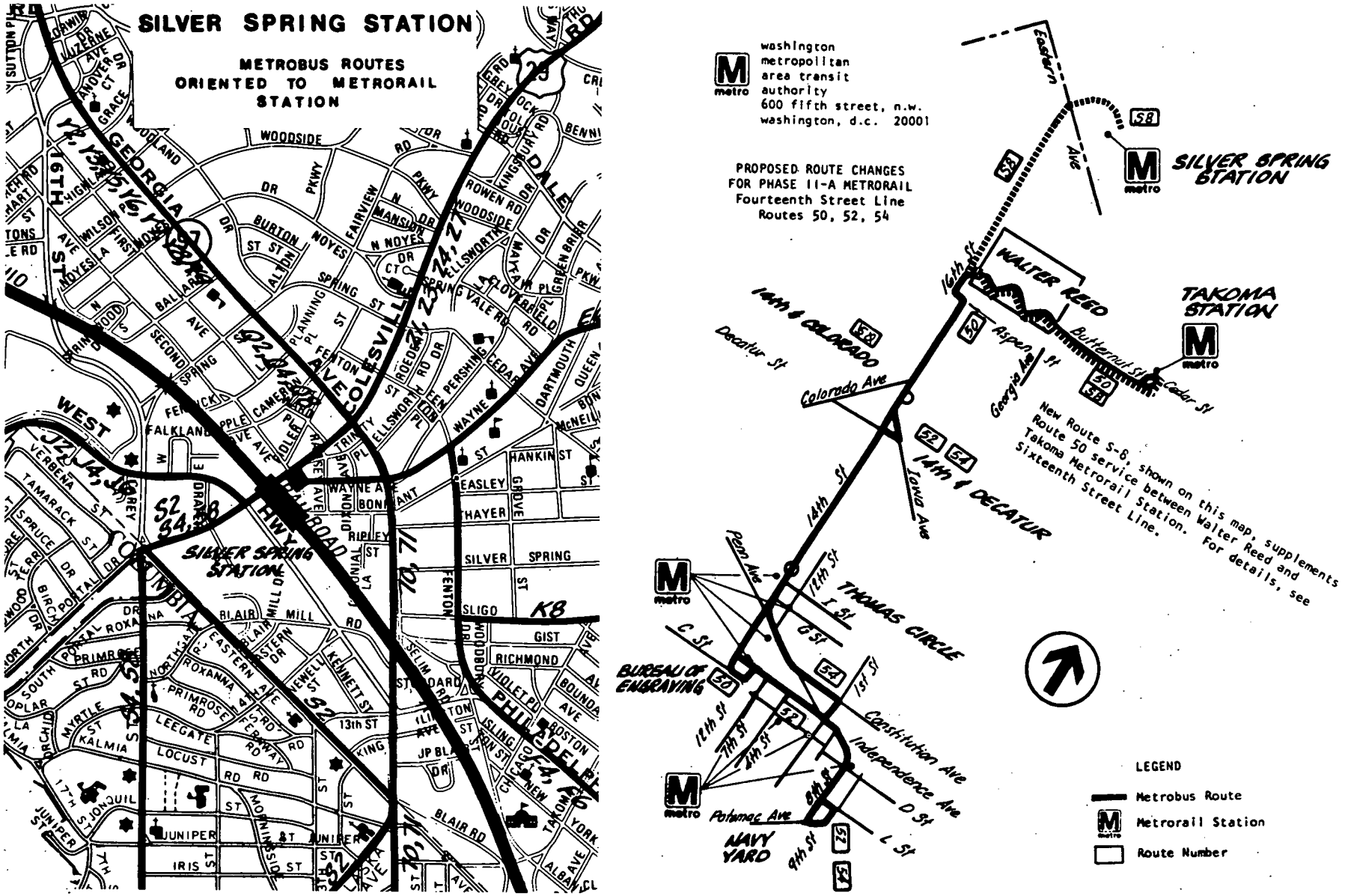



*Figure 28. Bus service changes associated with operation of rail transit (Washington, D.C.).*

CHAPTER SEVEN

# MONITORING AND SCHEDULING SERVICE

The bus system should be closely tuned to ridership requirements from both a capacity and a cost standpoint. The challenge is to carry passengers comfortably and expeditiously at minimum expense to the agency. If service could be performed in equal hourly amounts throughout the day, the task would be simple. However, ridership varies throughout the day, week, and year on each section of a route. It is affected by such things as downtown sales, industrial conditions, school operations, weather, and changes in urban development. These traffic variations by space and time call for constant monitoring and adjustments of service.

Although it is desirable to proportion service to traffic, this cannot be done absolutely. Constraining factors include the high costs of providing buses and bus operators for a very short period, the desirability of providing convenient (or policy) headways throughout the day, and work agreements that entail additional labor costs. If a bus driver is paid for 6 hr, it is poor policy to use him or her only 2 or 3 hr, because labor costs are the largest part of total operating expense.

The resulting peak-to-base ratios vary among agencies. Whereas 50 years ago ratios of 1.5 were common, large properties currently have ratios approaching or exceeding 2.0, even when they allow for providing additional off-peak service (Table 16).

TABLE 16

TYPICAL PEAK-TO-BASE BUS RATIO

| Period | Chicago (1975) | Toronto (1972) | Properties < 300,000 Residents (1973) |
|---|---|---|---|
| A.M. Peak | 2172 | 862 | -- |
| Base | 1096 | 346 | -- |
| P.M. Peak | 2172 | 861 | -- |
| Peak-to-Base Ratio | 1.98 | 1.87 | 1.98 |

## SELECTING VEHICLES

Selecting the appropriate vehicle for specific properties and routes is relatively simple today. The limited number of bus manufacturers, general standardization of equipment sizes and types, and UMTA's involvement in specifications restrict the options available. Most agencies use, and will continue to use, standard 40- or 50-passenger buses (Figure 29). However, where operating conditions permit, passenger ridership on heavily traveled local and express lines may benefit from articulated buses. In contrast, feeder services may require smaller and lighter vehicles with shorter turning radii, and special shuttle services for shoppers may benefit from smaller vehicles.

In all cases, ridership and route characteristics should be the determining factors. However, system planners should avoid too many different varieties and sizes of equipment that may limit use of vehicles or complicate maintenance procedures. Before ordering buses, each agency should analyze the costs, operating conditions, and service quality (headways, speed, etc.) that would result from using various types of equipment. Selection of vehicle type should be based on the results of this analysis.

As of 1978, diesel-powered vehicles remained the principal choice for most U.S. and Canadian systems, except for those places, such as Boston, Dayton, Philadelphia, San Francisco, Seattle, Edmonton, Toronto, and Vancouver, that continue to operate trolley coaches.

## DATA REQUIREMENTS AND TYPES

Transit companies collect and compile a variety of data in planning, monitoring, and scheduling service; revising schedules; and assessing efficiency. Not all agencies need nor are they able to collect all of the potential data or to compute all the indicators. For some, data may not be available or may be considered redundant. However, most management data and indicators are useful for analyses and audits of operations, planning of improvements, and checking the effects of changes in operating practices.

Passenger and traffic surveys normally used in service planning and adjustment are given in Table 17. The extent and frequency of these surveys as well as the methods of data collection vary.

Information is collected on ridership at maximum load points, at the downtown cordon, and along the bus route. Travel time checks indicate actual bus performance, types of delay, schedule adherence, and need for change. Rider origin-destination patterns and trip characteristics are obtained from on-vehicle surveys and, in some cases, surveys at major traffic generators or at residences.

To the extent that resources permit, the transit system should obtain and maintain a current data file to help achieve efficient scheduling, effective marketing, and sound planning decisions. Major, detailed surveys, such as passenger origins and destinations, should be conducted at long intervals, whereas on-off, maximum load point, operating speeds, and traffic delays should be measured more frequently on regular routes.

Ridership checks should be made for both peak and off-


*Figure 29. Typical buses currently in service: (from the top) new look, advanced design, and articulated.*

TABLE 17

TRANSIT SURVEY TECHNIQUES

| INVENTORY DATA ITEM | TYPE OF SURVEY | | | | |
|---|---|---|---|---|---|
| | On-Board Transit Vehicle | | | Stationed Observer | Site Interviews |
| | Observation by Checker | Interview | Self-administered/mail back | | |
| Transit ridership, passenger loads | Refs 1,3,4 | | | Refs 2,3 | |
| Transit ridership, boarding and alighting counts; determination of maximum load points | Refs 1,3,4 | | | | |
| Transit ridership, passenger origins and destinations | Refs 1,2,3 | Refs 3,5 | Refs 3,5 | | |
| Transit ridership, passenger characteristics, access mode, trip purpose, attitudinal factors | | Refs 3,5 | Refs 3,5 | | |
| Transit ridership, potential, shoppers | | | | | Refs 3,5 |
| Transit ridership, potential, employees | | | | | Refs 3,5 |
| Operations, schedule adherence | Refs 1,3,4 | | | Refs 2,3,4 | |
| Operations, running speeds, and delays | Refs 1,2,3,4,5 | | | | |
| Transit supply | | | | Ref 2 | |

References:


1. Manual of Traffic Engineering Studies, 4th Ed. (Arlington, Va: Institute of Transportation Engineers, 1976) pp. 153-170.

2. Hamburger, W. S., Urban Mass Transit Planning, (Berkeley, Calif. The Institute of Transportation and Traffic Engineering, Univ. of Calif., 1967) pp. 23-48.

3. "Manual of Transit and Traffic Studies," (Washington, D. C.: American Transit Association, 1947).

4. National Committee on Urban Transportation, "Measuring Transit Service," Procedure Manual 4A, (Chicago, Ill.: Public Administration Service, 1958).

5. Urban Transportation Systems Associates, Inc., Urban Mass Transportation Travel Surveys, Report prepared for Federal Highway Administration in cooperation with Urban Mass Transportation Administration (Washington, D. C., Aug. 1972) (available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Stock Number 5001.00037; also available through National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22161, Item Number PB 220.199).

peak conditions. This makes it possible to quantify the ratios of peak-to-base ridership and, in turn, the ratios of peak-to-base service. Factors that may call for checking include changes in residential and commercial developments and shifts in ridership resulting from new shopping centers or industrial developments. The actual counts provide an objective basis for responding to community demands regarding changes in service.

#### Data Collection Methods and Practices

Information may be obtained from drivers' records, line inspectors or supervisors, traffic checks, or specially hired survey crews.

PATransit has bus drivers fill out day cards that give a detailed account of each trip. Special surveys of senior citizens and handicapped ridership are made each quarter. An occasional questionnaire survey is done either on the bus or by mail.

Knoxville conducts quarterly passenger checks.

WMATA makes maximum load point checks set up and analyzed by the service planning department. Their goal is to check all lines at least 3 times a year. The frequency of checks depends on the number of complaints received. Traffic checks are summarized by 15-min periods. Special ridership surveys in which questionnaires are distributed to passengers are made about once a year for revenue allocation purposes. In addition, inspectors (called street supervisors) monitor bus movements.

The Akron transit system checks on-time performance by the supervisors in the CBD. Two full-time employees do continuous passenger checking; passenger check sheets that give all stops and list ons and offs for every stop are made 2 or 3 times per year for each route.

The Greater Cleveland Regional Transit Authority has 13 fulltime people doing passenger checks. There are two types of checks: the maximum load at a corner and on-vehicle checks. They try to check each line at 4- to 6-week intervals, but the smaller lines are checked perhaps once a year and the larger ones at 2- to 3-week intervals. Special ridership surveys are done in general once a year or as needed.

CTA has 33 traffic checkers. They are studying computerized schedule making.

*Drivers' Records*

A simple form of traffic analysis is based on the driver's daily receipts (see Figures 30 and 31). Two problems are common. First, the records do not identify loads at different points along the route, and, second, drivers' runs are often keyed to vehicles and not necessarily routes (this is most conspicuous where farebox receipts alone are used, because they are keyed to buses, not bus routes).

*Line Inspectors*

Line inspectors (sometimes also called street supervisors) can be used to monitor operations at key passenger load points—both in terms of passenger loads and on-time performance. However, their primary purpose is to ensure that buses operate on schedule, not to obtain data.

*Traffic Checks*

Larger agencies in particular should have a staff of traffic checkers who systematically obtain passenger loading information. Checks may include passenger loads at given points, on-and-off counts, and schedule adherence studies. The size of this staff should vary with the system length, frequency of investigations, and amount of detail required.

*Automatic Counters*

Automatic counting devices built into the doors on buses provide a means of obtaining continuous data on passenger boardings and alightings.

**SENIOR CITIZEN & HANDICAPPED DAY CARD**

Operator _____
LAST NAME FIRST NAME INITIAL

Run No. _____ Pay No. _____ Date _____

| | | | |
|---|---|---|---|
| Vehicle Number | | | |
| Unit Number | | | |
| Till Number | | | |
| Route Number | | | |
| REGISTER READINGS | | | |
| Ending | | | |
| Starting | | | |
| HOW MANY (Free) SENIOR CITIZENS. | | | |
| HOW MANY (1/2 Fare) HANDICAPPED | | | |
| SCHEDULED TIME | | | |
| Start | M | M | M |
| Finish | M | M | M |

ONLY SENIOR CITIZENS & HANDICAPPED ARE TO BE REGISTERED ON THIS DAY CARD AND ONLY DURING HOURS LISTED BELOW

APPLICABLE HOURS

9 A.M. to 4 P.M. — 6:30 P.M. to 6 A.M.

MONDAYS through FRIDAYS
AND ALL DAY
SATURDAYS-SUNDAYS-HOLIDAYS

PATransit

Operator _____
LAST NAME FIRST NAME INITIAL

Run No. _____ Pay No. _____ Date _____

| | | | |
|---|---|---|---|
| Start | M | M | M |
| Finish | M | M | M |
| Vehicle # | | | |
| Mileage | | | |
| Route # | | | |

*Figure 30. PATransit day card for senior citizens and handicapped.*

**DAY CARD**

FORM 03-101-4
REV. 6-72

OPERATOR _____
LAST NAME FIRST NAME INITIAL

RUN NO. _____ PAY NO. _____ DATE _____

| | | | | |
|---|---|---|---|---|
| VEHICLE NO. | | | | |
| UNIT NO. | | | | |
| TILL NO. | | | | |
| ROUTE NO. | | | | |

REGISTER READINGS

| | | | | |
|---|---|---|---|---|
| ENDING | | | | |
| STARTING | | | | |
| REGISTERED | | | | |

| SCHED. TIME HR. | SCHED. TIME MIN. | TERMINUS LOCATION | REGISTER READING | NO. REG. | TRANS. COLL. |
|---|---|---|---|---|---|
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| | | | TOTAL | | |

OPERATOR _____
LAST NAME FIRST NAME INITIAL

RUN NO. _____ PAY NO. _____ DATE _____

| | | | | |
|---|---|---|---|---|
| START | M. | M. | M. | M |
| FINISH | M. | M. | M. | M |
| VEHICLE NO. | | | | |
| MILEAGE | | | | |
| ROUTE NO | | | | |

OPERATOR _____
LAST NAME FIRST NAME INITIAL

PAY NO. _____

INCOMPLETE TRIPS

TRIP NO. _____ TIME _____ M. DIRECTION BEFORE TURNING-IN-OUT

TURNED AT _____

CAUSE _____ ORDER OF _____

TRIP NO. _____ TIME _____ M. DIRECTION BEFORE TURNING-IN-OUT

TURNED AT _____

CAUSE _____ ORDER OF _____

TRIP NO. _____ TIME _____ M DIRECTION BEFORE TURNING-IN-OUT

TURNED AT _____

CAUSE _____ ORDER OF _____

REMARKS: _____

Scheduled leaving time must be filled in for each trip. If complete trip is not made, mark an X in the "TERMINUS LOCATION" column and give detail of "TURNING" on this side.

Place register readings opposite the location at which the statement is taken. Reading must be taken upon arrival at each inbound and outbound terminus, when leaving and arriving at the division, and when being relieved or making a relief.

ACCIDENT MEMORANDUM

COLLISION OCCURRENCE

Distance from the middle of the intersecting street, approx. _____ feet

Opposite what fixed object _____

Street: level ☐ upgrade ☐ downgrade ☐ straight ☐ curved ☐

Paving: wood-block ☐ stone ☐ concrete ☐ asphalt ☐ brick ☐ unpaved ☐

License No. _____ State _____ Year _____

Type of vehicle _____ Vehicle lights burning _____

Condition of tires: _____ Snow tires _____ Chains applied _____

Occupants in vehicle, including driver: men _____ women _____ children _____

After collision, how far did street car / bus move before stopping, approx. _____ ft.

After collision, how far did vehicle move before stopping, approx. _____ ft.

BOARDING, ALIGHTING, FALLING OCCURRENCES

Nearest service stop to point of accident is _____

Front doors were:

approx. _____ feet short of service stop named

approx. _____ feet beyond service stop named

Opposite what fixed object _____

REMINDER: NOT AT FAULT CARD
SECURE WITNESSES
CALL TRAFFIC DISPATCHER
321-1690

*Figure 31. Typical PATransit day card.*

### Passenger Load Checks

Passenger load checks identify the number of passengers riding buses at selected points along the route. This makes it possible to quantify the maximum passenger volume on any one section of line, locate that section, and analyze the service quality (load factors). Two basic types of load checks are common: counts at maximum load points are keyed to bus service requirements and load factors; and boarding and alighting (on-and-off) counts portray the number of passengers using different sections of a bus route. They help determine the locations where short-line or turn-back service is desirable.

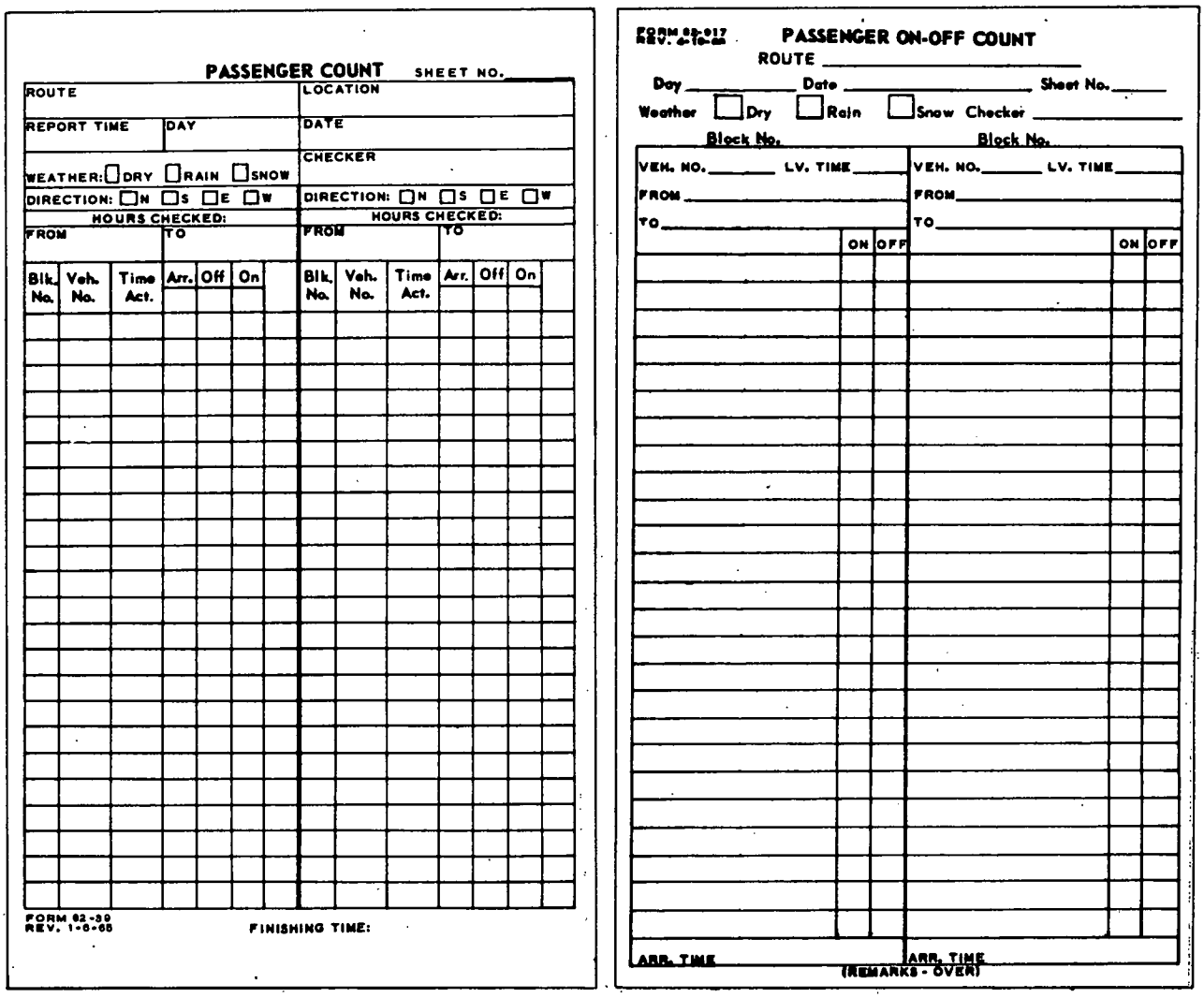
Figures 32 and 33 show typical forms used in checking ridership. Load point forms identify run number, actual and scheduled times, weather, and number of passengers on arriving vehicles, alighting and boarding, and on departing vehicles. Counts are then summarized by 15- or 20-min periods (peak) or 30- or 60-min periods. On-and-off count forms identify route and vehicle number, weather, departure times, and boarding and alighting passengers by stop.

Passenger loads can be superimposed on the seats available by time of day and section of route to determine load factors and to identify areas of service change. Passengers should be related to seats on an individual basis. Statistical analysis of data can then identify the standees on each bus and the proportion of buses that are overloaded.

Exact counts often cannot be made because of short vehicle standing time, so that observers must know how to quickly estimate the number of people in each group or seating section. Therefore, the observer must know the exact seating and total capacity of vehicles to make an accurate estimate of the number of passengers in a full vehicle or to add standees to the seating capacity of the bus.

### Running Time Checks

Surveys of bus running times and delays should be made regularly for scheduling purposes. These studies normally include measures of passengers' boarding and standing time and driver practices (creeping, speeding) (Figure 34).


PASSENGER COUNT SHEET NO.

ROUTE | LOCATION
REPORT TIME | DAY | DATE
WEATHER: ☐ DRY ☐ RAIN ☐ SNOW | CHECKER
DIRECTION: ☐ N ☐ S ☐ E ☐ W | DIRECTION: ☐ N ☐ S ☐ E ☐ W
HOURS CHECKED: FROM TO | HOURS CHECKED: FROM TO

| Blk. No. | Veh. No. | Time Act. | Arr. | Off | On | | Blk. No. | Veh. No. | Time Act. | Arr. | Off | On |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

FORM 62-39 REV. 1-8-65 FINISHING TIME:

PASSENGER ON-OFF COUNT
ROUTE
Day Date Sheet No.
Weather ☐ Dry ☐ Rain ☐ Snow Checker
Block No. | Block No.
VEH. NO. LV. TIME | VEH. NO. LV. TIME
FROM | FROM
TO | TO

| | ON | OFF | | ON | OFF |
|---|---|---|---|---|---|

ARR. TIME | ARR. TIME
(REMARKS - OVER)

*Figure 32. Cleveland load-point checks.*

CTA 8305 REV. 5/73

CHICAGO TRANSIT AUTHORITY
SCHEDULE-TRAFFIC DEPARTMENT

SHEET 1

## TRAFFIC SURVEY - 15 MINUTE AVERAGE
SURFACE SYSTEM

TYPE OF UNIT _____
SERIES _____
NO. OF SEATS _____
TABULATOR _____

Line _____ Day _____ Date _____

| | TIME AT | DIRECTION | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AT | | | AT | | | AT | | | AT | | | AT | | | AT | | |
| | 15-MIN. PERIOD ENDING | VEHI-CLES | AV. PER VEH. | TOTAL | VEHI-CLES | AV. PER VEH. | TOTAL | VEHI-CLES | AV. PER VEH. | TOTAL | VEHI-CLES | AV. PER VEH. | TOTAL | VEHI-CLES | AV. PER VEH. | TOTAL | VEHI-CLES | AV. PER VEH. | TOTAL |
| | 3:30 am | | | | | | | | | | | | | | | | | | |
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*Figure 33. CTA load-point check summary.*

Traffic studies should be made to identify reasons underlying delays; these may lead to suggestions for expediting bus and car flow (e.g., parking restrictions, bus lanes).

### Cordon Counts

Cordon counts of the number of buses and bus passengers entering, leaving, and accumulated in the CBD are important for a variety of service planning reasons.

- They provide an estimate of the transit ridership to the downtown area and the dependence of this area on transit. (In large cities, more than half of the downtown daytime population normally comes by transit.)
- They provide a basis for scaling and validating long-range ridership projections.
- They provide additional information on bus ridership and loadings.

These counts should be made every year or two in May or November. Counts should encompass a 12-hr period from 7:00 a.m. to 7:00 p.m. and should be made in conjunction with similar counts of pedestrians, cars, taxis, and trucks (including occupants).

### Traffic Flow and Density Diagrams

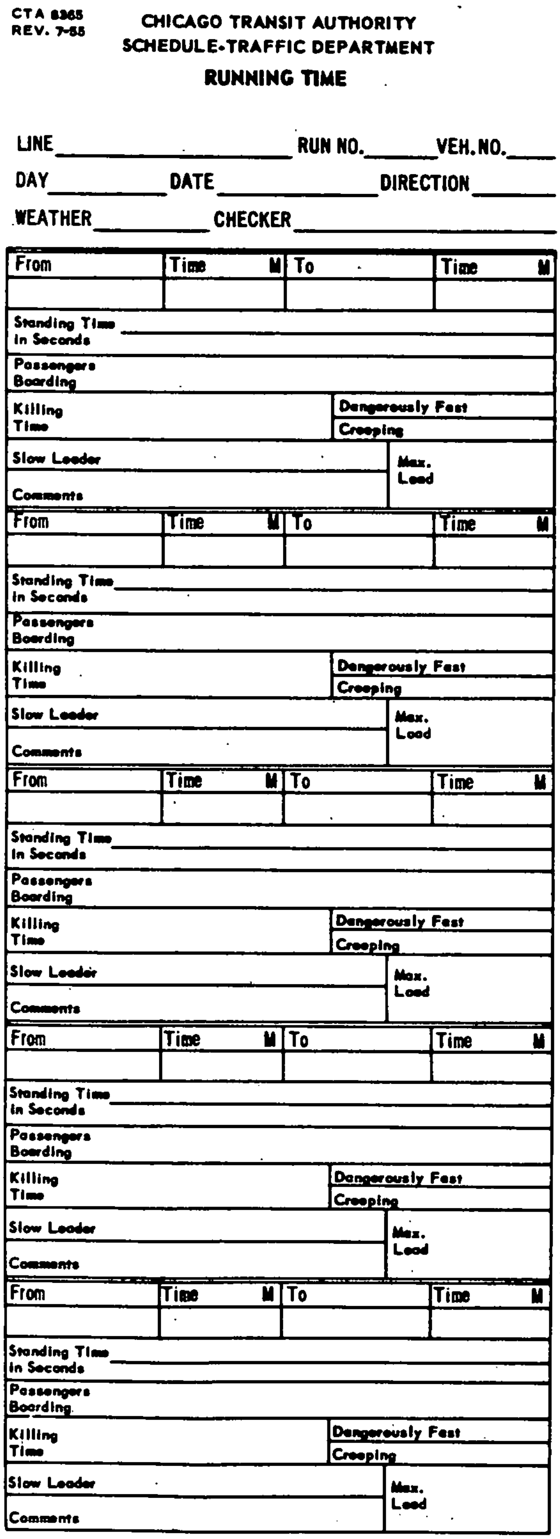
In the first half of the twentieth century, many transit agencies prepared flow or traffic density diagrams of bus and streetcar movement. These were usually prepared for peak hours in a manner similar to vehicle traffic flow maps. Today, such diagrams can provide a basis for allocating the impact of changes in routing associated with street changes or bus priority measures. They (or their numerical equivalents) are essential in downtown areas where curb loading space is taxed and where route additions or changes are anticipated.

### Travel Pattern Studies

Special studies of travel patterns should provide a base for long-range ridership projections keyed to rapid transit development and major system changes. Such systemwide studies are appropriate wherever major service changes are anticipated, and in some cases they may be the basis for establishing subsidy allocations among various municipalities. They are also useful in obtaining information on potential markets and as guides to transit marketing studies. They are commonly made as part of UMTA-sponsored transit technical studies.

The studies should be keyed to specific service planning objectives, a common procedure. For example, in planning bus service to a major shopping center, shoppers could be interviewed to obtain their origins and trip frequencies. Similarly, service expansion to a new residential development might be preceded by a selective household survey.

The main point of collecting origin and destination data is to determine where present transit riders are coming from and where they are going. It is also desirable to obtain some socioeconomic data on the transit riders. The origin and destination data can be obtained from a questionnaire completed while the rider is on the bus; the



CTA 8365
REV. 7-65

CHICAGO TRANSIT AUTHORITY
SCHEDULE-TRAFFIC DEPARTMENT
RUNNING TIME

LINE ____________ RUN NO. ______ VEH. NO. ____
DAY ________ DATE ____________ DIRECTION ______
WEATHER ________ CHECKER ____________

| From | Time M | To | Time M |
|---|---|---|---|
| | | | |

Standing Time In Seconds ____
Passengers Boarding ____
Killing Time ____ Dangerously Fast ____ Creeping ____
Slow Leader ____ Max. Load ____
Comments ____

| From | Time M | To | Time M |
|---|---|---|---|
| | | | |

Standing Time In Seconds ____
Passengers Boarding ____
Killing Time ____ Dangerously Fast ____ Creeping ____
Slow Leader ____ Max. Load ____
Comments ____

| From | Time M | To | Time M |
|---|---|---|---|
| | | | |

Standing Time In Seconds ____
Passengers Boarding ____
Killing Time ____ Dangerously Fast ____ Creeping ____
Slow Leader ____ Max. Load ____
Comments ____

| From | Time M | To | Time M |
|---|---|---|---|
| | | | |

Standing Time In Seconds ____
Passengers Boarding ____
Killing Time ____ Dangerously Fast ____ Creeping ____
Slow Leader ____ Max. Load ____
Comments ____

| From | Time M | To | Time M |
|---|---|---|---|
| | | | |

Standing Time In Seconds ____
Passengers Boarding ____
Killing Time ____ Dangerously Fast ____ Creeping ____
Slow Leader ____ Max. Load ____
Comments ____

*Figure 34. CTA running-time survey form.*

questionnaire must be short, usually no longer than 15 questions and to be completed in less than 5 min. If more data are desired from transit riders, they must be acquired through a mail-in questionnaire or through a telephone or a personal interview.

Direct interviews with passengers can be obtained where vehicles are not overcrowded. However, during peak periods, such a procedure would be difficult on a heavily used bus route. Only a limited number of questions could be asked. Figure 35 shows a questionnaire used by PATransit in planning a service change.

PATransit

64 A Extension Transit Survey

Please complete and return this survey as soon as possible to the person who distributed it. The results of the survey will be used to evaluate transit service in this area. Thank you for your cooperation.

1. Where do you live?

   Essex House ☐ Centre-Negley Apts. ☐

   Kennilworth Apts. ☐ Other_____

2. Indicate your reasons for going to Squirrel Hill.

   Work ☐ Shopping ☐ Medical ☐

   Recreation ☐ Visiting ☐

   Religious ☐ Other _____

3. List the times that you would be going to and coming from Squirrel Hill.

   Times Going

   ____ ____ ____ ____ ____

   Times Returning

   ____ ____ ____ ____ ____

4. Indicate the days of the week you would be going to Squirrel Hill.

   Mon. ☐ Tues. ☐ Wed. ☐ Thurs. ☐

   Fri. ☐ Sat. ☐ Sun. ☐

5. Are you willing to transfer to another bus?

   Yes ☐ No ☐

6. Do you have a car available for your trip?

   ☐ No (bus is the only way)

   ☐ Yes (but it is inconvenient)

   ☐ Yes (but I prefer the bus)

*Figure 35. PATransit questionnaire.*

Postcard surveys of bus riders (distributed on-vehicle) also provide information. Here the objective should be to obtain a statistically representative sample. A 20 percent survey response is common.

Major generator and employer surveys are commonly used to ascertain salient characteristics of travel markets—travel pattern, motivation, and attitude data from both bus and car riders.

In addition, telephone surveys are sometimes used to obtain information on market attitudes and habits. However, they are of little use for specific route changes.

### MBTA Survey

A systemwide survey of the MBTA bus riders conducted in 1979 included 2-day ridership and revenue counts of all bus lines during peak, midday, and evening periods. The numbers of bus trips surveyed on each route were sufficient to produce estimates of ridership within ±10 percent precision at 95 percent confidence. Preliminary surveys found a coefficient of variation of about 50 percent in the number of passengers per trip. In addition, an attempt to obtain 1-day samples of passenger origins and destinations for 100 respondents per route per time period was made. Figure 36 shows the basic survey form.

### Surveys of the Physically Handicapped—TTC Experience

Surveys of transportation requirements of the elderly and physically handicapped are desirable to quantify needs and provide a basis for meaningful actions. Such data will become increasingly important as a result of current legislative requirements.

A 1973 survey conducted in Toronto (*38*) illustrates the method and analyses that could be used to evaluate needs and travel patterns of the transportation handicapped. TTC sent a letter to 59 organizations that provide service to or have contact with handicapped people. As a result of this letter, 1500 survey forms were distributed directly to individuals and organizations. Forms were also supplied to Metro Toronto's Commissioner of Social Services for distribution to the handicapped. Figure 37 shows the form used and the follow-up reminder advertisement.

Responses were received from 336 individuals, of whom 280 were unemployed. Another 1112 replies were obtained from organizations dealing with the handicapped. Figures 38 and 39 show the locations of the respondents and the home-to-work trips of employed respondents. Maps such as these clearly show the dimensions of handicapped people's travel patterns.

## RADIO AND ELECTRONIC MONITORING

Almost every major bus property now uses or is planning to install two-way radio systems. Acquiring the ability to monitor driver performance, coupled with increased needs for driver and passenger security and prompt response to emergency conditions, is the reason for these

№ 507985

M.B.T.A. PASSENGER SURVEY

Please COMPLETE and RETURN this questionnaire before leaving the bus. This survey is being conducted for the MBTA in order to plan for better service. Your cooperation is appreciated. Please drop your questionnaire in the envelope when you leave the bus. If this is not convenient, drop it in any mailbox (we will pay the postage). It is NOT necessary to sign this form or otherwise identify yourself.

1. Where did you come from before boarding this bus? __Home __Work __School __Shopping __Social/Recreation __Medical/Dental __Other
   The place you came from is located at: Address: 8 NUMBER 11 12 STREET (or nearest intersection, store, school, etc.) 32
   33 TOWN OR CITY 46
2. How did you get to this bus? __Walked __Drove car __Rode in car __Commuter Train __Taxi __Bus or streetcar
   Which bus or streetcar_____ Route Number or Name
   __Took the Subway
   At what station did you board?_____
   At what station did you exit?_____
3. If you arrived by car, was the car __Parked on street __Parked in lot or garage __Not parked
4. What type of fare did you pay on this bus? __Elderly ½ fare __Handicapped ½ fare __Student ½ fare __Student transfer __Pre-paid pass __Adult cash fare __Other
5. Where will you go after leaving this bus? __Home __School __Work __Shopping __Medical/Dental __Social/Recreation __Other
   The place you will go is located at: Address: 8 NUMBER 11 12 STREET (or nearest intersection, store, school, etc.) 32
   33 TOWN OR CITY 46
6. How will you get to your destination after leaving this bus: __Walk __Drive car __Ride in car __Taxi __Commuter Train __Bus or Streetcar
   Which bus or streetcar_____ Route Number or Name
   __Ride a Subway
   From what station?_____
   To what station?_____
7. How often do you ride this bus? __Once per week or less __2-3 days weekly __4-5 days weekly __More than 5 days weekly
8. In the last 2 years has your use of the bus __Increased __Decreased __Stayed the same
9. Are you __Grade school or High school student __College student __Housewife __Retired __Employed __Unemployed
10. Are you __Male __Female
11. What is your age? __Under 16 __16–24 __25–44 __45–59 __60–64 __65 or older
12. How many persons (including yourself) live in your household? __One __Two __Three __Four __Five __Six or more
13. How many cars in operating condition do you have at your household? __None __One __Two __Three or more
14. Do you have a driver's license? __Yes __No
15. How many other members of your household have a driver's license? __None __One __Two __Three __Four or more
16. What is the combined annual income of your entire household? __Under $5,000 __$5,000 to $8,000 __$8,000 to $12,000 __$12,000 to $15,000 __$15,000 to $20,000 __$20,000 to $25,000 __Over $25,000
17. Comments and suggestions_____

DO NOT WRITE IN THIS SPACE OFFICE USE ONLY

7
47
48–51
52–53
54–55
56
57
7
47
48–51
52–53
54–55
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60
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62
63
64
65

*Figure 36. MBTA bus interview form.*

installations. Current costs of radio communications (less than $5,000 per unit) also make such installations feasible.

Agencies are also beginning to use automatic vehicle location (AVL), identification (AVI), and monitoring (AVM) systems. Their use is more widespread in Europe, although a few agencies such as CTA use automatic vehicle locator systems that provide information on location of buses at signposts along fixed routes. Because most agencies believe that the use of field supervisors would still be required, however, they have not installed such systems. Continued advances in electronic technologies and proven performance in actual operations are likely to bring about greater acceptance of AVI, AVL, and AVM systems.

## SCHEDULE PREPARATION AND IMPLEMENTATION

Careful and detailed scheduling computations and precise presentation of schedules are extremely important aspects of transit system operation, because they affect the efficiency and economy of operation, the regularity and reliability of service, and the facility with which the public can use the system. Consequently, use of scientific and analytical methods is growing in the transit industry, as is the trend toward computer-assisted schedule making.

### Scheduling Objectives

Good scheduling should bring transit vehicles to people on a pattern of service designed specifically for passenger convenience. This means spacing transit vehicles at appropriate intervals throughout the day and evening to maintain an adequate level of service (*39*). Therefore, schedulers should (a) provide riders with fast, frequent service; (b) provide this service at efficient economic levels to meet budgetary constraints; and (c) set operator work shifts that best reflect riding patterns and union contracts. This involves preparing service schedules, identifying equipment needs, and determining driver requirements.

### Schedule Design Considerations

The following factors are important in preparing schedules and timetables (*27*):

- Loading criteria in relation to passenger traffic,
- Policy headway guidelines,
- Ridership characteristics by time of day and along route,
- Time required to complete a full cycle (round trip, including layover allowances for delay-recovery time, crew relief, and headway matchup time),
- Bus travel time variations throughout the day,
- Schedule coordination and timed-transfer requirements,
- Opportunities for short-turning buses, and
- Need and desirability of closed-door operations (i.e., route sections where passengers are not allowed to board or alight).

Several elements contribute to a good schedule. Passenger riding patterns to work, shopping, school, or recreation locations can be determined with a reasonable degree

**METRO-TTC SURVEY:**

**TRANSPORTATION FOR THE PHYSICALLY HANDICAPPED**

The Municipality of Metropolitan Toronto and the Toronto Transit Commission are examining the feasibility of providing transportation for physically handicapped persons so that consideration may be given to the operation of a pilot project.

Completion of the survey form below will assist in determining the size and scope of the proposed Metro area demonstration project.

The great variety and extent of physical handicaps are recognized and the transportation needs of all handicapped persons will not be overlooked in future considerations.

Initially, however, specific information is required to determine the transportation requirements of Metropolitan Toronto residents who are confined to wheelchairs or who because of special handicaps are unable to use standard motor car transportation.

It is likely that first consideration in any pilot project which may later be approved will have to be given to persons who are now employed or who could be employed if suitable transportation were available.

Plans to extend service to off-peak hours for all persons confined to wheelchairs will also be developed later, and such persons are urged to complete and return the questionnaire.

IF YOU RESIDE IN METROPOLITAN TORONTO AND ARE CONFINED TO A WHEELCHAIR OR ARE PHYSICALLY UNABLE TO TRAVEL VIA STANDARD MOTOR CAR TRANSPORTATION, PLEASE COMPLETE THE FOLLOWING QUESTIONNAIRE AND MAIL TO:

**Toronto Transit Commission**
1900 Yonge Street
Toronto M4S 1Z2, Ontario

**Attention: Planning Department**

Name_____

Address_____

Telephone No._____ Postal Code_____

Age_____ Now Employed: Yes_____ No_____

Could you accept employment if low cost transportation were available? Yes_____ No_____

Business Address (if applicable)_____

Hours of Work (e.g. 9.00-5.00) (if applicable)_____

Work Days (e.g. Mon. to Fri.) (if applicable)_____

Confined to Wheelchair: Yes_____ No_____

Do you normally travel with an escort? Yes_____ No_____

If not confined to a wheelchair, please state the nature of your handicap_____

Times, days and nature of principal non-work trips (e.g. to therapy clinic on Tuesdays and Fridays, 1-3 p.m.)

"REMINDER" ADVERTISEMENT — WEEK OF JULY 24TH

**METRO-T.T.C. SURVEY**

**TRANSPORTATION FOR THE PHYSICALLY HANDICAPPED**

Have you sent us your questionnaire?

All Metropolitan Toronto residents who are confined to wheelchairs or who, because of special handicaps, are unable to use standard motor car transportation and who have not yet responded to the Metro Toronto-T.T.C. survey are urged to do so as soon as possible. We want your special transportation needs to be included in this study.

If you did not clip the newspaper questionnaire published recently, please call the T.T.C. Public Relations Department — telephone 481-4252. A copy will be mailed to you promptly.

TORONTO TRANSIT COMMISSION

*Figure 37. TTC physically handicapped survey forms.*

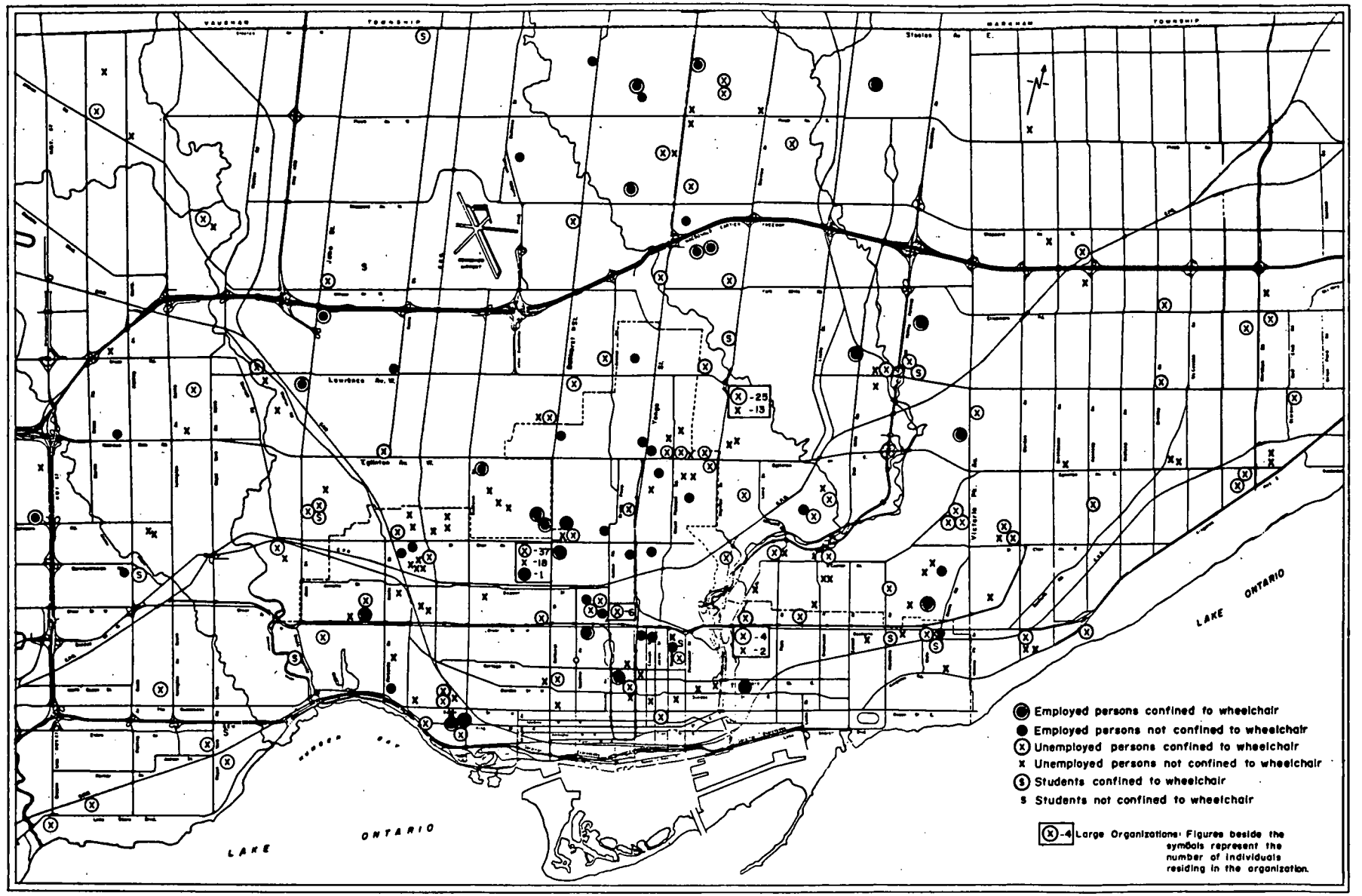



*Figure 38. Location of people responding to TR survey of the physically handicapped.*

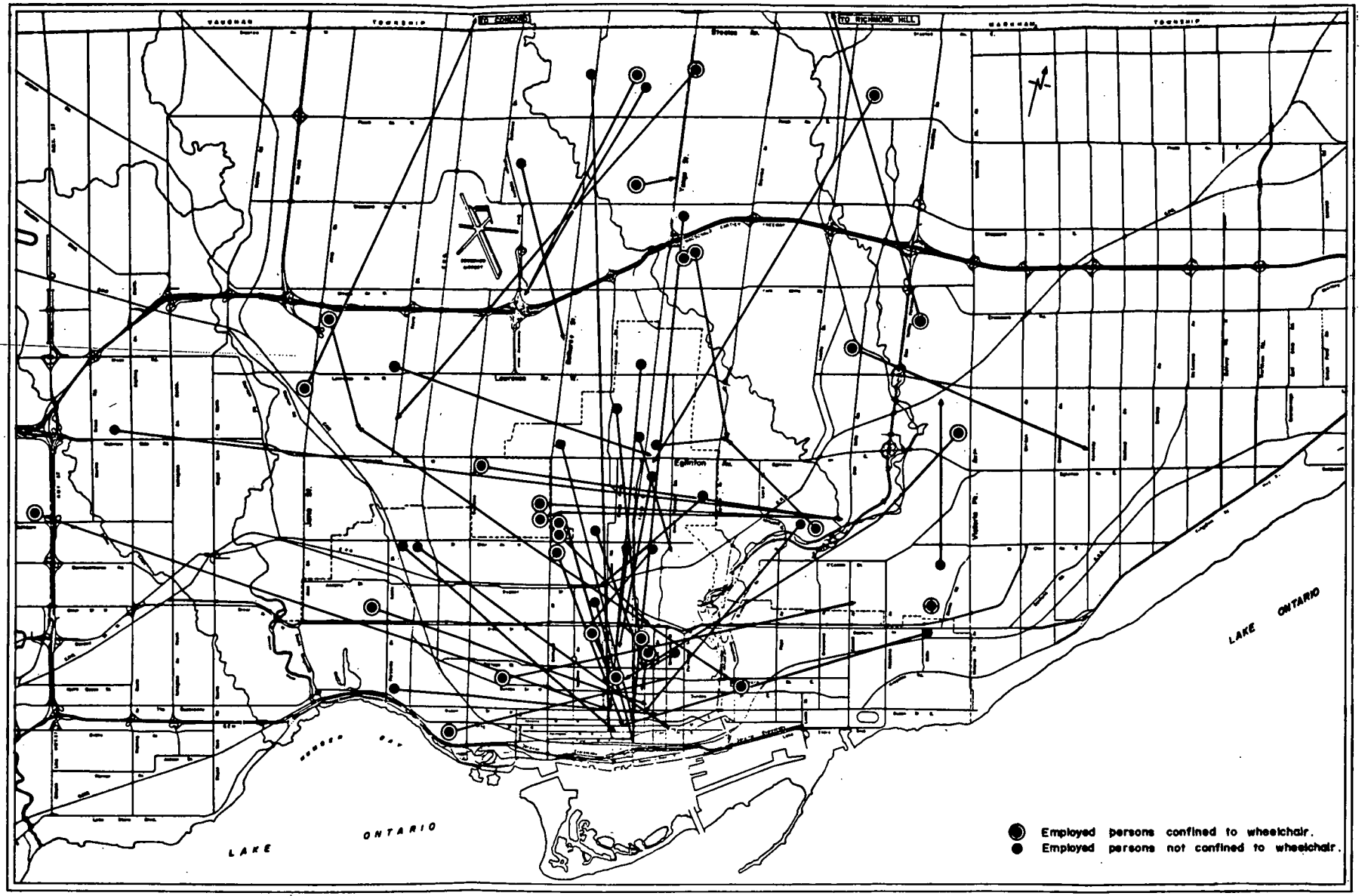



*Figure 39. Home-to-work trips of employed people responding to TR survey of the physically handicapped.*

of accuracy. Points of maximum loadings on many routes may remain constant although loadings and times of loadings may shift. However, demand for service can change appreciably, such as when large plants are relocated or residential developments are built. In such cases, schedule revisions might be required.

Weather, the length of route, available terminal facilities, and type of equipment must be considered in the scheduling process. Winter, for example, brings longer hours of darkness, snow and ice, and traffic congestion. These conditions must be anticipated and schedules must be adjusted to allow for slower operation and additional recovery time to ensure schedule adherence.

A critical factor in this process is staff availability. Operators' work shifts must both conform with the current labor contract and result in the best possible division of work for the service to be provided.

Another essential part of the scheduling activity is measuring the effectiveness of scheduled service in terms of passenger demand and operational performance. This can be accomplished by continuously gathering passenger and operating traffic data.

CTA, for instance, employs a field force of 33 traffic checkers who measure schedules against use by passengers and check every bus and rail line on the system at the rush hour points of maximum loading on 2 days during each of the four seasons. At other times, these checkers make midday, evening, and weekend checks as well as riding checks to determine running time adjustments or boarding and alighting activities on a given route. They also measure operational performance and record the times of each vehicle at various points. When discrepancies occur between scheduled and actual running times between points, on-bus riding checks are taken to identify the causes. Seven traffic clerks transfer the passenger traffic data to summary sheets on which the passenger volumes, number of buses, and average load per bus are listed by 15-min periods. The information is then transferred to a passenger flowchart where it can be compared with past summaries to identify trends in ridership patterns. These data also serve as valuable source materials for planning efforts.

#### Scheduling Steps

When passenger traffic and running time data indicate that service adjustments are necessary, schedule specifications should be prepared to reflect the prescribed changes. These may involve adding or removing trips, shifting a series of trips, or providing a new running time.

Schedule makers generally follow this procedure:

1. Running time is corrected or adjusted for the route.
2. A series of headway sheets that list the leaving and arrival time of every trip is prepared, by using the time intervals between trips as indicated in the specifications. These can be graphic representations of the route.
3. The individual trips in both directions are joined together in blocks of consecutive trips (or service) provided by one bus.
4. The blocks of trips are copied from the headway sheet onto a separate train sheet.
5. When all trips on the headway sheets have been included in one of the various blocks, the train sheet can be used to determine the number of vehicles needed to provide the specified service on the route during any period of the day. Counts are normally made of morning, midday (base), afternoon, evening, and (where operated) owl vehicles required.
6. The blocks of trips are divided into portions of operators' work, generally 3 to 5 hr long. These portions of work are then paired into work shifts called runs, which are usually separated by a 30- to 60-min meal break. First, evening work is paired up, then midday. This leaves solely rush-hour portions, which are then paired into swing runs with a break of 3 to 6 hr between portions of work. The goal is to provide as many straight runs as possible, but, because the nature of people's work habits requires twice as many vehicles in each rush period as in midday, swing runs must be constructed.
7. The size of each portion of work is then readjusted and the pairing process repeated until the schedule reaches the most economical position for the service required.

The new schedule should then be reviewed by schedule clerks who check for mathematical accuracy and conformity to union contract requirements. It is then transcribed onto a drawing or pick sheet for use by operators in selecting work. The trip information is often fed simultaneously into a computer, and the subsequent printouts are used to reproduce timetables for use by supervisors (inspectors) to measure and control schedule adherence.

Before a schedule goes into effect, it should be field checked. A schedule that goes into effect about July 1 should be field checked during April, given to a schedule maker by early May, and revised before June 1. The revised schedule should be sent for picking about 2 or 3 weeks before it becomes effective. Although every schedule should be field checked, not every schedule is changed. Changes should focus on the most heavily used routes, which involve the most riders, bus drivers, and greatest economic impact to the transit agency (*40*).

#### Graphic Schedules

Schedules may be developed graphically (time-space diagrams) or numerically (timetables). The graphic schedule, which shows the time-distance relationship for each vehicle, was used in the past, often to identify passing points along single-track rail lines. Distance is plotted on one axis and time on the other; the path of each vehicle is then traced graphically.

#### Schedule Recapitulation

Transit agencies normally recapitulate their service in a schedule service summary. Table 18 gives a portion of such a summary for Toronto, and Table 19 summarizes the resulting vehicles required for various time periods.

TABLE 18

TTC SCHEDULED SERVICE

BOARD PERIOD COMMENCING: Sunday June 27, 1976

| ROUTE / BUSES: | ROUND TRIP DISTANCE (MILES) | DAILY: ROUND TRIP TIME (MINUTES) RUSH | DAILY: ROUND TRIP TIME (MINUTES) NORM. | DAILY: SCHEDULED SPEED (M.P.H.) RUSH | DAILY: SCHEDULED SPEED (M.P.H.) NORM. | DAILY: HEADWAY (MINUTES-SECONDS) A.M. RUSH | DAILY: HEADWAY NORM. | DAILY: HEADWAY P.M. RUSH | DAILY: HEADWAY EVE. | SATURDAY: ROUND TRIP TIME (MINS.) | SATURDAY: SCHED. SPEED (M.P.H.) | SATURDAY: HEADWAY (MIN.-SEC.) P.M. NORM. | SATURDAY: HEADWAY EVE. NORM. | SUNDAY: ROUND TRIP TIME (MINS) | SUNDAY: SCHED. SPEED (M.P.H.) | SUNDAY: HEADWAY (MIN.-SEC.) P.M. NORM. | SUNDAY: HEADWAY EVE. NORM. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anglesey | | | | | | | | | | | | | | | | | |
| Royal York Stn. - Mill Rd. | 10.6 | 45 | 45 | 14.1 | 14.1 | 6-26 | 15-00 | 6-26 | 20-00 | 45 | 14.1 | 15-00 | 20-00 | 40 | 15.9 | 20-00 | 20-00 |
| Scheduled Vehicles | | | | | | 7 | 3 | 7 | 2 | | | 3 | 2 | | | 2 | 2 |
| Armour Heights | | | | | | | | | | | | | | | | | |
| Bombay - Roe | 1.9 | 15 | 15 | 7.6 | 7.6 | 15-00 | 15-00 | 15-00 | - | - | - | - | - | - | - | - | - |
| Scheduled Vehicles | | | | | | 1 | 1 | 1 | - | | | | | | | | |
| Avenue Road | | | | | | | | | | | | | | | | | |
| Eglinton - Queen's Park | 7.7 | 49 | 44 | 9.4 | 10.5 | 7-00 | 11-00 | 7-00 | - | 48 | 9.6 | 12-00 | - | - | - | - | - |
| Lonsdale - " " | 4.7 | 28 | - | 10.1 | - | 7-00 | - | 7-00 | - | - | - | - | - | - | - | - | - |
| Eglinton - Front | 11.0 | | 66 | - | 10.0 | - | - | - | 11-00 | 66 | 10.0 | - | 16-30 | 66 | 10.0 | 16-30 | 16-30 |
| Combined | | | | | | 3-30 | - | 3-30 | - | | | - | - | | | - | - |
| Scheduled Vehicles | | | | | | 11 | 4 | 11 | 6 | | | 4 | 4 | | | 4 | 4 |
| Bathurst | | | | | | | | | | | | | | | | | |
| Bathurst Stn. - Steeles | 18.9 | 100 | 95 | 11.3 | 11.9 | 5-00 | 10-00 | 5-00 | 8-00 | 95 | 11.9 | 10-00 | 8-00 | 90 | 12.6 | 12-00 | 8-00 |
| " " - Sheppard | 12.6 | 75 | 75 | 10.1 | 10.1 | 5-00 | 10-00 | 5-00 | - | 75 | 10.1 | 10-00 | - | 66 | 11.5 | 12-00 | - |
| Combined | | | | | | 2-30 | 5-00 | 2-30 | - | | | 5-00 | - | | | 6-00 | - |
| Scheduled Vehicles | | | | | | 33 | 17 | 35 | 11 | | | 17 | 11 | | | 13 | 11 |
| BAY | | | | | | | | | | | | | | | | | |
| Dupont - Jarvis (Via Docks) | 7.3 | 60 | 52 | 7.3 | 8.4 | 4-00 | 4-00 | 4-00 | 6-15 | 56 | 7.8 | 4-00 | 6-15 | 48 | 9.1 | 5-40 | 7-17 |
| Bloor - Jarvis (Via Docks) | 6.0 | 52 | - | 5.9 | - | 4-00 | - | 4-00 | - | - | - | - | - | - | - | - | - |
| Combined | | | | | | 2-00 | - | 2-00 | - | | | - | - | | | - | - |
| Scheduled Vehicles | | | | | | 27 | 13 | 28 | 8 | | | 14 | 8 | | | 9 | 7 |
| Bayview | | | | | | | | | | | | | | | | | |
| Lawrence Stn. - Sheppard | 8.8 | 50 | 36 | 10.6 | 14.7 | 10-00 | 12-00 | 10-00 | 15-00 | 36 | 14.7 | 12-00 | 15-00 | 30 | 17.6 | 30-00 | 30-00 |
| Scheduled Vehicles | | | | | | 4 | 3 | 5 | 2 | | | 3 | 2 | | | 1 | 1 |
| Bayview North | | | | | | | | | | | | | | | | | |
| Sheppard Stn. - Steeles | 8.3 | 40 | 36 | 12.5 | 13.8 | 10-00 | 12-00 | 10-00 | 15-00 | 36 | 13.8 | 12-00 | 15-00 | 30 | 16.6 | 30-00 | 30-00 |
| Scheduled Vehicles | | | | | | 4 | 3 | 4 | 2 | | | 3 | 2 | | | 1 | 1 |

TABLE 19

SUMMARY OF TTC SCHEDULED SURFACE VEHICLES (1976)

| | DAILY | | | | SATURDAY | | SUNDAY | |
|---|---|---|---|---|---|---|---|---|
| | A.M. RUSH | NORMAL | P.M. RUSH | EVE. | P.M. NORMAL | EVE. NORMAL | P.M. NORMAL | EVE. NORMAL |
| STREET CARS | 231 | 113 | 239 | 85 | 118 | 79 | 82 | 66 |
| TROLLEY COACHES | 83 | 38 | 84 | 30 | 41 | 30 | 31 | 30 |
| BUSES | 969 | 414 | 972 | 317 | 419 | 288 | 287 | 254 |
| MINI-BUSES | 4 | 3 | 4 | - | - | - | - | - |
| TOTAL | 1,287 | 568 | 1,299 | 432 | 578 | 397 | 400 | 350 |

CHAPTER EIGHT

# IMPROVING BUS FLOW

An increase in bus operating speeds benefits the transit passenger and operator. Higher speeds give the passenger a more attractive ride and, in some cases, may attract new riders. Express bus service, especially in priority lanes on freeways, is often competitive with car travel. It benefits the transit agency by increasing vehicle productivity, reducing fleet size, and, in turn, reducing costs. Therefore, transit agencies should make every effort to achieve as high a speed as conditions allow.

Many of the ways to expedite bus flow call for close cooperation between the bus operator and the community: for example, spacing and location of stops, elimination of parking along bus routes, bus-related traffic engineering improvements, and bus priority measures.

## RUSH HOUR

The most serious problems associated with bus operations occur during weekday rush periods. Fleet capacities are normally taxed, street space is limited (particularly in central areas), and congestion is most intense. The results are high costs of operations.

### Cost Factors

Although the number of passengers carried is greatest during peak hours, it does not necessarily follow that these periods are the most profitable. Much of the excess service uses equipment that is only needed for the short peaks. Moreover, work rules have made it difficult to hire bus drivers only for these short peaks.

The increased costs of additional peak services are primarily composed of the extra driver costs of increased split shifts and penalty payments. Another component is the increased cost of extra peak vehicles.

The problem of peak-hour costs has been both persistent and pervasive in the transit industry. A 1916 study by the American Electric Railway Transportation and Traffic Association set out to prove that "It is the relation of income to expenditure between the hours of 9 A.M. and 4 P.M. that is the most favorable to the company" (*41*). Current operating experiences suggest that high peak-to-base ratios of buses in service, without a corresponding increase in load factors, can produce a relatively poor cost-revenue picture for peak-hour service. For example, a 1974 analysis of costs and revenues for the Merseyside Transit System (England) revealed that revenue received from peak travelers was not covering costs of providing peak service, whereas off-peak revenue was more than covering costs (*42*).

A variety of cost-allocation models has explored the economics of peak-period bus service. Figure 40 shows how the relative profitability of peak-hour bus service can be approximated from three basic ratios (*46*):

1. The ratio of additional buses required for peak service to those required for base service ($x$). This is, in essence, a peaking factor that represents the peak-to-base ratio minus 1.
2. The ratio of pay hours per bus operated for the additional peak buses required to those for the base buses ($y$). This reflects schedule efficiency and in turn work rules regarding split shifts and overtime.
3. The ratio of peak-hour passengers per bus to off-peak passengers per bus ($e$). This reflects peak and off-peak load factors.

Figure 40 shows that there would have to be 50 to 100 percent more passengers per bus in the peaks than in the base period if the peaks are to be as profitable as off-peaks when the peak-to-base ratio is 2.0.

Operating speeds are normally lower in peak periods, even though urban traffic congestion has generally decreased during the last several decades. Nevertheless, buses stop longer and the opportunities for schedule disturbance are greater. And many buses may return empty during the peak, so that only half the total trip is producing revenue.

### Alleviating Conditions

Rush-hour cost conditions can be alleviated by spreading the peaks, increasing schedule speeds, and operating larger vehicles. For rail transit, train lengths can be increased.

There is, in theory, a good opportunity to stagger work periods, especially at large plants, in major CBDs, and at large government employment centers. Such programs were successful during World War II and are part of many current transportation system management (TSM) proposals. Staggered hours have been in effect in lower Manhattan since April 1970 and have relieved critical peaking in one subway terminal by 15 percent in the peak 15-min. However, except for lower Manhattan, central Washington, and Ottawa, relatively little has been accomplished by staggering work periods or establishing flexi-time working arrangements. Because so little has been accomplished in staggering work periods, most agencies must rely on increasing schedule speeds to improve their economic performance. The effects of speed on labor costs (platform expense) is very pronounced. On a bus line operating at a speed of 8 mph (13 km/hr) and at a cost of $16/hr, the cost is $2 per bus mile ($1.24 per bus km). If the schedule speed is increased to 10 mph (16 km/hr), the cost is reduced to $1.60 per bus mile ($1 per bus km).

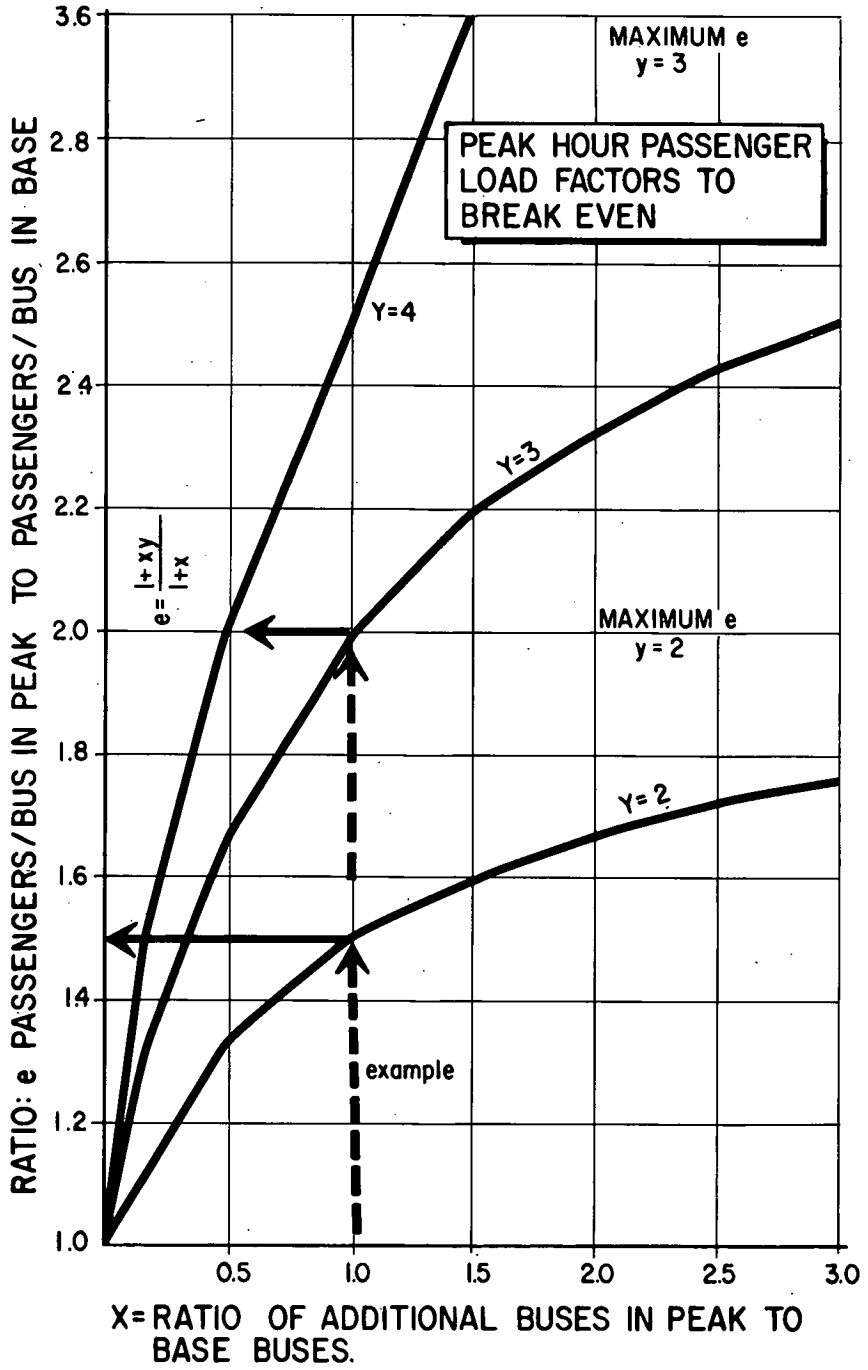



*Figure 40. Peak-hour passenger load factors to break even. Note that y is the ratio of pay hours to bus for extra buses in the peak to that in the base period.*

## INCREASING BUS SPEEDS

It is clear that high schedule speeds will produce a gain at all times and speeds can be increased without increasing the maximum speeds by (a) making the duration of stops as short as possible by letting passengers on and off the bus quickly, (b) making as few stops as possible for passengers, and (c) making as few stops as possible for traffic delays. Each of these methods has been used by major agencies. The steady rise in express bus service is a step in this direction. It should, however, be recognized that one-man bus operations, and single front-door entrance for security reasons have a negative effect on minimizing dwell times.

### Reducing Dwell Times

Bus dwell times at stops can be reduced by providing (a) multiple-berth stops, (b) fare prepayment at major load

points, (c) use of exact fares (preferably single-coin fares), and (d) auxiliary platform loaders at heavy passenger loading points to permit use of all doors.

Wider, double-channel entrance and exit doors can expedite passenger loading and unloading. Such doors are common in Europe, but in North America they are mainly limited to older trolley coaches.

Lower floors on buses can expedite loading and unloading.

The use of tokens, multiple-ride tickets, or weekly or monthly passes, purchased before boarding, expedites fare collection. Although common in Western Europe, the honor fare system, which involves presale of tickets, remains to be tried in the United States.

Table 20 gives comparative dwell times based on U.S. experience and provides a basis for estimating the travel time reductions that result from various fare collection policies and door configurations.

Pittsburgh and Seattle have a pay-as-you-enter system for inbound trips to the city center and a pay-as-you-leave system for outbound trips. This reduces overall bus dwell times in the city center and makes possible (as in Seattle) a free-fare zone. However, it may not necessarily reduce overall bus journey times, because the driver must collect fares the entire distance on each trip.

#### Accelerating Movement on the Bus

Passenger movement on the bus should be facilitated, especially at major boarding points. Prepayment of fares and, to some extent, use of single-coin fares are consistent with this objective. Interior circulation may be improved on urban transit buses by eliminating one row of seats between the front and center doors or by providing transverse seating on one side of the bus.

Some agencies, such as NYCTA, use a transverse seating arrangement to facilitate passenger flow and provide more space for standing passengers. (It is interesting to note that seating arrangements, like issues of bus performance, were not identified as a major consideration by the various transit properties surveyed.)

#### Reducing Frequency of Stops

Most transit agencies now provide reasonable spacing between bus stops. The practice of stopping at every corner, i.e., stops 300 to 500 ft (100 to 150 m) apart,

TABLE 20

REPORTED PASSENGER SERVICE TIMES ON AND OFF BUSES (FROM *32* AND *44*)

| OPERATION | CONDITIONS | TIME (Sec.) |
|---|---|---|
| UNLOADING | Very little hand baggage and parcels; few transfers | 1.5 - 2.5 |
| | Moderate amount hand baggage or many transfers | 2.5 - 4 |
| | Considerable baggage from racks (intercity runs) | 4 - 6 |
| LOADING (1) | Single coin or token fare box | 2 - 3 |
| | Odd penny cash fares multiple zone fares | 3 - 4 |
| | Pre-purchased tickets and registration on bus | 4 - 6 |
| | Multiple zone fares; cash; including registrations on bus | 6 - 8 |
| | Prepayment before entering bus or pay when leaving bus | 1.5 - 2.5 |

(1) Add one second where fare receipts are involved.

should be discouraged except in downtown areas. The most notable example of transit stop reduction was on the Chicago rapid transit lines where station closures, and peak-period skip-stop (all-express) service substantially increased speeds.

The advantages of increased spacing between bus stops are apparent from Figure 41, which shows the declines in operating speeds as bus stop spacing and traffic delay increase. On-street bus speeds are approximately 13 mph (21 km/hr) with 4 stops/mile (2.5 stops/km), 9 mph (14 km/hr) with 8 stops/mile (5 stops/km), and 7 mph (11 km/hr) with 12 stops/mile (7.5 stops/km). Actual speeds as low as 3 to 5 mph (5 to 8 km/hr) may result from extensive street congestion. Off-street bus speeds average about 30 mph (50 km/hr) with 1 station or stop/mile (0.5 stop/km), 22 mph (35 km/hr) with 2 stops/mile (1.2 stops/km), and 15 to 17 mph (24 to 27 km/hr) with 3 stops/mile (1.9 stops/km).

Bus speeds may be increased by increasing distances between stops on local bus routes, by giving only limited-stop service along arterial streets (as in Chicago and St. Louis), or by using express (zonal) operations (Milwaukee's Freeway Flyers).

Express service remains an especially promising way of improving bus speeds, and today almost every agency (except those in small cities) operates some express lines. Express bus operation is provided mainly on freeways at speeds that are substantially higher than the typical local bus speeds of 10 to 12 mph (16 to 19 km/hr). Table 21 gives typical express bus speeds, which range up to 40 mph (65 km/hr). Express bus service is also provided in Boston, Hartford, Miami, Pittsburgh, Portland, and Washington, D.C., often over high-occupancy vehicle lanes or busways, at comparable speeds.

Milwaukee uses freeways to deadhead buses to or from

TABLE 21

EXPRESS BUS SPEEDS ON URBAN FREEWAYS (1972) (*26*)

| CITY | NUMBER OF ROUTES WITH RUSH-HOUR SPEED DATA | RANGE IN TERMINAL-TO-TERMINAL RUSH-HOUR SPEED (MPH) |
|---|---|---|
| Atlanta | 11 | 15–19 |
| Baltimore | 1 | 26 |
| Chicago | 2 | 13–23 |
| Cleveland | 6 | 17–26 |
| Dallas | 14 | 13–21 |
| Detroit | 6 | 12–24 |
| Houston | 11 | 14–24 |
| Los Angeles | 19 | 13–28 |
| Milwaukee | 6 | 28–42 |
| Minneapolis-St. Paul | 6 | 18–29 |
| New York-New Jersey | 59 | 11–34 |
| Philadelphia | 7 | 17–24 |
| St. Louis | 15 | 14–20 |
| San Francisco-Oakland | 11 | 21–32 |
| Seattle | 7 | 16–25 |

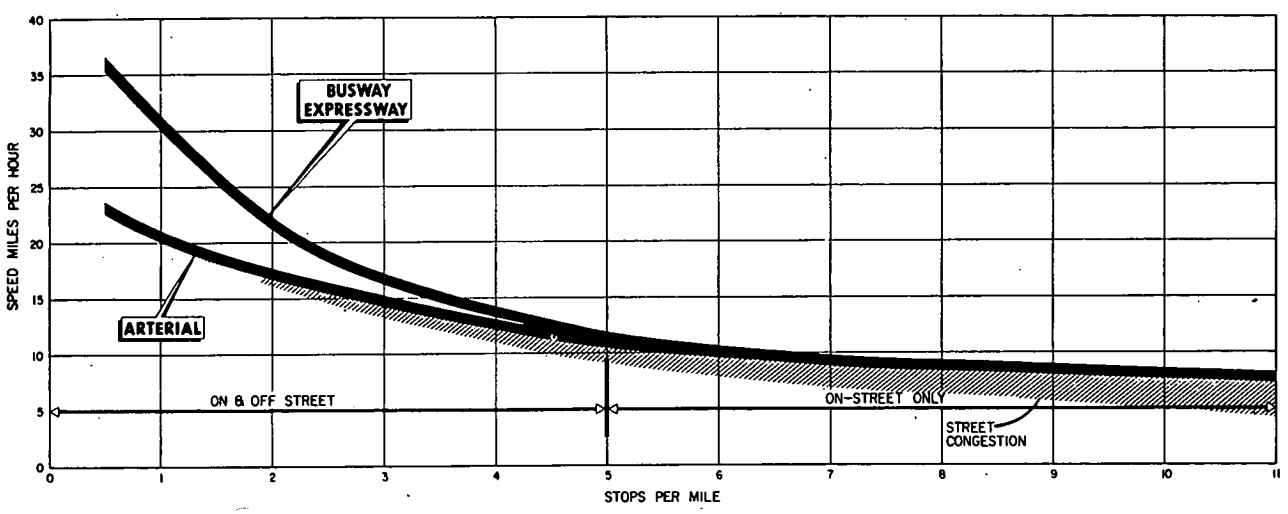



*Figure 41. Bus speeds in relation to stop frequency (45).*

garages to reduce trip times—a practice that has potential in other areas.

Focusing long-distance bus trips into outlying rail transit systems is another way of reducing passenger delays, bus miles in congested areas, and transit hours operated per passenger served.

## REDUCING TRAFFIC DELAYS

Methods of reducing stops from traffic delays include (a) better regulating traffic flow, including enforcement procedures; (b) providing priority measures for buses; and (c) rerouting buses to avoid congested districts or slow movements.

### Traffic Engineering Improvements

Effective traffic engineering along bus routes is essential and will benefit overall bus movement. There are many locations where turn controls, parking restrictions, widened radii, and intersection channelization will allow buses to operate more effectively along their logical routes. Enforcement of parking restrictions and prompt towing of illegally parked vehicles are desirable. Washington, D.C., has established a $50 fine for cars that are parked illegally in no-standing areas and are subsequently towed.

#### *On-Street Parking Prohibitions*

The peak-hour prohibition of curb parking will prove especially beneficial to bus movements. Similarly, street changes that eliminate bottlenecks or allow direct service into new areas will prove beneficial.

Because a transit agency generally does not have authority over parking regulations, cooperation is required from appropriate city agencies to introduce effective on-street parking regulations. Although eliminating parking (peak-hours or all-day) is usually desirable to speed up bus movement, access needs of residences and commercial activities along the street should be considered. There is a tradeoff between the benefits to moving traffic and the access required to serve activities. In some cases, the needed parking can be provided off-street.

In the CBD, on-street parking should be prohibited along bus routes. This is common practice in most cities already, especially where bus lanes are involved. Generally, off-street municipal and private parking facilities are available for motorists.

In neighborhoods without off-street parking facilities, prohibition of on-street parking may be difficult because sufficient parking is often not available on cross streets. This is frequently the case in older areas around the CBD. Farther out, in newer suburban areas, off-street parking is usually provided, and a no-parking policy on transit streets is common.

#### *Enlarged Corner Radii*

Although transit agencies are not directly responsible for the design of street intersections, whenever existing intersections are modified or where new intersections are being designed that may be used by buses, agencies should check the adequacy of the design.

Most bad problems at intersections are associated with turning movements, especially on residential streets. For buses, the inside rear wheel follows an arc close to the curb, whereas the outside of the front fender follows an arc far from the curb. Figure 42 illustrates a turning movement and the turning radius data for several different models. The more a curb is cut back at the corner, the less the bus must pull out of its lane to avoid running over the curb. However, in the downtown areas of many cities, extensive curb flaring may reduce the sidewalk area needed for pedestrians at intersections. This flaring should be limited so as not to seriously interfere with pedestrian movement and safety.

### Bus Priority Measures

Bus priority measures are viewed by transit agencies as a means of rationalizing bus routes to serve specific activity centers and reducing traffic delays. The actual application of measures—especially from a public transit perspective—is highly selective within each urban area.

A vast body of literature that has emerged in recent years describes the state of the art, planning guidelines, and operational experiences. These include *NCHRP Reports 143* and *155* on bus use of highways (*26, 46*), the NATO report on bus priority systems (*47*), and the DOT-TSC-sponsored reports on various priority treatments for high-occupancy lanes (e.g., *48, 49*). Table 22 gives an overview of the state of the art in 1979.

#### *State of the Art Overview*

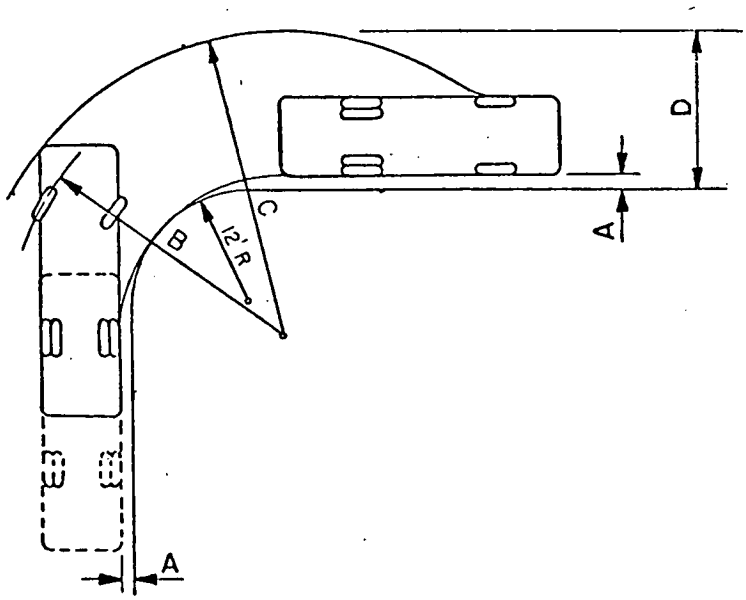
Most bus priority measures are reserved bus lanes on city streets, usually in the direction of traffic flow. However, the number of bus-only streets—such as State Street in Chicago, Nicollet Mall in Minneapolis, and Chestnut Street in Philadelphia (Figure 43)—is increasing.

Pittsburgh's South PATway, opened in December 1977, is unique in that it is the only exclusive bus road in the United States built entirely on its own right-of-way and not in connection with or part of a highway project. The 4.5-mile (7.2-km) busway connects the southwestern suburbs of Pittsburgh to the Golden Triangle and reduces bus travel times by 15 to 30 min; it serves about 20 000 riders daily.

Park-and-ride lots are tied to express bus services in many communities including Washington, D.C., Miami, Los Angeles, Boston, New York, and Hartford. Traffic signal preemption by buses is not widespread.

#### *Planning Considerations*

Planning and implementing bus priority measures require a reasonable concentration of bus services, a high degree of bus and car congestion, and community willingness to support public transport. There is little value in providing bus priority measures where service is poor or costly; where there is no congestion; and where the community has no desire to maintain and improve bus service.




| CHARACTERISTICS OF BUS | | | | | TURNING RADIUS DATA | | | |
|---|---|---|---|---|---|---|---|---|
| GMC MODEL | No. of Seats | Body Width | Body Length | Length Wheel Base | A | B | C | D |
| TDH3301A | 35 | 8'0" | 29'3" | 15'7" | 1'8" | 29'2" | 33'0" | 17'5" |
| TDH4521 SDH4501 SDH4503 | 45 | 8'0" | 35'0" | 19'7" | 0'10" | 31'2" | 36'1" | 22'2" |
| TDH4520 | 45 | 8'6" | 35'0" | 19'7" | 0'10" | 31'4" | 36'3" | 22'4" |
| TDH5306 S8M5303A | 53 | 8'0" | 39'11" | 23'9" | 1'9" | 37'1" | 42'1" | 26'3" |
| TDH5305 | 53 | 8'6" | 39'11" | 23'9" | 1'9" | 37'3" | 42'3" | 26'5" |
| PD4107 PD4108 | 41 | 8'0" | 35'1" | 21'7" | 4'0" | 39'6" | 43'6" | 22'3" |
| PD4903 PD4905 | 49 | 8'0" | 40'0" | 26'6" | 4'9" | 45'0" | 48'6" | 25'0" |

*Figure 42. Turning characteristics of transit buses (GM Truck and Coach Division).*

Planning calls for a realistic assessment of demands, costs, benefits, and impacts. Measures should be applied that

- Alleviate existing bus service deficiencies,
- Achieve attractive and reliable bus service,
- Serve demonstrated existing demands,
- Provide reserve capacity for future growth in bus trips,
- Attract auto drivers, and
- Relate to long-range transit improvement and downtown development programs.[8]

Key factors include the intensity and growth prospects of the city center; the historic and potential future reliance on public transport; street width, configuration, continuity, and congestion; the suitability of existing streets and expressways for express bus service; bus operating speeds and service reliability in the city center; availability of alternative routes for displaced auto traffic; locations of major employment centers in relation to bus routes; goods and service vehicle loading requirements; express and local bus routing patterns; bus passenger loading requirements along curbs; and community attitudes and resources.

Bus priority measures must fit real-world street systems. They must be reasonable, not only in how they improve bus service but how they affect other traffic as well. Community acceptance and support are essential—especially over the long run. Effective enforcement and maintenance are necessary.

Buses must be able to enter and leave priority lanes easily, and alternative routings must be available for po-

TABLE 22

SUMMARY OF CURRENT BUS PRIORITY TREATMENTS (1979) (AFTER 50)

| TYPE OF TREATMENT | SIGNIFICANT EXAMPLES OF EXISTING TREATMENTS |
|---|---|
| 1. Freeway-Related Treatments | |
| A. Busways | |
| 1. Busway on special right-of-way | South PATway, Pittsburgh<br>Runcorn, England Busway |
| 2. Busway on freeway, median, or right-of-way | Shirley Busway, Washington Area[1]<br>San Bernardino Busway, Los Angeles[1] |
| 3. Busway in railroad right-of-way | None |
| B. Reserved Lanes and Ramps | |
| 1. Bus pre-emption of freeway lanes | Ottawa River Parkway |
| 2. Bus lanes on freeways - normal flow | U.S. 101, Marin County, California[1]<br>9th Street Expressway, Washington, D.C.<br>I-95, Miami[1]<br>I-280, San Francisco[1]<br>Moanalua Freeway, Hawaii[1]<br>Banfield Freeway, Portland, Oregon[1]<br>I-580, Oakland |
| 3. Bus lanes on freeways - contraflow | I-495, New Jersey<br>Long Island Expressway, New York<br>U.S. 101, Marin County, California<br>North Freeway, Houston |
| 4. Bus lane bypass of toll plaza | San Francisco-Oakland Bay Bridge[1] |
| 5. Exclusive bus access to nonreserved freeway (or arterial) lanes | Seattle Blue Streak express bus service and bus ramp<br>Braddock Avenue, Pittsburgh |
| 6. Metered freeway ramps with bus bypass lanes | South Capitol Street Bridge, Washington, D.C.<br>Harbor Freeway, Los Angeles<br>I-35W, Minneapolis (9 locations)<br>San Diego Freeway, Los Angeles[1]<br>Golden State Freeway, Los Angeles<br>San Diego Freeway, Los Angeles |
| 7. Bus stops along freeways | Hollywood Freeway, Los Angeles |
| 2. Arterial-Related Treatments | |
| A. Reserved Lanes and Streets | |
| 1. Bus tunnels | Harvard Square, Cambridge |
| 2. Bus streets | Fifth and Sixth Streets, Portland<br>10th Street, Washington, D. C.<br>Nicollet Mall, Minneapolis<br>Halsted and 63rd Streets, Chicago<br>Granville Street, Vancouver<br>Chestnut Street, Philadelphia<br>State Street, Chicago<br>State Street, Madison |

*continued on next page*

TABLE 22 (*continued*)

| | |
|---|---|
| 3. CBD curb bus lanes - normal flow | Washington, D.C.<br>Baltimore, Maryland<br>New York City, New York<br>San Francisco, Calif. |
| 4. Arterial curb bus lanes - normal flow[4] | Hillside Avenue, Queens, New York City<br>Connecticut Avenue, Washington, D.C.<br>Lincoln Avenue, Denver<br>Olive Street and Lindell Boulevard, St. Louis<br>Post, Suther, Geary, O'Farrel St., San Francisco |
| 5. CBD median bus lanes - normal flow | Canal Street Neutral Ground, New Orleans<br>Washington Street, Chicago |
| 6. Arterial median bus lanes - normal flow | N.W. 7th Avenue, Miami[3]<br>Broadway, Denver<br>Barbour Boulevard, Portland[5]<br>S. Dixie Highway, Miami |
| 7. CBD curb bus lanes - contraflow | Spring Street, Los Angeles<br>Alamo Plaza, San Antonio<br>Market Street, Harrisburg<br>Marquette - 2nd Avenues, Minneapolis<br>Fifth Avenue, Pittsburgh<br>Canal Street, Chicago<br>Second Avenue, New York |
| 8. Arterial curb bus lanes - contraflow | Ponce de Leon, Fernandez Juncos, San Juan<br>College Avenue, Indianapolis<br>Kalanianole, Honolulu |
| B. Miscellaneous | |
| 1. Bus signal pre-emption | Barbour Boulevard, Portland<br>Kent, Ohio |
| 2. Special signalization | Cermak Road, Chicago |
| 3. Special turn permission | "No Left Turn, Buses Excepted," Los Angeles, Washington |
| 3. Terminals | |
| A. Central area bus terminals | Midtown Terminal, New York City<br>Transbay Terminal, San Francisco |
| B. Outlying transfer terminals | Dan Ryan - 69th Street Bus Bridge, Chicago<br>Dan Ryan - 95th Street Bus Bridge, Chicago<br>Eglinton Terminal, Toronto |
| C. Outlying park-and-ride terminals | Lincoln Tunnel approach at I-495 contra flow bus lane, New Jersey |

(1) Includes priority use by car pools.
(2) Under construction.
(3) Interim operation prior to operating buses on I-95.
(4) Selected examples.
(5) Reversible lane - peak-hour.


*Figure 43. Chestnut Street Bus Mall (Philadelphia). Note the bus shelter.*

TABLE 23

GENERALIZED APPLICABILITY OF BUS PRIORITY TREATMENTS (*26*)

| TYPE OF TREATMENT | GENERAL APPLICABILITY TO: LOCAL BUS SERVICE | GENERAL APPLICABILITY TO: LIMITED-EXPRESS BUS SERVICE | PLANNING PERIOD (YEARS) | DESIGN-YEAR CONDITIONS: RANGE IN ONE-WAY PEAK-HOUR BUS VOLUMES | DESIGN-YEAR CONDITIONS: RANGE IN ONE-WAY PEAK-HOUR BUS PASSENGER VOLUMES | RELATED LAND-USE AND TRANSPORTATION FACTORS |
|---|---|---|---|---|---|---|
| *Freeway Related:* | | | | | | |
| Busways on special right-of-way | x | x | 10–20 | 40–60 | 1,600–2,400 | Urban population, 750,000; CBD employment, 50,000; 20 million sq ft of floor space. |
| Busways within freeway right-of-way | | x | 10–20 | 40–60 | 1,600–2,400 | Freeways in corridor congested in peak hour. |
| Busways on railroad right-of-way | x | x | 5–10 | 40–60 | 1,600–2,400 | Not well located in relation to service area. Stations required. |
| Freeway bus lanes, normal flow | | x | 5 | 60–90 | 2,400–3,600 | Applicable upstream from lane-drop. Bus passenger time saving should exceed other road-user delays. |
| Freeway bus lanes, contra-flow | | x | 5 | 40–60 | 1,600–2,400 | Freeways 6 or more lanes; where imbalance in traffic volumes permits level of service D in off-peak travel directions. |
| Bus lane bypass at toll plaza | | x | 5 | 20–30 | 800–1,200 | Adequate reservoir on approach to toll station. |
| Exclusive bus access ramp to nonreserved freeway or arterial lane | x | x | 5 | 10–15 | 400–600 | |
| Bus bypass lane at metered freeway ramp | | x | 5 | 10–15 | 400–600 | Alternate surface street route available for metered traffic. Express buses leave freeways to make intermediate stops. |
| Bus stops along freeways | | x | 5 | 5–10 | 50–100[a] | Generally provide at surface street level in conjunction with metered ramp. |
| *Arterial Related:* | | | | | | |
| Bus streets | x | x | 5–10 | 20–30 | 800–1,200 | Commercially oriented frontage. |
| CBD curb bus lanes, main street | x | | 5 | 20–30 | 800–1,200 | Commercially oriented frontage. |
| Curb bus lanes | x | | 5 | 30–40 | 1,200–1,600 | At least 2 lanes available for other traffic in same direction. |
| Median bus lanes | x | x | 5 | 60–90 | 2,400–3,600 | At least 2 lanes available for other traffic in same direction; ability to separate vehicular turn conflicts from buses. |
| Contra-flow bus lanes, short segments | x | | 5 | 20–30 | 800–1,200 | |
| Contra-flow bus lanes, extended | x | x | 5 | 40–60 | 1,000–2,400 | At least 2 lanes available for other traffic in opposite direction. Signal spacing greater than 500-ft intervals. |
| Bus turnouts | x | | 5 | 10–15 | 400–600 | Points of major passenger loadings on streets with more than 500 peak-hour autos using curb lane. |
| Bus preemption of traffic signals | x | | 1–5 | 10–15 | 400–600 | Wherever not constrained by pedestrian clearance or signal network constraints. |
| Special bus signals and signal phases, bus-actuated | x | | 1–5 | 5–10 | 200–400 | At access points to bus lanes, busways, or terminals; or where special bus turning movements must be accommodated. |
| Special bus turn provisions | x | | 1–5 | 5–10 | 200–900 | Wherever vehicular turn prohibitions are located along bus routes. |

[a] Boarding or alighting passengers in peak hour.

tentially displaced car traffic. New problems should not be created, nor should existing problems merely be transferred from one location to another.

Before any treatment is put into effect, an assessment should be made of its benefits and effects. This is important for forming a rational basis on which to implement the treatment and to ensure its good operation. A commitment should also be obtained from city agencies regarding enforcement and maintenance. Unless enforcement is strict, frequent violations may occur, defeating the advantages of priority measures. When the frequency of buses is very high (more than 90 buses per hour), the lanes are often self-enforcing.

*Installation Guidelines*

Criteria for introduction of transit priority measures vary among cities. The guidelines given in Table 23 are based on NCHRP studies (*26, 46*) and reflect both an extension and a modification of the Institute of Traffic Engineers' guides (*51*). They generally specify that the number of bus riders in the exclusive lane be at least equal to the number of auto occupants in the adjoining lane for the period that the priority measures would apply. They are expressed in terms of peak-hour buses and passengers, but they also identify other relevant factors and should be based on future "design year" corridor demands—a 10- to 20-year horizon for busways and a 5-year horizon for other priority measures—to allow for generated traffic. However, approximately 75 percent of the warrants should apply to base-year (existing) conditions. This approach allows flexibility for the future, and it safeguards against unrealistic demand forecasts.

*Expected Benefits*

The benefits resulting from bus priority measures vary widely by type of treatment. The potential time savings generally will depend on the degree of congestion prevailing before the priority measure was installed. The greater the congestion—the greater the benefits. The anticipated benefits shown in Figure 44 reflect a synthesis of current experiences and will depend on each specific application.

**Traffic Engineering in Transit Agencies**

Many large properties, such as CTA, have their own traffic engineering sections. In Detroit, both bus operation and traffic engineering functions are part of the city's department of transportation. In all cases, close cooperation is essential.

The street traffic section should prepare temporary rerouting plans for buses to avoid building or roadway construction, bridge repairs, public utility projects, and parades. It should also help obtain necessary operating permits. It should direct pavement marking programs and supervise the installation of bus stops, bus stands, bus shelters, and public information displays, where these activities are the responsibility of the transit agency.

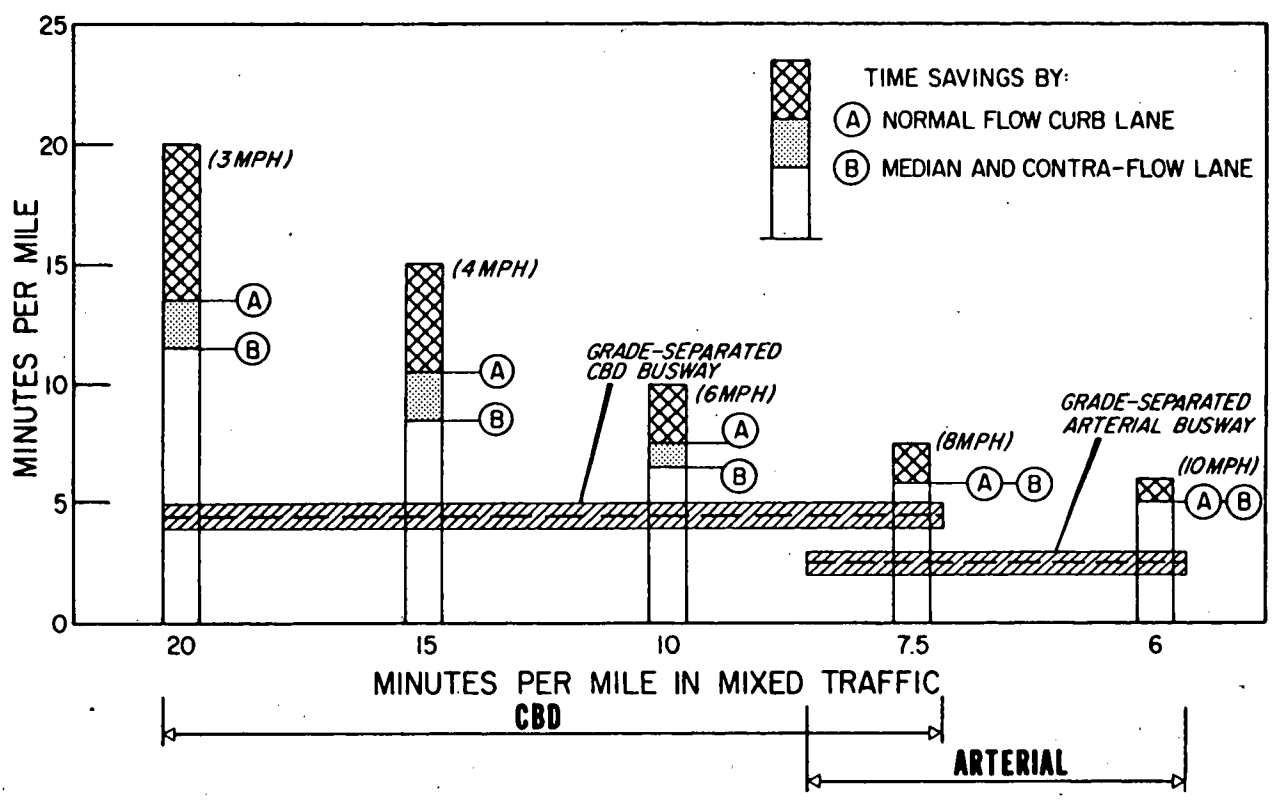



*Figure 44. Typical time savings from bus priority measures (45).*

*Chicago*

CTA has worked with the city of Chicago to make the State Street Mall become a reality. The mall extends nine blocks on State Street from Wacker Drive on the north to Congress Parkway on the south. The existing roadway is narrowed to two exclusive bus lanes with boarding bays at the intersections. Traffic on the transit mall is limited to buses and emergency vehicles. East-west streets crossing State Street remain open to traffic. Sidewalks are widened to include landscaping and other amenities.

Before the mall was built, 2300 buses traveled State Street daily, more than 168 of them in the predominant direction. Passenger loading took place both at the curb and at the center lane safety areas. With the transit mall, buses operate in one lane in each direction, and there is a passing lane in each intersection at the bus stop.

With the widened sidewalk area, an assortment of improvements benefit the pedestrian and transit passenger. In the eight blocks between Lake Street and Congress Parkway, existing entrances to the State Street Subway will be remodeled. In each of these blocks there are four stairways that lead down to the subway mezzanine fare collection areas. Two of the stairways will be replaced with escalators, and the other two stairways will be renovated. A cover will be constructed over each stairway or escalator to protect it from the elements.

On four east-west streets, Washington, Madison, Adams, and Jackson, reverse-flow bus lanes will be established in lanes from which parking will be removed. These exclusive lanes will increase the speed of buses on these streets and will accommodate all bus routes that currently use the eight east-west streets between Lake and Van Buren. For the 0.8 mile (1.3 km) between Canal Street and Michigan Avenue, one-way travel times will be reduced by 5 to 7 min. The segregation of bus traffic will also allow the automobile traffic on these streets to move faster.

*Boston*

MBTA participated in the Boston "Auto Restricted Zone" Project, which was implemented during 1979. This zone includes a Washington Street transit mall, several street closings, pedestrian amenities, and rerouting of buses within the city center.

CHAPTER NINE

# BUS OPERATION RESEARCH

## CONTEXT

Most public transit agencies are involved primarily in operations, not research. Their main concern is providing desired services within existing fiscal and regulatory requirements. They are looking for ways to relax labor, regulatory, and cost constraints rather than looking closely at technical aspects of innovation and research (*52*).

Before UMTA's involvement, many agencies were privately owned and were not oriented to research in the traditional sense. Research was mainly limited to the few larger agencies, often those involving rail transit systems. The increasing role of federal and state governments in public transport research has been accompanied by a growing interest in research among transit providers—although service remains their principal concern.

## RESEARCH AREAS

Research in bus service planning should include ways to better and more efficiently serve riders and improve internal activities that promote management efficiency (*53*). The following research areas are relevant.

- Simplified procedures for evaluating the market response to changes in bus service need to be developed. The transit operator and planner need to know the effects of headways, routing patterns, stop frequencies, and fare changes on ridership. The approaches should be easily applied, yet reliable for estimating traffic on new routes as well as revised services. They should include expansion and verification of available ridership elasticity data.
- Transit operators' responses to energy changes need to be identified and assessed. Consideration should be given to service policies, frequency of bus stops, effects of air conditioning, and bus types and engine. Service-related measures that have been taken to improve energy efficiency should be identified.
- Fare policies and collection practices need more research. Areas include flat, zone, and time- or distance-based fares; honor systems and "free-fare areas"; and devices used for fare collection.
- Additional research is needed on passenger service times in relation to fare collection and door arrangements. Existing work (*26, 54*) provides a starting point. However, additional studies are needed on such questions as what the

patterns of passenger turbulence on the vehicles are and how dwell times per passenger vary as the number of passengers on the bus increases.

• Better methods of evaluating transit service efficiency and making management performance audits are needed. Computerized transit schedule preparation offers promise of saving labor in schedule design and in pretesting service changes.

• The service patterns in low-density areas that should be researched are types, frequencies, and configuration of service demand; actuated systems and paratransit; and timed-transit systems.

• Research needs in information and marketing have been identified by many transit agencies. A logical first step is to pull together a state of the art that describes the results of ongoing and completed marketing efforts.

• Research and development are needed to improve bus speed and dependability. Policies regarding stop spacing, traffic congestion, and bus priorities are called for. Traffic engineering programs that focus on major bus routes should be implemented, and their results should be studied for savings in bus travel times and costs. Improved automatic vehicle monitoring (AVM) systems should be applied, and their results should be assessed.

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# APPENDIX A

## GENERAL CHARACTERISTICS OF SELECTED TRANSIT SYSTEMS, 1976-1978

| Item | Akron, Ohio | Chicago | Cleveland | Knoxville | Oakland Co. |
|---|---|---|---|---|---|
| Operating Agency (Public versus Private) | Regional Transit Authority | Chicago Transit Authority | Greater Cleveland Transit Authority | Knoxville Transit Corporation | Alameda-Contra Costa Co. Transit District |
| Type of Operation and Services Provided | bus | rapid transit, bus | rapid transit, light rail, bus | bus | bus |
| Service Area Population (and Metro or Urbanized Area Population) | 364,000 | 4,083,000 (3,102,000 in city) (1970) | 1,800,000 (670,000 in Cleveland) | | 1,600,000 (26 cities, 14 major unincorporated areas) |
| Square Miles in Service Area | 75.1 | 225--Chicago, plus 75--suburbs | 463 (75--Cleveland) | 77.6 | 620 |
| Fleet Size | 82 | 2,400 buses 1,100 rail cars | 1,000 bus 170 rail cars | 80 | 817 |
| Maximum Vehicles in Service | 71 | 2,145 buses 900 rail cars | 740 buses | 59 | 707 |
| Passenger Seats/Bus | 43-45 | 50 | 43 | 45 | 48 (25 at 69 seats) |
| Routes Operated | 27 | 135 bus, 7 rail | 105 bus, 3 rail | 12 | 198 |
| Route Miles | 175 | 2,054 bus 273 rail | NA | 498 | 2,263 (one-way) |
| Annual Passengers Carried (Revenue) (Millions) | 3.8 | 632 | 106 | 3.4 | 59 |
| Annual Rides/Capita in Service Area | 10.4 | 204 (city) | 59 (service area) | NA | 37 |
| Approximate % of Person Trips by Transit | 5 | 20 (Chicago) | 10 | 3 | 8 |
| Employees | 179 | 12,500 | 2,231 | 129 | 1,950 |
| Annual Revenue/Passengers per Employee | 21,200 | 50,600 | 47,500 | 36,400 | 30,300 |
| Basic Fare | NA | 50¢ | NA | 40¢ local 60¢ express (1977) | 35¢ local 75¢-$1.25 transbay |
| Transfer Cost | 5¢ | 10¢ | NA | NA | NA |
| Approximate % of Cost Recovered From Fares | 33 | 65 (1976) | County Sales Tax Covers Deficit | <100 | 35 |
| Organization for Bus Service Planning | Asst. General Manager | Operations Planning Dept. | Service Dev. Dept. | Supt. of Transp. | Transp. Engineering & Planning Dept. |
| Service Planning Standards | None | Informal | None | None | In 5-yr. plan |

Note: NA--Not available

Source: Interviews with transit agencies

APPENDIX A (*continued*)

| Item | Milwaukee | Nashville | Pittsburgh | Toronto | Washington |
|---|---|---|---|---|---|
| Operating Agency (Public versus Private) | Milwaukee County Transit System | Nashville Metr. Transit Authority | Port Authority Allegheny County | Toronto Transit Commission | Washington Metro Area Transit Authority |
| Type of Operation and Services Provided | bus | bus | bus, light rail | rapid transit, street car, trolly, & diesel bus | rapid transit, bus |
| Service Area Population (and Metro or Urbanized Area Population) | 950,000 (1,250,000) | 366,000 (446,000) | 1,605,000 | 2,200,000 | 2,840,000 (3,037,000) |
| Square Miles in Service Area | 141 | 250 | 730 | 240 | 1,486 |
| Fleet Size | 518 | 146 | 973 buses 95 trolleys | 416 subway cars, 389 street cars, 1,165 motor buses, 151 trolley buses | 1,825 buses, 300 subway cars |
| Maximum Vehicles in Service | 470 | 117 | 795 buses 71 trolleys | 1,500 (1972) 1,300 (1976) | 1,590 buses, 235 subway cars |
| Passenger Seats/Bus | 51-53 | 41-45 | 47-51 | NA | 47-51 |
| Routes Operated | 58 | 42 | 163 bus 5 trolley | 114 surface 2 subway | 145 bus lines 3 rail |
| Route Miles | 495 | 459 | NA | 1,390 | 1,320 bus 31 rail |
| Annual Passengers Carried (Revenue) (Millions) | 46 | 7.9 | 105 | 330 | 159 |
| Annual Rides/Capita in Service Area | 48 | 21 | 65 | 150 | 49 |
| Approximate % of Person Trips by Transit | NA | NA | 10 | 20 | 10 |
| Employees | 1,300 | NA | 2,877 | 7,565 | 6,500 |
| Annual Revenue/Passengers per Employee | 35,000 | NA | 37,000 | 43,600 | 24,500 |
| Basic Fare | 50¢ | 35¢ | NA | 50¢ cash 40¢ tokens | 40¢ off peak 50¢ peak |
| Transfer Cost | free | free | free | free | free |
| Approximate % of Cost Recovered From Fares | 70 | <100 | <100 | 71 (1974) | 48 |
| Organization for Bus Service Planning | NA | Transp.Dept. Operations & Scheduling Sections | Rates & Services Dept.;Schedule Dept. | Planning Dept. | Office of System & Service Planning |
| Service Planning Standards | yes | none | none | yes | draft form |

# APPENDIX B

## GOALS AND OBJECTIVES: ALAMEDA-CONTRA COSTA COUNTY TRANSIT DISTRICT

**GOAL I:** To provide residents of the Alameda-Contra Costa Transit District the highest quality service possible to meet the needs of the local areas in a fully equitable manner.

**Objective A: To Provide Reliable Service.**

Indicator 1: Increase the interval between road calls.

Indicator 2: All service should operate on time at least 95 percent of the time.

Indicator 3: Provide the service scheduled.

**Objective B: To Operate in a Safe and Comfortable Manner.**

Indicator 1: Buses exceeding 15 years of age should be replaced or refurbished. Refurbished buses should be removed from service after 5 additional years.

Indicator 2: Provide passenger shelters at locations which will be safe for passengers, at which no other form of shelter is available, and which (a) are major transfer points; (b) are near a large traffic generator; (c) serve a clinic or hospital; or (d) have infrequent service; or (e) serve a large number of senior citizens. In all instances, there must be sufficient space to safely locate a shelter.

Indicator 3: Provide benches at locations meeting shelter location criteria—except adequate space.

Indicator 4: Continue AC Transit's history of decreasing frequency of traffic accidents.

Indicator 5: Continue AC Transit's history of decreasing frequency of passenger accidents.

Indicator 6: Over 0.5 hr during the peak period there shall be sufficient seats available for the passengers during that 0.5 hr.

**Objective C: To Provide a Level of Transit Opportunity to All Residents of the County.**

Indicator 1: Implement actions identified in the Elderly and Handicapped Planning Study which will make the system easier to use for the elderly and handicapped.

Indicator 2: All new buses shall be accessible by wheelchair.

Indicator 3: Continue reduced fare for elderly and handicapped passengers during off-peak hours.

Indicator 4: Residents of the District should have transit service within 0.25 mile of their residence.

Indicator 5: No line will have headways greater than 30 min during peak periods of service or 60 min during off-peak periods.

Indicator 6: Transit dependent ridership will be considered when a reduction in service on a line is under consideration.

**GOAL II:** To operate as efficiently and economically as possible in order to provide the service at the lowest possible cost to both the user and the taxpayer.

**Objective A: To Maintain District Staff at the Most Efficient Level to Perform the Work of the District.**

Indicator 1: Pursue a ratio of 1.29 drivers per scheduled driver assignment.

Indicator 2: Maintain a ratio of three or more revenue vehicles to each maintenance person.

**Objective B: To Provide the Most Cost-Effective Physical Facilities to Meet Current and Projected Needs of the District.**

Indicator 1: Improve or replace outdated facilities.

**Objective C: To Provide a Level of Service Such That All Routes Are Productive.**

Indicator 1: A minimum of 33 percent of the District's operating costs should be recovered from the farebox.

Indicator 2: At least two passengers per bus mile should be carried on trunk lines and one passenger per bus mile on feeder lines.

Indicator 3: Trunk lines should carry at least 28 passengers per hr. Feeder lines

should carry at least 14 passengers per hr.

Indicator 4: Average subsidy per passenger trip should not exceed $0.72 on any line.

**Objective D: To Provide Necessary Management Information to Aid in Consistent Policy Development and Evaluation.**

Indicator 1: Improve the management information system.

Indicator 2: Annually update the Five-Year Transit Development Plan.

Indicator 3: Install vehicle mileage monitoring devices on all buses.

**GOAL III:** To encourage the general public to use transit.

**Objective A: To Increase Systemwide Use.**

**Objective B: To Provide Transit Information in a Manner That Is Convenient to and Understandable by the Public.**

Indicator 1: Response time to calls for transit information should not exceed 2 min on weekdays, 45 sec on Saturday, and 1 min on Sunday.

Indicator 2: Provide bilingual or multi-lingual information operators in the Transit Information Center.

Indicator 3: Provide transit information and pocket schedules at places convenient to the public.

Indicator 4: Identify a single person or office responsible for receiving and responding to complaints.

**Objective C: To Develop and Implement Goal-Oriented Marketing Program.**

**GOAL IV:** To coordinate AC Transit service with other transportation services to meet regional travel needs.

**Objective A: To Coordinate with Other Transit Operators in the Region in Order to Cooperatively Provide a Regionwide Transit Service.**

Indicator 1: Actively participate in planning and joint operating efforts of the Regional Transit Association.

Indicator 2: Participate in the Transit Operators Coordinating Council.

Indicator 3: Continue AC Transit-BART coordination.

**Objective B: To Assist and Encourage Paratransit Coordination in the District.**

Indicator 1: Provide assistance to Alameda and Contra Costa counties in the development and implementation of coordinated paratransit programs.

**GOAL V:** To provide an effective alternative to the use of the private automobile in order to help relieve air pollution, traffic congestion, and demands on increasingly scarce energy resources.

**Objective A: To Research New Concepts and Ideas That Might Improve the District's Operation While Decreasing Costs.**

Indicator 1: Study and evaluate for possible implementation techniques which will allow buses to move quickly and on-time through traffic.

Indicator 2: Seek safe and reliable passive wheelchair lift for installation in district buses.

Indicator 3: Explore new types of coaches to increase vehicle productivity.

Indicator 4: Improve scheduling and related functions.

Indicator 5: Simplify transfer procedures for passengers.

Indicator 6: Complete evaluation of vehicle monitoring system.

Indicator 7: Implement a pass program as a demonstration project.

**Objective B: To Strive to Be More Competitive with the Automobile.**

Indicator 1: Reduce total passenger trip time.

Indicator 2: The District will keep fares at a level that is competitive with the costs of driving an automobile.

**Objective C: To Encourage The Integration of Transit in Land-Use Planning and Development by Working Closely with Public and Private Agencies and by Urging Incentive Programs That Would Foster Transit-Oriented Developments.**

# APPENDIX C SERVICE PLANNING GUIDELINE EXAMPLES

| | BOSTON | CHICAGO | NEW JERSEY | SEMTA | TORONTO | WASHINGTON, D.C. |
|---|---|---|---|---|---|---|
| | Massachusetts Bay Transportation Auth. | Chicago Transit Authority | New Jersey Dept. of Transportation | Southeastern Michigan Transportation Authority | Toronto Transit Commission | Wash. Metropolitan Area Transit Authority |
| 1. SERVICE PATTERN<br>Service area | Boston and suburbs | Chicago and Some Contiguous Suburbs | | Detroit area outside city limits | Metropolitan Toronto | D.C. and adjacent counties in Md. & Va. |
| 1-1. Service coverage | 1/2 mi of 90 percent of residents where population density exceeds 4000/mi$^2$ | 90 percent of residents within 3/8 mi of a bus route | 75-90 percent urban area—local<br>50-75 percent suburban areas, depending on density & access | 1/4 mi except where physical barriers require closer<br>CBD—3 blocks, 900 to 1200 ft | | 1/4 mi except where physical barriers will not permit operations<br>CBD - 3 to 4 blocks |
| 1-2. Route structure (Pattern, orientation, confirguration) and<br>1-3. Route spacing | Predominantly radial pattern with focus on rail transit stations<br>Operate only on paved streets with at least 10-ft lanes.<br>Avoid areas without adjacent land dev.<br>Spacing—see Table 3 | Grid system 1/2 mi sp.<br>Service keyed to rapid transit stations<br>Radial service to CBD, esp. in corridors without rail<br>Generally every 1/2 mi; closer in CBD; 1 mi in outlying areas | Local: 1/4 mi general—population; 500 ft—senior citizens<br>Suburban: low-density, high auto ownership—1 mi; moderate density & auto ownership—1/2 mi; high density, low auto ownership—1/4 mi | | Grid on major streets complemented by rail | Overlapping radial routes being replaced with shorter routes focusing on rail transit stations |
| 1-4. Route directness or diversion | Minimize crosstown paths; route deviations not to exceed 8 min per round trip—made permanent if 10 new customers per round trip; no more than 25 percent transfers | Minimal diversion | | Not over 1.2 times that for car; minimize transfers—20% desirable target | Diversion subject to patronage impacts | Provide direct alignment and avoid circuitous routings |
| 1-5. Route length; through vs. breaking routes | Two routes with common term. may become through route if—they have more than 20 percent transfer rate, they serve opposite directions, have similar service hours & freq., & combined route trip not over 4 hrs; route ext. less than 1 mi o.k. if it eliminates transfers of at least 20 percent; link two infrequent services; schedule adherence takes precedence over through-routing | Avoid excessively long routes | | Link and through—route buses in CBD; cross-town service where serving substantial movements and avoid excessive travel distance; otherwise, group riding or paratransit | | Link crosstown routes, avoid excessively long routes—orient radial routes as feeders to the rapid rail stations |
| 1-6. Route duplication | Avoid competitive, overlapping service except at a major activity center | Generally, one route per street except on CBD approaches | | | One route per arterial | Provide evenly spaced headways on each route; coordinate multiple routes on common line |
| 1-7. Express service | Provided on freeways in corridors without rail service | On freeways, blvds, & arterial streets—nonstop and limited stop; concentrated in corridors without rail transit | | | Not provided | Provided into suburbs; most such service is concentrated on Shirley busway |
| 1-8. Special transit (school, paratransit) | Special community—based service where there is a substantial percentage of the population which is handicapped or over 65 | | | | | May be provided by jurisdiction where bus service is not provided by the Authority |
| 2. SERVICE LEVELS<br>2-1. Service period | Premium service: 7-9 a.m. & 4-6 p.m. M-F; regular routes 6 a.m.-6 p.m. M-f; school & industrial det. by potential; community service 9 a.m.-4 p.m. M-F | 3/4 of bus routes and 5 transit routes operate 24 hr | Local: min. 6 a.m.-7 p.m. M-F; des. 5 a.m.-11 p.m. M-F, 7 a.m.-11p.m. Sat., 9 a.m.-7 p.m. Sun.<br>Feeder: weekday peaks 6-9 a.m. & 4-7 p.m. | Weekdays: 6 a.m.-7 p.m. all fixed routes; weekends, holidays: selected routes | | Rail—<br>6 a.m. to 12 a.m.<br>5 min peak & 10 min base<br>Bus—<br>Regular: 5 a.m. to 1 a.m.<br>Peak: 7 to 9 a.m. & 4 to 6 |

| | BOSTON | CHICAGO | NEW JERSEY | SEMTA | TORONTO | WASHINGTON, D.C. |
|---|---|---|---|---|---|---|
| 2-1. (continued) | | | Suburban: same as local but stop before 11 p.m. | | | p.m.<br>Suburban: 6:30 a.m. to 11 p.m.<br>Owl: 1 a.m. to 5 a.m. |
| 2-2. Policy headways | Reg. routes: 30 min peak and midday, 60 min eve.; Community-based: 60 min midday and eve., peak det. by demand | 20-30 min midday; reflect need for transfers on grid system | Local: 10-20 min peak, 15-30 min off-peak, suburban: 15-30 min peak, 30-60 min off-peak;<br>Feeder: related to rail schedule | 30 min if average 10 pass./1-way trip; 60 min evenings and weekends; based on high 15 min at max. load | Peak: 20 min; off-peak 30 min | 60 min for off-peak and eve. except 30 min in D.C. midday |
| 2-3. Loading standards | Peak 30-min: 140 percent, intra-commun. 120 percent;<br>Peak total: 120 percent, intra-commun. 110 percent;<br>Midday & ev.: 100 percent;<br>Line-haul: no stds., sched. less than 100 percent | Peak, 4 min or less: 70-75 per bus, 150 percent<br>Peak, 10 min or more: 50 per bus, 100 percent<br>Base: 25-40 per bus<br>Eve.: 20-35 per bus | Local & feeder: 125 percent peak, 100 percent off-peak, 100 percent peak trip greater than 15 min;<br>Suburban: 1 seat/pass. at all times | Peak: 4 across seats—125 percent, 3 across—140 percent<br>Off-peak: 100 percent | Peak max. 30 min: 65-75 pass./veh., 160-180 percent<br>Peak max. 1 hr: 55-65 pass./veh., 135-160 percent<br>Trans. period: 41-55 pass./veh, 100-135 percent<br>Off-peak: seated, 100 percent | Peak: 140 percent; Midday and Saturday: 120 percent; Eve. & Sunday: 100 percent; Express: 100 percent |
| 2-4. Bus stop (frequency, location, length) | Res. areas 8/mi max., Commercial 12/mi max.;<br>Length (min.): near—60 ft, far & midblock—80 ft; far-side perferred; multiple length for combined headway 5 min or less | 1/8 mi general policy, predominately near-side | Commercial areas and CBD: by demand; residential 700 ft min., max. 8/mi, ave. 4-5/mi | 600-700 ft, near-side; min. length 80 ft near-side, 70 ft far-side; additional positions for multiple routes with headway of 5 min or less | Major signalized intersections & intermediate locations; major generators; ave. 750 ft, range 400 to 1500 ft | CBD 1-2 blocks; res. neighborhoods 2-3 blocks; rural areas "flag stops" on signal |
| 2-5. Route speeds | Ave. operating & sched. speed within 1 quartile deviation; 1975 $\bar{x}$ = 13.9, 11.0; a = 2.3, 2.4; $S_x$ = 11.8, 8.6;<br>Proportion of layover to running time should be less than 20 percent, never to exceed 30 percent | | Min. speed 10 mph | Running speed 13-14 mph, sched. speed (incl. layover & access to garage) 12-13 mph | | City—10 mph<br>Suburbs—15 mph<br>Express—20 mph |
| 2-6. Passenger journey times | | | Local: less than 3 times by car, less than 45 min<br>Feeder: less than 3 times by car, less than 20 min<br>Suburban: less than 2 to 2.5 times by car | | "Access" index based on 270 ft/min:<br>$T_t = \Sigma P_i t_i + \sqrt{h}$<br>where h = headway<br>$P_i$ = population in strata i<br>$t_i$ = distance of strata i divided by 270 | Accessibility to CBD<br>Suburbs 30-40 min<br>City 15-20 min |
| 2-7. Service reliability | 95 percent of service on time except headways less than 10 min—80 percent | | See Table 14 | On-time to 3 min late: 80 percent, 90 percent midday, 100 percent other | | Less than 1 min early—all<br>Less than 5 min late—90 percent |
| 2-8. Equipment reliability | 10,000 rev. mi/disruption; 99.9 percent of sched. trips completed per quarter | | | 7000 mi/mech. road failure | | 3800 miles avg. bus miles betw. road calls |
| 3. NEW ROUTES & SERVICE CHANGES<br>3-1. Steps and procedures and<br>3-2. Service evaluation process | Planning principles:<br>—Community involvement<br>—Reasonable, affordable cost<br>—Monitor existing and trial service against standards and guidelines; analyze substandard services and | Terminal with facilities for drivers is essential<br>Adequate street geometry<br>Assess potential traffic including interviews with industries | | | Existing routes:<br>— Rank routes in order of net profit or loss, analyze lowest 25 percent<br>— Rank routes by ave. number of pass. on board between each pair of adjacent stops | Existing lines:<br>—Check riding and environment along line<br>—Review pass. and revenue by jurisdiction—<br>-pass. carried<br>-revenue/mi<br>-revenue/trip |

| | BOSTON | CHICAGO | NEW JERSEY | SEMTA | TORONTO | WASHINGTON, D.C. |
|---|---|---|---|---|---|---|
| 3-2. (continued) | prepare remedial action<br>—Planning changes involves screening, analysis, revenue and evaluation | | | | — Assess routes that have disparate net revenue and use<br>— Assess revenue pass. quarterly to review ridership changes; if greater than 10 percent, count ridership and possibly adjust service<br>New routes:<br>— Examine physical constraints for practicality<br>—Estimate ridership and costs<br>—Evaluate economic viability; if loss less than 50¢/bus mi or if "access time" less than 10,000 person min., continue evaluation based on other factors | —Check loads along line and at max. load points<br>—Identify rider characteristics<br>New services—check:<br>—Population and density in service area<br>—Distribution and concentration of employment<br>—Income and age structure of population<br>—Travel generators along service corridors<br>—Evaluation of ridership<br>—Projected revenues<br>—Lines of travel demand<br>—Cost of operation<br>—Availability of manpower & equipment<br>—Terrain and street pattern |
| 3-3. Service warrants (economic criteria) | New routes should not duplicate existing service and should meet at least one of these criteria:<br>—min. 25 pass./bus hr<br>—min. 2000 persons/mi$^2$<br>—Min. 20 pass./revenue mi.<br>Minimum ratios of revenue to direct cost:<br>regular route—0.30;<br>premium—0.50;<br>school—0.10;<br>contract/manifest—1.00;<br>industrial—0.50;<br>community-based—0.20<br>Passengers/hr: min. 15<br>Pass./mi: peak 2.5, off-peak 1.5<br>Adjustments for: 60 percent transit dependent, 25 percent elderly; reduction of 200 or more VMT; or 60 percent transfer—a) ratio revenues to cost 0.10, b) 10 pass. per revenue hr, c) pass./mi 2.5 peak, 1.0 off-peak<br>Discontinue service if it fails to meet economic, social, or environmental standards, and if it does not produce external benefits | | Local/feeder: revenues cover 40 percent of total line cost or cover "over-the-road operating expense. If neither of these, and 1/2 of deficit cannot be subsidized by county, consider curtailment<br>Suburban: revenues should exceed total operating expense. Otherwise 3/4 of route deficit subsidized by county, or curtail service | Fares should cover 50 percent of all cost of operations<br>Fixed route, scheduled all day: 6000 pers/mi$^2$, CBDs, and major outlying centers<br>Fixed route, times of specified demand only: residential densities 2000-6000/mi$^2$, and factories, schools, & institutions generating traffic at opening and closing hours<br>Demand services: Subscription—taxi, etc.—densities less than 2000/mi$^2$ | Selection process for new or adjusted service:<br>1. Assess economic and access performance of existing & new routes<br>2. If route does not meet criteria for revenue, access, & travel time, evaluate transit-dependency & land use<br>3. Routes that do not meet 1 & 2 would not be considered further<br>4. Rank routes for net revenue, access change, access/unit cost, ridership/unit cost, & contribution to transit-dependent or land-use planning goals<br>5. Implement changes first for routes that rank in top 10 percent of all factors<br>6. Progressively implement routes that rank in top 10 percent of ridership/unit cost of access<br>7. If resources are available, recycle for next 10 percent | If a jurisdiction is willing to assume 100 percent of cost, then provide service assuming availability of manpower and equipment |
| 3-4. Frequency of change | Major changes 4 times/yr with new system schedules. Minor changes at other times | | | | | Minor changes and schedule adjustments are made weekly<br>Major changes are made 2 times/yr |
| 3-5. Length of trial period | Min.—6 months | | | | 6-month trial period for experimental service | 6 months for experimental service |

| | BOSTON | CHICAGO | NEW JERSEY | SEMTA | TORONTO | WASHINGTON, D.C. |
|---|---|---|---|---|---|---|
| 4. PASSENGER COMFORT & SAFETY<br>4-1. Passenger shelters | All stops that serve 300 or more boarding or transferring pass. per weekday (for priority guide see Table 5) | | Local/feeder: 300+ boarding pass./day min. preference—high senior citizen population & transfer points<br>Suburban: 100+ pass. plus major transfers and park & ride | 350 or more boarding or transferring passengers on a typical weekday | | At boarding and transfer stop that serves 100 or more riders on a typical weekday (long-term aim)<br>At all major downtown loading stops<br>On inbound stops only in residential neighborhoods |
| 4-2. Bus maintenance | | | Clean vehicles with destination clearly indicated; stops well lighted, schedule & fare info. at each stop; suburban buses—air conditioning & shelters | Average age: 1/2 depreciable life; spares should not exceed 10 percent of max. vehciles in service<br>Use proper fuel for city and suburban services<br>Establish procedures for drivers and road inspectors to report smoke, noise, and vibrations<br>Provide daily outside wash and interior sweeping, biweekly glass cleaning floor mopping<br>3000-mi preventive maintenance inspection<br>Body & paint work should maintain good appearance | | Avg. fleet age is 7-yrs<br>Spares should not exceed 12 percent of scheduled fleet; 5,000 mi preventive maintenance inspection; one maintenance employee for every 2.6 buses; exterior cleaning 2 times weekly; air-conditioning 98 percent operable |
| 4-3. Bus route & destination signs | | | | Provide simple, uniform, eaily understood route numbering system displayed in as large lettering as possible in illuminated destination signs | | New buses: 3-digit route number displayed front, right side, and (with reservations) rear; display destination on front and right side; auxiliary info. (e.g., class of service) in lower corner of windshield |
| 4-4. Passenger information service | | | | Telephone route number & schedule info. should be available from well-publicized numbers and with sufficient operators to avoid delays | | Answer 85 percent of all calls for information within 5 min of time call received |
| 4-5. Route maps & schedules | | | | Provide uniform schedule folders including route map and trip departure times from major departure points not over 10 min apart<br>Provide printed schedule folders on buses, at bus system offices, & on a regular mailing list basis | | Provide public timetables including route maps for each route. Information is available for some 145 individual lines and 888 separate routes. System route maps are not published at present |
| 4-6. Driver courtesy, efficiency, & appearance | | Reasonable appearance, no unduly long hair | | Careful selection, training, retraining, supervision, and disciplining of drivers | | 6-weeks intensive training program for drivers |
| 4-7. Security (passengers & revenue) | | Exact fare procedure<br>Bus monitor system<br>Uniform and other police patrols | Fare structure and collection methods should provide for security of fare revenue and permit compilation of necessary statistics | Provide radio communication for driver, secret emergency alarm system, special transit police<br>Surveillance of principal stops<br>Minimize fare evasion and maximize security of fares on bus and at depot | | Keene Vacuum System for fares<br>Radio communication on all vehicles<br>Silent alarm and flashing lights on buses<br>Separate transit police force and coordination with jurisdictional and local police |

# APPENDIX D

## TTC ROUTE SELECTION PROCESS

### PHASE A. INFORMATION GATHERING AND EARLY FILTERING

i. Guidelines for schedule design and operating performance will be applied to all existing routes throughout the year. This allows for identification of possible economies or, alternatively, identifies where service should be improved on existing routes if resources are available. Coincident with this, proposed new service requests will be gathered throughout the year.

ii. Revenues and costs will be allocated to existing routes. Those routes in the bottom quartile of this ranking will be compared to new routes only if a detailed examination reveals that these routes cannot be improved through routing or schedule adjustments and if these nonimprovable routes have a low average occupancy.

iii. At this point, there may be new service proposals awaiting consideration as well as existing routes that perform poorly economically and existing routes that require service improvements, where resources are not currently available.

iv. If resources are available, the first priority is to improve service on those existing routes identified in step i as requiring an improvement in service. This would leave only poorly economically performing existing routes, and new service requests for further consideration.

v. The net revenue for those routes in the bottom quartile is known and consequently new service proposals will be examined to determine their potential net revenue. If this examination reveals that the potential revenue exceeds that of the economic filtering point, the new route would be considered for ranking in phase B regardless of the new proposal's performance with regard to the other evaluation factors.

vi. For those new proposals whose potential net revenue is lower than the economic filtering point and for existing routes being considered (where it is known that their net revenue is below the filtering point as per step ii), the access index will be determined. Should this figure exceed 40 000 person minutes for any existing service or new service proposal, the service would be considered for ranking in phase B regardless of its performance with regard to the other evaluation factors.

vii. For those routes not qualifying for phase B on the basis of net revenue or access, any improvement in transit travel time will be assessed. If this improvement exceeds a value yet to be determined in the light of future research, the service would be considered for ranking in phase B.

viii. For those routes that do not attain the filtering levels as they relate to net revenue, access, and travel time, analyses will be undertaken to determine the contribution to land use planning or transit dependency. Should either of these be high, a special subsidy would be sought and the routes would be considered for implementation according to the level of the subsidy forthcoming.

ix. Any service either existing or requested that does not meet the net revenue, access or transit travel time filters, and which does not contribute to land use planning or aid transit dependency to such a level that a subsidy would be forthcoming, would not be considered further in phase B.

x. Coincident with all of the above, community input would be sought.

### PHASE B. COMPARATIVE RANKING AND IMPLEMENTATION EVALUATION

i. At this point all routes determined to be eligible for phase B as determined through phase A would be ranked for net revenue, access change, access per unit of cost, ridership per unit of cost, and improvement in transit travel time and identified as either contributing or not contributing to aiding transit dependents or land-use planning goals.

ii. Any service considered in phase B that ranks in the top 10 percent of all factors and contributes to both aiding transit dependents and land use planning would be implemented.

iii. If resources were still available, routes ranking in the top 10 percent of ridership per unit cost and access only would be implemented.

iv. If resources were still available, those in the top 10 percent of ridership per unit cost would be implemented.

v. If resources were still available, those in the top 10 percent of access per unit cost would be implemented.

vi. If resources were still available, those that exceed the transit travel time filter would be implemented.

vii. Should resources still be available, steps ii to v inclusive would be repeated for routes in the top 11 to 20 percent.

viii. This process would be repeated in each 10 percent increment up to 100 percent or until resources were depleted.

Once implemented under phase B all new services or extensions selected for implementation will be experimental for 6 months. They will be reviewed 90 days after service commences and, if necessary, service will be altered to improve ridership or reduce costs or both. After 6 months, the service will be reviewed and a decision made as to its future.

A new service that ranks in the top 40 percent but is not implemented in the current year would automatically be considered in future years.

# APPENDIX E

## MBTA SERVICE PLANNING PROCESS

The MBTA service planning process includes two basic types of short-range service planning activities:

1. *Performance evaluation and analysis* consist of (a) monitoring existing and trial services against established standards and guidelines; (b) reviewing and analyzing substandard services; and (c) preparing remedial action plans to rectify deficiencies.

2. *Planning for new or improved services* consists of development of plans for new or improved services in conjunction with affected communities and using Service Design Guidelines and including coordination with new rail transit station planning.

The process consists of the following four stages:

I. *Screening.* Proposals for service changes (requests, suggestions, complaints) are screened for validity by the Service Committee; a proposal is either sent on to stage II or is rejected for cause (tried within the past 12 months or patently impractical or unfeasible within policy guidelines at the time).

II. *Investigation and Analysis.* Proposals for service changes are investigated and analyzed by the appropriate department or office. During this stage, interaction and discussion occur with the Advisory Board representative(s) involved and other community representatives on proposals. The analysis and investigation of a proposal can be undertaken cooperatively by more than one department or office. The output of this stage is a feasibility report.

III. *Review.* Proposals for service changes and attendant feasibility reports are reviewed first by the Service Committee. The Service Committee will either recommend the proposed change, reject it, or request further analysis and investigation. If the Service Committee recommends a proposed service change, then it is reviewed by the Budget Director and Director of Operations for the Authority and the Advisory Board representative(s) from the community involved. The Director of Operations has the ultimate responsibility for making the decision on whether or not a service change should be implemented. In making this decision, the Director of Operations will obtain the concurrence of the MBTA Budget Director and will consult with the Advisory Board representative(s) from the community (ies) affected by the change.

IV. *Operation and Evaluation.* Once a proposal clears the study, review, and decision-making process, it is put into operation at the earliest practicable time. The service will be operated for a minimum trial period during which time its performance is monitored. During the trial period, a decision is made on whether or not the service should become a regular feature of the Authority's surface system. This decision will be based upon an evaluation of the service's performance against established criteria. No service operated by the Authority is considered permanent. All services are monitored continuously and their performance evaluated.

This process forms a closed feedback loop. Services are operated and evaluated in stage IV. This evaluation identifies those services that are "substandard." This evaluation is performed by the Operations Planning Department and is reported to the Service Committee along with preliminary proposals for remedying the substandard performance. This reporting mechanism closes the feedback loop. The Service Committee reviews the evaluation reports and screens the proposals for improving substandard performance thereby triggering the planning process.

The performance evaluation and subsequent identification of remedies for substandard services (remedial analysis) are conducted 4 times annually.

# APPENDIX F

## BUS SERVICE CHANGE EXAMPLES

### CTA PLANS

| Depot Shuttle Service | OP-x74543 |
|---|---|
| Recommended Improvements | 12/31/74 |

The tremendous growth in activity on North Michigan Avenue in recent years has created two of CTA's most successful services; route 158 Wacker-North Western (particularly the trips to Walton Street) and route 158A Wacker Express. The volume of passengers being carried makes it possible to support additional and better quality service to the area. In addition, trips which are difficult on the present system, such as from the Hancock Building area to Union Station and from Streeterville to the Merchandise Mart and the area west of the River, have grown considerably in recent years.

Overcrowding is a problem on both the 158 and 158A, particularly at North Western Station. Rather than simply adding buses to these lines CTA has the opportunity to provide a more marketable route network in this area.

There is presently no midday or Saturday service from North Western Station to North Michigan Avenue. Anyone wishing to make this trip either transfers or walks a considerable distance to complete his trip.

To better serve riders and attract potential riders, a new route structure is recommended:

—Create two new routes, one serving Union Station and one serving North Western Station, replacing the current #158A.
—Establish a new business day (about 7:00 AM to 6:00 PM) and Saturday express route to connect the North Michigan Avenue area and the railroad stations via Ohio/Ontario and the Merchandise Mart.

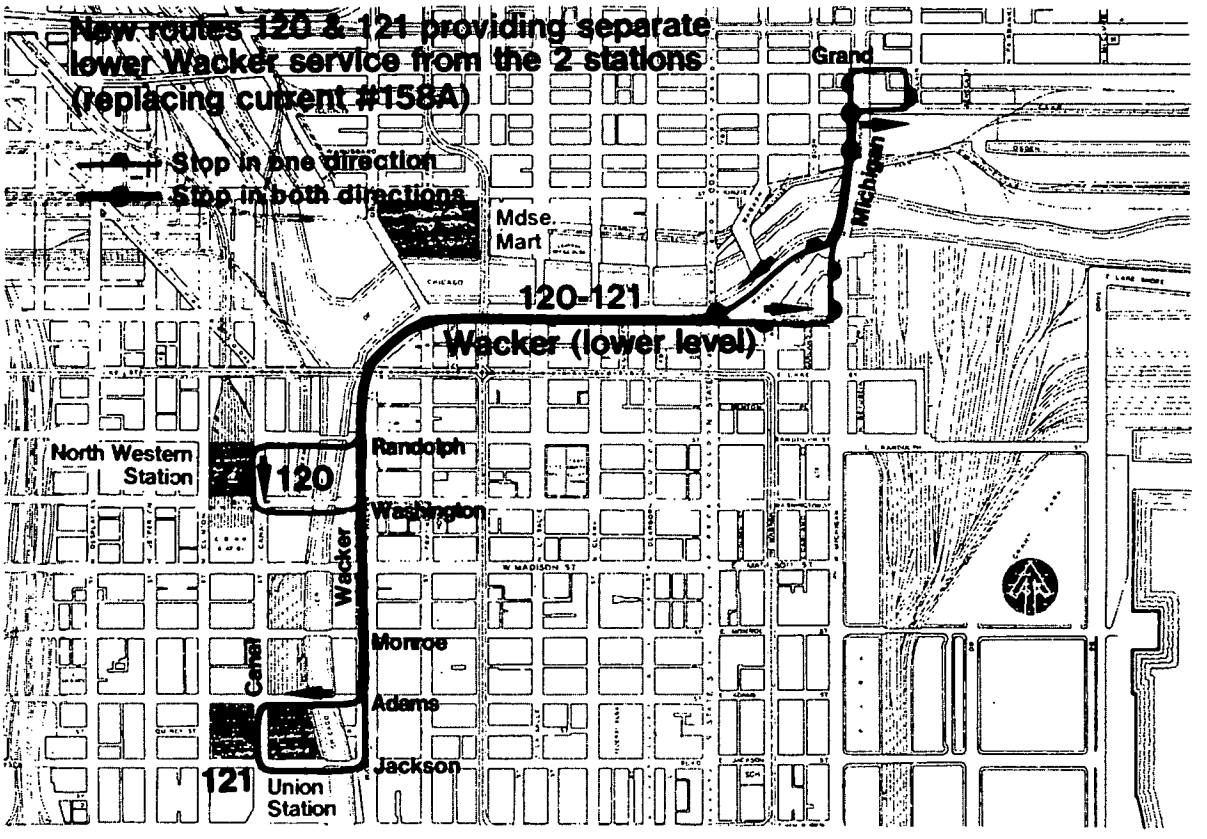
These changes would allow the discontinuance of #158 and #128 except those trips to Montgomery Ward.

Related recommendations in the area served by 35¢ shuttle routes are also made in this report.

Create two routes replacing #158A Wacker Express

These routes, providing separate services from Union and North Western Stations, would operate via the lower level of Wacker Drive with no passenger stops between the stations and State Street. The route would be designated #120 NW/Wacker Express and the #121 Union/Wacker Express. The present combined route was established in 1958 with four trips each rush hour. Riders of the service (particularly North Western Station users) would be greatly benefitted by

separation of these routes. Service would continue to operate in rush hours only. Since midday and early evening service is provided to this area by the newly-rerouted #157, service on the fringes of the rush can be eliminated.




One major advantage of operating #120 just to North Western Station is that it would operate into the bus lane at the Station, avoiding the need for passengers to cross Canal Street in both the morning and afternoon. The route of the two services is shown on the above map.

Create a new route from Union and North Western Stations to North Michigan Avenue

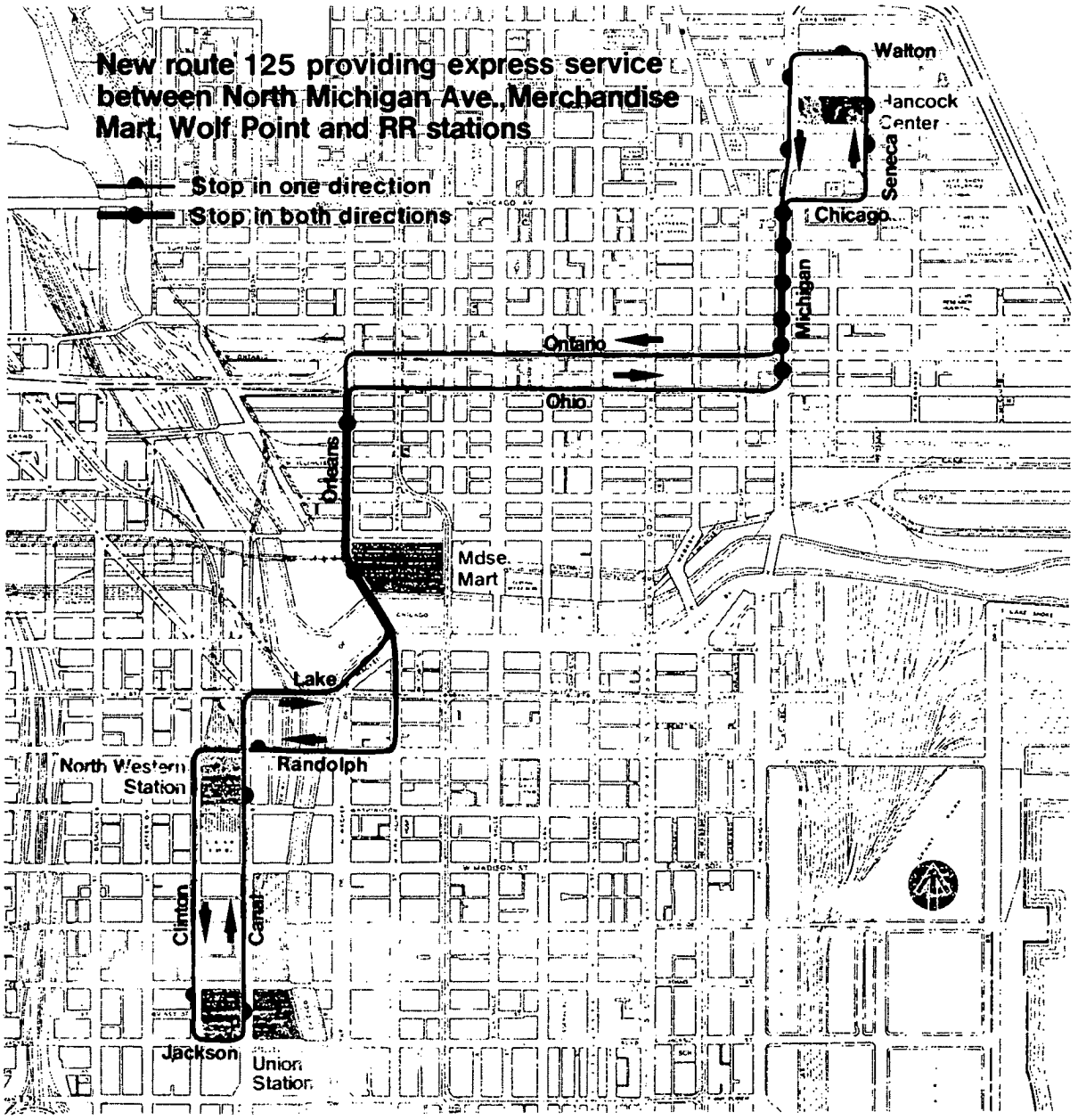
This route would operate via the Merchandise Mart (and the new Wolf Point Development) and feature non-stop use of the timed traffic signal sequences on Ohio and Ontario Streets It is recommended that it be designated route #125 Water Tower Express. This route would operate during the business day Monday thru Saturday. The only stops should be at the stations, the Merchandise Mart, Grand Avenue, and then regular stops north of Michigan/Ontario.

With the changes recommended in this report, passengers will be better served. Passengers destined north of Ohio Street will have express service on new route #125. To points between Wacker/State and Michigan/ Ohio passengers can ride the new #120 or #121 routes avoiding traffic by

traveling on Lower Wacker Drive. The few passengers who travel to points short of State Street can ride the #15 Canal-Wacker operating on the upper level of Wacker Drive.

This is the most exciting of this set of recommendations. This new route would give CTA a significant marketing advantage against competitive modes. Use of the Ohio/Ontario pair between Orleans and Michigan will make the route competitive with taxicabs. From the John Hancock Building travel time would be five minutes faster than the present #158 service to North Western Station and ten minutes faster than the #151 Sheridan service to Union Station.

This route would perform most of the work now performed by the #128 Wacker-Orleans between the stations and the Merchandise Mart. #128 trips would be maintained for trips to and from Montgomery Wards at Chicago/ Larrabee.



| South Commons Area | OP-x74369 |
|---|---|
| Partial rerouting of #1, #3, and #38 | 9-20-74 |

Considerable residential and commercial development has occurred in recent years in the South Commons area, south of the Stevenson Expressway between Michigan Avenue and King Drive. In order to better serve this developing area and reduce service to adjacent areas that are being vacated, rerouting portions of #1 Drexel-Hyde Park, #3 King Drive and #38 Indiana north of 31st Street are recommended as follows:

#1 Drexel-Hyde Park

#1 Drexel-Hyde Park buses could serve additional traffic generators if routed along 26th Street between King Drive and Michigan, instead of Cermak Road, serving the Mercy Hospital complex, South Commons apartments and Prairie Courts housing project. The proposed route would be north along the present route to King Drive and 26th Street, then via 26th, Michigan, Indiana, Cermak and Michigan to and over the present route. Several populated housing and employment complexes are in this area, and expansion of Mercy Hospital is continuing to further increase the need for public transportation. Mercy Hospital officials indicate that most of their employees reside on Chicago's South Side and would benefit from a direct service such as this. The present trips usually involve one or more transfers and/or a three block walk to the hospital complex. Since 2200 people are presently employed at Mercy Hospital (many of whom now drive or car pool) there exists a potential for transit ridership.

The residents of South Commons, a middle class integrated apartment complex of approximately 3500 people, have requested additional service since the discontinuance of #5 Jeffery and #2 Hyde Park local, leaving only #38 Indiana on South Michigan between 31st and 26th as transportation to the CBD. In South Commons many of the residents commute to and from the Loop to work, shop and for various other activities. Routing #1 via 26th Street would provide additional service for these residents, especially those in the northern end of the complex, as well as to the 1800 residents of Prairie Courts public housing project on 26th Street between King Drive and Prairie.

Riders on the #1 route average 44/bus in the morning rush period and 57/bus in the evening rush period at 26th/King Drive. Little traffic is generated on the present route between King Drive/26th and Michigan/Cermak. During a recent check, only 19 passengers

boarded and 26 alighted all day, so that very few riders would be inconvenienced by the proposed change. Additionally, there is little ridership generated on Indiana between Cermak and 16th Street. A handful of small light industry factories are in this area; however, the #4 Cottage Grove buses would remain on Indiana to 16th Street to serve these few riders after the #1 and #3 are moved to Michigan Avenue. The additional 3/5 mile that the proposed routing involves would cost approximately $9500 per year in mileage costs at 53¢ per mile. Additional vehicles or manhours would not be required. Running time would be approximately the same as present.

#3 King Drive

The #3 King Drive buses would have a more direct routing by remaining on King Drive to Cermak, then Cermak to Michigan and over the present route, rather than via 24th Street between King Drive and Michigan. Virtually no traffic is generated on 24th Street as there is only a Brinks' storage garage along this two block stretch, surrounded by fields and empty lots. Also, very few people board and alight #3 King Drive buses on Michigan between Cermak and 24th Street. The #38 Indiana bus and the #1 Drexel-Hyde Park bus would continue to provide service to this area.

Approximately 1500-1700 riders per rush period using the #3 King Drive service through this area would benefit by possibly reducing the running time and providing a more direct service to and from the Loop area.

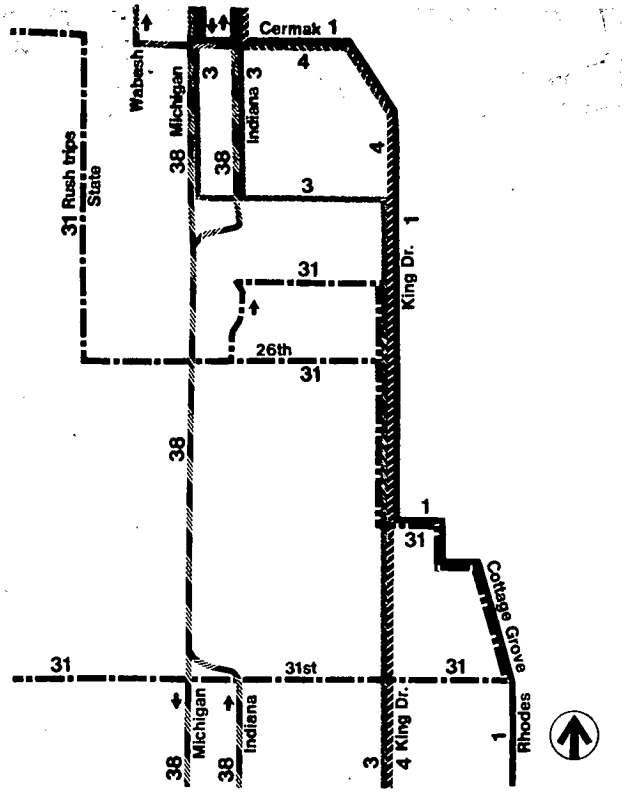
#38 Indiana

A more efficient and less confusing routing of #38 Indiana could be accomplished by operating it in both directions on Michigan north of Cermak rather than southbound on Michigan and northbound on Wabash. The proposed routing would be over the present route from the south terminal to Cermak, then continuing north on Michigan rather than via Wabash to Adams and over the present route.

There is presently no northbound bus service on South Michigan between Cermak and 16th Street where there are two large apartment complexes housing approximately 2100 persons. These complexes, in addition to the rental units, house a day care center, visiting nurse association and various other facilities--all potential traffic generators. Little traffic is generated on Wabash Avenue because most businesses are wholesale auto parts dealers or warehouses. Neither attracts transit riders.

Since so little traffic is generated on both Wabash and Indiana north of Cermak, it seems most advantageous to route all three lines (#1, #3, #38) both north and south on Michigan. This continuity of service on Michigan is desirable when few people are boarding and alighting in the area; additionally the large apartment complex will be adequately served.

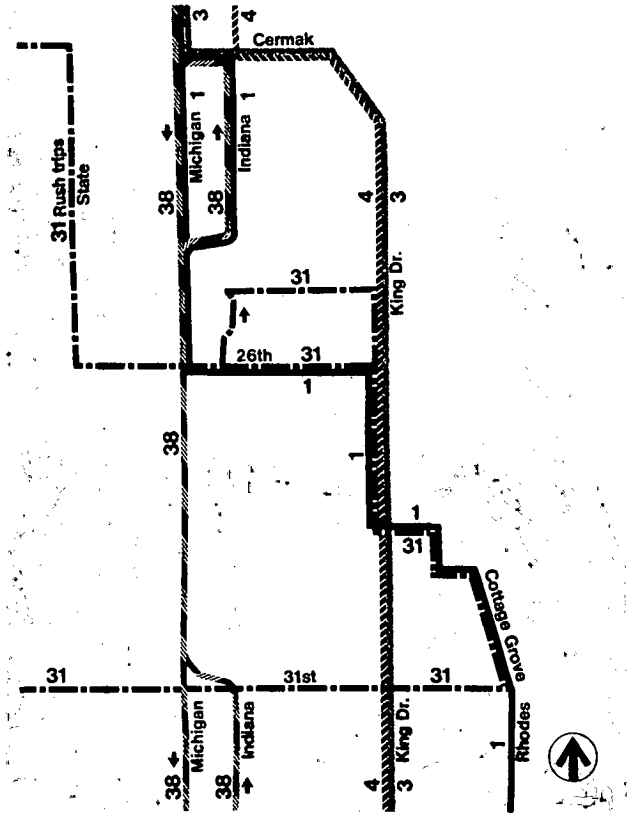
## Present Service




**Route Legend**

1 Drexel-Hyde Park
3 King Drive
4 Cottage Grove
31 26th-31st
38 Indiana

## Proposed Service



### Route 12 (Main Line)

This line serves the Oakland Army Base at one end and the Piedmont Avenue neighborhood on the other. From driver and traffic checks, it appears that the Army Base end is very weak in the off-peak periods. It passes through a part of Oakland which is and has for several years been under redevelopment. Some minor rerouting was planned in March 1979 because of construction of the Grove-Shafter Freeway. Headways are 15 min in the peak hours and 20 or 30 min in the off-peak. The 88 and 83 lines in combination offer service in most of the same area of West Oakland as the 12 line.

Possible remedies include a reduction in headways during off-peak hours to 60 min or a rerouting during off-peak to serve both the Oakland West BART station and Amtrak with the line terminating at one of the two instead of continuing to the Oakland Army Base. However, an analysis of origin-destination and passenger loading data from the on-board survey should be done before any changes other than schedules are made. As the Oakland Redevelopment projects are completed, the ridership may improve due to a more stable environment and more residents in the area.

### Route 32 (Main Line)

This route offers commute-hour-only express service from South Hayward through San Lorenzo to downtown Oakland with 20-min headways. It extends 35 one-way miles with boardings and deboardings only at each end and a long middle stretch with no stops. Although the bus runs full, there is a large segment that generates no new revenue or ridership for its length, thereby reducing the line's performance under revenue and ridership indicators to below standard. A load factor of 83 percent indicates fairly high patronage, confirming this analysis. A marketing effort may increase ridership some, but there is not much room for additional riders at existing service levels.

From South Hayward to downtown Hayward, this line runs parallel to the BART system and the 82 line. From San Lorenzo to the Freeway, the line serves an area also served by the 36 line. In the next year, the full line should be evaluated with the possibility of moving the Hayward portion to the west to serve an area without transit service and combining the line with the 36 line in the San Lorenzo area.

### Route 36 (Main Line)

This peak-hour-only express service operates between San Lorenzo and the downtown Oakland with three trips in the morning peak direction and three trips in the evening peak direction. Initially, the revenue for one trip in each direction was intermixed in other lines and costs for supplemental service on another line were charged to this line. After making the appropriate corrections, the line still failed four indicators: farebox recovery, subsidy per passengers, passengers per mile, and passengers per hour. The load factor of 53.9 percent indicates the buses are running slightly over half full implying a service level in excess of the demand. This line originates in an area that is also served by the 32 line. Transit service in that area should be evaluated with the possibility of combining the 32 and 36 lines.

### Route 84 (Feeder)

This route was designed specifically as a feeder to BART from Castro Valley. The area is served by an express to downtown Oakland (34), a transbay line (RCV), and two local lines (80 and 91). Both the 80 and 91 also feed BART although not to the same station as the 84. While neither of the local lines exactly duplicate the 84, in combination they provide service over the same area. The headways of the 84 are 15 min in the peak period and 30 min in the off-peak period with weekday service only. The 80 has less frequent headways while the 91 has approximately the same. This line could be curtailed or eliminated and the riders encouraged to use the available alternate service.

A reduction of service to 30 and 60 min headways would reduce the equipment requirements by one bus at a savings of about $90 000 annually. Elimination of the service would save approximately $210 000 per year.

# APPENDIX G TRANSIT PLANNING AND MANAGEMENT FACTORS (55)

| Variable or Statistic | Definition |
|---|---|
| (1) Total Annual Bus Miles Operated | Sum of all passenger vehicle miles operated in line (regular) service, special (charter) service, and nonrevenue service.[1] |
| (2) Annual Bus Miles in Charter Service | The ratio of total annual charter revenue to total annual operating revenue (regular service revenue plus charter service revenue) multiplied by total annual bus miles operated. |
| (3) Annual Bus Miles in Regular Service | Total annual bus miles operated less annual bus miles in charter service. |
| (4) Service Area Population | The population of the area accessible to transit service. Accessibility to transit service is determined by the reporting system, but is normally a measure of distance, e.g., any person residing within four blocks of a transit route has access to transit service.[2] |
| (5) Annual Bus Miles Operated (Regular Line Service) per Person Served | (3) ÷ (4) |
| (6) One-Way System Route Miles | The sum of the actual length (one way) of all streets or highways traversed by motor buses. When several routes pass over portions of the same street or highway, each route is counted separately.[2] |
| (7) One-Way System Route Miles per 1,000 Persons Served | [(6) ÷ (4)] [1,000] |
| (8) Peak-Period Buses | The maximum number of motor buses operated during one morning or evening peak service period.[2] |
| (9) Peak-Period Buses per 100,000 Persons Served | [(8) ÷ (4)] [100,000] |
| (10) Annual Revenue Passengers (Regular Line Service) | Total number of rides taken by originating passengers paying a full adult cash fare, child fare, student fare, senior citizen fare, handicapped person fare, or other reduced fare.[2] |
| (11) Annual Revenue Passengers (Regular Line Service) per Regular Service Bus Mile | (10) ÷ (3) |
| (12) Weekday Passengers per One Way Route Mile | $\frac{[(10) \div (6)]}{295.5}$ |
| (13) Passenger Revenue | Fares, including transfer charges and zone charges, paid by transit passengers traveling aboard transit vehicles operating in regular service.[1] |
| (14) Passenger Revenue per Bus Mile | (13) ÷ (3) |
| (15) Total Operating Cost | The sum of all transit system operating expenses. |
| (16) Operating Cost (Regular Line Service) | Total operating cost minus the ratio of total annual charter revenue to total annual operating revenue multiplied by total operating cost. |
| (17) Operating Cost per Bus Mile | (16) ÷ (3) |
| (18) Operating Ratio (operating revenue ÷ operating cost) | (13) ÷ (16) |
| (19) Average Fare (passenger revenue ÷ revenue passengers) | (13) ÷ (10) |

[1] APTA. Transit Fact Book: 1975-76.

[2] APTA. Transit Operation Report for Calendar/Fiscal Year 1974.

| Variable or Statistic | Definition |
|---|---|
| (20) Operating Cost per Passenger | (16) ÷ (10) |
| (21) Net Income per Passenger | [(13) − (16)] ÷ [(10)] |
| (22) Buses in the Base Service Schedule | The greatest number of buses operated during one-day base service period.[2] |
| (23) Ratio of Peak to Base Buses | (8) ÷ (22) |
| (24) Total Buses Active | Number of buses regularly maintained in condition for active service including vehicles temporarily out of service for repairs. |
| (25) Percent Spare Buses to Total Buses | The ratio of spare buses to total buses active. |
| (26) All Employees, Average Number | The average number of total transit system employees including bus operators employed by a transit system during the reporting period.[2] |
| (27) Employees per Peak Bus | (26) ÷ (8) |

[1]APTA. Transit Fact Book: 1975-76.

[2]APTA. Transit Operation Report for Calendar/Fiscal Year 1974.

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