NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT **143**

BUS USE OF HIGHWAYS

STATE OF THE ART

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AREAS OF INTEREST
- HIGHWAY DESIGN
- TRAFFIC CONTROL AND OPERATIONS
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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 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 Highway Research Board of the National Academy of Sciences-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 departments and by committees of AASHO. 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 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 Highway 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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FOREWORD

By Staff

Highway Research Board

This report will be of particular interest to those highway officials responsible for planning, design, and traffic engineering. It constitutes a state of the art of bus utilization of highway facilities and, therefore, contributes to a better understanding of the effectiveness of bus operations on highways in terms of priority treatments relating to freeways, arterials, and terminals. Highway engineers will find this report of special value in helping to identify the multimodal potentials of urban freeway projects, as well as in evaluating the impact of bus operations on the capacity and traffic flow characteristics of existing roadway facilities.

Highways are capable of moving large numbers of people on buses through the design of special facilities and control measures that produce a high level of service for peak commuter loads in heavy-volume corridors. Fundamental to this objective, however, is the employment of bus priority facilities that include preferential bus lanes and ramps; exclusive bus lanes and ramps; traffic controls for smooth, uncongested flow; loading points and shelters; and park-ride lots. Although transportation planners and traffic engineers strive for rapid, convenient, reliable bus service, their ability to implement advanced concepts for bus utilization is hindered by the lack of planning experience and design guidelines. Consequently, there is a need for a single reference source of information on bus utilization applications that increase the person-carrying capacity of existing highway facilities, including freeways, access ramps, arterials, local streets, and the bus terminals associated with each.

The study reported herein was conducted by Wilbur Smith and Associates and constitutes a first phase of the over-all research. It was concerned primarily with a literature search and a survey of transportation agencies involved with commuter bus operations. More than 200 bus priority treatments were identified throughout the world. Principal focus was on domestic bus transportation projects; however, significant foreign experience was included.

This overview of contemporary practice disclosed such significant factors as the ability to schedule busways for construction by stages, thereby permitting service improvements to be inaugurated while parts of the facility are still being built. It identifies the importance of bus priorities along arterial streets. Implicit is the need to view bus priority measures as systems of improvements designed to expedite person flow. Exclusive busways should be developed at costs that are less than for rail transit, and should provide a clear "transit image." Because public transport makes possible high land-use and employment concentrations, the existence of these concentrations, in turn, makes capital investments in public transport feasible. The extent and feasibility of bus priority treatments must, therefore, relate to and reflect urban growth objectives and policies to the extent of encouraging land-use arrangements conducive to more efficient bus operations responsive to the nature and intensity of the city center.

Results of the concluding phase of research will be published at a later date. They will cover the development of planning criteria for preferential bus facilities; the preparation of design guidelines for roadway geometrics, traffic control, and bus operation components of preferential bus facilities; and the provision of proposed measures of effectiveness for highway transportation systems giving particular attention to bus priority facilities.

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Sincere appreciation is expressed for the information obtained from the Federal Highway Administration, the Urban Mass Transportation Administration, the American Transit Association, the International Union of Public Transport, and the Transport and Road Research Laboratory (Britain); from various transit comapnies, and from various city, regional, and state highway and planning agencies, and bridge-tunnel authorities

BUS USE OF HIGHWAYS

STATE OF THE ART

SUMMARY

This report, based on a thorough review of ongoing and completed research, reflects the experiences of more than 200 bus priority treatments in the United States and elsewhere.

State of the Art

Bus priority treatments have been increasingly applied in cities throughout the world The types of treatment, the numbers of people they serve, and the design details they utilize vary widely. Treatments can be grouped into three broad categories: those relating to freeways, arterials, and terminals. Significant types and examples of these bus priority treatments are summarized in Table S-1 and as follows:

1. Existing freeway-related treatments include the San Bernardino, Shirley, and Runcorn Busways; contra-flow bus lanes on the Long Island Expressway (New York City), I-495 (New Jersey), the Southeast Expressway (Boston), and US 101 (Marin County); a special bus ramp for Seattle's Blue Streak express bus service; and the bus-car pool bypass lanes at the San Francisco-Oakland Bay Bridge toll plaza.
2. Existing arterial street treatments include bus streets in Chicago, Minneapolis, and Paris; contra-flow bus lanes in San Juan, Louisville, San Antonio, and London; median bus lanes in New Orleans and Chicago, and curb bus lanes in most major cities.
3. Significant bus terminals include New York's Midtown and George Washington Bridge terminals, Chicago's 69th and 95th Street "bus bridges" over the Dan Ryan Expressway, Toronto's Eglinton Terminal, and Cleveland's extensive bus-rail-car interchange facilities

Most bus priority treatments consist of reserved bus lanes on downtown city streets Busways and other freeway-related treatments are found or proposed mainly in large U.S. cities with rail transit systems, large downtown employment, and/or heavy peak-hour transit use. These specialized treatments, however, were of greatest concern to public officials, for they involved larger expenditures and produced the most significant benefits

Dimensions of Bus Use

Buses are the dominant form of public transport in the cities of the U.S., carrying more than 70 percent of all transit riders Passenger use of buses on radial freeways, on downtown streets, and in major bus terminals reaffirms the importance of bus priority treatments, as follows.

1. Buses carry more than 85 percent of all peak-hour person-trips through the Lincoln Tunnel, account for about one-half of all peak-hour travelers on the

San Francisco-Oakland Bay Bridge, the Shirley Highway, the Ben Franklin Bridge, and the Long Island Expressway; and for more than one-fourth of all passengers on radial freeways in other large cities.

2. Buses carry an even higher proportion of peak-hour travelers on city streets; more than 85 percent of all peak-hour travelers on Hillside Avenue (New York City), State Street (Chicago), Market Streets (Philadelphia and San Francisco), and Pennsylvania Avenue (Washington, D.C.) use buses. In many cities buses accommodate more than one-half of all peak-hour person flow on downtown streets

3. Urban bus terminals also serve heavy peak-hour movements. During a typical peak hour, New York's 184-berth Midtown Terminal serves 33,000 entrants; San Francisco's 37-berth Transbay Terminal, 13,000, Chicago's 22-berth 95th-Dan Ryan Terminal, 5,000, Toronto's 13-berth Eglinton Terminal, 15,000. Free transfer from bus to rail and a small number of short-headway bus routes account for the remarkably high flows accommodated in Toronto.

An Evaluative Overview

An overview of contemporary practice disclosed many significant factors. These include. ability to schedule busways for construction by stages, allowing service improvements to be inaugurated while parts of the facility are still being built, the value of clearly identifiable busways (the transit "image"); the development of busways at costs less than those for rail transit; the importance of parking at fringe transit stations, the suitability (or unsuitability) of specific freeways for bus service; the limited number of existing arterial bus lanes (although this number is increasing); the need for (and enforcement problems associated with) curbside bus lanes; the relatively small number of bus priority treatments that have been discontinued; and the problems of operating costs associated with providing peak-hour bus services

Planning and Design Considerations—Bus priority treatments vary widely in planning philosophies, design concepts, operating policies, and their documentation of costs, patronage, and impacts The most striking variabilities are found when busways and contra-flow lanes are compared. Standards for starting anew are viewed differently from those which optimize existing facilities

Variabilities in design standards reflect ranges in operating speeds, characteristics of existing freeways, and local design preferences. The highest bus volumes reported (nearly 500 buses per hour) use an 11-ft contra-flow lane on I-495 at speeds of 35 to 40 mph, with no shoulders for bus breakdown. This is in striking contrast to the California practice, which designs for 70-mph speeds, provides a buffer strip on the US 101 contra-flow bus operations, and provides 17-ft-wide lanes on the San Bernardino Busway with off-roadway provisions for bus breakdown. The New York metropolitan area experiences suggest that economies can be achieved by accepting lower speed levels without unduly sacrificing operating efficiency.

Shoulders are provided along the Shirley Busway (in anticipation of future use by other high-occupancy vehicles), and are proposed together with off-line stations in several busway designs (e.g , Milwaukee). Because in most cases peak-hour one-way bus flows would be less than two to three per minute, this raises questions regarding the cost-effectiveness of many proposed designs.

Implicit in the application of higher design standards is the key issue. will overdesign escalate costs and diminish or preclude feasibility? Design standards should consider the driving skills of professional bus drivers, the high levels of

TABLE S-1

SUMMARY OF THE STATE OF THE ART OF BUS PRIORITY TREATMENTS

TYPE OF TREATMENT	SIGNIFICANT EXAMPLES OF EXISTING TREATMENTS
1. *Freeway-Related*	
A. Busways	
1. Busway on special right-of-way	Runcorn, England, Busway
2. Busway on freeway, median or right-of-way	Shirley Busway, Washington, D C , area San Bernardino Busway, Los Angeles
3. Busway in railroad right-of-way	None
B. Reserved lanes and ramps	
1. Bus lanes on freeways, normal flow	9th Street Expressway, Washington, D.C
2 Bus lanes on freeways, contra-flow	Southeast Expressway, Boston; I-495, New Jersey; Long Island Expressway, New York, US 101, Marin County, Calif
3 Bus lane bypass of toll plaza	San Francisco-Oakland Bay Bridge
4 Exclusive bus access to non-reserved freeway (or arterial) lanes	Seattle Blue Streak express bus service and bus ramp
5 Metered freeway ramps with bus bypass lanes	I-35W, Minneapolis, Harbor Freeway, Los Angeles
6. Bus stops along freeways	Hollywood Freeway, Los Angeles
2 *Arterial-Related*	
A Reserved lanes and streets	
1 Bus streets	Nicollet Mall, Minneapolis, 63rd and Halsted Sts , Chicago
2 CBD curb bus lanes, normal flow	Washington, D C , Baltimore, Maryland
3 Arterial curb bus lanes, normal flow	Hillside Avenue, Queens, New York City
4 CBD median bus lanes, normal flow	Canal Street, Neutral Ground, New Orleans, Washington Street, Chicago
5. Arterial median bus lanes, normal flow	None
6. CBD curb bus lanes, contra-flow	Alamo Plaza, San Antonio
7 Arterial curb bus lanes, contra-flow	Ponce de Leon, Fernandez Juncos, San Juan, Louisville
B Miscellaneous.	
1 Bus signal preemption	Kent, Ohio
2 Special signalization	Cermak Road, Chicago
3 Special turn permission	"No Left Turn, Buses Excepted," Los Angeles
3 *Terminals*	
A Central-area bus terminals	Midtown Terminal, New York City
B Outlying transfer terminals	Dan Ryan, 95th Street bus bridges, Chicago, Eglinton Terminal, Toronto
C. Outlying park-and-ride terminals	Lincoln Tunnel approach at I-495 contra-flow bus lane, Seattle Blue Streak

vehicle maintenance, and the relatively light bus volumes needed to accommodate heavy passenger flows

It is significant to note that most existing express bus priority treatments represent either contra-flow operations on existing radial freeways or special treatments to bypass queues. Most major proposals, however, call for exclusive bus roadways Yet, measured in capital costs per person-minute saved, busways are far less "cost-effective" than contra-flow lanes and other operational treatments.

Intermediate stations do not play a significant role along most existing freeway-related bus facilities. This is because the facilities either represent contra-flow operations where stations are not possible (New York, San Francisco, Boston) or are located within or adjacent to freeway medians (Los Angeles, Washington, D.C.) Freeways usually are removed from high-density residential areas; pedestrian access is difficult; bus transfer facilities are limited; and park-and-ride lots are not provided

Downtown Distribution—Distribution of buses in central areas remains an important challenge. The downtown area and its approaches are among the few areas where buses can provide a time advantage over automobiles. However, current busway proposals (as well as existing treatments) generally provide good access to the CBD perimeter but do not substantially improve service within the downtown core. Many treatments rely on terminals or on-street distribution systems that in large measure duplicate service patterns and inefficiencies of former interurban railway lines.

Terminals are not always located near major employment concentrations, and may (as in Midtown New York) rely on secondary distribution systems; curb bus lanes do not appear to provide desired service levels; and the use of contra-flow downtown bus lanes has been limited. Elevated busways where proposed (i.e., Memphis, St Louis) have not been accepted; and underground busways have not been provided because of construction complexity and costs.

Buses using the Shirley Busway, for example, experience their greatest delays in downtown Washington, D C. The bus travel times required to reach the Shirley Busway from downtown Washington equal the travel times from downtown to the outer limits of rail transit lines in Boston, Chicago, and Cleveland (15 min).

The Runcorn New Town Busway (England) is a significant exception. The busway is elevated through the downtown area, and is on the surface, often with signal-controlled intersections, in outlying areas.

Conducive Factors—Successful freeway-related treatments serve real, demonstrated needs. Implementation and operating costs are low relative to actual and perceived problems. They are well patronized and produce peak-hour travel time savings of 5 to 30 min. These savings compare favorably with time savings resulting from rail transit improvements and extensions.

These treatments usually are characterized by (1) an intensively developed downtown area with limited street capacity and high all-day parking costs; (2) a long-term reliance on public transport; (3) highway capacity limitations on approaches to downtown; (4) major water barriers that limit road access to the CBD and channel bus flows; (5) fast non-stop bus runs for considerable distances; (6) bus priorities on approaches to or across water barriers; (7) special bus distribution within the CBD—often off-street terminals; and (8) active traffic management and operations programs. A major factor contributing to the "success" of the New York and San Francisco treatments has been their avoidance of on-street operations downtown and their coordination of systems of priority treatments.

Successful operation of bus priority facilities calls for more than planning, design, and construction Traffic management policies are a key part of bus priority treatments, particularly contra-flow bus lanes. Provisions for maintenance, monitoring, policing, and emergency services are essential, and costs for these provisions must be taken into consideration. State highway departments, as well as regional transportation agencies and municipalities, play important roles in planning and operating major treatments.

Most arterial bus priority treatments consist of bus lanes in the CBD. They are too localized in extent and too sensitive to enforcement practices to produce major identifiable benefits to users and achieve substantial economies for bus companies. Moreover, most systematic measures of bus-lane effectiveness are found in Europe; before-and-after studies in the United States have limited statistical significance.

Data Needs.—There is a significant need for detailed information on downtown employment and peak-hour cordon crossing changes in many cities as they relate to bus priority proposals. Consistent peak-hour bus and passenger volume data for proposals are lacking. There is little correspondence in many cities between existing and proposed corridor volumes as they relate to downtown development trends and intensities. Simultaneously, there is need for greater clarity in downtown distribution proposals, inasmuch as these will have an important bearing on costs, operational viability, and community acceptance.

Planning Objectives and Guidelines

Efficient use of urban highways calls for maximum person flow with minimum net person delay over the long run. This can be achieved by (a) optimizing total person flow and, in some cases, (b) optimizing bus flow The latter may be desirable in anticipation of a long-term shift to bus transit or in response to CBD development policies. Both objectives may contrast with the goal of maximizing vehicle flow. Both call for a system of bus priority improvements.

Bus Priority Sequence.—Measures that achieve "shared operations" and maximize person-flow efficiency by bus and car can have widespread application—i.e., metering of freeway ramps; effective enforcement of curb parking regulations; and traffic engineering improvements along bus routes Treatments that optimize bus flow, per se, will be limited to larger urban areas—and will closely relate to downtown employment intensities. The existing and potential magnitudes of CBD travel by bus in specific corridors will influence the extent to which buses should be given priority over cars.

In most urban areas, justification of capital-intensive bus priority improvements appears contingent on aggregating a sufficient volume of transit passengers to sustain the capital investments required in a particular corridor. It is more an issue of identifying sufficient transit potentials than one of overcoming capacity deficiencies. This suggests major emphasis on operational treatments rather than physical construction wherever conditions permit The sequence of bus priority treatments, in order of ascending travel demands, is as follows.

1 Existing highway use should be optimized through traffic operational improvements, including construction. Where highway capacity and downtown parking are constrained, emphasis should be placed on bus priority improvements.

2. Freeway ramps should be metered, with bypass lanes provided for buses.

3. Contra-flow bus lanes should be installed on freeways (and normal or contra-flow bus lanes on arterials) where sufficient bus volumes are aggregated, roadway conditions permit, and traffic volume imbalances exist.

4. Short busways that serve as "queue jumpers" should be developed to link contra-flow lanes with terminals.

5. Busways should be constructed where location and design conditions preclude contra-flow operations on freeways (for example, where stations are required to serve adjacent areas, or where freeways bypass tributary traffic areas). Busways can be developed in stages with interim operations on freeways or arterial streets.

Modifying Warrants—Existing criteria for bus priority treatments should be reevaluated in relation to the role that buses play in meeting peak-hour demands, reducing congestion, and reflecting specified urban design or environmental objectives.

The underlying principle is whether an exclusive bus lane or busway will carry more people than when it is used by cars during peak travel periods. The number of bus riders in the exclusive lane should at least equal the number of auto occupants in the adjoining lane. In the case of freeway and arterial bus lanes, the warrant should apply during the hours the lanes are in effect. For busways, the lanes should be based on peak-period travel. This principle should be modified to reflect desired downtown parking, transport, and development policy objectives, and the ability of other streets to carry potentially displaced traffic. Modification of existing warrants would allow more widespread installation of bus priority treatments.

Illustrative Guidelines—Selected planning guidelines include the following:

1. The identification of major overload points on existing freeways and anticipated overloads on proposed freeways provides important guides to where special bus priority facilities should be built. This approach is valid to the extent that the future road network has been committed and estimated future highway loads are realistic.
2. It is not feasible to remove existing freeway lanes from auto use in the heavy-flow direction and restrict these lanes to buses. If the freeway is already congested, reducing the number of lanes available to cars will further increase delay. The over-all loss in person-time to motorists will exceed the time savings achieved by bus patrons. When a bus lane is added in the existing flow direction, it is reasonable to expect a gain in peak-hour auto flows equal to the auto "equivalents" of the buses removed
3. Right-hand freeway lanes are not usually desirable for exclusive bus use because of frequent weaving conflicts with entering and existing traffic.
4. Standardization of freeway entrance and exit ramps to the right of the through traffic lanes will permit use of median lanes by buses, either in normal or contra (reverse) flow operations. Special bus entry and exit to and from the median lanes can be provided without interfering with normal auto traffic on the right-hand ramps.
5. Effective downtown passenger distribution facilities are an essential complement to regional bus rapid transit services Downtown distribution may take place in terminals, tunnels, bus lanes, and bus streets
6. Busways should be of economical design They should be built for lower per-mile capital costs than rail transit lines Not only will this offset the higher operating costs normally associated with bus service, but it also is a realistic approach to the provision of bus facilities that may serve an interim function. The need for shoulders along busways should be carefully assessed in light of low bus volumes, infrequent bus breakdowns, and low probabilities of delays to opposing traffic when stalled buses are passed.
7. Busways should be designed to allow for possible future conversions to rail or other fixed-guideway transit with provisions that maintain service during the transition period A 40- to 60-ft right-of-way generally would provide sufficient width for stations and permit continuity of service during the conversion period.
8. Metering of freeway ramps, with bus bypass lanes, should be introduced

only where the techniques will improve mainline through-flow. Metering may not alleviate congestion resulting from lane-use imbalances at freeway-to-freeway interchanges. Metering usually requires available alternative routes.

9. There may be merit in redirecting "busway emphasis" to developing facilities within the CBD, and on the close-in miles of radial corridors adjacent to it. Major bus priority treatments in the United States have focused mainly on the suburb-to-CBD trip component and provide little benefit to the majority of bus riders, who generally live within 4 to 5 miles of downtown. Arterial street bus lanes, bus streets, and grade-separated busways in or on approaches to the CBD would benefit these travelers. The two types of bus service are complementary, thereby permitting bus lanes on freeways and arterials in the same corridors where traffic densities warrant.

10. Effective enforcement of arterial bus lanes is essential. Many cities report major problems of curb lane availability. These sometimes can be solved by contra-flow bus lanes, which are not only self-enforcing but also produce a sense of transit identity.

11. A much wider application of bus lanes is necessary before speeds can increase sufficiently to produce operating economies or encourage additional riding. Although bus lanes can improve speed and reduce delay, they often represent comparatively short segments of over-all bus routes.

12. Extended bus lanes on radial arterial streets could produce important benefits in service dependability. These lanes could often be provided without reducing lanes for cars in the heavy-travel direction. On six-lane streets, four lanes could be designated in the heavy-travel direction, with the curb lane devoted to bus use.

13. Segregation of bus and auto traffic should be actively pursued in new town development, as well as in existing urban areas. The Runcorn (England) New Town Busway is an important step toward this objective.

Public Policy.—Implicit in providing bus priority treatments is the recognition of transit as an essential public service. Bus priority treatments should be complemented by appropriate policies that encourage and reinforce transit use. These include public support of low bus fares, downtown commuter parking supply and rate adjustments, and strict enforcement of bus priority treatments. Institutional changes that permit greater driver productivity will also become increasingly essential

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

This interim report on NCHRP Project 8-10, "Planning and Design Guidelines for Efficient Bus Utilization of Highway Facilities," describes existing and proposed bus priority treatments, evaluates their effectiveness, and appraises ongoing research efforts It also identifies significant data gaps and sets forth suggestions for further research

RESEARCH PROBLEM STATEMENT

Buses provide important mobility within the cities of the United States. Each year, they serve some 15 billion person-miles of travel. Nationally, they carry more than 70 percent of all public transit riders When New York City is excluded, they serve more than 85 percent of all public transportation passengers. They are the dominant form of public transport, even in most cities served by extensive rail transit facilities

Buses serve a wide variety of transportation functions They provide local and express service between downtown areas and residential neighborhoods. In larger cities, they provide for crosstown movements and serve as feeders to rapid transit lines They operate on local streets, arterial streets, and expressways. They provide a high degree of service availability and flexibility, for a single vehicle often provides both line-haul and distribution services They are an integral part of the modern multi-modal urban transport system

Most communities, because of their size and development densities, are not likely to warrant rail transit systems Therefore, they must rely on buses for public transport Buses also provide interim and feeder services in communities that are developing rail rapid transit Thus, the definition of practical ways to optimize urban bus movements has important national implications

Why Buses?

Each urban area has unique needs, resources, and attitudes toward transportation. Each has its own response to urban transport options. Each has its preferred mix of public and private transportation investments. However, because community impacts and disruption may take precedence over mobility requirements, an increasing number of cities—particularly older, high-density centers—look to mobility options that do not require major highway construction through high-density areas, as follows.

- Some look to increased efficiency from the existing street network TOPICS programs reflect this objective. Nevertheless, a 20 percent gain in system performance is probably the extent of over-all capacity increases that can be realized.
- Some are exploring ways to increase car occupancy. A doubling of car occupancy would permit a doubling of CBD growth without additional highway construction However, auto occupancy has been gradually declining, and to accomplish a reversal of this trend would call for bold public actions. The problem is compounded by the slow rates of CBD growth in older cities.
- Some are considering adoption of regional land-use development patterns that are designed to minimize travel. The self-contained "new town" offers substantial opportunity for success in this area However, residents of contemporary urban society usually choose their places of work and residence based on both transportation and non-transportation factors.
- Some are considering staggered work hours and road pricing mechanisms Nevertheless, except for a handful of cases (as in Manhattan, where office working hours are staggered and parking rates and bridge-tunnel tolls effectively serve as pricing constraints) pricing policies have not received wide public acceptance

Many cities view improved transit services as a way of serving centrally oriented trips and reducing radial highway requirements, as follows:

- Large cities have expanded, developed, or proposed rail rapid transit systems to both serve and channel growth (The new Lindenwold line serving Philadelphia has diverted many former motorists The new Bay Area Rapid Transit System in San Francisco and the Metro System under construction in Washington, D.C., will also help to meet major urban corridor travel requirements.) In most cities, however, imbalances between construction costs and revenues from expected patronage have limited the number and extent of rail corridors
- Improved bus service emerges as an important urban transport option. Improved bus utilization on existing streets can create a better public-private modal balance without requiring major capital investments.

The Role of Buses

Buses play an important role in reducing urban congestion. They effectively complement other modes in increasing the person-capacities in major travel corridors In the long run, a high level of bus use can reduce highway requirements, impacts, and investments. Thus, how effectively buses are used has an important bearing on the scale, investment, effectiveness, and impacts of the urban transportation system.

A 50 percent increase in peak-hour bus use on the downtown approaches in a city like Dallas or Milwaukee could bring about a 20 percent reduction in automobile traffic, or in the duration of the peak period. This increased bus use could also reduce CBD parking demand by about

6,000 spaces and provide person-carrying capacity equivalent to about 10 arterial street lanes (Table 1).

The heaviest transit riding, largest bus fleets, and greatest opportunities for major bus priority treatments are found in the traditionally transit-oriented cities. These cities have the highest downtown employment concentrations and the highest proportionate transit travel to the city center. Many have or are planning rail transit systems. More than 5,000 buses operate in New York City, for example, as compared with 1,000 in St. Louis, 500 in Atlanta, and 250 in Denver.

A high degree of bus use depends on achieving service levels that compare favorably with automobile travel in terms of trip times, costs, and service dependability. This can be accomplished through (1) effectively coordinating bus and highway operations, planning, and construction; (2) providing preferential bus facilities such as busways, lanes, and ramps, (3) adjusting street routing patterns and traffic controls to more effectively meet bus needs, and (4) operating express bus services on selected routes. These opportunities exist in most cities.

RESEARCH OBJECTIVES

Efficient bus service and efficient traffic flow are highly interdependent; both benefit from street and traffic improvements. Accordingly, urban streets and highways have been increasingly adapted to bus service priorities. Within the past decade more than 200 bus priority treatments have been implemented or are under active consideration. Thus, considerable progress has been made in developing preferential treatments for buses and in coordinating highway and bus services in planning and construction. There remains, however, a need for a systematic approach to more effective bus use of highways—for planning and design guidelines that can have wide applicability. This objective underlies the present study.

The 15-month research program was designed to produce a single reference source of information on bus-use applications that increase the person carrying capacity of existing highways. It documents existing and proposed preferential bus facilities and recommends needed research. It identifies economic and social benefits and costs.

Specific project objectives were to. (1) describe physical and operational characteristics of existing preferential bus facilities and controls for buses on urban highways, including costs and benefits, where available, (2) describe major current proposals for preferential bus facilities and bus guidance systems; (3) describe research applicable to preferential bus facilities and bus guidance systems, (4) determine the extent to which research and empirical information is lacking, thereby limiting the preparation of definitive planning criteria for preferential bus facilities; (5) develop planning criteria for preferential bus facilities (similar to warrants for traffic control devices); (6) prepare design guidelines for roadway geometrics, traffic controls, and bus operation components for preferential bus facilities, that could supplement the *AASHO Policy on Arterial Highways in Urban Areas*, the *Manual on Uniform Traffic Control Devices for Streets and Highways*, and standard transportation engineering reference texts, cross-referencing these sources, as appropriate, and (7) suggest measures of effectiveness for highway transportation systems, with particular reference to preferential bus facilities.

TABLE 1

EFFECT OF BUS USE ON AUTO TRAFFIC, TYPICAL LARGE-CITY[a] CBD

CONDITION	PM PEAK-HOUR OUTBOUND MOVEMENT[b]	MAXIMUM ACCUMULATION[c]
1 Existing condition		
People	54,000	65,000
By transit	15,000	18,000
By car	39,000	47,000
Cars (1.5 persons/car)	26,000	31,300
2 50 percent increase in transit use		
People	54,000	65,000
By transit	22,500	27,000
By car	31,500	38,000
Cars (1.5 persons/car)	21,000	25,300
Percent change in cars	−19	−19
3 50 percent decrease in transit use		
People	54,000	65,000
By transit	7,500	9,000
By car	46,500	56,000
Cars	31,000	37,300
Percent change in cars	+19	+19

[a] Arterial street lanes (500 cars per lane per hour). 50 percent increase in transit, +10 lanes, 50 percent decrease in transit, −10 lanes. Parking space change. 50 percent increase in transit, +6,000 spaces, 50 percent decrease in transit, −6,000 spaces.

[b] Hourly rate based on highest peak half hour.

[c] About noon.

RESEARCH PLAN

The over-all research program included ten basic study tasks, segregated into four principal phases, as shown in Figure 1.

Orientation and Research Approach

At the outset of the study, contacts were made with key agencies concerned with bus priority treatments. These included. (1) the Highway Research Board, (2) the Federal Highway Administration, (3) the American Association of State Highway Officials, (4) the Urban Mass Transportation Administration, (5) the American Transit Association, and (6) the International Union of Public Transport. City and state highway and transit agencies operating or planning bus priority treatments were interviewed. These agencies furnished valuable materials, insights, and observations. Major treatments were reviewed in the field. A detailed literature search provided additional information on bus priority treatments and on-going research. The materials and information were assembled and summarized for use in subsequent phases of the research.

The Interim Report

The interim report contains the principal findings of the first five research tasks. It analyzes existing and proposed bus priority treatments, reviews on-going research, and identifies significant data gaps. It systematically classifies and assesses bus priority treatments in relation to (1) type, location, and status of treatments; (2) control methods and design standards; (3) daily and peak-hour use; (4) capital and operating costs; and (5) user and nonuser benefits. Experiences both in the U.S. and elsewhere are analyzed. The report, which presents a selective overview of contemporary bus priority practice, is organized as follows:

Chapter One describes the context and research plan.

Chapter Two describes and assesses principal bus priority treatments.

Chapter Three summarizes relevant research.

Chapter Four sets forth planning and policy implications.

The appendices describe express bus operations on urban freeways; present detailed city-by-city discussions of principal bus priority treatments; and contain chronological and annotated bibliographies.

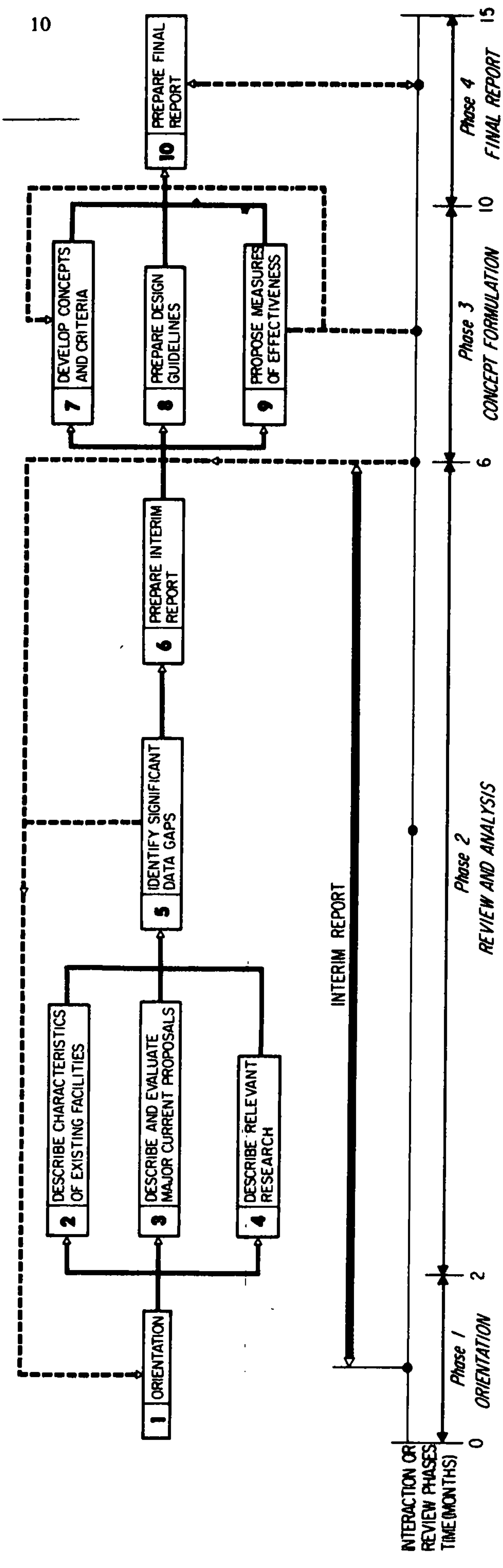

Figure 1. Ten basic study tasks in four phases of project research program

CHAPTER TWO

FINDINGS – BUS PRIORITY TREATMENTS

Major cities throughout the world are giving increased consideration to "traffic management" programs that give preferential treatment to high-priority vehicles. In this context, they have taken positive steps to coordinate bus and highway transport. Within the last decade, more than 200 bus priority treatments have been implemented or proposed.

Transit priorities on urban streets and highways are not a new concept. Historically they represent a recurring cycle in urban transportation planning with slight variations on the original theme. The evolution of bus priority treatments is shown in Figure 2.

Initially, transit vehicles were given certain operating privileges on city streets in return for their service obligations and regulated fares Streetcar lines either were built in the center of the roadway, relatively free from interference by other vehicles (except at major intersections), or were provided in the central median of wide streets, giving transit vehicles an exclusive right-of-way. Many streetcars operated on private rights-of-way or special bridge lanes (for example, the Queensborough Bridge in New York, the Canal Street Neutral Ground in New Orleans, and the Cabin John Line in Washington, D.C.) "Tram-only" reservations are still common in many European cities.

The conversion from streetcars to buses resulted from (1) increased conflicts between automobile traffic and streetcars, (2) the ability to easily extend bus service to newly developing areas, and (3) lesser roadway maintenance costs. Buses generally served passengers from curbside rather than median stops.

Increasing conflicts between buses and cars were initially alleviated by traffic engineering measures (such as one-way streets, curb parking restrictions, and traffic signal coordination) The competition for street space led to the reservation of curb and median lanes for buses Within the past few years an increasing number of busway proposals and actions have reintroduced the bus on its own separate roadway The basic difference is the provision for convertability to other modes as the need arises

THE CONTEXT

The following sections of this chapter describe and analyze bus priority treatments, including their impacts and institutional implications Analyses have been set forth for three major types of treatment, as follows·

1 *Freeway-related treatments,* such as exclusive busways, which generally serve the line-haul portion of the transit trip

2. *Arterial-related bus priority treatments,* which have broad general application for both line-haul and downtown distribution.

3. *Terminals,* including CBD terminals generally used for downtown distribution and outlying transfer terminals that link the neighborhood collection and line-haul functions.

A detailed functional classification of bus priority treatments is given in Table 2, which shows how each key element relates to basic public transport functions. A subsequent series of tables describes each treatment in terms of location, status, length or extent, hours of operation, development and operating costs, user benefits, and community impacts Within this framework, consideration was given to the following key questions.

1. Does the treatment work? Has it significantly improved bus travel times, schedule reliability, or both?

2 How many people use it? Does this patronage represent a significant change in modal split?

3. Has it affected safety, for better or worse? Is there any detectable impact on accident experience?

4 How has the bus priority treatment affected other travelers? Have they gained from improved road utilization? If they have been delayed, how does their delay compare with time savings experienced by bus passengers?

5 What does the treatment cost in terms of capital investments, operations, and maintenance?

6 Can monetary returns be identified, either from user cost savings or gains in revenues? Can the treatment be supported from revenues and tax resources on a long-term basis, or does it depend on a one-time demonstration grant?

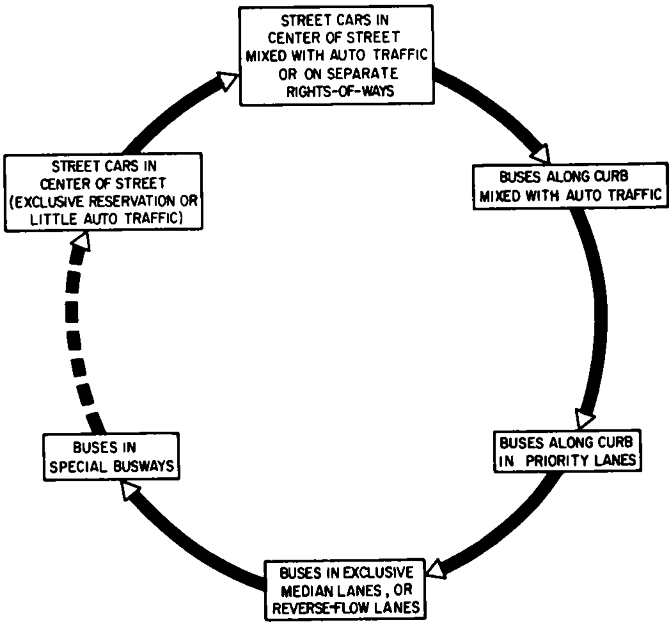

Figure 2 Transit priority cycle.

TABLE 2

FUNCTIONAL CLASSIFICATION OF BUS PRIORITY TREATMENTS ON URBAN HIGHWAYS[a]

ELEMENT	TYPE OF BUS SERVICE			
	RAPID TRANSIT	EXPRESS	LOCAL	DEMAND ACTUATED
1 *Freeways or Freeway Related*				
A Special busways:				
Exclusive subway (underpass in street or private right-of-way)	x	x	x	
Exclusive elevated way	x	x	x	
Other exclusive bus right-of-way (grade or depressed)	x	x	x	
Exclusive use of freeway median (reversible lanes, other)	x	x		
Exclusive busway in nonhighway rights-of-way (railroad, public utilities)	x	x		
B. Reserved freeway lane (peak hours, all day):				
Inside lane reserved, buses flow with traffic	x	x		
Inside lane reserved, buses flow against traffic	x	x		
C Bus ramps				
Exclusive bus ramps to freeway to nonreserved lanes	x	x		
Bus bypass lanes at toll booths	x	x		
Special bus access to exclusive bus lanes	x	x		
Ramp metering with preferential bus treatment	x	x		
D. Bus bays or turnouts on freeways				
2 *Urban Arterials*				
A Exclusive bus streets (peak hours, all day)				
CBD street or alley	x	x	x	x
Other arterial		x	x	x
B. Exclusive bus lanes (peak hours, all day)				
Flow with traffic				
CBD, curb lanes	x	x	x	
CBD, center lanes		x	x	
Arterials, curb lanes		x	x	x
Arterials, center lanes		x	x	x
Flow against traffic (contra-flow lanes)				
CBD	x	x	x	
Arterials		x	x	x
C. Exclusive bus bypass of congested locations:				
Underpass (as Wash, D C, streetcar underpasses)		x	x	x
Overpass (exclusive bus lanes)		x	x	x
Other exclusive short rights-of-way		x	x	x
Special bus turning lanes		x	x	x
D Bus stops:				
Bus bays or turnouts	x	x	x	x
Curb loading and unloading platforms	x	x	x	x
Median loading and unloading platforms	x	x	x	x
E Special traffic signalization:				
Bus preemption of intersection (driver actuated)		x	x	
Bus presence detector in street		x	x	
Special bus signal phase (turn provision)		x	x	
F. Special traffic controls:				
Turn lanes for buses only	x	x	x	
Permissive bus turns (other movements prohibited)		x	x	
3. *Bus Terminals*				
A. Central area terminals	x	x		
B Outlying terminals, park-ride facilities				
Freeway related	x	x		
Arterial related		x	x	x
Rapid transit related	x	x	x	x
4 *Other Traffic Operational Measures*				
A. Permissive bus turns (where movements by other vehicles are prohibited)		x	x	
B Parking prohibitions or restrictions to facilitate bus flow		x	x	
C. STOP sign or YIELD sign protection for streets used by buses		x	x	

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[a] Passenger facilities amenity and bus service operating procedures not identified

7 What social, environmental, and land development benefits or impacts can be identified? Are any of these of critical importance, justifying rejection or implementation of the treatment regardless of its transportation or economic aspects?

8. How compatible is the nature, extent, and scale of the proposed treatment with the existing and demonstrated future needs of the urban area it serves?

A review of published information and interviews with representatives of various state and local agencies disclosed a wide range of concern about the prospects and effects of bus priority treatments In general, there was more concern, and hence more investigation, regarding projects involving larger capital expenditures These, however, represent specialized treatments for large cities and may not necessarily be appropriate in most metropolitan areas

Most bus priority treatments consist of reserved bus lanes on city streets. Busways and other freeway-related bus priority treatments are mainly found (or proposed) in the United States, usually in cities that have or are planning rail transit (cities with large downtown employment and high peak-hour transit use).

FREEWAY-RELATED TREATMENTS

Freeway bus service is increasingly common in large cities The rise in express bus service parallels the growth in urban freeway mileage and underlies the increasing emphasis on freeway-related bus priority treatments For example:

- The number of routes in Atlanta increased from 6 in 1961 to 35 in 1971.
- The number of routes in Dallas increased from 5 in 1961 to 14 in 1971
- The number of routes in Los Angeles increased from 8 in 1961 to 29 in 1971
- The number of routes in Milwaukee increased from 4 in 1968 to 6 in 1971.
- Seattle had no freeways in 1961, hence, no freeway routes. In 1972 it had 8 routes operating on Interstate 5.

Buses substantially increase the peak-hour person-capacities on urban freeways. The number of peak-hour bus passengers on existing urban freeways (summarized in Table 3) underscores the importance and potentials of freeway bus operations in larger cities

Buses carry more than 85 percent of all peak-hour person trips through the Lincoln Tunnel They account for about one-half of all peak-hour travelers on the San Francisco-Oakland Bay Bridge, on the Shirley Highway (Washington, D.C), on the Ben Franklin Bridge (Philadelphia), and on the Long Island Expressway (New York). On many other radial freeways they account for more than one-fourth of all persons carried in the peak hour.

It is clear that buses provide a high potential capacity reserve on urban freeways A freeway lane can carry about 2,000 to 3,000 persons per hour in cars This lane can carry 35,000 to 40,000 people per hour in buses using off-line stations and adequate downtown distribution. When buses stop in travel lanes, however, capacity is reduced to about 120 buses or 6,000 persons per hour.

Freeway Priority Types and Examples

Buses operate rapidly and efficiently on uncongested urban freeways Many freeways, particularly radial routes leading to downtown areas, become routinely congested in peak hours, delaying buses as well as other freeway users. Moreover, freeways frequently do not serve corridors with high transit potentials, where it may be difficult, costly, or impossible to construct freeways As a result, many cities are considering bus priority treatments on freeways or special busways to achieve faster and more reliable bus travel.

Some of the general techniques that have been applied or are being considered are summarized in Table 4 The general locations of major existing and proposed treatments are shown in Figure 3.

Busways on Separate Rights-of-Way

Exclusive bus roadways on their own rights-of-way with complete control of access provide the highest type of service. These facilities can penetrate and effectively serve tributary areas. Intermediate stations and access ramps can be provided as necessary Design standards can be tailored to specific operations, and it is not necessary to limit vehicle size, operating speed, and hours of operation.

Busways can have major impacts (positive or negative) on adjacent areas. They assure segregation of buses from other vehicles, but are costly and slow to implement Their costs, environmental impacts, and land requirements are less than those for freeway construction Little-used or abandoned rail lines may provide inexpensive right-of-way and ready-made subgrades for busways. The more significant examples include the following·

1. Runcorn, England, has completed a 7-mile, 22-ft-wide busway in a planned town of 30,000 population The busway system eventually will total 12 miles and serve a population of 100,000.
2. Pittsburgh, Pa , has approved construction of two busways on their own rights-of-way. The South PATway will extend 4 miles, partially along the Saw Mill River Freeway, long-range plans call for an additional 5-mile extension along the Castle Shannon trolley right-of-way. The East PATway will provide an exclusive 8-mile busway between the Golden Triangle and the Penn Lincoln Parkway in Edgewood, using portions of the Penn Central Railroad right-of-way
3. Atlanta, Ga , has approved construction of three busways, some 14 miles in length The North Atlanta, Tucker-DeKalb, and East Atlanta busways will feed the proposed regional rail transit system.
4. Dayton, Ohio, proposes a 7.5-mile north-south Penn Central busway that will occupy an abandoned railroad right-of-way.
5. In Milwaukee, Wis , the East-West Transitway will extend 8 miles on its own and/or railroad rights-of-way.
6. Other busways on separate (or railroad) rights-of-way have been proposed for Kansas City, Mo ; New Haven, Conn. (Canal Line RR), Washington, D.C (Georgetown RR Branch); Redditch, England, Perth, Australia; and Dublin, Ireland.

TABLE 3

PEAK-HOUR BUS VOLUMES ON URBAN FREEWAYS, RANKED BY PERCENTAGE BUS PASSENGERS ARE OF TOTAL FREEWAY PASSENGERS, IN DOMINANT DIRECTION OF FLOW UNDER CURRENT CONDITIONS

FACILITY	METROPOLITAN AREA	VEHICLES PER HOUR		PASSENGERS CARRIED [a]			PERCENT CARRIED BY BUS
		BUS	AUTO	BUS	AUTO	TOTAL	
Lincoln Tunnel	New York	735	3,200	32,560	5,065	37,625	85 5
I-495	New York	490	3,000	21,600	4,750	26,350	82 0
San Francisco-Oakland Bay Bridge	San Francisco-Oakland	327	8,115	13,000	10,400	23,400	55 5
Shirley Highway (I-95)	Washington, D C.	110	3,200	5,550	4,500	10,050	53 0
Ben Franklin Bridge	Philadelphia	137	4,490	5,065	5,620	10,685	47 5
Long Island Expressway	New York	89	2,710	3,560	4,100	7,660	46 5
Memorial Bridge	Washington, D C	100	3,690	4,020	6,650	10,670	37.6
Lions Gate Bridge	Vancouver, B C.	45	3,300	2,000	4,600	6,600	30 2
Schuylkill Expressway	Philadelphia	78	5,300	2,800	6,650	9,450	29.5
Southeast Expressway	Boston	65	4,200	2,450	6,000	8,450	29.0
I-71	Cleveland	35	3,200	1,850	4,500	6,350	29 0
Golden Gate Bridge	San Francisco	80	6,650	3,750	9,250	13,000	28 8
South Capitol St. Bridge	Washington, D C.	32	3,335	1,920	5,000	6,920	27 7
George Washington Bridge	New York	108	9,440	4,245	13,215	17,460	24.3
14th St. Bridge	Washington, D.C	79	6,565	3,295	10,425	13,720	24.0
North Lake Shore Drive	Chicago	80	9,500	4,000	14,200	18,200	22.0
John C Lodge Freeway	Detroit	40	4,950	1,800	6,920	8,720	20 6
North Central Expressway	Dallas	32	4,000	1,200	5,600	6,800	17 5
Bayshore Freeway	San Francisco	35	6,800	2,270	10,880	13,150	17 3
South Lake Shore Drive	Chicago	24	5,700	1,400	8,000	9,400	14.9
I-5	Seattle	47	9,800	2,300	13,700	16,000	14.4
Hollywood Freeway	Los Angeles	36	7,650	1,755	10,500	12,255	14 4
North Expressway	Atlanta	24	4,550	1,070	6,380	7,450	14.4
East Memorial Shoreway	Cleveland	24	5,800	1,250	8,100	9,350	13 3
Memorial Drive	Houston	11	2,250	500	3,380	3,880	12.9
Stevenson Expressway	Chicago	16	4,600	840	6,900	7,740	10.9
Harbor Freeway	Los Angeles	23	7,200	1,050	10,000	11,050	9.5
I-45N	Houston	19	6,450	875	9,550	10,425	8 4
I-35W	Minneapolis-St. Paul	13	4,950	585	6,900	7,485	7 8
US 59	Houston	13	6,900	600	10,300	10,900	5.5
I-45S	Houston	11	6,000	505	9,000	9,505	5.3
I-10W	Houston	8	5,870	370	8,800	9,170	4.0
Jones Falls Expressway	Baltimore	3	2,780	125	3,900	4,025	3 1
Chrysler Freeway	Detroit	4	5,550	180	7,750	7,930	2.3

[a] Involves assumption in some cases as to car or bus occupancy

Busways on Freeway Rights-of-Way

A preferential bus facility may be located as a separate or shared roadway within a freeway right-of-way, either in the freeway median or along one side of the freeway This concept could adapt to staged "transportation corridor" development, and could lead to low implementation costs and minimum community disruption.

Use of a freeway median may constrain the number, size, and accessibility of stations Where users walk or arrive by car, locations outside of medians are preferred; however, such locations could complicate ramp design. Where transfer stations are located at the same cross streets as freeway ramps, congestion on local streets may occur.

1. Washington's Shirley Busway, the first exclusive bus roadway in the U.S , extends from downtown Washington, D.C , to I-495 in Virginia The 9-mile busway consists of

TABLE 4

ILLUSTRATIVE FREEWAY-RELATED BUS PRIORITY TREATMENTS[a]

TECHNIQUE	EXAMPLE	COMMENTS
1 Special exclusive rights-of-way for buses	Proposed, Pittsburgh PATways, Runcorn, England	
2 Reservation of all reversible lanes on a freeway·		
(a) Access via right-hand ramp.	Shirley Busway	Produces serious bus weaving across highway lanes
(b) Access via existing median ramp	Shirley Busway	
(c) Access via new ramp	Shirley Busway	
3 Reservation of the peak-period, peak-direction curb lane with access to or from right-lane ramp	Ben Franklin Bridge, Philadelphia	Limited to sections between ingress and egress ramps
4 Reservation of the peak-period, peak-direction median lane	No examples	Reduces peak-direction lanes to cars.
(a) Access to and from right-lane ramp.		Produces serious bus weaving across highway lanes
(b) Access to and from median ramp		
(c) Access via new one-lane reversible ramp		
(d) Access via new two-lane ramp		
5 Reservation of the peak-period, contra-flow direction median lane·	I-495 and Long Island Expressway, New York, Southeast Expressway, Boston	Intermediate stations are not practical
(a) Access to and from right-lane ramp.		Produces serious bus weaving across highway lanes
(b) Access to and from existing median ramp		
(c) Access via new one-lane reversible ramp.		
(d) Access via new two-lane reversible ramp.		
6. Reservation of the peak-period, peak and counter-peak directions of the median lanes with access (egress) via new pairs of median ramps.	No examples	
7 Reservation of one of the reversible lanes of a freeway.	Proposed, Mark Twain Expressway, St. Louis	
8. Special ramps for buses entering freeway		
(a) Normal lanes	Transbay Transit Terminal.	
(b) Reversible-flow lanes	Seattle Blue Streak I-5 service	
9 Metering of freeway with preferential entry of buses.		
(a) Via existing ramps	Hollywood, Harbor Freeways, Los Angeles	Does not help problems of freeway-to-freeway junctions.
(b) Via new or special ramps	Proposed, I-35W, Minneapolis	
10 Bypass lanes at toll stations	San Francisco—Oakland Bay Bridge.	
11 Special freeway bus stops.	US 101, Marin County, Calif.	

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[a] Adapted from Ref (3)

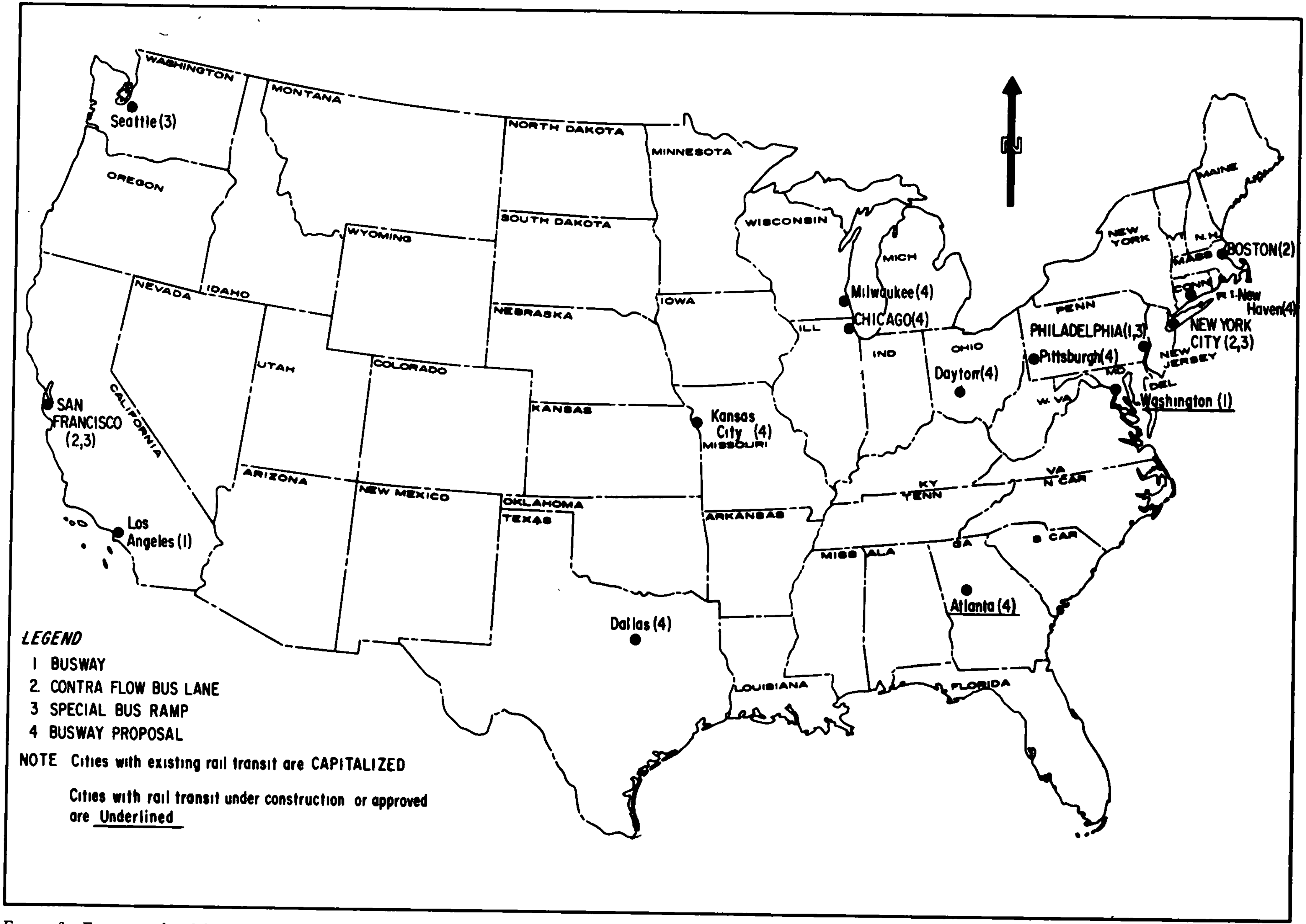


Figure 3 Freeway-related bus priority treatments in the United States

reversible median lanes on I-95, including a temporary one-way bus roadway pending completion of freeway reconstruction.

2. Los Angeles' 11-mile San Bernardino Busway, nearing completion between downtown and El Monte, occupies portions of the freeway median and an adjacent rail right-of-way. Intermediate access ramps are provided in the outer (median) portion. The inner (rail right-of-way) portion will have two intermediate stations.

3. Chicago's proposed 20-mile Crosstown Busway will be located both alongside and within the median of a divided freeway. It is the only crosstown busway being considered in the United States.

Reserved Freeway Lanes

The concept of reserved freeway lanes applies freeway traffic operations and control techniques to reserve a lane for buses and/or other designated vehicles (such as emergency vehicles, trucks, or high-occupancy cars). It involves minimum physical construction. However, it is difficult to provide stations or interim access

Normal-Flow Bus Lanes—Experience with normal-flow bus lanes is limited because of weaving problems and because bus flows have never equaled the capacity of a freeway lane Bus lanes can be provided in the normal direction of traffic only when ample reserve capacity exists (as along the 9th Street Expressway in Washington, D.C.), or where additional lanes are created (such as through widening or unbalanced operations). However, a queue bypass lane for buses upstream from a bottleneck, with buses metered back into the general traffic stream at the head of the queue, may provide significant benefits.

1 The San Francisco-Oakland Bay Bridge toll plaza lanes reserved for buses and car pools illustrate this latter concept A mile of preferential treatment allows buses and high-occupancy cars to bypass delays at the toll barrier and in the lane convergence area downstream from it.

2 Proposed bus use of a reversible lane on St. Louis' Mark Twain Expressway would help meter traffic before the point of lane convergence.

3. Washington's Urban Corridor proposal for the South Capitol Street Bridge utilizes both queue bypass lanes on the south approach and a short normal-flow bus lane southbound across the bridge in the evening peak hour In this case the bus lane would be newly added and would not reduce the total vehicular capacity of the bridge.

4. The right-hand lane of the Benjamin Franklin Bridge in Philadelphia is allocated to buses and trucks on a preferential rather than an exclusive basis This allows passenger cars to use this lane—if there are sufficiently large gaps in the flow and if the car drivers will accept the relatively slow pace of the heavy vehicles. Weaving problems are avoided because the lane is allocated only on the bridge, where there are no intervening ramps

Contra-Flow Bus Lanes.—A "wrong-way," or contra-flow, bus lane using a portion of the roadway that serves relatively light opposing traffic flow will not reduce peak directional highway capacity or efficiency It is an adaptation of the reversible-lane concept applied to urban freeways for more than three decades.

Potential problems include the need to remove median barriers at crossovers or transition points, blocking of the exclusive lane by accidents or stalled buses, safety, and possible congestion in the remaining off-peak direction. It is not possible to provide stations or interim access for buses, and successful application is contingent on a high directional imbalance in traffic volumes

Existing contra-flow bus lanes operate only in peak hours on freeways that are at least six lanes wide and provide at least two lanes for general traffic in the off-peak direction.

1. New Jersey's 2 5-mile I-495 contra-flow bus lane operates eastbound on the approach to the Lincoln Tunnel during the 7·30 to 9:30 AM peak period.

2. New York City's 2-mile Long Island Expressway contra-flow bus lane operates westbound on the approach to the Midtown Tunnel from 7:00 to 9 30 AM

3. Boston's 8-mile Southeast Expressway contra-flow bus lane operates northbound from Route 128 to downtown between 7:00 and 9 30 AM This is the only contra-flow lane not leading to or from a toll station

4 Marin County's 5-mile US 101 contra-flow bus lane operates northbound from the Golden Gate Bridge during the evening peak period

Ramp Metering and Special Bus Ramps

Provision of special bus ramps to and from freeways, and metering of other ramps with special priority for buses, can expedite bus flow with minimum construction costs and minimum delay to other users Bus ramps can bypass queues, reduce bus travel distances, and promote continuity in a system of bus priority treatments between terminals and freeways Ramp metering is designed to keep main freeway lanes operating at reasonable speed levels Both types of treatment can be provided at low initial costs.

Special freeway ramps have been integral parts of the San Francisco-Oakland Bay Bridge and Lincoln Tunnel express bus operations for more than a decade The most significant example of a special bus ramp, however, is Seattle's Blue Streak bus service—eight bus lines use the reversible lanes of I-5 to enter and leave the central business district via the Columbia-Cherry reversible ramp Other examples include· (a) a peak-hour bus-only ramp on the Harbor Freeway (Los Angeles) and (b) a proposed new eastbound bus ramp at O'Hare Field (Chicago) to eliminate circuitous bus travel.

For preferential bus entry to freeways that are controlled by ramp metering, special traffic signals on entrance ramps allow only those vehicles to enter the freeway that can be accommodated without reducing main-line speeds Cars are required to wait a few moments at ramp signals, although those on short trips may divert to parallel routes to avoid waiting Where ramp metering is in effect, it is often possible to provide a bypass lane for buses so that they can bypass automobile queues, and can then achieve better speeds on the freeway At metered locations, buses may enter and leave the freeway for passenger loading and unloading with minimum delay. Ramp metering is especially suitable for application in corridors with low peak-hour bus passenger demands and with frequent peak-hour congestion.

Experience has shown that ramp metering can significantly reduce over-all delay and accidents in an entire freeway corridor. Metering projects improve main-line traffic flow, but do not necessarily increase capacity through bottlenecks. In California, major emphasis was placed on metering ramps during the evening peak hours and initially there was no metering inbound during the morning. Metering schemes do not meter freeway-to-freeway ramp movements, which often limit the speeds and capacities of approach flows. Most existing schemes do not meter traffic in the downtown areas.

Although several cities (including Detroit, New York, Chicago, Houston) have extensive ramp metering projects, only Los Angeles provides bus bypass lanes On the southbound Harbor Freeway at 37th Street, buses use the striped shoulder to bypass car queues. Metered freeway proposals with bus priorities have been suggested for Atlanta (North-South Freeway), Dallas (North Central Freeway), and Minneapolis (I-35W). The I-35W proposal, being implemented, calls for an integrated system of bus bypasses at metered freeway ramps.

Bus Stops and Turnouts

Bus stops have been provided along urban, suburban, and some interurban freeways for several decades. Surveys by the American Transit Association (*38*), the California Division of Highways (1964), and the Institute of Traffic Engineers (*39*) indicate the following.

1 Freeway bus stops are provided in many states, including California, Michigan, Missouri, and New York Most stops on urban routes are located at transfer points where bus service on city streets crosses the freeway. Most stops on suburban or intercity routes are intended to serve adjacent land, or passengers who drive to and from stops in automobiles.

2. Most treatments are found in California, where it is reported that the stops have proved popular with transit operators and riders in San Francisco's suburbs, particularly Marin County (*1*) However, most such stops in California are seldom used, and serve less than 300 passengers per day. Fewer than 10 percent of all bus passengers using the Hollywood and Harbor Freeways, for example, actually use freeway bus stops (*2*). A freeway bus stop may require longer walking distances than do bus stops on arterial streets, thereby discouraging bus patronage. Street-level stops with priority for buses on metered ramps may be more appropriate.

Characteristics of Major Treatments

The locations of major treatments in relation to the city center are shown in Figure 4 The type, status, use, design features, operating characteristics, costs, and benefits of busways and reserved bus lanes are summarized in Tables 5 and 6, respectively Treatments vary widely among urban areas in planning, design, and operating philosophies, and in their response to demonstrated or perceived needs.

Planning Factors

Among the several planning factors involved, the following characteristics are pertinent.

System Length.—Existing busways in the United States range from less than 2 miles (Providence bus tunnel and Philadelphia's Red Arrow busway) to 11 miles (Los Angeles, San Bernardino Busway) in length. Planned or proposed busways range up to about 20 miles in length; lengths of 8 to 12 miles are typical.

Contra-flow bus lanes range from 2 miles (Long Island Expressway) to 8 miles (Boston Southeast Expressway) in length.

Relation to Rapid Transit.—Many busways and contra-flow bus lanes exist or are proposed in cities where rail rapid transit operates, is under construction, or is planned; for example.

- Contra-flow bus lanes in metropolitan New York and Boston are located in corridors not fully served by existing rail transit lines.
- The San Francisco-Oakland Bay Bridge westbound toll station bus bypass lane is in a corridor to be served by BART. The Marin County bus lane, however, serves a complementary corridor.
- Seattle's Blue Streak bus service reflects an early-action approach to rapid transit in a possible future rail corridor.
- Washington, D C.'s Shirley Busway eventually will connect with a proposed rail transit line, eliminating a 2-mile, 15-min trip over downtown Washington streets.
- The San Bernardino Busway is being built where a rail line was proposed and may subsequently be developed.
- Pittsburgh's PATways will be built in corridors not served by the proposed Transit Expressway Revenue Line (TERL).
- Proposed busways in Atlanta and Chicago are designed as rail feeder and crosstown lines, respectively.
- The superseded St. Louis Busway System and the proposed Milwaukee Transitway were planned as total bus-freeway systems. Busways formed the heavy-duty spine of freeway bus service, and rail transit was not envisaged Dallas, Kansas City, and New Haven, where busways also have been proposed, do not currently plan rail transit

Coordination of Treatments (*Systems Approach*)—Existing bus priority installations largely reflect combinations of treatments. This principle extends established traffic planning procedures, for example

- The Shirley Busway is complemented by peak-hour reserved bus lanes in downtown Washington and by special bus ramps to the reversible roadway in Virginia. However, buses must weave across through travel lanes under YIELD TO BUS signing at several locations in Washington and Virginia
- The I-495 exclusive bus lane in New Jersey is complemented by reversible-lane operations in the Lincoln Tunnel, direct bus ramps to the multi-storied Port Authority Midtown Bus Terminal, a special bus transition roadway at the west end of I-495, and a 1,500-space

fringe parking lot in New Jersey. The terminal, in combination with non-stop bus operations on I-495, permits unusually high peak-hour person capacities. Similar preferential treatment is being planned through the Queens Midtown Tunnel to facilitate continuity of the contra-flow express bus lane on the Long Island Expressway.

- The Transbay Transit Terminal at the San Francisco end of the Bay Bridge has direct ramps to and from the bridge that complement the inbound bus-lane bypass at the toll station.
- Seattle's Blue Streak express bus service is expedited by a 500-car parking lot at the northern terminus, a reversible bus-only ramp to and from the downtown area, and a contra-flow bus lane on downtown streets.
- Proposed facilities (such as Pittsburgh's PATway, Milwaukee's East-West Busway, and Dallas' North Central Busway) will be aided by bus lanes and bus streets in the downtown core.

Design Considerations

Design standards vary widely between busways and contra-flow bus lanes, and between existing and proposed treatments.

Design Speeds.—Design speeds, where specified, range from 50 to 70 mph. Design speeds of reserved freeway lanes reflect those for the highway itself, which are usually in this range

Bus Flow Patterns.—Normal-flow bus routing patterns dominate busway planning, although some contra-flow busways are proposed. Chicago's proposed Crosstown Busway and a portion of Los Angeles' San Bernardino Busway incorporate reverse flow to simplify station locations and access. Contra-flow (keep-to-the-left) bus operations permit island-platform stations that require only one set of access facilities (stairs, escalators, elevators) and that simplify manning of stations Contra-flow operations also permit provision of a common central shoulder—in Chicago, a 16-ft separation between opposing lanes will accommodate passing and breakdown.

Busway Convertibility —Many busways are planned for eventual conversion to rail service or for use by multiple-occupancy cars. Los Angeles' San Bernardino Busway is designed to eventually accommodate multiple occupancy cars Chicago plans to reserve a 43-ft right-of-way for its Crosstown Busway, allowing future conversion to rail transit.

Cross-Section and Lane Widths —A major consideration in busway width is the need for passenger unloading, transfer, and shelter in case of bus incidents on the main alignment. Most roadway cross-sections range from about 30 to 50 ft in width. The widest cross-section (54 ft) is planned for a portion of the San Bernardino Busway Dayton's proposed busway cross-section will vary from 32 to 42 ft, depending on whether it is used for travel in one or both directions

Shoulders substantially increase cross-section requirements Designs for the Kansas City, Milwaukee, and Shirley Busways include shoulders, whereas portions of the San Bernardino Busway lanes share shoulders with other highway traffic. Busways generally widen at stations to facilitate passenger loading and unloading.

Lane widths vary from about 11 ft on the I-495 and Long Island Expressway contra-flow bus lanes and the temporary Shirley Busway to 17 ft for the San Bernardino Busway Pittsburgh's PATways and Milwaukee's Transitway will have 28-ft roadways to allow a 12-ft lane each way plus center and/or edge clearance These variations in lane widths reflect ranges in existing and anticipated bus operating speeds

Median Division.—Most busways plan no physical median barrier. The San Bernardino Busway, however, plans a New Jersey-type unmountable barrier on the reverse-flow section Separation of opposing bus and car flows on I-495 contra-flow bus lane is accomplished by lane signals, signs, and traffic posts. Traffic posts, cones, and signs delineate the Long Island, Boston, and Marin County contra-flow bus lanes The Marin County bus lane is separated from car traffic by traffic posts in the center of the lane adjacent to buses, thereby creating a one-lane buffer

Stations.—Station frequency depends on the type of area serviced, the transit route pattern, and the type of preferential treatment There are no stations along reserved freeway lanes However, most new busway proposals call for stations. the closest spacing will be found on proposed busways in Chicago and Pittsburgh, where stations will be at intervals of about 1 mile Stations on the San Bernardino Busway are being located about 2.5 miles apart

Tentative bus station designs incorporate parallel and shallow "sawtooth" loading arrangements. Contra-flow bus stations allow loading parallel to the curb from central island platforms with provision for passing

Intermediate Access to Bus Lanes —Intermediate bus access depends on (1) bus service patterns, (2) facility design, and (3) facility length No interim access is provided to or from any of the existing contra-flow freeway lanes, because it would involve serious problems of weaving and gap acceptance Interim access to the Shirley Busway utilizes a special set of ramps in one location, and (temporarily) a weave across traffic lanes in another

Most proposed busways will provide intermediate points of access In Milwaukee, interim access will be limited to freeway junctions Chicago's Crosstown Busway, because of its distribution function and design constraints, plans no interim access; however, provisions for additional bus access are under study

Terminal Points and Downtown Distribution —Terminal points of busways and reserved freeway lanes generally require transition treatments either to normal traffic lanes or into special terminals. Effective transition and downtown distribution are essential to successful operations.

Most existing treatments provide good access to the CBD perimeter, but not within the core. In several cases (Seattle, Washington, D C) downtown bus lanes are provided. Except for the Runcorn New Town Busway, none of the current proposals calls for off-street CBD distribution Bus terminals—as in New York and San Francisco—represent one alternative, provided terminals are located near major employment concentrations and have direct access to freeway-type facilities

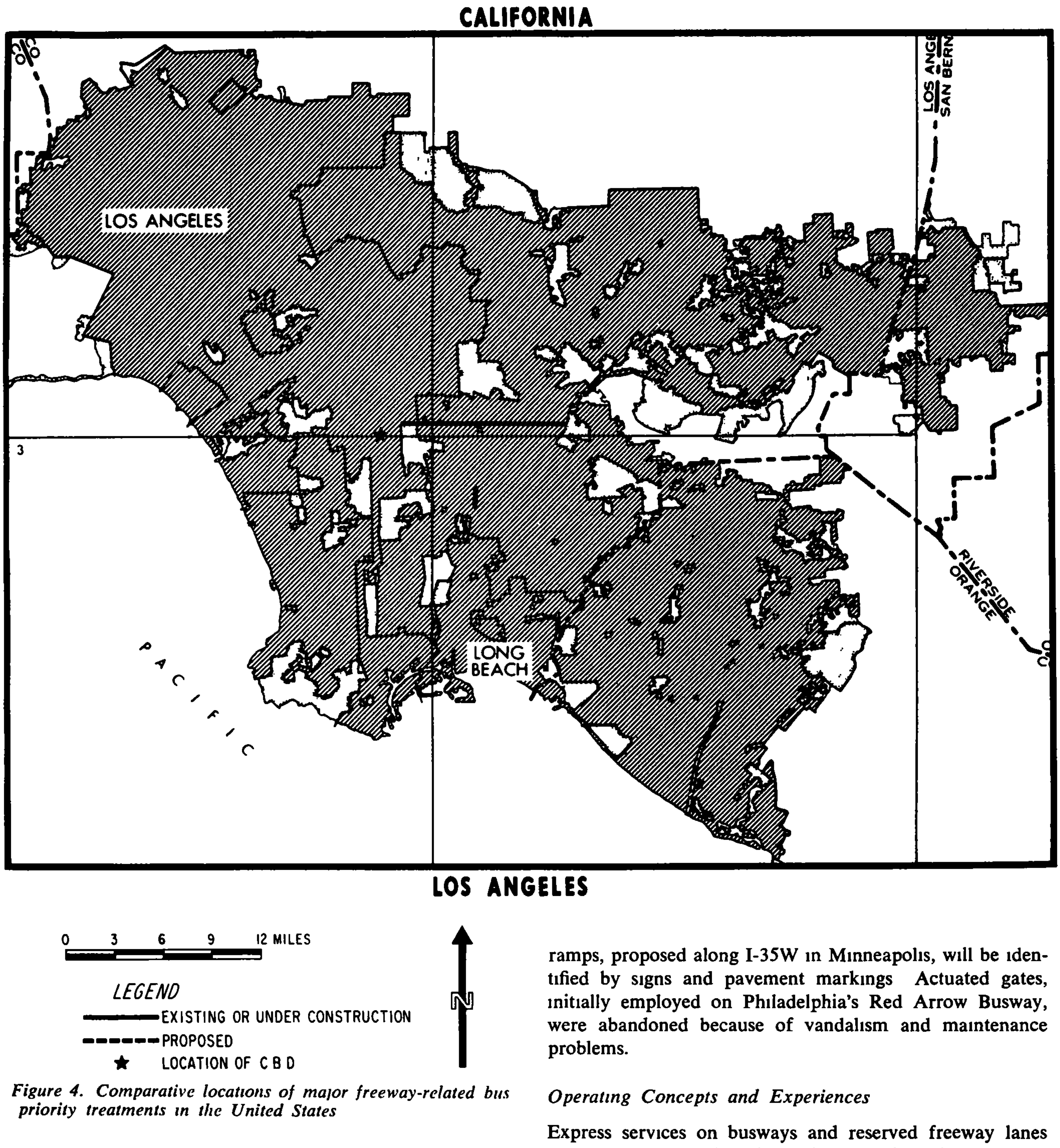


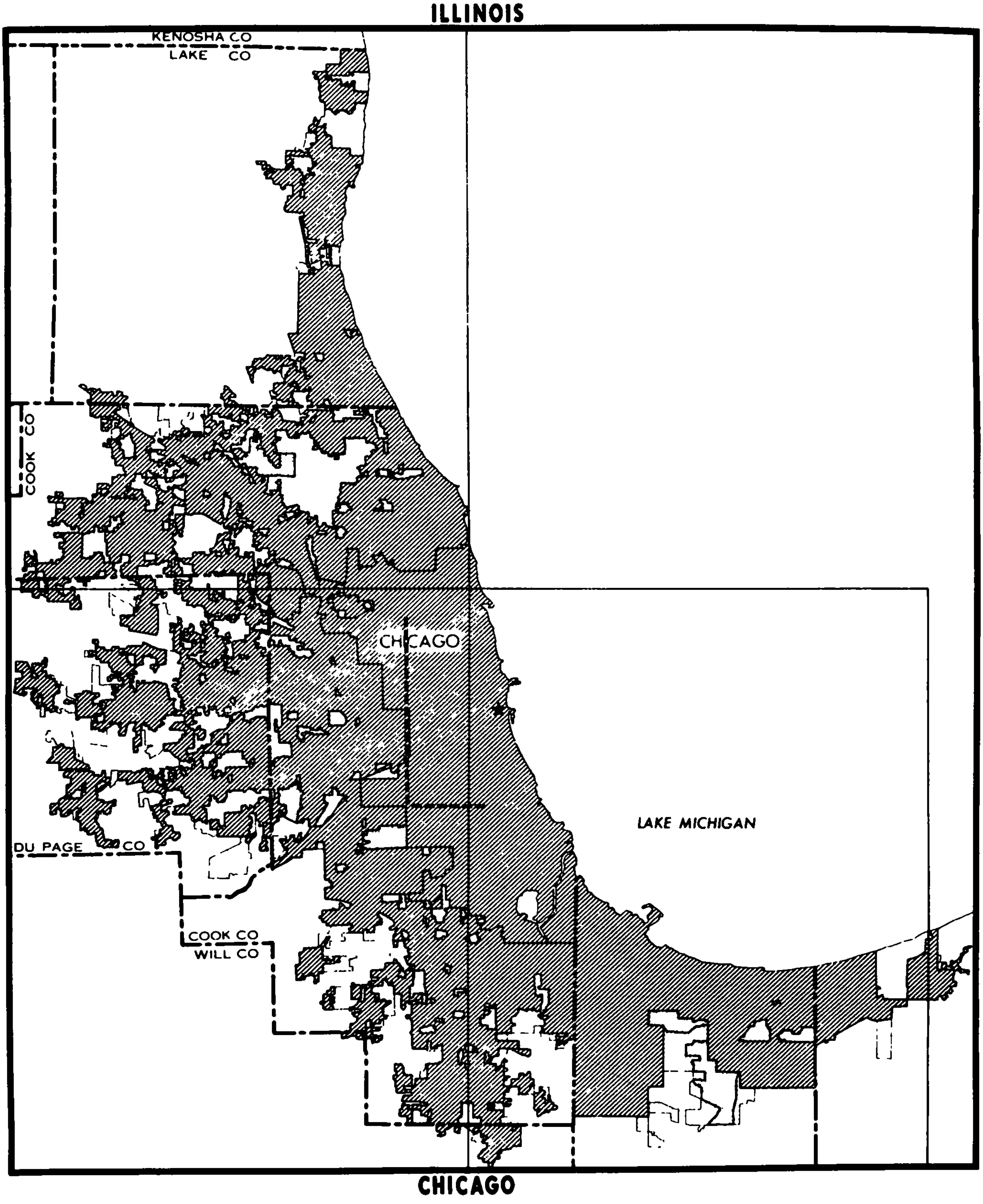
Figure 4. Comparative locations of major freeway-related bus priority treatments in the United States

Traffic Controls.—Traffic controls are used to (a) separate cars from buses, and (b) provide bus priorities at terminals. The I-495 bus lane relies on electronic overhead lane-control signals in combination with traffic posts to designate bus lanes, changeable message signs ease the transition. The Shirley Busway and the I-5 Blue Streak bus ramp use changeable-message signs at entry and exit points only The second lane of two-lane on-ramps can be painted out and designated for buses (e.g., Los Angeles, Calif, and Washington, D.C.). Special bus-only entry ramps, proposed along I-35W in Minneapolis, will be identified by signs and pavement markings Actuated gates, initially employed on Philadelphia's Red Arrow Busway, were abandoned because of vandalism and maintenance problems.

Operating Concepts and Experiences

Express services on busways and reserved freeway lanes can use (1) a single vehicle that combines line-haul and distribution functions, or (2) separate vehicles for express (line-haul) and local (collection and distribution) services The choice depends on passenger demand levels, operating economics, and facility design. Illustrative operating concepts are shown in Figure 5, as follows:

- The "idealized turnback" (Concepts 1, 2). This concept attempts to closely match capacities with demands to minimize bus miles, but is difficult to achieve in practice. Bus service is turned back at successive interchanges in proportion to reductions in travel demand. Passengers



would board at each turnback loop, and the bus would run express to the city center

- Limited-stop trunk-line service (Concepts 3, 4). These concepts provide limited stops along the busway, with route extensions along outlying streets and expressways. The Los Angeles and Milwaukee busway proposals reflect this concept. The Runcorn busway is essentially a local bus street, largely on exclusive right-of-way constructed to eliminate the need for local feeder service, it also reflects this concept.

- Express (non-stop) service with surface extensions (Concept 5). Reserved contra-flow freeway bus lanes along I-495 in New Jersey, the Long Island Expressway in New York, the Southeast Expressway in Boston, and US 101 provide this type of service. Non-stop service is also provided on I-5 in Seattle and the Shirley Busway in Virginia.
- Combination of express and local service (Concept 6). This is a combination of Concepts 4 and 5. The proposed Pittsburgh PATways and Chicago's Crosstown Busway will provide express and local (i.e., limited-stop) service. Many busway designs provide "off-line" stations, thereby allowing both express and local service. Chicago, however, will provide all service on the busway and local distribution will require transfer.
- Rail rapid transit extension (Concept 7). This concept permits busways to serve as collector-distributor facilities for rail transit. Atlanta's proposed busways are of this type.

Routing Patterns

The I-495 bus lane-Lincoln Tunnel serves more than 90 routes that mainly approach the bus lane on the New Jersey Turnpike and New Jersey Route 3. The Shirley Busway serves approximately 10 routes, of which most enter the busway at intermediate points. The Alameda-Contra Costa County and Greyhound bus systems on the Bay Bridge serve more than 25 routes. Seattle's Blue Streak involves eight bus routes. Although routing patterns are not yet established for proposed treatments, most of them will operate fewer routes. Chicago's proposed Crosstown Busway will essentially provide a single-route service.

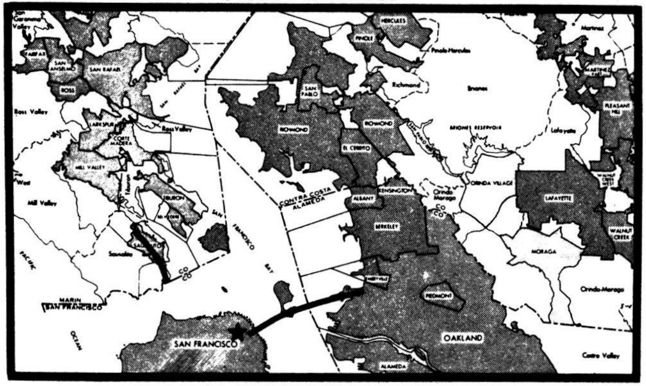
Existing express bus services are provided to and from CBD terminals (as in San Francisco) or they loop on downtown streets (as in Washington, D.C.). No through service is provided by existing express bus priority treatments, despite the potential advantages afforded by through-routing. One reason for this condition is the jurisdictional differences between carriers providing express and local service.

Bus services on I-495, Shirley Busway, US 101, the Bay Bridge, and the Southeast Expressway are provided by carriers different from those operating in the cities. As a result, there is considerable deadheading of buses in peak hours. This precludes through bus service and reduces passenger loads in the off-peak direction.

In contrast, Pittsburgh's East and South PATways will permit through-routing of buses in the Golden Triangle. This will produce several advantages: (1) Through bus riders will not need to transfer; (2) turnaround times, excessive route mileage, and conflicts in the central area will be minimized; and (3) load factors may be increased.

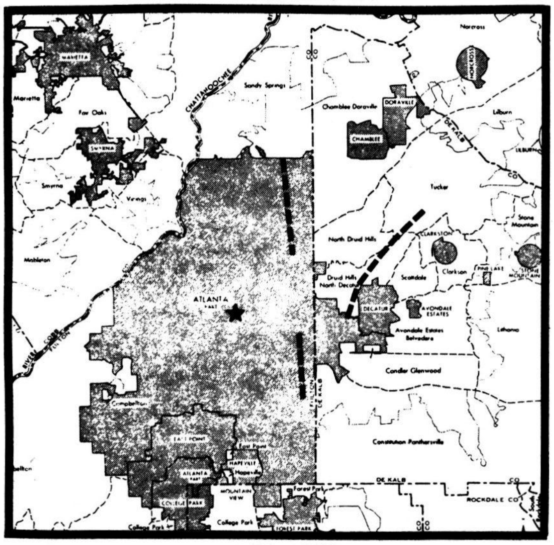
Los Angeles envisions through-routing of buses using the San Bernardino Busway, but will have to overcome problems of local street operations to the west of the CBD. In downtown Los Angeles (as in other downtown areas) heavy peak-hour boarding volumes require relatively long dwell times at stops; allowance must be made for these long stops in scheduling through services to assure schedule reliability downstream from the CBD.

CALIFORNIA



SAN FRANCISCO

GEORGIA



ATLANTA

Operational Workability

No major bus operating problems were reported on existing special bus facilities, although several areas of delay and conflict were identified, as follows:

- Queues at the northern single-lane exit from the I-5 reversible lanes in Seattle often extend beyond the exit ramp where the buses leave the freeway. Plans are under way to reconstruct the ramps in this area and to provide direct bus ramps into a new 1,000-space park-and-ride lot.
- Bus access to and from the Shirley Busway at Shirlington Circle involves weaving across two highway lanes. Buses are given a special priority lane on the entry ramp and the highway traffic has to yield to entering buses. (Little or no additional delay is incurred by the already congested traffic, but this arrangement would be unacceptable on a free-running facility.)
- At the northern end of the Shirley Busway, buses weave to and from the median bus lanes across automobile traffic to and from the 14th Street curbside bus lanes.
- Pittsburgh's South PATway buses will share the Mount Washington tunnel with the Castle Shannon trolleys—at least initially. Major conflicts could arise at the north end

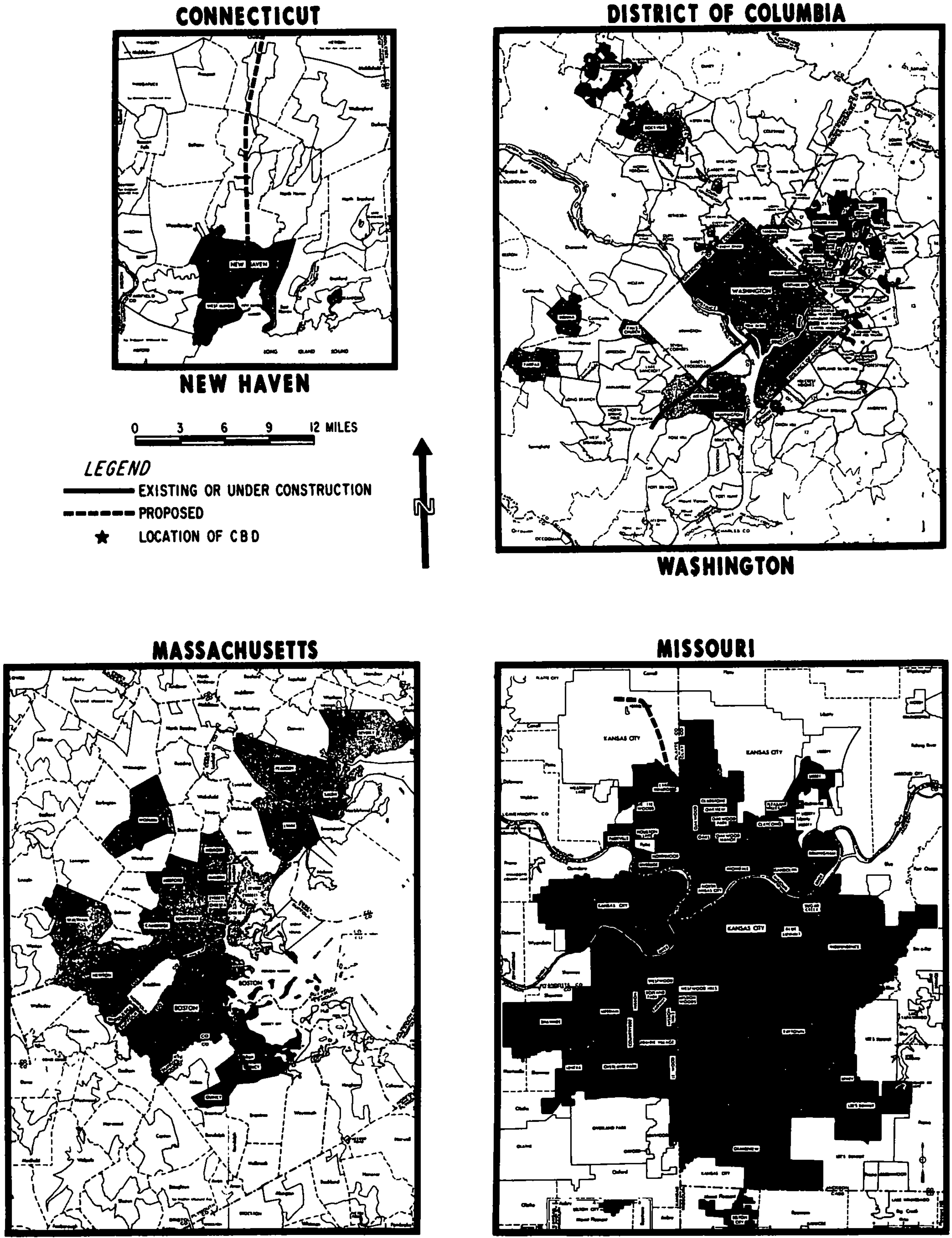


Figure 4. (Continued)

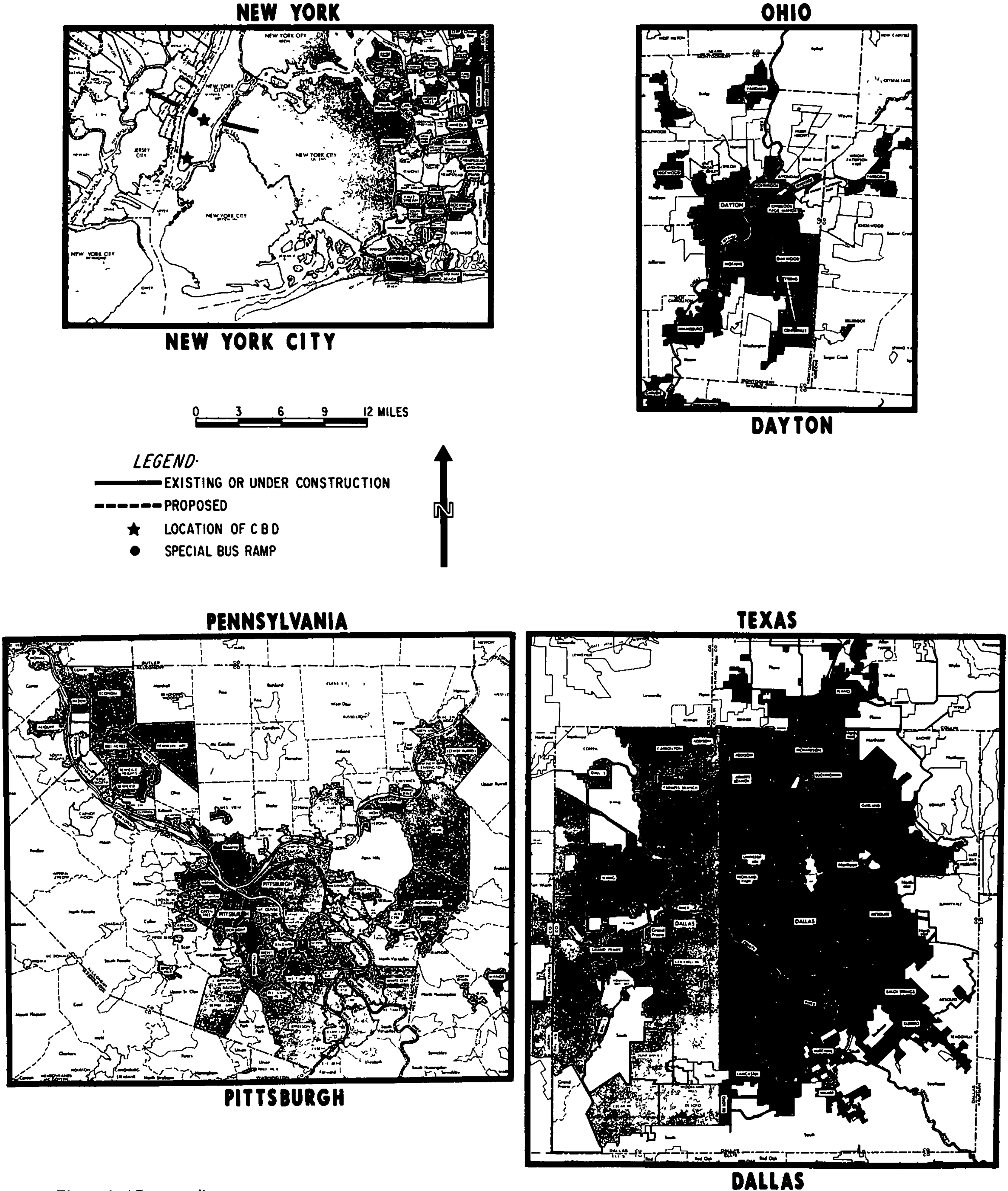
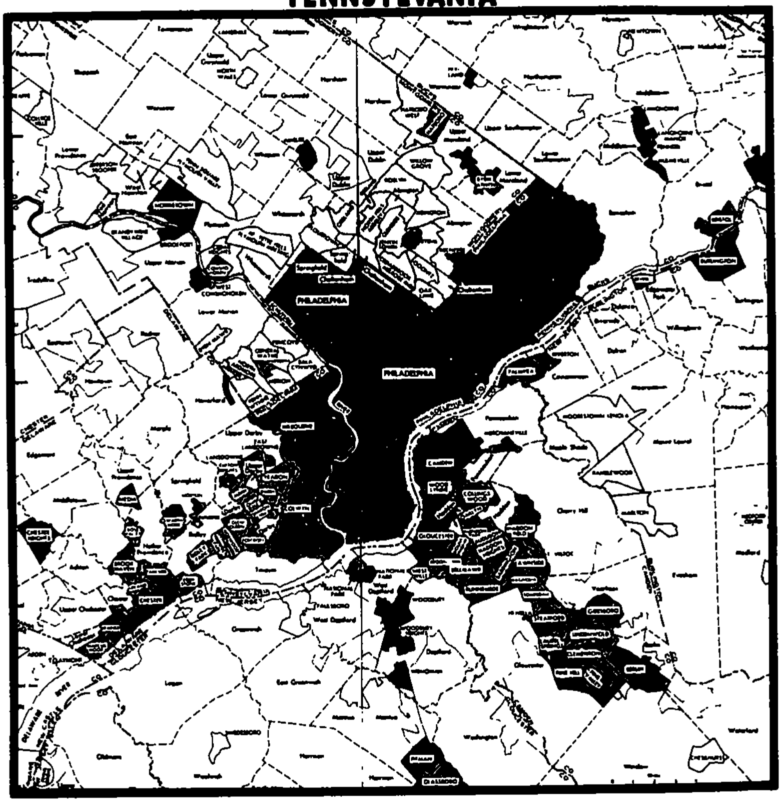


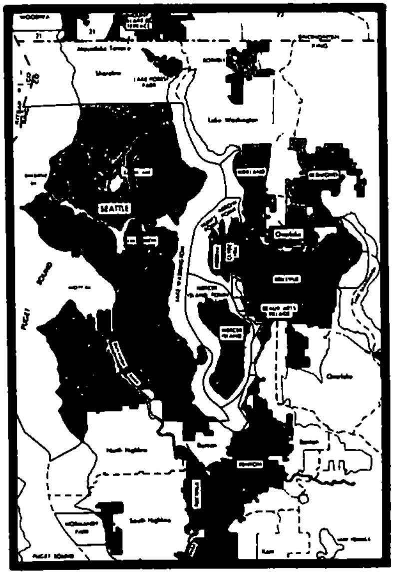
Figure 4 (Continued)

PENNSYLVANIA



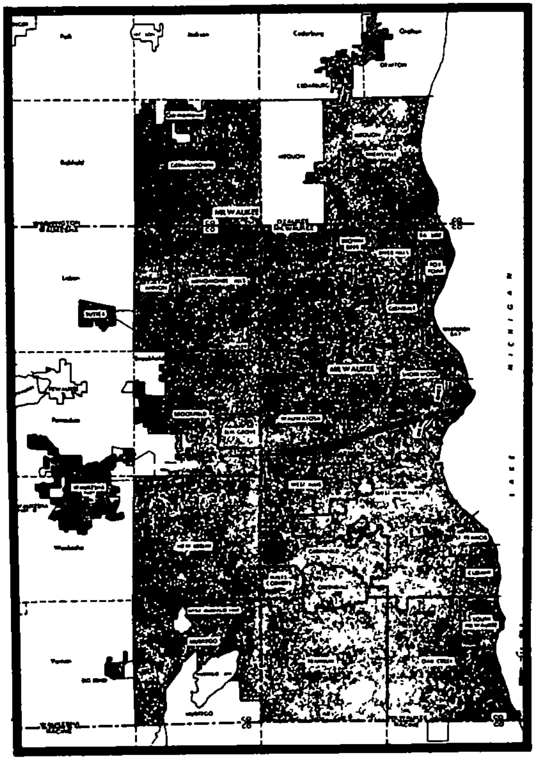
PHILADELPHIA

WASHINGTON



SEATTLE

WISCONSIN



MILWAUKEE

TABLE 5

BUSWAY DESIGN AND OPERATING CHARACTERISTICS

CITY AND POPULATION (1970 Urbanized Area)	NAME OF TREATMENT	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	TYPE OF RIGHT-OF-WAY	TYPE OF CONSTRUCTION (predominant)	DIRECTION OF FLOW	INTERIM ACCESS (No of Locations)	STOP-STATION FREQUENCY	DOWNTOWN DISTRIBUTION	CROSS-SECTION WIDTH	ROADWAY OR (LANE WIDTH)	MEDIAN DIVISION	STATION TURN OUTS
UNITED STATES														
Philadelphia (4,021,066)	Red Arrow Busway	1967	1 5	6 A M 10 P M	Former Tramway	Surface	Normal	None	4	69th St Terminal	---	24' approx	None	None
Providence, R I (532,550)	Tunnel	1948	0 5	24 hours	Former Street Railway	Tunnel	Normal	None	None	On-street	25	25'	None	None
Washington, D C (2,481,489)	Shirley Busway (I-95)	1969-71	9 0	6:30-9 A M. 4-6:30 P M	Freeway median	Surface	Normal	5 Temp 3 Perm.	None on Busway	Curb-bus lanes	12-28' Temp 44'	11-18' Temp 24'	None	None
Los Angeles (8,351,266)	San Bernardino Freeway Busway	Under construction	11 0	24 hours	In median and alongside freeway	Surface	Contra-flow at stations	2	3	Probably bus lanes	27'-half section, 54'-full section	(17')	Yes	24' wide road at stations
Atlanta (1,172,778)	North Atlanta, Tucker DeKalb, East Atlanta Busways	Approved by MARTA 1971	14 4	24 hours	2-In freeway medians, 1 in separate R/W	Surface	Normal	2 points on each busway	2 Stations on 1 Busway; 1 on each of other two	Feeds rail Rapid Transit	30-50'	24-34'	In some Busways	Yes
Chicago (6,714,578)	Crosstown Busway	Approved 1971	20 0	24 hours	In median and alongside freeway	Surface and depressed	Contra-flow	None	Approx 35	Not required	43-45'	(12')	16'6" passing lane between "island" stations	None
Pittsburgh (1,846 042)	East Patways	Approved by PAT-UMTA 1970	8 0	24 hours	Penn-Central Right-of-Way	Surface	Normal	7	11	Bus lanes	28' plus 10' shoulders in some sections	24-28'	None	Yes
	South Patways	Approved by PAT-UMTA 1970	4 0	24 hours	Special	Surface (some elevation)	Normal	6	8	Bus lanes	28' plus 10' shoulders in some sections	24-28'	None	Yes
Dallas (1,338,684)	North-South Central Expressway Busway	Proposed 1971-72	10 0	24 hours	Above Railroad right-of-way	Elevated	Normal	4	9	Bus lanes and/or bus street	33 between parapets	24'	None	Yes
Dayton (685,942)	Multi-Use Penn-Central Busway	Proposed 1971	7 5	24 hours	Railroad right-of-way	Surface	Normal - one-way only in southern section	16	3	On-street to proposed CBD terminal	32-42'	16-26'	None	Yes - stations off-line
Kansas City (1,101,787)	KCI-Airport Bus Rapid Transitway	Proposed 1968	19.0	24 hours	Special	Surface	Normal	None initially	None initially	Elevated to proposed CBD terminal	36'	24'	None	None
Los Angeles (8,351,266)	Century Freeway Busway	Proposed 1972	22 0	24 hours	Freeway median	Surface-depressed	Normal	Not Finalized	1-3 miles	Not required	Generally within 40-50'	14-17'	Yes	Probably none
Milwaukee (1,252,457)	East-West Transitway	Proposed 1971	8 0	24 hours	Special and adjacent to Railroad R/W in part	Surface	Normal	2 (from inter-section freeways)	4	Bus lanes or streets	42-50'	26'	4' flush median	Yes
New Haven (348,341)	Canal Line Busway	Proposed 1971	13.3	6 A M - 10 P M.	Railroad Right-of-way	Surface Pave -but retain tracks	Normal	Yes	6	On-street	50	30'	None	Yes
St Louis (1,882,944)	Busways Bus Rapid Transit	Proposed 1959	42 0	24 hours	Special or in freeway median	Elevated	Contra-flow	Yes	37	Elevated bus loop one-way	60' elevated road, 42' busway	37' road elev loop 3-12' lanes between stations	None	64' widt at islan stations
Washington D C (2 481 489)	Georgetown Busway	Proposed 1969	12 0	7-9 A M 4:30-6:30 P M	Railroad Right-of-way	Surface-pave but retain tracks	One-way	Yes	Not specified	Surface street		18'	None	
FOREIGN														
England Runcorn (100,000)	Local Busway	Partially Open-1971	7-0 miles open 12 0 miles ult	24 hours	Special	Surface & elevated	Normal	None	¼ mile intervals	Elevated elevated busway	Varies	22'	---	47' wide at stati
England, Redditch (70,000)	Local Busway	Proposed 1971 Open June, 1972	15 0 1 0	24 hours	Special	Surface	Normal	---	1/3 mile intervals	Bus streets or busway in open cut or elevated	Varies	24'	---	---
Australia, Perth (580,000)	Regional Busways	Proposed 1971	65 0 Ult	24 hours	Railroad Right-of-way	Surface	Normal	Yes	Yes	Underground busway and station	--	--	---	---
Ireland Dublin (900 000)	Regional Busways	Proposed 1971	40 0	24 hours	Partial Railroad Right-of-way	Surface	Normal	None specified	Not specified	Bus lanes on radials & CBD	--	--	---	---

CONVERTABILITY POTENTIAL (TO RAIL OR FIXED GUIDEWAY) (Where Specified)	TRAFFIC CONTROLS	PARKING PROVISIONS	EXISTING BUS (OR PASSENGER VOLUMES) PEAK DIRECTION PEAK-HOUR OR PEAK PERIOD*	EXISTING BUS (OR PASSENGER VOLUMES) TWO WAY DAILY	ANTICIPATED BUS (OR PASSENGER VOLUMES) PEAK DIRECTION PEAK-HOUR OR PEAK PERIOD	ANTICIPATED BUS (OR PASSENGER VOLUMES TWO WAY DAILY	CONSTRUCTION COSTS	REPORTED BENEFITS	REMARKS
None	Formerly bus actu-acted gates	None	4	128	---	---	---	---	25 MPH Operating speeds Vandalism and bus slow-ups caused gates to be inactivated Former rail right-of-way
Yes	Signs	None	20	600	---	---	---	5-10 Min Time Savings	Natural ventilation
None	Signs, variable message signs, barricades	Proposed	290 - 6:30-9 A M * (11,300) 310 - 4-6:30 P M * (12,100)	23,400	---	---	$2 8 million for four-mile temp busway April, 1971	Time savings 15-20 mins. for longer bus trips	Permanent costs part of I-95 Interstate funding Bus service now breaking even in terms of cost and revenues
Yes	Proposed automatic guidance control	About 400 spaces at El Monte Terminal initially 1,200-1,400 ultimately	---	(7,000)	(4,000)	(17,000)	$53 0 million	Anticipated time savings 20-25 mins	Ultimately may be used by high occupancy cars Former Interurban Right-of-way
Yes	---	---	---	---	---	---	---	---	---
Yes	None required	None	(1,000-)	---	(3,000-9,000)	(23,000-60,000)	$97 2 million	---	Feeds radial transit lines
Yes	Signs, markings, signals	None	---	---	(7,000)	(37,000)	$21.4 million	Anticipated time savings 13-30 mins	CBD distribution not finalized Express and loc bus service planned
Probably	Signs, markings, signals	None	---	---	(7,000	(28,000)	$16 8 million	Anticipated time savings 6 mins	Shares Mt Washington Trolley Tunnel Express and local bus service planned
Yes	---	2 Park-ride lots with 3,000 spaces	32 (1,200)	---	(7,700) 7-9 A M *	1,000 (19,300)	$32 2 million	---	Operating ratio of 0 988 forecasts Urban Corridor Proposal
None	Traffic signals signs	Parking at stations	---	(5,000-10,000) In Corridor	(2,200)	(3,000-20,000)	$ 4 8 million	$830,000 in annual time saving benefits	Would also be used in peak periods by high occupancy cars Urban Corridor Proposal
None	---	---	---	---	---	(7,000)	$29.5 million	---	Concept Inactive - 1972
Yes	---	---	---	---	---	---	---	---	Concept in formative stages
None	---	33,000 spaces system 2 200 along transitway	(71 5 million annual system total)	(1990) (167,000)	175 - (1980) 250 - (1990) (12,500) - (1990)	---	$40 2 Transitway $66 2 Parking $ 7 8 Stations $11 6 Access, Lands etc $24 9 Buses	$37-55 million parking savings CBD Avg speed increase 11 4 to 28 2 MPH	8 mile - Transitway generally follows interurban R/W Part of 107 mile freeway bus systems with 39 outlying stations
Track to remain	Traffic signals	None	10 per hour in corridor	---	---	---	$15 0 million	---	Rail freight to operate 10 PM - 6 A M Implementation unlikely Urban Corridor Proposal
None	None	9,200 spaces recommended (total system)	---	---	(34,000) - All lines - 1980 Max load point 548 buses CBD Loop	---	$165 million	---	86 mile bus rapid transit 42 miles on private rights-of-way Proposal not accepted
Track to remain	Radio operated access-barrier gates	Utilize shopping center parking	---	---	---	---	$ 1 7 million	Time savings up to 14 mins	Rail to operate in off-peak periods
None	Signs and signals	None	12	---	40 ultimate	---	$ 6 0 million	Minimum need to own and use private cars	New town concept with special local-bus street Ult population 100,000
None	Signs, and signals	None	---	---	56 - (1980) (3,360) - (1980)	---	$9 0 million	Reduce use of private cars	New town, ultimate population 90,000 Busways will be open to all vehicles except for some exclusive-bus sections
None	---	---	---	---	---	500 new buses will use facility	$413 million	---	-----
None	---	---	---	---	---	---	---	---	Busways will penetrate existing and new suburbs

TABLE 6

RESERVED BUS LANES ON FREEWAYS

CITY AND 1970 URBANIZED AREA POPULATION	NAME OF TREATMENTS	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	LANES ON FREEWAY	DIRECTION OF FLOW-BUS LANE	INTERIM ACCESS	STATION FREQUENCY
Boston (2652,575)	Southeast Expressway Bus Lane	May-Nov. 1971, March, 1972	8.4	7-9:30 A.M. 4-7 P.M.	6	Reverse flow in 12 ft. lane.	None	None
New York - (16,206,841) New Jersey	I-495 - Bus Lane on approach to Lincoln Tunnel	1970	2.5	7:30 - 9:30 A.M.	6	Reverse flow EB in 11 ft. lane	None	None
	Long Island Expressway Bus Lane	1971	2.0	7-9:30 A.M.	6	Reverse flow WB in 10.5 foot lane	None	None
Philadelphia (4,021,066)	Ben Franklin Bridge	Prior to 1971	1.0	24 hours	7	Normal flow - curb lanes both directions	None	None
San Francisco- (2987850) Oakland	Bay Bridge	1970-Bus Bypass 1971-Bus & Carpool Bypass Lanes of Toll Plaza	1.0	6-9 A.M.	17 in Toll Plaza; 5 on Bridge	Normal flow - WB	None	None
San Francisco (2987850)	Marin County US 101 Bus and Car Pool Lane	September, 1972	5.0	P.M. Peak	8	Contra-flow	None	None
Seattle (1238107)	I-5 Blue Streak Reversible Bus Ramp	1970	8.5	7 A.M.- 12 Noon IN 12 Noon- 8 P.M. OUT	4-2-4 to 4-4-4	Note: No lane is reserved	2 Points	Buses do not stop on freeway
St. Louis (1882,944)	Mark Twain Expwy.Bus Lane	Proposed 1971	6.0	AM & PM Peak	3-2-3	Buses would use one of two reversible lanes	None	On-Street
Washington, D.C. (2481489)	S. Capitol St. Bridge	Proposed 1971	0.5	P.M. Peak	5	Normal flow southbound curb lane	None	None

DOWNTOWN DISTRIBUTION	PARKING PROVIDED	TRAFFIC CONTROLS	EXISTING BUS (AND PASSENGER) VOLUMES PEAK DIRECTION PEAK HOUR OR PEAK PERIOD*	CONSTRUCTION COSTS	REPORTED BENEFITS	REMARKS
On-Street	--	Traffic cones - signs - overhead signs	65 (2,500)	$34,000 Maintenance Costs $545 per day	Patronage increased from 2,150 - 2,450 in peak (one-way). Bus travel times reduced from 24 to 10 minutes.	Initially discontinued because expressway was not illuminated, also rail transit extended to corridor. Resumed March, 1972 between 7-9:30 A.M. Buses drive with flashers on.
Ramps to Port Authority Bus Terminal	1,500 spaces at N.J. Tpke.	80 directional lane signals-traffic posts-signs	485 (22,000) 820 - 970 (35,000) * peak 2-hours	700,000	Time savings of 15 minutes - $3.7-$5.5 million annuallly - auto times reduced bus riding up 6 per cent or 2,300 more riders.	Lincoln Tunnel operates 4 lanes in heavy travel direction.
				Maintenance $200,000/Yr.	No change in total accidents or bus accidents.	
On-Street	None	Cones and signs, plus 14' cut in median to achieve transition	160 (7,500) *Peak Period	$ 30-50,000 Maintenance Costs $150,000/Yr.	No change in eastbound speeds. Buses save 12 minutes daily.	Buses drive with headlights on and use toll booth #7.
On-Street	None	Signs	140 (5,100)	---	---	Buses and trucks use lanes. Lane is preferential - not exclusive.
Ramps to Transbay Transit Terminal	Overhead signs	Signs	330 buses (13,000) over 500*	$ 58,000 Maintenance Costs $12,000/Yr.	Bus passengers saved 34,300 minutes per day. Other vehicles lost 38,400 person-minutes.	About 2,300 cars use 2 multiple occupancy bypass lanes.
					Buses arriving late reduced from 84%to 45% in peak hour. Buses save about 10 min/trip.	Eastbound buses have preferential ramp entry from terminal to bridge.
On-street	--	Signs and Post	80	$200,000 Est.	-----	Southbound traffic restricted to two lanes.
Local Streets including 3-block contra-flow bus lane	500 car lot	Variable message signs & gate	40 8-9 A.M. 47 5-6 P.M.(2,500) 290 All Day	$ 114,000, Traffic Controls; $ 405,000, Parking; $ 1.9 million Total Demonstration Project Costs	Riding increased from 9,000-12,000. Time savings 15-25 min. over bus; 5 min. over car.	3 block CBD contra-flow bus lane.
On-Street	None	Adapt Existing Signing		---	Would reduce car queuing in P.M. where reversible lanes end.	11 bus lines use highway
On-Street, Curb Bus Lanes	--	Signs	32 (1,700)	----	$156,000 bus riders. $117,000 motorists Annual Benefits	Urban Corridor Proposal Northbound buses would be given special signal pre-empt.

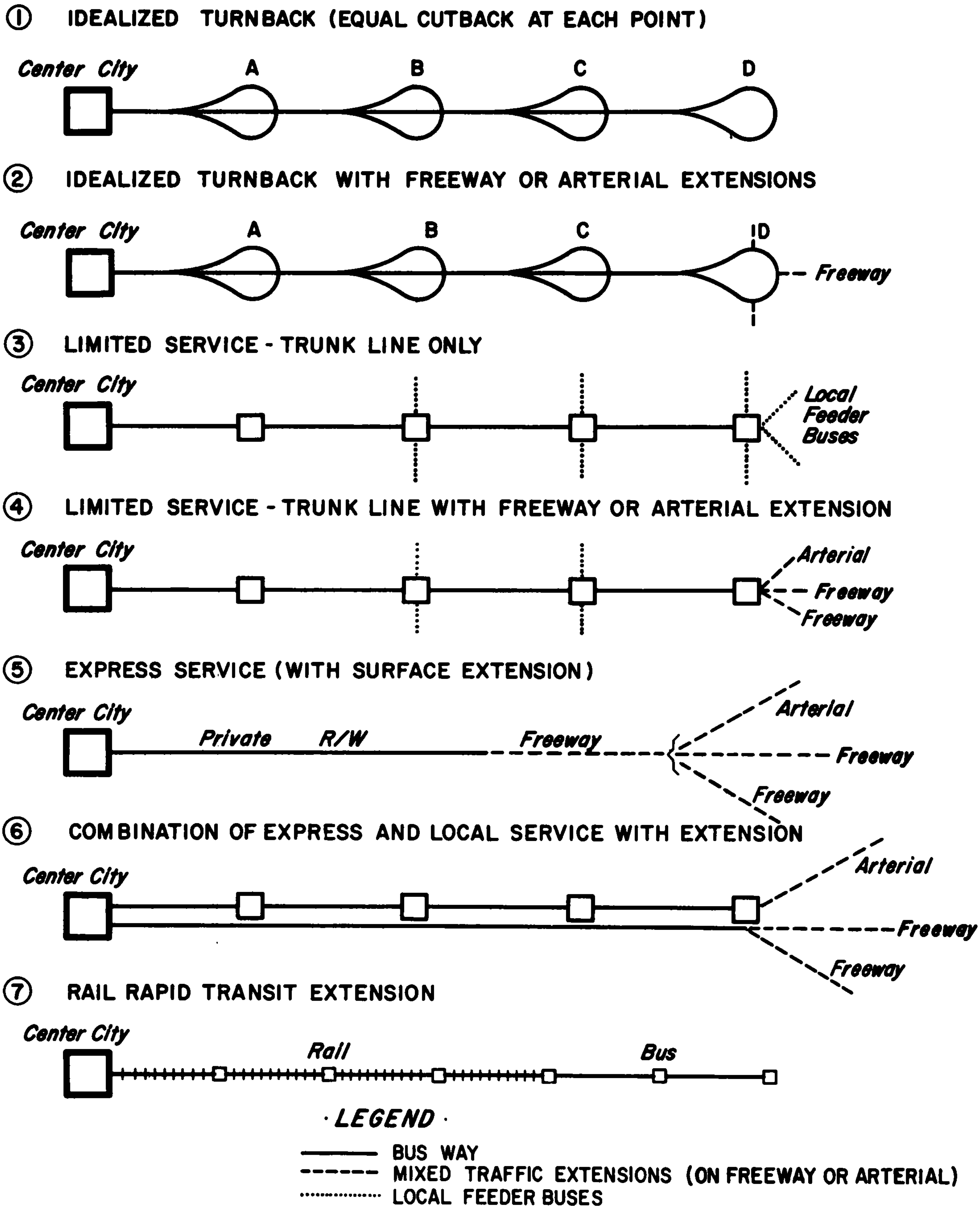


Figure 5. Bus rapid transit operating concepts

of the tunnel on the approach to the Smithfield Street Bridge over the Monongahela River.

Except during initial periods of operation, no major enforcement problems were reported in the operation of busways or reserved bus lanes.

Accidents

A review of accident experience along I-495 for the period from January to September 1971 identified three accidents that involved vehicles using the exclusive bus lane; all occurred in March The Lincoln Tunnel and I-495 reported no increase in accident rates as a result of implementing the contra-flow bus lane. This is significant, in view of the high bus volumes (more than the total bus fleets in many cities) and the minimum design standards Maintenance vehicles are always available to remove stalled buses. the typical incident lasts about 7 min. Similarly favorable accident experience is reported for the Long Island Expressway and the Southeast Expressway (Boston) contra-flow lanes

The number of bus accidents on the Bay Bridge declined from 20 to 13 in the year after the bus lane was installed.

Bus Volumes and Patronage

The largest bus passenger volumes are found in cities that have or are building rapid transit. These cities have large downtown employment concentrations, high all-day parking costs, heavy peak-hour transit riding, and the largest bus fleets.

During the morning peak period approximately 35,000 bus passengers use New Jersey's I-495 contra-flow bus lane (7 30 to 9:30 AM) and 13,000 bus passengers use the San Francisco-Oakland Bay Bridge (7:00 to 10 00 AM). During the morning rush hours more than 12,500 bus riders use some portion of the Shirley Busway, of which 8,500 cross the Potomac River and 6,200 enter the busway before Shirlington

Peak-hour bus flows reported for existing bus priority facilities are given in Table 7. Estimated peak-hour bus flows based on available patronage forecasts for proposed bus priority facilities are given in Table 8

Anticipated bus volumes bear widely varying relationships to existing flows Chicago's Crosstown Expressway, for example, would have a peak-hour one-way load of 6,000 to 7,000 persons as compared with about 20 buses and 1,000 passengers on parallel Cicero Avenue Pittsburgh's East and South PATways would carry approximately 7,000 one way in the peak hour as compared with 3,500 persons carried by existing streetcar lines in the same corridor

Milwaukee's East-West Transitway would carry about 42 million riders annually by 1990 (167,000 per day) as compared with 72 million for the total system in 1971 In Dallas, 1975 peak-hour busway passengers would approximate 4,500, as compared with 1,200 currently carried by buses on the North Central Expressway

TABLE 7

PEAK-HOUR BUS FLOWS REPORTED FOR EXISTING BUS PRIORITY FACILITIES

LOCATION	ACTUAL BUSES PER HOUR[a]
Contra-flow bus lane, I-495, New Jersey	485
San Francisco-Oakland Bay Bridge	330
Shirley Busway, Washington, D.C.	110
Contra-flow bus lane, Long Island Expressway, New York	90
Contra-flow bus lane, US 101, Marin County, Calif	70
Contra-flow bus lane, Southeast Expressway, Boston	50
Contra-flow bus lane, Blue Streak, I-5, Seattle	45
Busway, Runcorn New Town, England	12

[a] One way, rounded

TABLE 8

ESTIMATED PEAK-HOUR BUS FLOWS PROJECTED FOR PROPOSED BUS PRIORITY FACILITIES

LOCATION	ESTIMATED BUSES PER PEAK HOUR[a]
East-West Transitway, Milwaukee	175–250
Crosstown Busway, Chicago	120–150
PATways, Pittsburgh	120–140
North Central Busway, Dallas	90–110
San Bernardino Busway, Los Angeles	80–100
KCI Transitway, Kansas City	30–40
S. Capitol St Bus Lane, Washington, D C	30–40
Penn Central Busway, Dayton	20–30
Canal Line Busway, New Haven	10–15

[a] One way, rounded

Costs

Costs of existing and proposed treatments vary between (1) busways and (2) reserved bus lane treatments (Table 9)

Busways —Construction costs of busways range from $1 million to $5 million per mile. The cost range among proposed busways reflects construction type and level of service desired Where construction is at grade, especially for busways that use railroad rights-of-way, costs average about $1 million per mile Busways that require elevated or depressed construction average $3 million to $5 million per mile For example

- Shirley Busway.—Costs for the temporary 4.5-mile roadway of the Shirley Highway were $2.8 million, but this does not include the costs associated with Interstate highway construction.
- San Bernardino Busway —Costs for the 11 miles under construction approximate $54 million

Reserved Bus Lanes.—Maintenance costs for reserved bus lanes are more significant than initial construction expenditures For example:

- I-495 —Costs for the 2 5-mile reversible-lane opera-

TABLE 9

COSTS OF BUSWAYS AND RESERVED BUS LANES ON URBAN FREEWAYS

FACILITY	DISTANCE (MI)	CONSTRUCTION COSTS ($ MIL) TOTAL	PER MILE
Busways			
East-West Transitway, Milwaukee	8.0	40.2	5.0
San Bernardino Busway, Los Angeles	11.0	54.0	4.9
Crosstown Busway, Chicago	20.0	97.2	4.8
South PATways, Pittsburgh	4.0	16.8	4.2
North Central Busway, Dallas	10.0	32.2	3.2
East PATways, Pittsburgh	8.0	21.4	2.7
KCI Transitway, Kansas City	19.0	29.5	1.6
Canal Line Busway, New Haven	13.3	15.0	1.1
Penn Central Busway, Dayton	7.5	4.8	0.7
Shirley Busway, Wash., D.C.	5.0	2.8	0.7[a]
Reserved Lanes[b]			
I-495	2.5	0.780	0.310
San Francisco—Oakland Bay Bridge	1.0	0.058	0.058
Long Island Expressway	2.0	0.050	0.025
Southeast Expressway	8.4	0.034	0.004

[a] Based on 4-mile section. Busway extends 9 miles.

[b] Annual operating and maintenance costs not included.

tion averaged $700,000, of which $134,000 was for construction and the balance was for traffic controls. Traffic controls included 80 overhead directional lane signals, 350 changeable traffic posts, and 50 changeable traffic signs. Annual maintenance costs were $200,000, or $80,000 per mile.

- Long Island Expressway.—Costs for implementing the 2.0-mile Long Island Expressway contra-flow bus lane approximated $50,000, or $25,000 per mile. Annual maintenance costs approximate $150,000, or $75,000 per mile.
- Boston Southeast Expressway.—Costs for implementing the 8.0-mile Southeast Expressway contra-flow bus lane were estimated at $97,000 for the 106 days it was in operation. About $33,700 represented physical changes; the remainder included operating costs except for police assistance.
- San Francisco-Oakland Bay Bridge.—Costs for implementing the bus and car-pool bypass lanes totaled about $60,000. Maintenance costs approximate $150,000 annually.

Benefits

A wide range of benefits has been reported, including increased bus patronage, passenger time savings, and favorable public response. Ancillary benefits include out-of-pocket savings resulting from reduced parking costs and reduced needs for second cars. Significant user benefits are derived when time savings are given monetary values. Two salient points stand out: (1) Time savings equal or exceed those achieved by rail transit improvements, and (2) existing bus priority treatments have maintained or increased bus patronage.

Shirley Busway.—Ridership on bus routes using the Shirley Busway—about 24,000 persons per day, during morning and evening peak periods—has increased more than 30 percent since the busway opened. About one-half of the bus patrons use the busway south of Shirlington, these particular volumes more than tripled from 1,900 one-way in September 1969 to 6,200 in January 1972. Riders on buses entering north of Shirlington were largely diverted from other existing bus routes and have not significantly increased in number. Patronage gains reflect increasing (a) the length of the busway and (b) the number of buses in peak-hour service. The continued increase in patronage, approaching capacity as buses are added, is similar to the increase in radial freeway use as capacities are increased. Current peak-period bus occupancy averages 55 persons. The busway provides nonstop express service of up to 12 miles, saving up to 30 min over automobile commuting. This represents an annual benefit to bus users of $4,500,000 (assuming a 15-min average time saving, 250 days per year, at $3.00 per hour).

Some 5,600 one-way peak-hour bus riders would require about three additional traffic lanes at existing occupancy rates if they were accommodated in cars. At an assumed cost of $2 million per lane-mile, the bus operation obviates the need for three traffic lanes, or approximately $54 million in equivalent freeway construction.

Blue Streak Express Bus Service.—Approximately 12,000 Blue Streak bus passengers use Seattle's Columbia-Cherry bus ramp daily, as compared with 8,000 persons per day by all modes prior to this service. Bus ridership is reported to have increased from 9,000 to 12,000 since service began, representing an increase of about 30 percent in the same period that total bus ridership in Seattle declined. A 500-space park-and-ride lot established at a shopping center 8 miles from downtown and served by Blue Streak buses is filled before 9:00 AM each working day.

Buses carry about 2,500 people each peak hour, approximately 25 percent of the peak-hour person flow on I-5. Success has stimulated consideration of exclusive transit lanes on the proposed I-90 bridge over Lake Washington.

The Blue Streak has overcome normal reluctance of motorists to use park-and-ride facilities. The bus service saves 5 to 10 min over driving to the downtown area. All-day downtown parking costs are $1.50 to $2.25, but parking is free at the bus park-and-ride lot, and the one-way fare is only $0.35.

The daily time savings produce an estimated annual benefit to bus users of $1,125,000 (7.5-min average time saving, 250 days per year, at $3.00 per hour).

San Francisco-Oakland Bay Bridge.—The number of peak-hour bus passengers crossing the San Francisco-Oakland Bay Bridge is reported to have increased 100 percent in the last decade, whereas automobile passengers increased by only 30 percent. This is, in part, due to restrictions in road capacity.

The bus bypass lane saves 18,000 passengers in 500 buses about 10 min per trip. The California Department of Public Works reports that the lane as initially installed saved bus passengers 34,400 person-minutes, but added 38,400 person-minutes of auto delay (in part because of weaving problems downstream from the toll barrier) Use of the experimental car-pool lanes during the first two weeks of operation resulted in an increase from 1,260 to 2,000 cars, but has had no measurable effect on congestion or bus patronage

I-495 Contra-Flow Bus Lane —A 6 percent gain in bus patronage has been reported, representing 2,300 additional peak-period riders The bus lane removed about 500 buses from the normal highway lanes in the morning peak hour, this capacity was absorbed by motorists, resulting in reduced delays and a slight shortening of the peak period Total eastbound peak-hour vehicle flow increased 40 percent (from 3,300 to 4,500 vehicles) The same number of westbound vehicles is accommodated

The peak-period bus lanes reduced travel times from 20 to 25 min to 10 min for some 35,000 commuters The Tri-State Regional Planning Commission and the Port Authority of New York and New Jersey estimate $3.7 million to $5 5 million in annual benefits, based on $150 worth of time saved by each commuter, annually The 21,000 peak-hour riders would require about 10 equivalent freeway lanes At $2 million per lane-mile, the bus operation obviates the need for $50 million in equivalent freeway construction, plus the costs of additional trans-Hudson capacity.

Long Island Expressway Bus Lanes —Buses on the Long Island Expressway reverse bus lane carry about 6,500 passengers during the morning peak period. The buses average 3.5 min to traverse the 2-mile section, cars in the parallel lanes average 15 to 20 min. This represents an annual time savings equivalent to $1,175,000.

Southeast Expressway Bus Lane.—The AM contra-flow bus lane saved 2,450 passengers 14 min each morning Based on $3 00 per hour, this represents an annual saving of $429,000 The annual value of the time lost by southbound traffic in the AM peak hour approximated $15,000

Treatments Proposed or Under Construction.—Los Angeles' San Bernardino Busway will reduce average trip times by 20 to 25 min. Pittsburgh's proposed PATways will save their riders 6 to 30 min per trip. Dayton's multipurpose Penn Central Busway would produce $830,000 in annual time savings.

Impacts on Transit Operations

Meaningful data on bus costs and revenues on a line or service basis are difficult to find Bus system feasibility depends on (a) service provided per passenger carried, (b) wage rates in relation to fares charged, (c) over-all management efficiency, (d) peak-to-base bus ratios, and (e) bus operating speeds

In theory, all express bus operations should be financially successful; both load factors and speeds are high. However, available information suggests otherwise. High peak-to-base ratios, coupled with low driver productivity and one loaded trip per bus in each peak period, limit the revenue-cost relationships. Moreover, many express bus lines parallel local services, which must be retained although they are no longer profitable

The high-speed nonstop runs across the Bay Bridge, along I-5, and along the New Jersey Turnpike are conducive to profitable operations. These services encounter minimum downtown bus delays and sustain high over-all operating speeds.

Public Service Coordinated Transport, the major carrier using the I-495 reserved bus lanes, has reported a slight operating deficit, however, it is hard to segregate I-495 bus costs from other components of the system

Seattle's Blue Streak service, reported as profitable because of a favorable peak-to-base ratio, has experienced a 30 percent patronage gain at a time that the over-all system lost patronage. However, service will be reduced during midday to avoid duplication with local routes that must be retained Service is municipally operated and supported in part by nonuser charges.

The Shirley Highway bus services have begun to derive sufficient revenues to meet operating costs. This service has a high peak-to-base ratio, and many drivers cannot effectively make a second full trip It is impeded by congested street operations in Washington, D.C., and ineffective routing patterns—there are no routes through Washington as part of an integrated bus system

ARTERIAL-RELATED BUS PRIORITY TREATMENTS

Most urban bus service will continue to operate on arterial streets Busways and reserved bus lanes on freeways mainly will be limited to larger cities (metropolitan population usually over 1,000,000) where freeways provide direct service to the downtown area. All cities, however, will benefit from effective bus utilization of downtown and radial arterial streets, and from effective coordination of transit and traffic improvements Radial bus routes generally converge on a few downtown streets where bus priority treatments can expedite flow. Bus headways frequently range from 30 sec to 3 min

Buses carry more than one-half of all peak-hour travelers on arterial streets leading to and within the downtown area The relative use of buses—and in many cases the actual number of bus passengers—exceeds those on freeways Typical peak-hour bus and passenger characteristics, summarized in Table 10, underscore the importance of bus use on arterial streets and the need for bus priority treatments to maintain and increase patronage.

Buses on Hillside Avenue (New York City), State Street (Chicago), Market Street (Philadelphia), Market Street (San Francisco), and Pennsylvania Avenue (Washington, D.C.) carry more than 85 percent of the peak-hour travelers on those streets. Buses on downtown streets in Los Angeles, Atlanta, Pittsburgh, and Milwaukee carry more than 70 percent of all peak-hour travelers.

Arterial Priority Types and Examples

Significant examples of bus priority treatments on arterial streets are given in Tables 11 through 22. Treatments include (1) measures designed to separate car and bus movements and (2) general traffic engineering improvements designed to expedite over-all traffic flow.

TABLE 10

PEAK-HOUR BUS VOLUMES ON URBAN ARTERIALS, RANKED BY PERCENTAGE BUS PASSENGERS ARE OF TOTAL PASSENGERS, IN DOMINANT DIRECTION OF FLOW UNDER CURRENT CONDITIONS

ARTERIAL LOCATION	CITY	VEHICLES PER HOUR		PASSENGERS CARRIED			PER CENT CARRIED BY BUS
		BUS	AUTO	BUS	AUTO	TOTAL	
Nicollet Mall	Minneapolis	64	0	2,900	0	2,900	100.0
Market Street (East of Broad)	Philadelphia	143(2)	465	8,300	695	8,995	92.5
State Street @ Madison	Chicago	151(2)	465	6,100	660	6,760	90.0
Hillside Avenue	New York	170(2)	630	8,500	950	9,450	90.0
Pennsylvania Avenue @ Seventh	Washington, D.C.	120	600	6,000	900	6,900	87.0
Market Street @ Van Ness	San Francisco	155(2)	1,200	9,900	1,550	11,450	86.5
Main Street @ Fourth Street	Los Angeles	115	720	5,850	1,100	6,950	84.0
Main Street @ Harwood Street	Dallas	100	635	4,400	900	5,300	83.0
Hill Street @ Seventh Street	Los Angeles	109	800	5,250	1,200	6,450	81.5
Broad Street @ Hunter Street	Atlanta	48	290	1,920	435	2,355	81.5
Seventh Street @ Main Street	Los Angeles	91	705	4,500	1,050	5,550	81.0
Forbes Avenue @ Wood Street	Pittsburgh	47	400	2,300	560	2,860	79.5
Fifth Avenue @ Smithfield	Pittsburgh	47	420	2,300	590	2,890	79.5
Liberty Street @ Sixth Avenue	Pittsburgh	66	650	3,250	910	4,160	78.2
"K" Street NW @ 13th Street	Washington, D.C.	130	1,300	6,500	1,950	8,450	77.0
Eye Street @ 13th Street	Washington, D.C.	104	1,100	5,200	1,600	6,800	76.5
Smithfield Street @ Fifth Avenue	Pittsburgh	50	550	2,450	770	3,220	76.0
Thirteenth Street @ "F" Street	Washington, D.C.	101	1,050	5,000	1,600	6,600	75.8
Broadway @ Sixth Street	Los Angeles	78	850	4,000	1,390	5,390	74.5
Adams Street Bridge	Chicago	107	785	3,425	1,220	4,645	73.7
Granville Street @ Georgia	Vancouver	70	900	3,150	1,200	4,350	72.5
Wisconsin Avenue	Milwaukee	78	935	3,100	1,200	4,300	72.0
Chestnut @ 12th Street	Philadelphia	67	890	3,350	1,350	4,700	71.5
State Street @ Roosevelt	Chicago	72	670	2,305	935	3,240	71.4
Washington Street @ Wacker	Chicago	108	1,100	3,800	1,540	5,340	71.4
Wood Street @ Forsyth Ave.	Pittsburgh	55	800	2,700	1,120	3,820	70.8
Seventh Street @ Pennsylvania Ave.	Washington, D.C.	80	1,150	4,000	1,720	5,720	70.0
Main Street @ Pratt	Hartford	75	625	1,875	815	2,690	70.0
Jackson Blvd. Bridge	Chicago	88	845	2,815	1,325	4,140	68.0
Sixth Avenue @ Smithfield	Pittsburgh	33	560	1,620	780	2,400	67.6
Eglington Avenue @ Bathurst	Toronto	80	1,200	3,300	1,700	5,000	66.0
Elm Street @ Harwood	Dallas	80	1,345	3,500	1,880	5,380	65.2
Sacramento Street	San Francisco	25	410	1,000	535	1,535	65.0
Constitution Avenue @ 15th	Washington, D.C.	120	2,200	6,000	3,300	9,300	64.5

(Continued)

ARTERIAL LOCATION	CITY	VEHICLES PER HOUR		PASSENGERS CARRIED			PER CENT CARRIED BY BUS
		BUS	AUTO	BUS	AUTO	TOTAL	
Spring Street @ Seventh Street	Los Angeles	111	1,500	4,450	2,500	6,950	64.0
Sixteenth Street @ Florida Ave.	Washington, D.C.	80	1,500	4,000	2,250	6,250	64.0
Fourteenth Street @ Constitution Ave.	Washington, D.C.	80	1,550	4,000	2,350	6,350	63.0
Connecticut Avenue @ Cathedral Ave.	Washington, D.C.	90	1,800	4,500	2,700	7,200	62.5
Walnut @ 15th Street	Philadelphia	48	960	2,400	1,450	3,850	62.5
Commerce Street @ St. Paul	Dallas	72	1,415	3,300	2,120	5,420	61.0
Sheridan @ Hollywood	Chicago	32	500	1,100	700	1,800	61.0
Michigan Avenue @ Roosevelt Rd.	Chicago	77	770	1,815	1,210	3,025	60.0
Asylum @ Main Street	Hartford	35	450	875	585	1,460	60.0
Michigan Avenue Bridge (Upper Level)	Chicago	116	1,590	3,580	2,390	5,970	60.0
Sutter Street	San Francisco	63	1,300	2,500	1,700	4,200	59.5
Madison Avenue @ 42nd Street	New York	96	2,400	4,800	3,600	8,400	57.1
Second Avenue @ 42nd Street	New York	110	2,800	5,500	4,200	9,700	56.8
First Avenue @ 44th Street	New York	110	2,800	5,500	4,200	9,700	56.8
Sixth Street @ Figueroa	Los Angeles	29	965	1,875	1,430	3,305	56.7
Georgia Avenue @ Granville	Vancouver	45	1,200	2,000	1,600	3,600	55.5
Clay Street	San Francisco	26	650	1,050	850	1,900	55.3
Ninth Street @ Market Street	Philadelphia	22	600	1,100	900	2,000	55.0
Second Avenue North	Birmingham, Ala.	44	1,400	2,300	1,950	4,250	54.0
Grand Avenue @ Temple Street	Los Angeles	24	855	1,400	1,215	2,615	53.5
Geary Street	San Francisco	43	1,250	1,720	1,630	3,350	51.4
Howard Street @ Fayette Street	Baltimore	30	470	790	755	1,545	51.0
Marietta @ Spring Street	Atlanta	35	1,050	1,400	1,580	2,980	47.0
Peachtree @ Ellis	Atlanta	55	1,700	2,200	2,550	4,750	46.5
Tryon Street	Charlotte, N.C.	40	1,150	1,200	1,700	2,900	41.4
Eighth Street @ Los Angeles St.	Los Angeles	30	1,155	1,290	1,895	3,130	41.3
O'Farrell Street	San Francisco	27	1,200	1,080	1,550	2,630	41.2
Trade Street	Charlotte, N.C.	30	1,000	1,000	1,500	2,500	40.0
Pratt Street @ Paca St.	Baltimore	64	2,390	2,215	3,825	6,040	36.7
Charles Street @ Madison St.	Baltimore	33	1,915	1,480	3,060	4,540	32.6
Lombard Street @ Greene St.	Baltimore	42	1,750	1,335	2,800	4,135	32.0
Eleventh Street Bridge	Washington, D.C.	54	4,120	2,870	7,735	10,605	27.1
Cathedral Street @ Eager	Baltimore	36	1,545	880	2,470	3,350	26.3
St. Paul Street @ Preston	Baltimore	45	2,815	1,375	4,505	5,880	23.4
Calvert Street @ Lexington	Baltimore	39	2,645	1,185	4,230	5,415	21.9

(1) Data compiled by Wilbur Smith and Associates involves assumptions in some cases as to car or bus occupancy.

(2) Buses operate in more than one lane.

TABLE 11

EXISTING AND PROPOSED CBD BUS STREETS, UNITED STATES, CANADA, AND OTHERS

COUNTRY, CITY, LOCATION	1970 URBANIZED AREA POPULATION	DATE STARTED OR STATUS	LENGTH MILES	HOURS OF OPERATION	PEAK-HOUR BUS VOLUMES (AND PASSENGERS/ HEAVY DIRECTION)	REPORTED BENEFITS	REMARKS
Chicago, Ill.(1) Halsted St. between 62nd St.-64th St.	6,714,578	Existing	0.25	24 hours	22	No cross auto traffic 22' wide streets	Part of Englewood Conservation Plan
Chicago, Ill.(1) 63rd St. between Emerald Ave.-Peoria St.		Existing	0.19	24 hours	13	No cross auto traffic 22' wide streets	Part of Englewood Conservation Plan
Minneapolis, Minn. Nicollet Mall	1,704,423	1968	0.68	24 hours	64	Part of Downtown Revitalization Plan	24 wide roadway
Atlanta, Ga. Broad Street	1,172,778	Prop. 1970	0.64	24 hours	69		Center City Transportation Project Proposal 40' wide streets
Dallas, Tex. Main St. CBD	1,338,684	Prop. 1970	0.90	24 hours	100		Center City Transportation Project Proposal.
Hartford, Conn. Main Street	465,001	Prop. 1971	0.25	24 hours			Commission of the City Plan Proposal
St. Louis, Mo. Locust St.	1,882,944	Prop. 1971	0.40	4-6 P.M.	100		North Curb - Farside Local Bus - Loading Median - Nearside Express Bus Loading
Vancouver, B.C., Canada Granville Bus Hastings and Howard St.	440,000	Prop. 1971	1.00	24 hours	90		Greater Vancouver Regional District Proposal
Bournemouth, England	153,000	Existing	.06	24 hours	90		25' wide roadway
Chatham, England	225,000	1967	.02	24 hours	30		20' wide roadway
Leeds, England	1,153,000	1970	--	24 hours	--		Minibus service in pedestrianized central business district.
Newcastle Upon Tyne, England	1,400,000	Existing	.06	24 hours	85		22' wide roadway
		Existing	.03	24 hours	104		30' wide roadway
Oxford, England	200,000	Existing	.06	24 hours	17		35' wide roadway
Reading, England Broad Street	178,000	1970	0.23	24 hours	130		Main Shopping street reserved for buses and access to premises.
Queen Victoria Street		1970	0.06	24 hours	50		Part of larger traffic management scheme. Bus lines ware rerouted so that each line now passes through Broad Street.
Rugby, England Market Street	56,500	1969	.02	24 hours			Street narrows to 12 feet - 2 way bus flow
Workingham, England	21,000	Existing	.02	24 hours	3		15' wide roadway
Leeds, England	1,153,000	Proposed	.09	24 hours			20' wide roadway
		Proposed	.04	24 hours			24' wide roadway
London, England Oxford Street	12,000,000	Approved	.67	11 A.M. to 9 P.M. Mon-Sat			Shopping street with large pedestrian volumes Taxis and delivery vehicles will be permitted on roadway which will be narrowed from 4 to 2 lanes.
Oxford, England	200,000	Proposed	.08	24 hours	45		25'-25' roadway
Tynemouth, England	72,400	Proposed	.06	24 hours	55		11' wide roadway
Johannesburg, South Africa Twist St. Bus Street Plein-Wolmarans	2,075,000	1966	1.30	24 hours			
Hillbrows Pk. Bus Street Edith Cavelle-Clarendon Pl.		1960	0.10	24 hours			
Madrid, Spain Fuencarral between Perez Galdos to Jose Antonio	2,900,000	Existing	.16	24 hours		Saves about one minute per trip.	One-way bus taxi street
Stockholm, Sweden Kungsgatan between Vasagatan and Sveagan	1,300,000	Existing	0.31	24 hours	60	Saves buses 3 minutes per trip	Taxis, delivery vehicles, bicycles allowed

(1) Outlying business district.

TABLE 12

EXISTING CBD CURB BUS LANES, UNITED STATES, CANADA, AND OTHERS

CITY AND LOCATION	DATE STARTED OR STATUS	LENGTH (MILES AND BLOCKS)	HOURS OF OPERATION	TRAFFIC SIGNAL CONTROLS	TRAFFIC SIGNS (Where Specified)	PAVEMENT MARKINGS	PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
Atlanta, Ga. Walton St. Broad-Forsythe	1958	.08 miles	7-9 A.M. 4-6:30 P.M.	No		Median Loading Island	30		
Chicago, Ill. Washington St. Wacker Dr.-Michigan Ave.	1956	0.60 miles	24 hours	No		Yellow and white paint Barriers and islands	108	14-28 per cent speed up in transit operations	One-way street 8 nearside stops
Chicago, Ill. State St. Wacker Dr.-Congress St.	1958	0.60 miles	24 hours	No		Yellow islands and stanchions			Two-way street Buses and mixed traffic. Carryover from streetcar operations.
New Orleans, La. Canal St. Neutral Ground between Miss. River and N. Claiborne St.	1966	1.25 miles	24 hours	Traffic signals for buses			55		Track removal and street resurfacing. Cost $4 million. 375 buses/day.
Philadelphia, Pa. Market St. 6th - Broad	1956	0.65 miles	24 hours	No		Concrete pedestrian loading islands	120		Two-way street buses and mixed traffic. Carryover from streetcar operations.
London, England Vauxhall Bridge	1968	0.17 miles	4-7 P.M.		Some signing	Solid White Paint marking line	100	Reported savings - 3 min./journey. 180 bus passenger hours and 50 car passenger hours during peak period.	10' median bus lane on 5 lane street
Milan, Italy Via Ponte Sevesu			24 hours			Small concrete barriers			Trolley bus lane
Milan, Italy Via Sofia			24 hours			Small concrete barriers			Trolley bus lane
Milan, Italy Via Dante			24 hours			Small concrete barriers			

Bus Lanes

Bus lanes comprise the treatment most commonly used. These lanes either are used exclusively by buses or are shared with taxis and right-turning vehicles They are located along curbs or in street medians, and they operate in or counter to automobile traffic flow. Bus lanes generally involve removing a travel lane from automobile use and giving it to buses. They are sometimes implemented in conjunction with one-way street routings and curb parking prohibitions, in these cases, there is usually no net loss in street capacity In other cases, buses normally dominate the lanes used and the designation of bus priority lanes causes no appreciable change in automobile capacity.

Curb Bus Lanes, Normal Traffic Flow —Curb bus lanes in the normal direction of flow are the most common. They occur in more than 20 cities in the United States and Canada, and in a number of European cities. Baltimore, New York City, San Francisco, and Washington in the United States, and London, Madrid, Milan, and Paris in Europe have extensive installations

These lanes are usually in effect during peak periods, although some operate continuously. They are easy to implement and involve minimum street routing changes at

TABLE 13

EXISTING AND PROPOSED NORMAL-FLOW ARTERIAL CURB BUS LANES, UNITED STATES, CANADA, AND OTHERS

CITY AND LOCATION	DATE STARTED OR STATUS	LENGTH (MILES AND BLOCKS)	HOURS OF OPERATION	RIGHT TURNS ALLOWED	SIDE STREETS BLOCKED	SPECIAL SIGNAL CONTROLS	TRAFFIC SIGNS	PAVEMENT MARKINGS	PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
Chicago, Ill Cermak Rd.-47th Ave. Turnaround	Existing	0.03 miles	24 hours	Yes	No	Yes	Yes	Median island separates lanes	12		Bus turnaround with special bus signal controls
New York, N.Y. Hillside Ave., Queens Francis Lewis Blvd. 167th St.	1969 Approx.	2.0 miles	7-9 A.M 4-7 P.M.	Yes	No	No	Curb lane islands, right turns only	Solid yellow lines w/ white dashes	170		10' lanes in flow direction only on 6 lane street 120 buses/hour observed in curb lanes
Livingston St., Brooklyn Flatbush Ave.-Boerm Pl.	1963	0.68 miles	7-9 A.M 4-7 P.M.	Yes	No	No	Curb lane, 11 buses right turns only	Solid yellow lines w/ white dashes	77		10' lanes.
Victory Blvd., Staten Isl Bay St.-Forest Ave	1963	1.0 miles	7-9 A M 4-7 P.M.	Yes	No		Canti-levered signs 'Buses Curb Lane Only'	Solid yellow lines w/ white dashes	64		10' lanes
Toronto, Canada Eglinton Avenue between Bathurst St. and Brentcliffe	1972	3.2 miles	7-9 A M. 4-6 P.M.			No				42 second time savings	Est. Cost - $50,000 for signs, channelization removal and markings.
Houston, Tex Cochran Brooks to North Loop	Prop 1970	3.35 miles	A.M. & P.M. Peak								"Suburbia, Ltd Inc."
Elyston, Tex. Commerce to Calycade	Prop. 1970	3.00 miles	A.M. & P.M. Peak								Proposal by Houston Rapid Transit Lines, Inc
Sherman, Tex Commerce to 69th	Prop. 1970	3.20 miles	A.M. & P.M. Peak								
Polk, Tex. Fannin to Wayside	Prop. 1970	3.70 miles	A.M. & P.M. Peak								
Main Texas to Hiram Clark	Prop 1970	9.60 miles	A.M. & P.M. Peak								
West Dallas Main to Dunlavy	Prop. 1970	2.10 miles	A.M. & P.M. Peak								
Center Street Houston to Hempstead	Prop. 1970	3.00 miles	A.M. & P.M. Peak								
Houston Ave Reisner to White Oak	Prop 1970	1.00 miles	A.M. & P.M. Peak								
St. Louis, Mo Natural Bridge Rd	Prop. 1971	9.00 miles	Flow Direction Peak Hour	Yes	No	No			30		Proposed by Bi-State Transportation Agency
St. Louis, Mo. Olive St.	Prop. 1971	2.0 miles	Flow Direction Peak Hour	Yes	No	No					
St Louis, Mo. Lindell Blvd.	Prop. 1971	2.2 miles	Flow Direction Peak Hour	Yes	No	No					
St. Louis, Mo. Market St.	Prop. 1971	2.5 miles	Flow Direction Peak hour	Yes	No	No					
St Louis, Mo. Vandeventer Dr.	Prop. 1971	3.75 miles	Flow Direction Peak Hour	Yes	No	No					
St. Louis, Mo. Gravois Dr.	Prop. 1971	7.5 miles	Flow Direction Peak Hour	Yes	No	No					
Washington, D.C. Connecticut Ave. NW Cathedral & Jennifer	Prop 1972	2.0 miles	Flow Direction Peak Hour	Yes	No				90		
Pennsylvania Ave. SE Sousa Bridge - 2nd St.	Prop. 1972	1.30 miles	Flow Direction Peak Hour	Yes	No	No			60		
Benning Rd. NE between 34th St.-Bladensburg Rd.	Prop. 1972	1.65 miles	Flow Direction Peak Hour	Yes	No	No			--		
H Street NE between Florida-2nd St.	Prop. 1972	1.1 miles	Flow Direction Peak Hour	Yes	No	No			--		
Dublin, Ireland North Strand Rd. and Fairview between Portland Row and Howth Rd.	1971 One-Week Experiment Only	2.1 miles	8-9 30 A M.	Yes	No	No		4"x40' white line with 10' gaps	170		Saves 2 mins. for buses Loses 2½ min for cars. Variance of bus trip times reduced. Allows taxis.

TABLE 14

EXISTING AND PROPOSED CONTRA-FLOW ARTERIAL CURB BUS LANES, UNITED STATES

CITY AND LOCATION	DATE STARTED OR STATUS	LENGTH (MILES AND BLOCKS)	HOURS OF OPERATION(1)	SPECIAL SIGNAL CONTROLS	TRAFFIC SIGNS	PAVEMENT MARKINGS	PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
Chicago, Ill. N. Sheridan Rd.	1939	1.25 miles	7-9:30 A.M. 4-6:30 P.M.	No	Portable Slip Signs	Orange and white lane lines	32 (1,100)		Local traffic allowed with buses.
Indianapolis, Ind.	1965	2.75 miles	24 hours				10		
Louisville, Ky. 3rd St. between Breckenridge and Avery	1971	1.50 miles	7-9 A.M.		Yes		12(2)	25% reduction in travel time	$4,600 cost 3 express bus lines
Madison, Wisc. University Ave.	1966	2.0 miles	24 hours				15		Limited-Use Lane 7 Stops: 4 Farside, 3 Nearside
Buffalo, N.Y. Delaware Ave Lafayette and North	Proposed 1972	1.7 miles	9-11:00 A.M.						
Louisville, Ky. 3rd St. between Oakdale Ave. and Brandeis Ave.	Proposed	1.50	7-9 A.M.				12		Urban Corridor Proposal
Louisville, Ky. 4th St. between Oakdale Ave. and Brandeis Ave.	Proposed 1971	1.50 miles	406 P.M.				12		Urban Corridor Proposal

(1) Hours of lane operation; hours of bus operation may vary.
(2) Express bus volumes.

little cost. However, they are often difficult to enforce and may produce only marginal benefits to bus flow. Right-turning vehicles either conflict with buses or must be prohibited. In several European cities taxis are permitted to use these lanes and sometimes represent the dominant vehicle flow.

Median Bus Lanes—Median bus lanes are an outgrowth of streetcar operations Examples are found in Chicago (Washington Street), Philadelphia (Market Street), and New Orleans (Canal Street)

These lanes are in effect throughout the day They are removed from traffic conflicts along the curb, and they allow other traffic to make right turns without conflicting with buses. However, they require wide streets with provisions for service stops and pedestrian refuge in the median. Passengers are required to cross active traffic lanes to reach bus stops Left turns must be prohibited or controlled to minimize interference with buses

Contra-Flow Bus Lanes.—Contra-flow bus lanes, in which buses operate opposite to normal traffic flow, are increasing in number. They are found in Chicago, Harrisburg, Honolulu, Louisville, Madison, San Antonio, and San Juan in the United States; in at least ten English cities; and in Marseilles, Milan, Paris, and Rome on the Continent. The Louisville and San Juan installations, unlike most of the others, extend for considerable distances along arterial streets.

Contra-flow bus lanes operate on one-way streets, usually throughout the day, however they can be provided in conjunction with peak-hour bus service. Buses using the lanes are separated from other traffic flow, and are therefore not affected by peak-hour congestion at signalized intersections They are largely "self enforcing" and are subject to less infringement by taxis They frequently are located to permit more direct bus routing. They can create a sense of transit identity, and they separate bus loading from passengers in other vehicles.

The lanes may complicate loading and access to adjoining properties They increase left-turn conflicts with opposing traffic. On one-way streets with frequent signals, buses may have to operate against the signal progression.

TABLE 15

EXISTING AND PROPOSED NORMAL-FLOW CBD CURB BUS LANES, UNITED STATES AND CANADA

CITY, LOCATION AND LIMITS	1970 URBANIZED AREA POPULATION	DATE STARTED OR STATUS	LENGTH	HOURS OF OPERATION	RIGHT TURNS ALLOWED	SIDE STREETS BLOCKED	SPECIAL SIGNAL CONTROLS	TRAFFIC SIGNS	PAVEMENT MARKINGS	EXPECTED PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
Baltimore, Md.												
Charles St. From Madison - 26th St. (East Side)	1,579,781	1958-1959	1.50 miles	4-6:30 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	38	Buses: Speeded up 21% A.M. Peak, 87% P.M. Peak Other Traffic: Speeded Up 39% A.M. Peak 22% P.M. Peak	Average distance between stops 4 blocks. Effectives limited by enforcement. Effective 6 days/week
St. Paul St. From Eager-Preston (West Side)		1958	0.23 miles	7:30-10 A.M. 4-6 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	30		
Calvert St. Lexington-Madison (East Side)		1959	0.53 miles	3-6:30 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	39		
Howard St. Franklin-Fayette (West Side)		1958	0.30 miles	7-10 A.M. 4-6 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	26		
Paca St. Redwood-Mulberry (East Side)		1958	0.36 miles	7-10 A.M. 4-6 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	14		
Greene St. Fayette-Franklin (West Side)		1958	0.30 miles	7-10 A.M. 4-6 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	10		
Saratoga St. Cathedral-St. Paul (North Side)			0.15 miles	24 hours	Yes	No	No	"Buses Only"	Solid yellow lines	--		
Lombard St. Greene-Hanover (South Side)			0.40 miles	7-9 A.M.	Yes	No	No	"Buses Only"	Solid yellow lines	42		
Pratt St. Paca-Light (North Side)		1959	0.48 miles	4-6:30 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	64		
Baltimore St. Hopkins Pl.-Gay St. (South Side)		1963	0.30 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	10		
Fayette St. Eutaw-Calvert (North Side)		1963	0.47 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	"Buses Only"	Solid yellow lines	--		
Birmingham, Ala.												
Third Ave.	558,099	1958	0.80 miles	7-9 A.M. 4-6 P.M.	Yes	No	--	--	--	44	27.7 per cent decrease in bus travel time; 29 per cent decrease in auto travel time	Average distance between stops - 0.1 mile
Buffalo, N.Y. Church St. east of Main	1,086,594	1969	0.11 miles	24 hours	Yes	No	No	"Curb Lane - Buses Only 4 P.M. to 6 P.M. Ex.Sunday"	Solid yellow lines	10		Bus lane protected by raised curb both sides of street.
Main St. from Church-Chippewa	-	1964	0.70	4:30-6:30 P.M.	Yes	No	No	"Buses Only"		50		
Dallas, Tex.												
Elm Street Harwood-Akard	1,333,864	1958	0.55 miles	7-9 A.M. 4:30-6 P.M.	Yes	No	No	"Buses Only"		75		370 buses per day.

Commerce Street Griffin-St. Paul		1958	0.55 miles	7-9 A.M. 4:30-6 P.M.	Yes	No	No	"Buses Only"		75		370 buses per day.
Houston, Tex. Main Street Franklin - Leeland	1,677,863	1971	0.87 miles	7 A.M. to 6 P.M.	Yes		No	"Curb Lane Buses Only"	Dashed white lines	65		1,270 buses per day.
Nashville, Tenn Capitol Blvd. Dederick & Union	448,444	1956	0.25 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Overhead Neon Sign	Yellow lines	--	5% reduction in bus running time	First bus lane installation in United States
6th Avenue Charlotte & Broadway		1956	0.42 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Overhead Neon Sign	Yellow lines	--		
4th Avenue Deaderick & Broadway		1956	0.36 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Overhead Neon Sign	Yellow lines	--		
Union Street 2nd Ave.-Capitol Blvd.		1956	0.32 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Overhead Neon Sign	Yellow lines	--		
Broadway		1958	0.25 miles	7-9 A.M. 4-6 P.M.	Yes	No	No			--		
Newark, N.J. Market Street	382,417	1956	0.34 miles	4-6 P.M.	Yes	No	No	Overhead Neon Sign	Yellow lines	100	7 Min time savings over previous plan. Est. Annual benefits $87,000 to bus riders.	Curb Bus Lane Revised 1969.
New York City 42nd Street 3rd - 8th Ave.	16,206,841	1969	1.90 miles	7-10 A.M 4-7 P.M. Weekdays	Yes	No	--	Curb Lane Buses and Right Turn Only	Solid yellow lane lines	60		All bus lanes 10 ft. wide.
Fifth Avenue 86th - 35th Sts.		1969	2.50 miles	7 A M. - 7 P.M.	Yes	No	No	Bus Zone No Standing 7 AM - 7 PM		120	42 per cent reduction in bus travel time	Bus Zone.
Madison Ave. 34th-59th Sts.		1969	1.12 miles	7 A.M.- 7 P.M.	Yes	No	No	Bus Zone No Standing 7 A.M. - 7 P.M.	--	96	42 per cent reduction in bus travel time	Bus Zone
1st Ave. 34th-72nd St.		1969	1.90 miles	7-10 A.M. 4-7 P.M.	Yes	No	No	"Curb lane Buses and Right Turns Only 7-10 AM and 4-7 PM"	Solid yellow lane lines	110	27 per cent reduction in bus travel time	
2nd Ave. 34th-72nd St.		1969	1.90 miles	7-10 A.M. 4-7 P.M.	Yes	No	No	Same as Above	Solid yellow lane lines	110	22 per cent reduction in bus travel time	
57th St.		1971	1.20 miles	4-7 P.M.	Yes	No		Same as Above 4-7 PM	Solid yellow lane lines	80		
Lexington Ave. 34th and 59th			1.12 miles	7-10 A.M. 4-7 P.M.	Yes	No		Same as Above 7-10 AM 4-7 PM	Solid yellow lane lines	60		
3rd Ave. 34th - 59th St.			1.12 miles	7-10 A.M. 4-7 P.M.	Yes	No		Same as Above		60		
Montreal, Canada Rue St. Catherine	2,436,817	1966	0.06 miles	24 hours	Yes	No	No	--	--	17		

TABLE 15 *(continued)*

CITY, LOCATION AND LIMITS	1970 URBANIZED AREA POPULATION	DATE STARTED OR STATUS	LENGTH-MILES	HOURS OF OPERATION	RIGHT TURNS ALLOWED	STREETS BLOCKED	SPECIAL SIGNAL CONTROLS	TRAFFIC SIGNS	PAVEMENT MARKINGS	EXPECTED PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
Peoria, Illinois Adams St.	247,121	1959	4 blocks	3-6 P.M.	Yes	No					25 and 10 per cent increase in speeds for buses and automobiles, respectively.	
Jefferson St.		1959	4 blocks	3-6 P.M.	Yes	No					Same as Above.	
Providence, R.I. Weybosset St.	795,311	1968	0.50 Miles	AM Peak Period	Yes	No	No	"Bus Lane No Parking"	Solid white line (length of lane)	60		500 ft. between stops. 2 min. bus headway midday
Washington St.		1968	0.70 miles	PM Peak Period	Yes	No	No	"Bus Lane No Parking"	Solid white line (length of lane)	60		500 ft. between stops 2 min. bus headway midday
Rochester, N.Y. Main St.	601,361	1957	1.50 miles	All Day in CBD 7-9 A.M. 4-6 P.M. Elsewhere	Yes	No	No	"No Stopping Bus Lane"	--	20		
Lake Avenue Ridge to Lyell		1970	2.0	7-10 A.M. 3-7 P.M.	Yes	No	No	"For Buses" and Right Turns Only"	4" solid white line	19 (600)		
San Francisco, Calif. Clay St. Battery and Stockton	2,987,850	1970	0.43 miles	7-9 A.M.	Yes	No	No	"Tow Away Bus Only Except Right Turns"	--	26	Solid white line (length of lane)	
Sacramento St. Drumm and Larkin		1970	1.30 miles	4-6 P.M.	Yes	No	No	Same as Above	--	25	Same as Above	
Sutter St. Sansome and Gough		1970	1.40 miles	4-6 P.M.	Yes	No	No	Same as Above	--	63	Same as Above	
Geary St. Gough and Kearney		1971	1.20 miles	4-6 P.M.	Yes	No	No	Same as Above	--	43	Same as Above	
O'Farrell St. Grant and Hyde		1970	0.65 miles	7-9 A.M.	Yes	No	No	Same as Above	--	27	Same as Above	
Syracuse, N.Y. Salina St. Area Blvd. to Adams St.	376,169	1970		7-9 A M. 4-6 P.M.	Yes	No	No	--	--	80		Two 8 ft. curb bus lanes on 6-lane 56 ft. street
Warren St. Area Blvd. to Adams St.		1970		7-9 A.M. 4-6 P.M.	Yes	No	No	--	--	--		
Fayette St.		1970		7-9 A.M. 4-6 P.M.	Yes	No	No	--	--	--		
Vancouver, B.C. West Georgia Burrard-Pender	440,000	1963	0.50 miles	4-6 P.M.	Yes	No	No	"Curb Lane Buses Only"	--	40	Bus running time reduced approx. 20 per cent	
Washington, D.C. 14th N.W. D St. SW and New York Ave. NW	2,481,489		1.00 mile	7-9 A.M.	Yes	No	No	Blue-red signs Curb Lane Buses and Right Turn Only 7-9 and	6" yellow dashed lines 10' long 10' spaced plus "Bus Lane" Designation	60		

								4-6 as Approp.			
14th St. NW Pa. Ave. NW and D St. SW			0.75 miles	4-6 P.M.	Yes	No	No	Same as Above	Same as Above	80	
7th St. NW Pa. and Indep.			0.40 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Same as Above	Same as Above	80	
16th St. NW Eye and U			1.10 miles	4-6 P.M.	Yes	No	No	Same as Above	Same as Above	80	
16th St. NW Florida and L			0.40 mile	7-9 A.M.	Yes	No	No	Same as Above	Same as Above	80	
13th St. NW F and H			0.20 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Same as Above	Same as Above	100	
Eye St. NW 14th and 17th			0.35 miles	7-9 A.M. 4-6 P.M.	Yes	No	No	Same as Above	Same as Above	100	
Eye St NW 13th and 14th			0.15 miles	4-6 P.M.	Yes	No	No	Same as Above	Same as Above	100	
H St. NW 14th and Conn.			0.35 mile	7-9 A.M. 4-6 P.M.	Yes	No	No	Same as Above	Same as Above	60	
Winnipeg, Canada Main Street Selkirk Ave. and Redwood Ave.	508,759	1958	0.50 miles		From middle lane w/ Police. Superv.						
Buffalo, N.Y. Delavan Delaware & Main	1,086,594	Proposed 1972	0.70 miles	24 hours	Yes	No	No	--	--		
Michigan Main & Perry		Proposed 1972	0.23 miles	24 hours	Yes	No	No	--	--		
Charlotte, N.C. Tryon St. Moorehead, 11th	279,530	Proposed 1972	1.3 miles	7-9 A.M.	Yes	No	--	--	--	40	
Trade St. McDowell-Graham		Proposed 1972	1.0 miles	7-9 A.M.	Yes	No	--	--	--	30	
Hartford, Conn. Main St.	465,001	Proposed 1971	0.57 miles	AM & PM Peak Hour	Yes	No	--	--	--	75	
Asylum St.		Proposed 1971	0 43 miles	AM & PM Peak Hour	Yes	No	--	--	--	35	
Pearl St.		Proposed 1971	0.32 miles	AM & PM Peak Hour	Yes	No	--	--	--	35	
Pittsburgh, Pa. Smithfield St. Ft. Pitt Blvd. to Liberty Ave.	1,846,042	Proposed 1970	0.53 miles		Yes	No	No	--	--	50	Center City Transp. Project Proposal 36' Street-Downtown Patway Distribution
Wood St. Liberty-Blvd. of Allies		Proposed 1970	0.32 miles		Yes	No	No	--	--	50	36' Street - Downtown Patway Distribution
Stannix St. Liberty-Ft. Duquesne Blvd.		Proposed 1970	0.15 miles		Yes	No	No	--	--	74	50' Street - Downtown Patway Distribution
Sixth St. Liberty-Ft. Duquesne Blvd.		Proposed 1970	0.15 miles		Yes	No	No	--	--	50	36' Street - Downtown Patway Distribution
Ninth St. Liberty-Ft. Duquesne Blvd.		Proposed 1970	0.15 miles		Yes	No	No	--	--	24	36' Street - Downtown Patway Distribution
Forbes Ave. Stanwix-Ross St.		Proposed 1970	0.45 miles		Yes	No	No	--	--	47	34' Street - Downtown Patway Distribution
Fifth Ave. Liberty-Ross St.		Proposed 1970	0.40 miles		Yes	No	No	--	--	74	36' Street - Downtown Patway Distribution
Liberty St. Sixth-Stanwix		Proposed 1970	0.10 miles		Yes	No	No	--	--	100	48' Street - Downtown Patway Distribution
Liberty St. 11th - Ninth		Proposed 1970	0.20 miles		Yes	No	No	--	--	100	48' Street - Downtown Patway Distribution
Liberty St. Smithfield St.-Grant		Proposed 1970	0.15 miles		Yes	No	No	--	--	100	48' Street - Downtown Patway Distribution

TABLE 15 (*continued*)

CITY, LOCATION AND LIMITS	1970 URBANIZED AREA POPULATION	DATE STARTED OR STATUS	LENGTH	HOURS OF OPERATION	RIGHT TURNS ALLOWED	SIDE STREETS BLOCKED	SPECIAL SIGNAL CONTROLS	TRAFFIC SIGNS	PAVEMENT MARKINGS	EXPECTED PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
St. Louis, Mo. 6th Street Market-Franklin	1,882,944	Proposed 1971	0.60 miles	3-6 P.M.	Yes	No	No	--	--	90		
7th Street Market-Franklin		Proposed 1971	0.60 miles	3-6 P.M.	Yes	No	No	--	--	90		
8th Street Market-Franklin		Proposed 1971	0.60 miles	3-6 P.M.	Yes	No	No	--	--	30		
9th Street Market-Franklin		Proposed 1971	0.60 miles	3-6 P.M.	Yes	No	No	--	--	30		
Market Street Broadway - 12th		Proposed 1971	0.50 miles	7-9:30 A.M. 3-6 P.M.	Yes	No	No	--	--	50		
Washington St. 16th - Jefferson Memorial Expansion		Proposed 1971	1.10 miles	7-9:30 A.M. 3-6 P.M.	Yes	No	No	--	--	100		
Olive Street 12th - 4th Sts.		Proposed 1971	0.50 miles	7-9:30 A.M. 3-6 P.M.	Yes	No	No	--	--	80		
Vancouver, B.C. Hastings St. Granville-Main		Proposed 1971	0.90 miles	A.M.&P.M.	Yes	No	No	Curb lane buses only	--	80	Proposed for Greater Vancouver Regional District	
Washington, D.C. Constitution Ave. NW 6th - 15th Sts. Both Sides		Proposed 1971	0.75 miles	A.M.&P.M.	Yes	No	No	--	--	120		Same traffic controls as for existing lanes
K St. NW 21st and 13th Sts. South Side		Proposed 1971	0.90 miles	A.M.&P.M.	Yes	No	No	--	--	80		

Bus Streets

Bus streets represent a major commitment to downtow transit and development. The best-known examples ar Nicollet Mall in Minneapolis, and 63rd and Halsted Stree (Englewood) in Chicago. Short lengths of bus streets ar found in several English cities, including Chatham, Londo Newcastle upon Tyne, Oxford, Rugby, Sunderland, an Tynemouth, and in Madrid and Stockholm. Bus stree have been proposed for Atlanta, Dallas, Hartford, S Louis, and Vancouver. Most allow bus movement in bot directions.

In Liege, Belgium, a segregated bus right-of-way abou 1¼ miles in length exists on the principal bus route crossin the city from north to south. A 3,600-ft section run through a park between two rows of trees 25 ft apart, an the ½-mile section following it is sited in the middle of boulevard Another segregated right-of-way, nearly 2 mile long, is under construction

Bus streets provide complete separation of cars an buses They improve transit identity and create easie pedestrian access by removing vehicles They are difficul to implement, however, because of access requirements t adjacent buildings, and the need for alternate, paralle traffic routes The presence of parking garages along street may prevent exclusive use of the street by buses Thi factor precludes designating Pittsburgh's Smithfield Stree as an all-transit street.

The bus street concept could be extended to a series o streets or to an entire downtown area This results in "traffic-free zone " In 1972 there were no such zones in the United States, although several exist in European cities

Bus Priorities at Traffic Signals

Bus priorities at traffic signals—particularly special bu signal phases—are common in Europe. Many, however are an outgrowth of special tram signals. In Leicester England, bus-actuated signals have significantly improve bus travel times, and in Southampton, England, signals wil be timed to favor buses along a major artery leading to th city center.

A few examples are found in the United States These include the special bus lane and signal phasing at the Cermak Road bus turnaround in Chicago; bus actuation of signals along East Main Street in Kent, Ohio; and the bus preempt systems being installed in downtown Washington, D.C , and in Louisville.

Traffic Engineering Improvements

Coordination of road construction and traffic improvements with bus service will improve street efficiency Street improvements that relieve bottlenecks will improve bus effectiveness. The range of transit-related TOPICS-type improvements that help buses include. street extensions to increase traffic capacity or bus routing continuity; traffic signal improvements, such as system coordination, modernization, and preemptions or overrides for buses; intersection improvements; turn controls with special permits for buses; bus turnouts for loading and unloading; bus stop lengthening or relocation; longer curb radii and corner rounding;

TABLE 16

EXISTING AND PROPOSED NORMAL-FLOW CBD CURB BUS LANES, GREAT BRITAIN

CITY LOCATION (Population)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK-HOUR BUS VOLUME	REPORTED BENEFITS AND OTHER OBSERVATIONS
Liverpool (1,700,000)	Existing	0.08	24 hours	25	55' wide street. 12' bus lane.
Liverpool	Existing	0.01	24 hours	10	30' wide streets. 15' bus lanes.
London (11,000,000)					
Albert Embankment	1971	0.23	8-10 A.M.	55	Signs - Solid white stripe on pavement. 10' bus lane.
Brixton Road	1969	0.23	7-9:30 A.M.	105	Signs - Solid white stripe on pavement. 10' bus lane. 3 lanes wide, one-way street ends 300 ft. from intersection. 1½ minute saving per bus trip on Brixton Road; ½ minute loss to buses on cross routes. ½ minute gain to autos. Traffic flow same.
Park Lane	1968	0.10	4-7 P.M.	160	Signs - solid white stripe on pavement. 10' bus lane; recommend modification. ½ minute loss per bus per trip. ½ minute loss per auto per trip. Up to 500 violations per peak.
Newcastle-Upon-Tyne (1,400,000)	Existing	0.68	8-9:30 A.M.	100	44' wide street. 11' bus lane.
Salford (143,000)	Existing	0.08	24 hours	140	56' wide street. 10' bus lane.
Salford	Existing	0.09	24 hours	140	56' wide street. 10' bus lane.
Southampton (375,000)	Existing	0.30	24 hours	18	38' wide street. 12' bus lane.
Manchester (2,885,000)	Existing		24 hours	140	Part of a one-way street system -- to divert autos from CBD.
Gateshead (101,000)	1970	0.13	24 hours	90	40 foot wide street.
Salford	Proposed	0.34	24 hours	--	

NOTE: Additional bus lanes exist in Cardiff (0.14 miles); Glasgow (0.93 miles); Gloucester (0. 17 miles); Hereford (0.07 miles); and Sheffield (0.13 miles).

effective enforcement and extension of parking regulations; improved spacing of bus stops, and bus shelters

Los Angeles has extensive peak-hour left-turn restrictions that exempt buses at locations where roadway width or capacity constraints preclude provision of left-turn lanes. Buses are exempt from left-turn or right-turn restrictions in the London metropolitan area These turn allowances are part of a broad traffic management policy designed to keep buses on their traditional routes while increasing street capacity

Proper bus stop location can reduce bus travel times. Alternate stop patterns (i.e , near-side, far-side, near-side, far-side, etc.) may be superior to all-near-side or all-far-side patterns where signals are frequent if this pattern of stops allows buses to reach more signals on green. Revision of stopping patterns in relation to street directions and signal locations usually involves small costs (relocation of the bus-stop signs and adjustment of parking regulations) (*4*). Care should be exercised to avoid passenger confusion resulting from lack of stop consistency

Significant Characteristics

A review of contemporary practice indicates the common characteristics outlined in the following.

Location and Extent

Most bus priority treatments relate to points of major congestion where buses concentrate and/or where there is a need to produce "bus route identity."

1 Most treatments are found in central business districts and are designed to alleviate local problem situations. They are usually short sections, a few blocks long. Relatively few treatments occur or are proposed on arterial streets that radiate outward from the CBD.

2 In the United States, curb bus lanes in the prevailing direction of flow are the most common treatment; both contra-flow and median bus lanes are special cases.

3. European treatments involve relatively more contra-flow lanes on one-way streets. They are short, generally about 500 ft long, and are primarily spot controls designed to overcome specific bottleneck conditions Bus lanes in France are not as restricted lengthwise and represent the most extensive network of contra-flow bus lanes on the Continent.

4. The "bus mall" concept is becoming increasingly popular. In the United States, use of bus streets usually is motivated by environmental planning considerations rather than by bus flow requirements Although only a few

TABLE 17

EXISTING AND PROPOSED NORMAL-FLOW CBD CURB BUS LANES, FRANCE

CITY AND LOCATION (POPULATION)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK-HOUR BUS VOLUME	REPORTED BENEFITS	OTHER OBSERVATIONS
France, Paris (8,850,000)						
Avenue F.D. Roosevelt Avenue Selvesto-Ave. Champs Elysses	1966	0.12	8 A.M.- 9 P.M.	37	Comment: 28 existing streets; total length 5.5 mi. About 60 per cent of bus lanes replaced parking on street.	3 bus routes serve 5-lane street. 10' bus lane; no bus stops.
Boulevard St. Germain Carrefour de L'Odeon	1966	0.05	8 A.M.- 9 P.M.	27		3 bus routes serve 7-lane street. 9' bus lane; one bus stop.
Avenue De L'Opera Rue de l'Echelle to Place du Theatre Francais	1966	0.05	8 A.M.- 9 P.M.	25		2 bus routes serve 3-lane street. 9' bus lane; one bus stop
Place De L'Opera Rue Auber to Boulevard des Capucines	1966	0.03	8 A.M.- 9 P.M.	60		5 bus routes serve 6-lane street. 10' bus lane; one bus stop.
Quai De Louvre Pont du Carrousel to Pont Neuf	1964	0.42	8 A.M.- 9 P.M.	95	Peak bus speeds increased by 4.5 mph; off peak bus speeds increased by 2.3 mph.	11 bus routes serve 5-lane street. 10' bus lane; one bus stop.
Quai De La Megisserie Pont Neuf to exit riverside expwy.	1964	0.22	8 A.M.- 9 P.M.	97	Peak bus speeds increased by 4.5 mph; off peak bus speeds increased by 2.3 mph.	12 bus routes serve 5-lane street. 2 bus stops.
Avenue De Fountainebleau au Kremlin-Bicetre (RN 7)	1967	0.43	7 A.M.- 8 P.M.	92		8 bus routes serve 3-lane street. 10' bus lanes; two bus stops.
Boulevard St. Michel Rue Soufflot to Place St. Michel	1968	0.41	1 P.M.- 8:30 P.M.	62	Peak bus speeds increased by 2.0 mph; off peak bus speeds increased by 2.1 mph.	5 bus routes serve 3-lane street. 10' bus lane; two bus stops
Rue de Rivoli Rue Des Archives to Rue St. Martin	1968	0.20	1 P.M.- 8:30 P.M.	60		8 bus routes serve 5-lane street. 10' bus lanes; one bus stop.
Avenue de L'Opera Rue Ste. Anne to Rue Louis-le-Grand	1968	0.30	1-8:30 P.M.	82		7 bus routes serve 3-lane street.
Avenue de L'Opera Rue Louis-le-Grand to Rue du 4 Sept.	1967	0.04	8 A.M.- 9 P.M.	82		7 bus routes serve 3-lane street. 10' bus lane; no bus stops
Blvd. St. Germain Rue des Saints-Peres to Rue des Rennes	1967	0.09	8 A.M.- 9 P.M.	47	Peak bus speeds increased by 2.3 mph. Off-peak bus speed increased by 1.0 mph.	4 bus routes serve 7-lane street. 12' bus lane; one bus stop.
Blvd. St. Michel Rue Auguste Comte to Rue Gay Lussac	1968	0.25	1-8:30 P.M.	39		3 bus routes serve 3-lane street
Rue de Rivoli Rue St. Paul to Rue des Archives	1968	0.20	1-8:30 P.M.	60		4 bus routes serve 5-lane street.
Rue de Rivoli Rue des Halles to Rue de l'Arbre Sec	1968	0.24	1-8:30 P.M.	90		12 bus routes serve 5-lane street. 10' bus lane; two bus stops
Rue Beaubourg Rue du Renard	1968	0.55	1-8:30 P.M.	35	Peak bus speeds increased by 2.1 mph. Off-peak bus speed increased by 0.5 mph.	4 bus routes serve 5-lane street
Rue du Faubourg Montmartre	1968	0.25	1-8:30 P.M.	52	Peak bus speeds increased by 1.7 mph. Off-peak bus speed increased by 0.7 mph.	4 bus routes serve 4-lane street
Boulevard des Invalides	1968	0.28	8 A.M.- 9 P.M.	34	Peak bus speeds increased by 4.6 mph. Off-peak bus speed increased by 1.0 mph.	3 bus routes serve 4-lane street.
Rue La Boetie Av. Percier to Place Chassaigne Goyon	1968	0.15	1-8:30 P.M.	63		6 bus routes serve 4-lane street.
Quai des Orfevres Pont Neuf to Pont. St. Michel	1968	0.25	8 A.M.- 8:30 P.M.	20	Peak bus speeds increased by 5.0 mph. Off-peak bus speed increased by 2.2 mph.	2 bus routes serve 3-lane street.
Quai des Grands-Augustins	1968	0.24	8 A.M.- 8:30 P.M.	20		2 bus routes serve 6-lane street.

TABLE 17 (*continued*)

CITY AND LOCATION (POPULATION)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK-HOUR BUS VOLUMES	REPORTED BENEFITS	OTHER OBSERVATIONS
France, Paris (Cont.)						
Rue de Rome Rue de Provence to rue d'Isly	1968	0.05	1-8:30 P.M.	68		6 bus routes serve 4-lane street.
Avenue de la Porte D'Orleans Rue St. Albin to Av. Paul Appell	1968	0.15	8 A.M.- 8:30 P.M.	74	Peak bus speeds increased by 0.9 mph. Off-peak bus speeds increased by 4.2 mph.	7 bus routes serve 7-lane street.
Avenue du Presidente Wilson	1968	0.14	1-8:30 P.M.	30		2 bus routes serve 3-lane street.
Avenue de Wagram Rue Beaujon to Place des Ternes	1968	0.14	1-8:30 P.M.	30	Peak bus speeds increased by 2.9 mph. Off-peak bus speeds increased by 2.9 mph.	2 bus routes serve 4-lane street.
Avenue de Wagram Rue Cardinet to Rue Courcelles	1968	0.03	1-8:30 P.M.	18	Peak bus speeds increased by 0.6 mph. Off-peak bus speeds increased by 0.2 mph.	1 bus route serves 4-lane street.
Boulevard De l'Hopital Cour d'Austerlitz to Place Valhubert	1968	0.05	8 A.M.- 8:30 P.M.	21		2 bus routes serve 4-lane street.
Place du Carrousel	1968	0.14	8 A.M.- 8:30 P.M.	53		4 bus routes serve 3-lane street.
Rue Montmartre Rue de Clery to Blvd. Poisson-niere	Proposed	0.30	1-8:30 P.M.	52		4 bus routes serve 3-lane street.
Rue St. Martin Rue Vertbois to Rue Reaumur (left side)	Proposed	0.14	8 A.M.- 9 P.M.	18		2 bus routes serve 3-lane street.
Boulevard Beaumarchais Rue du Pas de la Mule to Place de la Bastille	Proposed	0.10	1-8:30 P.M.	33		3 bus routes serving 3-lane street.
Boulevard du Palais Quai de Marche' Neuf to Quai de Corse	Proposed	0.13	1-8:30 P.M.	56		5 bus routes serving 3-lane street.
Rue de la Tacherie Quai de Gesvies to Avenue Victoria	Proposed	0.03	8 A.M.- 9 P.M.	66		4 bus routes serving 2-lane street.
Boulevard St. Germain Rue Danton to Rue de Cluny	Proposed	0.20	8 A.M.- 9 P.M.	29		3 bus routes serving 5-lane street.
Boulevard St. Germain des Pres Blvd. St Germain to rue de L'Abbeye	Proposed	0.03	8 A.M.- 9 P.M.	35		3 bus routes serving 3-lane street.
Quai Malaquais Entrance to under-pass to rue des St. Peres	Proposed	0.06	8 A.M.- 9 P.M.	59		5 bus routes serving 6-lane street.
Boulevard de la Tour-Maubourg Place Santiago du Chili to Quai d'Orsay	Proposed	0.33	1-8:30 P.M.	27		3 bus routes serving 4-lane street.
Avenue F. Roosevelt Place Chassai-que Goyon to Rond-Point des Champs Elysees	Proposed	0.22	1-8:30 P.M.	64		4 bus routes serving 4-lane street.
Rue de las PePiniere Place St. Augustin to Rue Pasquier	Proposed	0.14	1-8:30 P.M.	79		6 bus routes serving 4-lane street.
Rue St. Lazarre Place Gabriel Peri to Place du Harre	Proposed	0.06	1-8:30 P.M.	108		9 bus routes serving 6-lane streets.
Avenue Matignon Rand-Point des Champs Elysees to Avenue Delcasse	Proposed	0.31	1-8:30 P.M.	83		6 bus routes serving 5-lane street.
Rue Tronchet Place de la Madaleine to Rue Vignon	Proposed	0.12	1-8:30 P.M.	16		2 bus routes serving 3-lane street.
Rue Hale'vy Rue Meyerbeer to Blvd. Haussmann	Proposed	0.03	8 A.M.- 9 P.M.	41		3 bus routes serving 6-lane street.
Rue La Fayette Rue Cadet to Blvd. Magenta	Proposed	0.48	1-8:30 P.M.	91		6 bus routes serving 4-lane street.
Rue de Maubuage Blvd. Magenta to Place Kossuth	Proposed	0.61	1-8:30 P.M.	100		7 bus routes serving 3-lane street.

TABLE 17 (*continued*)

CITY AND LOCATION (POPULATION)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK-HOUR BUS VOLUMES	REPORTED BENEFITS	OTHER OBSERVATIONS
France, Paris (Cont.)						
Blvd. Magenta Rue du Faubourg Poissonie're to Rue de Chabrol	Proposed	0.49	1-8:30 P.M.	53		6 bus routes serving 4-lane street.
Blvd. St. Martin Rue de Lancry to Porter St. Martin	Proposed	0.14	1-8:30 P.M.	27		2 bus routes serving 3-lane street.
Blvd. de Clichy Rue Lepic to rt. of Rue le Douai	Proposed	0.19	1-8:30 P.M.	62		4 bus routes serving 3-lane street.
Avenue de Versailles Blvd. Exelmans to Place de la Porte de St. Cloud	Proposed	0.15	1-8:30 P.M.	26		3 bus routes serving 3-lane street.
Blvd. Barbas Rue Castine to Blvd. Roche-Chouart	Proposed	0.15	1-8:30 P.M.	26		3 bus routes serving 3-lane street.
Rue Royale betweeo Place de la Concorde to Place de la Madaleine	Proposed	0.17	1-8:30 P.M.	46		6 bus routes serving 4-lane street.
Blvd. de Sebastopol and Blvd. de Stasbourg Rue de Rivoli to Blvd. Magenta	Proposed	1.20	1-8:30 P.M.	19		4 bus routes serving 5-lane street.
Marseille (870,000)						
Boulevard Longchamp	1967 Approx.	0.30		120	Before bus speeds 1-4 mph; after bus speeds 10 mph.	
Boulevard Michelet-Avenue de Prada	1967 Approx.	1.04		70	Before bus speeds 1-4 mph; after bus speeds 10 mph.	

examples exist, several more are in the planning stage.

5 Curbside bus lanes are usually in effect only during morning and evening peak hours, whereas contra-flow bus lanes, median bus lanes, and bus streets are usually reserved all day

Volume Warrants

The number of peak-hour buses is becoming a less significant factor in justifying bus lanes, both in the United States and in Europe Traditionally, streets with the highest bus volumes were given priority treatments These streets often carried 60 to 100 buses (or more) in the flow direction and generally meet established bus lane warrants The Institute of Traffic Engineers cites 60 peak-hour buses or 3,000 passengers as a minimum criterion; England uses a criterion of 50 buses or 2,000 passengers in the peak hour Both criteria assume the presence of at least one bus in each city block during the peak hour.

Recently implemented bus lanes have relaxed these warrants Several examples of existing and proposed bus priority treatments show volumes as low as 25 buses per hour. Bus lanes are increasingly installed (a) to improve bus operations in key locations, or (b) as a statement of transit policy. The contra-flow bus lanes installed in Louisville during 1971 serve less than 20 buses in the peak hour.

Design Features

The following design and traffic control features are important:

1 Bus streets penetrate major retail centers. The objectives are (a) to maintain transit service, (b) to increase width of areas available to pedestrians (24-ft-wide bus streets are common), and (c) to improve pedestrian amenity in other ways (benches, shrubs, flowers). There are opportunities in many cities for downtown bus streets, provided necessary emergency services and goods movement services are maintained Often, however, vehicular access requirements of the downtown street (street capacities, internal circulation requirements, and locations of off-street parking) may preclude designation of downtown "transit only" streets.

2. The geometric arrangements of bus lanes in relation to other lanes reflect available street widths Most bus lanes are 10 to 12 ft wide. Chicago's Washington Street median bus lane is about 9 ft wide; Syracuse's bus lanes are 8 ft 6 in. wide, New York has a 10-ft minimum lane width Bus lanes in Madrid are about 10.5 ft wide. Right turns by automobiles are generally permitted from curb bus lanes. Cross streets entering bus lanes are rarely closed.

3 Signs and pavement markings are an integral part of most treatments (Fig. 6) Several European cities (those without problems of snow removal) use mountable curbs to separate bus lanes Median bus lanes are usually designated by pavement stripes and, in some cases, by curbed loading islands and/or barriers Chicago removed most of the wooden loading islands along Washington Street because of maintenance and accident problems The types of signs and markings have little impact on the effectiveness of bus lanes

TABLE 18

EXISTING NORMAL-FLOW CBD CURB BUS LANES, SPAIN

CITY AND LOCATION (Population)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK HOUR BUS VOLUME & PASSENGER (VOLUME)	REPORTED BENEFITS	OTHER OBSERVATIONS
Madrid (2,900,000)						
Onesimo Redondo R. Ledesma Ramos and Bailén	Existing	0.33	24 hours	51 (3,643)	Peak bus speeds increased 1.6 mph. Peak auto speeds - no change. Off-peak bus speeds increased 1.3 mph. Off-peak auto speeds increased 4.0 mph.	10' bus lane on an 8-lane one-way street. 4 bus routes.
Serrano Goya a la Plaza de la Independencia	Existing	0.34	24 hours	93 (6,360)	Peak auto speeds decreased 3.3 mph. Off-peak auto speeds decreased 8.0 mph.	10.5' bus lane on 5-lane one-way street. 5 bus routes; 91 parking spaces eliminated, 6 in front of businesses.
Calle de Alcala Cibeles a la Plaza de la Independencia	Existing	0.15-0.18	24 hours	127 (8,300)	Off-peak auto travel time increased 17 seconds on one side and decreased 23 seconds on the other side.	10.5' bus lane on each side of 8-lane street, two-way street. 7 bus routes.
Calle de Alcala Claudio Coello to Plaza de la Independencia	Existing	0.06	24 hours	66 (3,700)	Off-peak auto travel time decreased 3 sec.	10.5' bus lane on 8-lane street. 4 bus routes.
Infanta Isabel Gayarre to Alfonso XII	Existing	0.18	24 hours	99 (7,600)		10.5' bus lane serving 4-bus routes. 54 parking spaces eliminated.
Paseo del Prado Neptune to Cibeles	Existing	0.12-0.18	24 hours	42-49 (4,200-5,600)	Peak auto speeds decreased approximately 1.7 mph on both sides of street. Off-peak auto speeds decreased approximately 4.0 mph.	10.5' bus lane on each side of 6 lane one-way street. 4 bus routes northbound, 2-northbound.
Paseo de Calvo Sotelo Cibeles to Villanueva	Existing	0.24	24 hours	103 (6,000)	Peak bus speeds increased by about 2.2 mph. Off-peak bus speeds increased by about 1.0 mph. Peak auto speeds decreased by about 2.0 mph. Off-peak auto speeds decreased by about 0.7 mph.	11' bus lane on 6-lane street. 5 bus routes.
Paseo de Calvo Sotelo Colon to Cibeles	Existing	0.34	24 hours	103 (6,000)	Peak bus speeds increased by about 3.9 mph. Off-peak bus speeds increased by about 3.5 mph. Peak auto speeds increased by about 3.0 mph. Off-peak auto speeds increased by about 4.0 mph.	10.5' bus lane on 6-lane street. 5 bus routes.
Paseo Castellana Colon and Villa Verde	Existing	1.42	24 hours	110 (6,000)	Peak bus speeds increased by 1.0-5.0 mph. Off-peak bus speeds generally increased by 1.0 mph. Peak auto speeds generally increased by 3.7 mph. Off-peak auto speeds generally increased by 4.0 mph. Note: Some sections showed a decrease.	11' bus lane on each side of 6-lane one-way street. 4 bus routes. Up to 723 parking spaces removed; some in front of businesses; bus lane instituted over existing tramway.
Avenida Generalismo Villa Verde and Plaza Castilla	Existing	1.38-1.41	24 hours	83-97 (3,300-4,300)	Peak bus speeds - no significant gain. Off-peak bus speeds - no significant gain. Peak auto speeds - small decrease. Off-peak auto speeds - no significant change.	13' bus lane on each side of 8-lane two-way street. 1 or 2 bus routes; bus lane instituted over existing tramway.

NOTE: Madrid runs large articulated buses, regular buses, and mini buses which charge higher fare but guarantee a seat for the above streets.

TABLE 19

EXISTING NORMAL-FLOW CBD CURB BUS LANES, OTHER EUROPEAN COUNTRIES

CITY AND LOCATION (POPULATION)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	TRAFFIC CONTROL	PEAK HOUR BUS VOLUMES AND PASSENGER (VOLUMES)	REPORTED BENEFITS AND OTHER OBSERVATIONS
Belgium						
Brussels (2,070,000) Rue Beillard	1966	0.71	24 hours	Solid yellow line	122 (8,200)	Trams and buses operate on this section. 2-3 minute gain per bus-tram trip.
Germany						
Hamburg (2,335,000) Colonnaden	1963	0.15	4-6:30 P.M.	Elevated rotating traffic signs		
Hanover (765,000) Prinzenstrasse	----	----	----	Solid double white line	40	Prohibition of parking and stopping. 10' bus lane on 34' wide street. Few bus delays on this segment.
Wiesbaden (260,000) Frederick Strasse	1968	0.68	6-9 A.M. 12-7 P.M.	Signs, solid white line	50	Bus reliability greatly improved.
Wiesbaden Dotzheimer Strasse	1968	0.68	6-9 A.M. 12-7 P.M.	Signs, solid white line	50	Bus reliability greatly improved.
The Netherlands						
The Hague (840,000) Lijnbaan	----	0.12	Peak Hours	----	---	Buses gained 1 minute in peak hour.
Prinsegracht	----	0.49	24 hours	----	---	Tram provided with reserved right-of-way which buses may use.
Sweden						
Stockholm (1,290,000)	Existing	0.45	7-9 A.M. 4-6:30 P.M.	----	36	Bus and taxis save 150 person-hours per day. Gain lost on approaches to lane; Taxis and cycles use bus lane.
St. Eriksgatan	Existing	0.40	7-9 A.M. 4-6:30 P.M.	----	---	Bus and taxis save 50 person-hours. Gain lost on approaches to lane; Taxis and cycles use bus lane.
Switzerland						
Bern (266,000) Bubengerplatz	1966	0.12	24 hours	----	---	Tram right-of-way converted to two-directional bus lane.

4 Special traffic signal controls are seldom used in conjunction with bus lanes They are used, however, for busways that cut across arterial streets or through rotary islands In one case (Wiesbaden, Germany) the terminals of bus lanes are signalized to facilitate transition and turning movements to other lanes and streets by buses.

5 Special traffic signal modifications are included as part of several bus lane and bus street treatments. Bus preemption of signals to provide additional green time is being implemented in Washington, D C., and is working in Southampton, England.

6 Provisions for taxis are common in European cities, although taxis are generally excluded from bus lanes and streets in the United States Taxis, for example, far outnumber buses on Stockholm's Kungsgatan bus street In contrast, implementation of St. Louis' Locust Street bus mall was deferred because of taxicab exclusion

7 Bus lane and bus street installations recognize the service needs of adjacent land uses that often result from long-established development patterns Many older buildings provide access for deliveries and shipments only through front entrances, a condition that may preclude development of bus streets and make implementation of peak-period bus lanes difficult. Establishing alternative (off-peak) pick-up and delivery times for mail trucks and other service vehicles may be necessary.

Operational Viability

The workability of arterial-related bus priority treatments depends on how effectively they are enforced. Bus streets and contra-flow bus lanes are largely self-enforcing. Observance of normal-flow curb lane regulations varies widely among communities.

Many CBD land uses require frequent access by cars and trucks As a result, many curb lanes have low efficiency and are avoided by bus operators. The Chicago Transit Authority, a major innovator in bus priority treatments, does not operate any CBD curb lanes. Many transit operators believe that effective enforcement of curb parking regulations is more important than the specific allocation of curb lanes to bus use Where curb parking takes up a needed traffic lane, restriction of parking may be a more

TABLE 20

EXISTING AND PROPOSED REVERSE-FLOW CBD BUS LANES, UNITED STATES

CITY LOCATION AND LIMITS	DATE STARTED OR STATUS	LENGTH (MILES AND BLOCKS)	HOURS OF OPERATION	SPECIAL SIGNAL CONTROLS	TRAFFIC SIGNS	PAVEMENT MARKINGS	PEAK-HOUR BUS VOLUMES (AND PASSENGER VOLUMES)	REPORTED BENEFITS	REMARKS
Chicago, Ill. Canal St. N.W. Station Randolph-Washington	1964	0.7 miles	24 hours	No	Overhead and Post Signs	Mountable jiggle-bar median	80	Pedestrian-vehicular conflicts reduced	7 bus routes serve 12,000 passengers per day
Chicago, Ill. Canal St. - Union Sta. Adams-Jackson	1969	0.7 miles	24 hours	No	Normal Signing	Median and fence	55		
Cleveland, Ohio Public Square Downtown	Existing	0.20 miles	24 Hours			Paint			Curb and adjacent lane used for buses.
Harrisburg, Pa. Market St. 2nd-5th Sts.	1956	0.3 miles	24 hours			Copes-white/yellow lines	15		
San Antonio, Tex. Alamo Plaza Houston-Commerce	1968	0.23 miles	24 hours			Paint only	30		
San Juan, P.R. Avenida Munoz Rivera (Old San Juan)	1971	1.4 miles	24 hours	No	Yes	Paint		Bus speeds increased from 8.5 to 12.5 MPH.	18-24 bus routes Approx. 10 bus lane plus 3-4 other lanes
San Juan, P.R. Avenida Ponce de Leon (Old San Juan-Santurce-Hato Rey)	1971	5.9 miles	24 hours			Paint	49		Est. costs of improvements - $100,000
San Juan, P.R. Avenida Fernandez Juncos (Santurce)	1971	3.0 miles	24 hours			Paint			
Seattle, Wash. 5th St. Terrace-Cherry-Columbia Ramp	1970	0.7 miles	24 hours			Paint	47		Part of Blue Streak operations. Outbound buses use lane to reach I-5 Fwy.
Minneapolis, Minn. Marquette Ave. Washington-11th	Proposed 1971	0.68 miles	24 hours						Part of Urban Corridor Proposal
Minneapolis, Minn. 2nd Ave. Washington-11th	Proposed 1971	0.68 miles	24 hours						Part of Urban Corridor Proposal
Portland, Ore. 5th St.	Approved 1972		24 hours						Curb and adjacent lane proposed for buses only on two four-lane one-way streets.
Portland, Ore. 6th St.	Approved 1972		24 hours						Same as above.

acceptable alternative, particularly where bus use is small relative to general traffic Examples of this approach are New York City's Madison and Fifth Avenue bus zones

Patronage

It is difficult to identify the effects of arterial bus priority treatments on bus patronage A downward trend of bus riding in many cities tends to overshadow patronage increases that may result from operational improvements on specific routes Local impacts are usually masked in gross ridership statistics, and differing service characteristics of individual lines further obscure comparisons

Costs

Identifiable costs of bus lane treatments are largely incidental and are absorbed in most traffic engineering pro-

TABLE 21

EXISTING AND PROPOSED REVERSE-FLOW CURB BUS LANES, GREAT BRITAIN

CITY AND LOCATION (POPULATION)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK-HOUR BUS VOLUMES	REPORTED BENEFITS AND OTHER OBSERVATIONS
Carlisle (71,000)	1968	0.13	24 hours	8	10' bus lanes; 30' wide streets.
	Existing	0.06	24 hours	55	10.5' bus lanes; 32' wide street.
Derby (270,000) Wardwick	1971			--	Part of extensive one-way network introduced with bus lane in 1970.
Queen St.	1971				Part of extensive one-way network introduced with bus lane in 1970.
Dundee (182,000)	Existing	0.04	24 hours	60	8' bus lane; 40' wide street.
Exeter (93,000) High Street	1967	0.50	5:30 A.M. 11:00 P.M.	35	11-15' bus lane, 23-28' wide street. Installation of bus lane coincided with introduction of one-way traffic system; savings of 50,000 annual bus-miles; peak period time savings of 20 minutes reported per trip.
Hertford (18,700)	1969	0.05		—	9' bus lanes; 18' wide street.
Isle of Wight	Existing	0.45	24 hours	12	10-12' bus lane; 20-24' wide street.
Leeds (1,530,000)	1965	0.11	24 hours	52	17' bus lane; 42-53' wide street.
Liverpool (1,705,000)	Existing	0.03	24 hours	10	16' bus lane; 34' wide street.
	Existing	0.05	24 hours	45	15' bus lane, 30' wide street.
	Existing	0.04	24 hours	40	15' bus lane; 30' wide street.
London (12,000,000) Tottenham High Rd.	1970	0.49	24 hours	70	400-600 fewer cars during peak. $400,000 cost for signals and markings. 4' wide island separates bus lane from 3 other lanes. Bus saving 2.4 minutes per trip in morning peak and 1.2 minute saving in evening peak. Forms part of large traffic management scheme and reported benefits may be partially due to that.
Newcastle-Upon-Tyne (1,400,000)	Existing	0.06	24 hours	85	10' bus lane; 40' wide street.
	Existing	0.08	24 hours	32	10' bus lane; 40' wide street.
Northampton (121,900)	1967	0.20	24 hours	22	11-15' bus lane; 22-32' wide street.
Oxford (200,000)	Existing	0.11	24 hours	15	
Reading (178,000) King's Road	1968	0.57	24 hours	48	10' bus lane; 32' wide street. Parking and waiting restricted. Slight increase in bus patronage and 2 per cent decrease in bus-mileage. 1 per cent misuse of bus lane. 29 per cent fewer vehicular accidents. 2-4 minutes saved by buses during westbound peak; 7 minutes saved by eastbound peak. Continuous double white line.
Oxford Road	1970	0.10	24 hours	--	
St. Mary's Butts	1970	0.09	24 hours	—	
Station Road	1970	0.07	24 hours	--	
Sandown (15,800)	1967	0.15	24 hours	12	
Southend (165,800)	Existing	0.06	24 hours	55	11' bus lane; 36' wide street.
Walsall (183,700)	Existing	0.02	24 hours	75	
Bury (64,500)	Proposed	0.34	24 hours	39	Bus lane 10-12' in a street 30-50'.
Halifax (168,000)	1971	0.11	24 hours		
Leeds (1,153,000)	Proposed	0.06	24 hours	--	12-13' bus lane; 36-43' wide street.
	Proposed	0.07	24 hours	--	12' bus lane; 36' wide street.
	Proposed	0.02	24 hours	—	11' bus lane; 37-48' wide street.
London (12,000,000) Buckingham Palace Rd.	Proposed 1971	0.13	24 hours	—	
Picadilly	Proposed 1971	0.30	24 hours	100	Allows direct bus connection.

Note: Additional reverse-flow bus lanes are found in Blackburn, Brimington, Longton, Nottingham, Preston, Stalybridge, Stoke-on-Trent, Tyneside, Trowbridge, Weymouth and Winchester.

TABLE 22

EXISTING REVERSE-FLOW CBD CURB BUS LANES, FRANCE

CITY AND LOCATION (POPULATION)	DATE STARTED OR STATUS	LENGTH (MILES)	HOURS OF OPERATION	PEAK-HOUR BUS VOLUMES	REPORTED BENEFITS AND OTHER OBSERVATIONS
Paris (8,885,000) Avenue Bosquet (whole length)	1965	0.55	24 hours	35	10' bus lane serving 5-lane street 3 bus routes, 4 bus stops (1)
Pont de l'Alma (whole length)	1966	0.10	24 hours	46	10' bus lane serving 6-lane street 4 bus routes, one bus stop
Avenue du President Kennedy Rue du Ronelogh to Pont de Bir-Hokein	1965	0.46	24 hours	10	10' bus lane serving 4-lane street 1 bus route; two bus stops
Rue de Lagny Rue des Pyrenees to rue des Maraichers	1966	0.04	24 hours	24	11' bus lane serving 3-lane street 2 bus routes; no bus stops
Avenue Gambetta Exit of terminus 1105 to Blvd. Montier	1967	0.06	24 hours	38	11' bus lane serving 3 lane street 4 bus routes; no bus stops
Rue de Rivoli Place du Palais Royal to rue du Louvre	1967	0.23	24 hours	54	6 lane street. 6 bus stops.
Boulevard de Strasbourg Rue St. Laurent to Blvd. Magenta	1967	0.02	24 hours	25	11' bus lane serving 7-lane street. 3 bus routes, no stops.
Boulevard de St. Germain Rue de Bac to Quai Anatole France	1968	0.49	24 hours	53	6 lane street. 4 bus routes.
Avenue Montaigne	1971 Proposed	0.33	24 hours	25	4 lane street.
Marseille (940,000)					
Rue de Rome	1966 Approx.	0.43	24 hours	70	Bus speeds increased 5 mph.
Cours de Gouffe	1966 Approx.	0.43	24 hours	20	Bus speeds increased by about 4-6 mph.
Rue de Paradis	1966 Approx.	0.62	24 hours	23	Bus speeds increased by about 4-10 mph.

(1) Paris received a general 1-4 mph increase in bus and auto speeds in peak hours on streets with a bus lane.

grams. Costs to implement 3 miles of bus lanes in Louisville, for example, were estimated at about $10,000 Costs of bus streets in Minneapolis (Nicollet Mall) and Chicago (Englewood) were absorbed as part of development plans.

Benefits

Benefits to motorists and bus riders have been reported in many cases However, systematic measurements of bus lane effectiveness have been limited mainly to studies in European cities.

The benefits achieved by bus lanes usually relate to "bus service dependability." No conclusive evidence exists to indicate patronage gains resulting from arterial priority treatments, or of bus operators being able to reduce the number of buses in service as a result of increased bus speeds and operating effectiveness.

Studies conducted immediately after bus lanes were installed frequently show modest time savings; but these may no longer be evident when new measurements are made after several years. Generally, the larger the extent of treatment, the greater the benefits. American cities generally find that the time savings do permit reductions in the numbers of buses operated along specific routes

Reported benefits of American bus lanes include the following.

1 Chicago's Washington Street bus lane saves one bus run during peak periods This corresponds to an estimated annual saving of more than $25,000 to the operator (100 miles per day, 250 days per year, $1.00 per bus-mile).

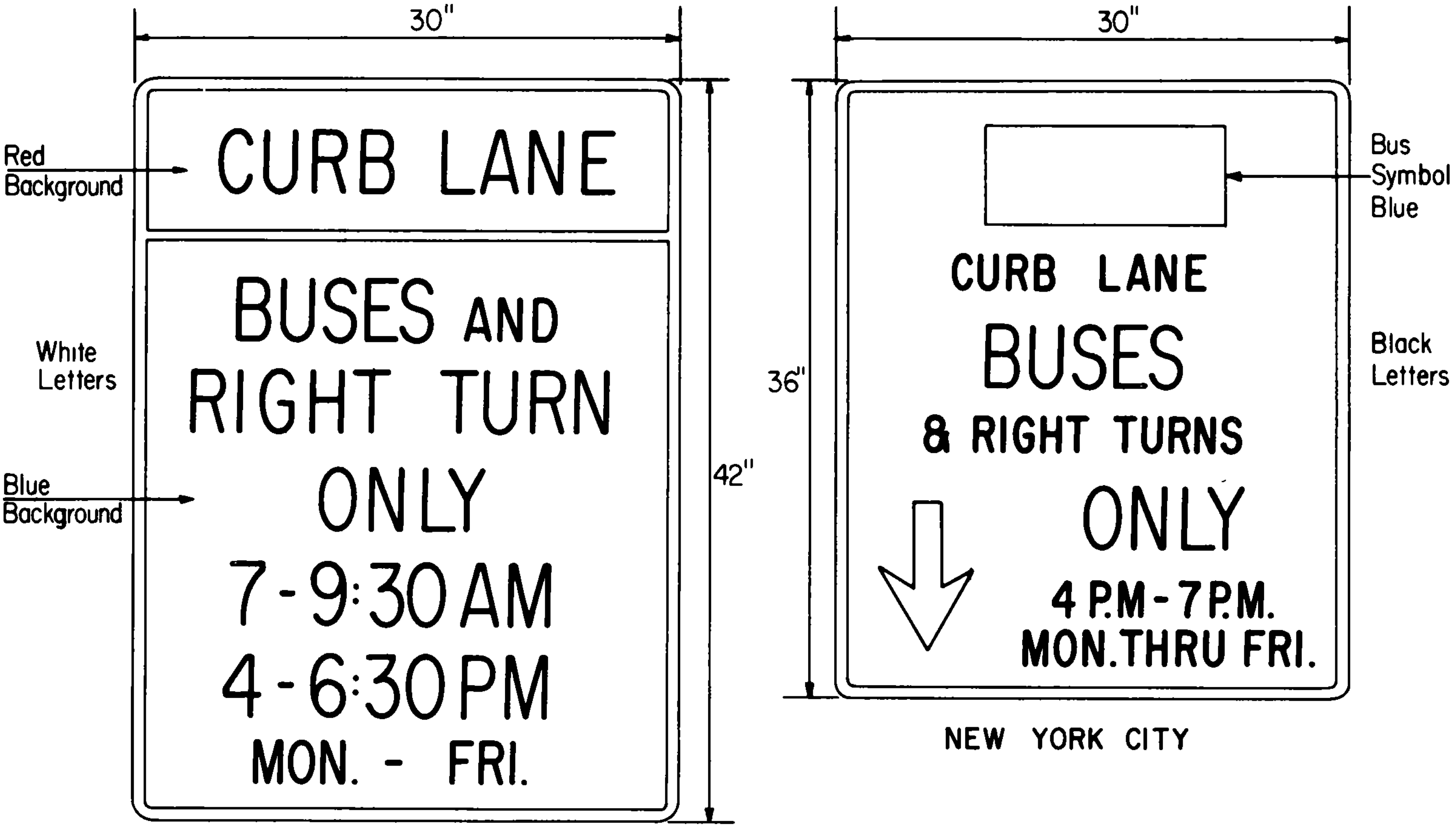


Figure 6 Typical bus lane signs

2 Louisville's Second-Third Street contra-flow bus lanes reduced travel times about 25 percent.

3 Newark's revised Market Street bus lane strategy saves 10,000 people approximately 1 min each PM peak period. This was reported to produce an annual time saving of $87,000

4. New York City's Fifth-Madison Avenue bus zone (86th-35th Streets) reduced midday bus travel times from about 11 to 6 5 min, other studies report that the bus companies save 10 hr on a typical day.

Typical benefits of European bus lanes are summarized in Table 23

1. In Dublin, bus lanes saved buses 2 min, increased patronage, and reduced the variance of bus trip times Cars lost 2 5 min and over-all vehicle flow was reduced 30 percent The average travel time per person per lane was reduced 1 min

2 Madrid's 5 miles of bus lanes resulted in increased speeds of 1 to 4 mph, with no significant increase in car trip times. However, nearly 800 curb parking spaces were removed in installing the lanes

3. Paris reports statistically significant decreases in bus and auto travel times, resulting from introduction of bus lanes and associated elimination of curb parking. Bus speeds increased from 2 to 6 mph.

Bus priority treatments in American and European cities are sometimes implemented as part of over-all traffic improvement plans In these cases, benefits mainly result from the complementary traffic changes

- San Francisco's downtown curbside bus lanes were installed in conjunction with major additions to the one-way street network expansion Bus travel time savings increased from 10 to 36 percent.
- San Juan's wrong-way reverse-flow bus lanes were established on Ponce de Leon, Fernandez Juncos, and Munoz Rivera after the Las Americas Expressway extension was completed into Santurce, and relieved traffic volumes on the streets used by buses Time savings to bus passengers ranged up to 30 min No problems have been encountered in enforcement, because the reverse-lanes are generally self-enforcing.

TERMINALS AND TRANSPORTATION CENTERS

Transportation terminals and interchanges serve several important functions First, they provide downtown distribution for radial express bus operations. Second, they help intercept motorists and local buses in outlying areas and facilitate transfers to express lines. In both cases, they permit fast, dependable transit services to the city core, with attendant reductions in vehicle-miles of car travel and downtown parking space demands

Several categories of transportation terminals were reviewed, including (1) central area facilities, (2) outlying auto and/or bus to express transit, and (3) outlying auto-to-bus transfer. Significant examples of each type of terminal are summarized in Tables 24 through 27

Central Area Terminals

Central area terminals usually serve as essential parts of freeway bus service by providing off-street loading for large concentrations of buses In conjunction with bus ramps and bus roadways, they allow grade-separated bus operations in congested centers and remove buses from downtown streets However, "one-point" delivery in the downtown area often requires secondary distribution by bus or rapid transit

The availability of central area terminals is essential to successful freeway bus service in New York and San Francisco In contrast, the lack of terminals with grade-separated access substantially handicaps bus rapid transit in Washington, D C., and Los Angeles

Locational Factors

Major terminals provide direct connections to expressways, and are usually located between expressways and the CBD core They are removed from points of high value except where air rights developments can reduce land costs Chicago's Greyhound Terminal, a few blocks from the prime retail location, provides for air rights Philadelphia's proposed Market Street East will be located in a large-scale multi-purpose development. New York City's Midtown Terminal, San Francisco's Transbay Terminal, and Cincinnati's Dixie Terminal are also within walking distance of many major employment concentrations. In most cases, there is a major water crossing on the approach to the terminal.

General Characteristics

Central terminals range in size from the 10-berth one-level Dixie Terminal in Cincinnati to the 184-berth three-level Port Authority Terminal in New York City. The older terminals, in Cincinnati and San Francisco, are carryovers from rail transit operations Both inherited direct ramp access from major bridges, accomplished by paving over railway viaducts. Terminals in New York and Chicago were built specifically to serve intercity and commuter buses These also have direct ramps to freeways, expressways, or major bridges

Transfer to local rapid transit and buses for CBD distribution is another essential feature of central terminals. In New York City, the Chicago Greyhound Terminal, and the planned Market Street East site in Philadelphia, rail rapid transit connections are available. In San Francisco, the five streetcar lines loop and lay over at the Transbay Terminal, so that empty cars are always available for incoming bus passengers Cincinnati's Dixie Terminal and Riverside Stadium both depend on local buses for distribution.

Design and Operations

Downtown terminals serve suburban and intercity carriers. Except for Chicago, suburban service dominates (Initially, suburban bus operations were provided in Chicago's Greyhound Terminal, because of the intercity space requirements, and the differing operating patterns, most suburban services were eliminated) There are no "local urban bus services" provided from downtown terminals, because local carriers prefer through routings on city streets

Suburban and intercity loading areas are separated, inasmuch as the two have different service requirements—intercity buses have longer layover times to allow for passenger loading, unloading, baggage, and parcels Berth capacity is low, typically about two buses per hour, and layover times of more than 30 min are common. All terminals use a closely stacked sawtooth platform design for intercity buses Intercity bus services may operate twice the number of scheduled runs in peak periods—a factor that must be recognized in establishing future capacities

For commuter buses, capacity is at a premium, baggage and parcels are rare, and there are few through passengers Unloading and loading are usually separated to provide one-way flow and take advantage of the ability to unload passengers at a faster rate (40 to 60 per door per minute) than the rate at which they can board (30 per door per minute, or less) Accordingly, terminals use linear loading platforms that allow several buses to queue at the same platform and eliminate reversing moves by the buses Berth capacities average from 8 to 10 buses per hour at both the New York and San Francisco terminals

Operation of the Dixie Terminal is unique in that buses are not held in the terminal between unloading and loading During the evening peak hour, platoons of up to six buses are marshalled on the Kentucky side of the Suspension Bridge and brought into the terminal for simultaneous loading Layover time is external to the terminal, and buses remain in the terminal only about 5 min Other terminals provide sufficient floor area to hold buses in reserve for heavy flows within the peak period and to compensate for variations from schedule of arriving buses, some marshalling is also done at the other terminals

Patronage and Bus Volumes

Terminal patronage relates to CBD employment density and to the tributary area served. New York City's Midtown Terminal serves more than 100,000 passengers in each direction per day, the Transbay Transit Terminal, 44,000; the George Washington Bridge Terminal, 20,000, and Cincinnati's Dixie Terminal, 5,000. Corresponding peak-hour (one-way) volumes are 33,000, 13,000, 4,200, and 1,800 persons, respectively. Philadelphia's proposed Market Street East Terminal will serve 6,000 people (one-way) in the peak hour High peaking (more than 30 percent of the one-direction travel) characterizes these terminals.

Bus volumes are scheduled to provide an average occupancy of 20 to 30 passengers per bus over the course of the day, rising to 35 to 45 passengers per bus in the peaks The Midtown Bus Terminal's exit ramps carry 700 buses

TABLE 23

REPORTED BENEFITS OF EUROPEAN BUS LANE TREATMENTS

LOCATION	TYPE OF SCHEME	BUS FLOW (Per Hr.)		EFFECT ON BUSES	EFFECT ON CARS	ECONOMIC BENEFITS	REMARKS
		Peak	Off-Peak				
Brussels Rue Beillard	.71 mile	120		2-3 min. gain per bus in peak hour			
Wiesbaden	2 one-way curb bus lanes AM - PM peak	50		Reliability of bus service improved			Bus routings changed
Albert Embankment	1,200 ft. normal curb bus lane A.M.	55		1½ min. saved by bus per trip			
London Brixton Rd. (1969)	With flow lane in 4-lane road. 350 m long, ends 100 m from junction AM peak only	105		2 min. saved 2 min. loss to buses on cross route at junction	0.5 min. saved (No change in flow)	Savings 225 bus passenger-hours during peak	5% violation
London Park Lane (1968)	550 ft. nearside with-flow bus and taxi lane at uncontrolled junction. PM peak only	160		0.5 min. lost	1-2 min. lost (No change in flows)	None	Up to 500 violations in peak hour. Recommend curtailment
London Tottenham High Road (1970)	Contra-flow lane in one-way system 800 m long 24 hour operation	70	40	1-2½ min. saved during peaks	Up to 2 mins. saved in peaks. (400-600 fewer cars entering area during peaks.)		Cost $400,000 Lane separated from opposing flow by raised reservation 1 mi. wide. Loading/unloading across bus lane.
London Vauxhall Bridge (1965)	920 ft. central with-flow lane. Ends 60 m from junction. PM peak only.	100		2 mins. saved speed nearly doubled	1-2 mins. saved (5% increase in flows)	180 bus passenger-hrs. 50 car passenger-hrs. saved during peak	Bollards removed from centre of bridge to create extra lane. 13% violation.
Manchester Piccadilly (1971)	With-flow lane. Cars diverted around one-way system. Buses allowed to go straight ahead.	140	65	1 min. saved by some buses using the lane. 1 min. lost by others. 1 min saved by buses continuing to use one-way system.	1 min. saved by S/N cars. ½ min. lost by cars on other routes. (10% decrease in flows in area)		Reduction in bus passengers of 9% in peak, 14% off-peak in area.

Reading King's Road (1968)	Contra-flow lane in one-way system 1,000 m long 24 hour operation	50	40	2-4 mins. saved during peak by westbound buses using lane. No change off-peak. 6-8 mins. saved by eastbound buses using one-way system. 1-2 mins. saved off-peak	Reduction in total vehicular volume.		Benefits partly due to improved traffic flow conditions effected by general traffic management scheme. Reduction in vehicle accidents of 29%.
Southampton	Signalization scheme over 3.5 miles to CBD on radials			Expected 5 minute bus travel time reduction	Expected slight increase decrease in volume		$260,000
Dublin Fairview (1971)	With-flow lane on commuter corridor. Three short "feeder" bus lanes Total length 2 miles AM peak	145(normally) 175 (during experiment)		2 min. saved by buses. 13% increase in patronage	2½ mins. lost by cars. (Flow reduced by 30%)	Average travel time per person reduced by 1 min.-270 hrs. of passenger time saved during peak along lane.	Fares on route reduced by 1 penny. 30 extra buses during experiment
Marseille	Several bus lanes Total length 5.2 km	20-120		14 KM/hr increase in speeds. 1%-4% increased patronage on routes using lanes 5% fall elsewhere.			
Paris (1964-9)	33 lanes (as of 1/69) Total length 12 km Most are with-flow lanes. Six greater than 500 m	35-100		4-10 km/hr increase in speeds	Cars often have reduced journey times		About 60% of bus lanes replaced lanes of parked cars. More lanes planned.
Madrid	14 bus lanes as of 1971. Total length 7,700 meters all with flow; 2 greater than 2200 meters.	38-127		Most buses increased peak-hour speed 1-4 mph	Overall no significant effect on auto travel time		Nearly 800 parking spaces removed. Some in front of businesses.

SOURCE: Adapted partially from Transport and Road Research Laboratory.

TABLE 24

PRINCIPAL CENTRAL AREA BUS TERMINALS, UNITED STATES

NAME OF TERMINAL	DEVELOPMENT COSTS (2)	TYPE OF BUS SERVICE	DATE & STATUS	NUMBER OF BUS LEVELS	NUMBER OF BUS LOADING DOCKS	CONTIGUOUS TRANSP. FACILITIES	ACCESS CONNECTIONS	NUMBER OF PASSENGERS (1)	
								Daily	Pk.Hr.
Port Authority Bus Terminal, New York, N.Y.	$58,000,000	Commuter and intercity	1950	3	184	Subway, local bus, auto parking	Direct ramp connections with Lincoln Tunnel	105,500	32,600
George Washington Bridge Bus Terminal New York, N.Y.	$15,300,000	Commuter and intercity	1963	2	43	Subway, local bus	Direct ramp connections with George Washington Bridge	20,000	4,200
Greyhound Bus Terminal, Clark and Randolph Sts. Chicago, Ill.	$ 8,000,000	Mainly intercity	1952	1	30	Subway, local bus, curb parking	Tunnel and ramp connections with Garvey St. and Wacker Dr.		10,000
Transbay Bus Terminal, San Francisco,Calif.	$11,000,000	Intercity and commuter	1960	1	37	Streetcar and bus, auto parking	Direct ramp connections with San Francisco-Oakland Bay Bridge	44,000	13,000
Dixie Terminal Cincinnati, Ohio	N.A.	Commuter	Railcars 1921, Buses 1936	1	6(3)	Local bus, auto parking	Direct ramp access to suspension bridge over Ohio River.	5,000	1,800
Market Street East Bus Terminal Philadelphia, Pa.	N.A.	Intercity and commuter	Planned	2	70	Subway, railroad, streetcar, local bus, auto parking	Direct ramp connections with Vine St. Expwy.	N.A.	5,900
Riverside Stadium Terminal Cincinnati, Ohio	$ 316,000	Local and shuttle	Proposed	1	12	Local bus	Connections with I-71 via adjacent local streets	N.A.	N.A.

(1) One direction only bus volumes.
(2) Data on maintenance costs and revenues are unavailable.
(3) Also four unloading and six loading docks.
N.A. - Not Available.

outbound in the evening peak hour on more than 90 routes at an average occupancy of 44 passengers The second-ranking terminal, the Transbay Terminal, has an exit ramp volume of 350 buses per hour on 21 routes, an average occupancy of 37 passengers These two terminal operations account for the only bus volumes exceeding 300 per hour on any exclusive bus roadway.

Costs

Development costs ranged from $8 million for the Chicago Greyhound Terminal to $58 million for the Port Authority Bus Terminal A typical cost per berth is about $250,000 to $300,000, depending on location and details of the terminal design The area actually devoted to bus berths and platforms forms only a small part of the costs of major terminals, because major investments are required for land acquisition and auxiliary facilities, including ramps, passenger services, offices, and automobile parking

Benefits

Central terminals make it possible to achieve high bus volumes on bridges, tunnels, and expressways Compared to on-street distribution of passengers, they permit substantial time savings for bus riders. The Port Authority Mid-

NUMBER OF BUSES(1)		AVERAGE BUS OCCUPANCY		AVG. NUMBER OF BUSES PER DOCK		AVERAGE BUS LAYOVER TIME		ANCILLARY LAND USES	REMARKS
Daily	Pk.Hr.	Daily	Pk.Hr.	Daily	Pk.Hr.	Daily (Hrs.)	Pk.Hr. (Hrs.)		
3,350	730	27.4	44.1	18.2	4.0	1.32	0.25	Retail convenience goods, restaurants	1,080 cars; saves buses 30 mins. over previous operations
850	108	23.5	39.0	19.6	2.5	1.22	0.4	Retail convenience goods, restaurants	Located over Cross Bronx Expressway
	---	---	---	---	---		---	Retail convenience goods and offices over.	Designed to allow office building over station
2,200	350	20.0	37.2	59.5	9.5	0.40	0.16	Retail convenience goods	Prior to 1960 Key System Taxis used terminal
195	48	25.4	37.5	32.5	8.0	0.16	0.08	Retail, offices, restaurants	Former interurban rail terminal, shared by rail and bus 1936-1950. Bus only since 1950.
N.A.	170	N.A.	35	N.A.	2.4	N.A.	0.42	Retail, offices hotel	3,000 or more parking spaces planned
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	None planned	Urban Corridor Proposal

town Terminal enables bus passengers to save 30 min per trip to or from outlying communities (This, however, is in conjunction with the I-495 bus lane, which provides access to the New Jersey portal of the Lincoln Tunnel.) The proposed Market Street East Terminal is expected to save passengers up to 15 min per trip Moreover, removing buses from Market Street will make it possible to free the curb lane for other vehicles

Outlying Transfer Terminals

Outlying transfer terminals form the interface between the neighborhood collection and line-haul functions. They recognize the need for auto and local bus distribution from areas where population densities are too low to rely on walk-in patronage. Parking at outlying express transit stations is essential, because automobiles provide important secondary distribution, particularly from areas where local bus service is uneconomical to operate (*5*, *6*).

Location and Types

Terminals are usually found (1) at or near outlying rapid transit stations (Cleveland, Lindenwold), (2) at ends of transit lines (Chicago, Philadelphia, Toronto), (3) at intersection points of major highway and transit lines (Route 128, Boston, Metro Park, New York), and (4) along express bus lines (Milwaukee). Terminals are located at substantial changes in population density, which form logical breakpoints for express service into the downtown area.

TABLE 25

PRINCIPAL OUTLYING BUS-RAIL TERMINALS, UNITED STATES AND CANADA

NAME OF TERMINAL	TYPE OF BUS SERVICE	DATE & STATUS	NUMBER OF BUS LEVELS	NUMBER OF BUS LOADING BERTHS	CONTIGUOUS TRANSPORTATION FACILITIES	ACCESS CONNECTIONS	NUMBER OF PASSENGERS (1)	
							Daily	Peak Hour
Boston, Mass. Kenmore Square Bus Terminal	Local	1967	1	4	MBTA, Subway	Arterial Streets	NA	1,500
Chicago, Illinois 69th Street Terminal Dan Ryan Expressway	Primarily Local	1969	1	4	Dan Ryan Rapid Transit	Arterial Streets and freeway frontage roads	8,000	2,000
Chicago, Illinois 95th Street Terminal Dan Ryan Expressway	Primarily Local	1969	1	22	Dan Ryan Rapid Transit	Arterial Streets and freeway frontage roads	20,000	5,000
Chicago, Illinois Jefferson Park Terminal	Primarily Local	1970	1	14	Kennedy Rapid Transit, CNW Railroad	Arterial Streets	12,000	3,000
Philadelphia, Pa. 69th Street and West Chester Pike Terminal	Local	Before 1930	1	10 (4)	Market Street Rapid Transit Suburban Rail	Arterial Streets	15,000	3,700
Toronto, Canada Eglington Avenue and Yonge Street Terminal	Local	1954	1	13	Yonge Rapid Transit	Arterial Streets	55,000	15,000
Washington, D.C. S.W. Bus Terminal	Suburban	1970	1	10	Local Transit	Arterial Streets	700	400

(1) One-way only - buses and passengers entering station.
(2) Data on operations and maintenance not available.
(3) Estimated.
(4) Some berths shared with streetcars.

Terminal size and location reflect (1) city size, (2) land costs and availability, and (3) bus and street patterns The ability of road nets to intercept cars is also a major factor. Terminals are mainly located 2 to 15 miles from the CBD However, in very large metropolitan areas (i.e , New York, Chicago) parking is provided along transit and rail lines as far as 45 miles out.

Terminals closest to the CBD, such as Kenmore Square and Harvard Square (Boston) and Eglinton-Yonge (Toronto), emphasize bus-rail transfer Most rail and bus park-and-ride facilities are located from 5 to 15 miles from downtown At distances over 10 miles, parking is emphasized

Bus-Rail Interchange

Bus-rail transfer facilities are designed to a smaller scale than downtown terminals (Table 25) Designs are simple, ancillary facilities are kept to a minimum, and relatively few bus bays serve heavy peak-hour loads.

Size —The 95th Street (Dan Ryan) Terminal in Chicago has 22 berths, of which 14 are normally used for loading. Jefferson Park Terminal has 14 loading positions in addition to curbside unloading areas. The most intensively used transfer station, the Eglinton Terminal of the Yonge Street Subway (Toronto) has 13 loading berths, accommodating 2 to 4 buses each. These berths are also used for unloading Philadelphia's 69th Street Terminal has 10 loading berths and 6 unloading berths, some of which are shared with suburban streetcars

Fewer routes converge on transfer terminals than on CBD bus terminals, with a maximum of 20 (14 CTA routes plus Greyhound and Union buses) at Jefferson Park (Chicago), Eglinton (Toronto) accommodates 12 feeder routes, 69th Street (Philadelphia) accommodates 14 bus routes.

Road Access —Road access is mainly from arterial streets, which are sometimes modified to improve bus access. Reserved bus lanes are provided on approaches to Toronto's Eglinton Station A special left-turn bus lane and traffic signal are provided at Chicago's Jefferson Park Terminal; a trumpet interchange is provided at Toronto's Warden Terminal Chicago's 69th and 95th Street Bus Bridge Terminals incorporated bus facilities in the basic freeway design as a result of advanced planning and reservation of right-of-way.

Design and Operations —Terminals are designed to allow rapid passenger interchange and to facilitate quick entry and exit by buses. Generally each bus route is given a specific loading area. Bus platforms are generally of the parallel pull-through type, although modified sawtooth berths are found at several Cleveland Transit System stations A primary design factor is the need for buses to load and unload parallel to curbs. The Cleveland Transit System discarded its initial loop-type terminals for this reason.

The balance between through and stub bus operations

NUMBER OF BUSES (1)		AVERAGE BUS OCCUPANCY		AVERAGE NUMBER OF BUSES PER DOCK		AVERAGE BUS LAYOVER TIME		DEVELOPMENT COSTS (2)	ANCILLARY LAND USES	REMARKS
aily	Peak Hour	Daily	Peak Hour	Daily	Peak Hour	Daily (Hrs.)	Peak Hour (Hrs.)			
N.A.	35	--	50	N.A.	9	--	.15	$ 280,000		In street median, linked to street by 25 foot busway pay - transfer
N.A.	40	--	--	--	10	--	.10	550,000		
N.A.	110	--	--	--	5	--	0.20	1,300,000		
N.A.	140	--	--	--	10	--	.20	1,800,000	Limited convenience retail	1,800 car parking planned
800	90	18.7	41	80	9	0.30	0.11	N.A.	Retail and convenience goods	modernization proposed in Urban Corridor Study
500(3)	250	34.6(3)	52	11.5(3)	19	0.21(3)	0.05	5,000,000	Retail and convenience goods 17 story building over station	Free transfer bus to subway; 2 to 4 buses can queue at each platform.
200	80	3.5	5	10.0	8	2.4	0.12	232,000	Government Center employing 100,000.	

varies among specific conditions Common practice is to reroute buses into the line-haul transit stations in an attempt to encourage longer trips by rapid transit. Some through routing exists, although outlying terminals provide convenient points for breaking up longer routes. This is especially feasible when terminals are at the break-points in urban density patterns.

Buses load almost continuously during peak periods. Layovers of 5 to 10 min and peak berth loadings of 10 buses per hour are typical. The maximum berth capacity (19 buses per hour) is found at the Eglinton Terminal in Toronto.

Patronage and Bus Volumes—The highest bus volumes are found at the Eglinton Terminal The terminal's 13 bus docks accommodate 55,000 entering passengers per day; 15,000 in the peak hour in 250 buses These peak-hour volumes represent nearly one-half of the peak volumes in New York's Midtown Terminal. They are achieved by loading through both front and rear doors (double-width doors on trolley buses) under free-transfer conditions

More typical volumes range from 15,000 to 20,000 entering passengers per day; with 3,500 to 5,000 in the peak hour in 90 to 140 buses. Peak-hour loadings of more than 50 passengers per bus are common.

Costs.—Transfer stations are considerably less costly than central area terminals. The most expensive (Eglinton) cost about $5 million in the early 1950's, whereas Jefferson Park and 95th Street in Chicago each cost under $2 million. Outlying rapid transit transfer stations—as in Cleveland—cost under $1 million, including parking

Rail-Bus-Auto Interchange

Parking along rail lines varies among transit systems (Table 26) Chicago provides a total of about 2,000 parking spaces, Cleveland, 8,000, New Jersey's Lindenwold Line provides about 8,800 parking spaces, or the equivalent of one space for every two inbound daily passengers.

The individual size of parking facilities ranges from 200 to 2,000 in Chicago and Cleveland, respectively The Cleveland Transit System indicates that 1,000 spaces is a good size for a fringe parking facility. Parking is free in Cleveland and Toronto, but involves nominal costs in the other cities.

Express Bus Outlying Parking

Fringe parking is provided along many express bus routes (Table 27) These facilities are simply designed, usually charge no fee, and provide neither special pedestrian facilities nor shelters. Existing facilities generally provide 100 to 300 spaces, although this varies New proposals usually call for larger facilities.

Few outlying park-and-ride lots sustain all-day transit service. Facilities are usually open during the morning and evening peak periods and primarily serve commuters All-day bus parking is provided in selected situations, such as the Lincoln Tunnel and Blue Streak parking lots.

Milwaukee reports success in using parking fields in outlying regional shopping centers as terminals for its "Freeway Flyer" bus service to the CBD In this way, it is attempting to establish routing and riding patterns that can be upgraded as part of its proposed bus rapid transit

TABLE 26

CHARACTERISTICS OF SELECTED BUS PARK-AND-RIDE SERVING MAJOR RAPID TRANSIT LINES, UNITED STATES AND CANADA

CITY AND LOCATION	TERMINAL OR STATION	APPROX. DISTANCE FROM CBD (Miles)	BUS LINES SERVING STATION	PARKING SPACES	PARKING COST (Dollars)	PARKING USAGE CHARACTERISTICS	
						Peak Accumulation	Turnover
Chicago							
Linden (Wilmette)	Terminal	14.0	2	470	0.25	57	0.6
Dempster (Skokie Swift)	Terminal	15.0	4	520	0.25	98	1.0
Howard	Terminal	9.5	12	300	0.25	104	1.3
Des Plaines (Congress)	Terminal	9.5	3	510	0.25	100	1.6
Cicero-Berwyn	Terminal	8.8	1	310	Free	77	0.8
Ashland - 63	Terminal	9.5	6	230	0.25	93	1.0
Kimball (Ravenswood)	Terminal	10.2	2	210	0.25	N.A.	1.0
Cleveland							
Brook Park	Station	10.5	2	1,300	Free	N.A.	1.0
Puritas - W. 150	Station	9.0	2	1,050	Free	N.A.	0.7
West Park	Station	8.0	5	2,000	Free	N.A.	0.9
Triskett	Station	6.5	3	1,200	Free	N.A.	1.0
W. 117 - Madison	Station	6.0	4	525	Free	N.A.	1.0
W.98 - Detroit	Station	5.0	3	315	Free	N.A.	1.0
E. 55	Station	2.2	1	85	Free	N.A.	1.0
Superior	Station	7.0	4	150	Free	N.A.	1.0
Windermere	Terminal	7.5	6	700	Free	N.A.	0.9
Toronto							
Islington	Terminal	9.0	6	1,300	Free	85	1.3
Warden	Terminal	9.2	9	1,530	Free		

system Savings of up to 30 min are reported. Patronage, however, is less than 1,000 passengers per day in 28 buses, 8 of them in the peak hour at the most heavily used facility

Patronage of fringe parking facilities is generally light Fringe parking has failed to attract bus passengers in medium-size communities where downtown parking is relatively inexpensive, and in larger cities when the park-and-ride trip does not compete with other modes from a cost-and-time standpoint. Fast express bus service to the CBD, competitive with car travel times and accelerated by bus priorities wherever possible, is essential for successful fringe parking

Comparative-Use Patterns

Bus and rail fringe parking lots in a number of cities are compared in Figure 7

1. Rail facilities are generally located farther from the CBD, largely reflecting locations along commuter rail lines
2. Eighty percent of the bus-serviced lots had peak-hour headways of 20 min or less, and 85 percent of the rail-serviced lots had peak-hour headways of 25 min or less. Use of bus-serviced lots decreased rapidly as bus headways exceeded 20 min, the decrease in rail-serviced lots with increasing headways was more gradual
3. Average daily CBD parking costs significantly influence use of bus-serviced lots. When parking costs are less than $1.50 per day, bus-serviced lots were used to less than 50 percent of capacity The effects of CBD parking costs on rail are less and are apparently offset by travel time savings Line-haul transit was faster than auto to the CBD for 85 percent of the rail-serviced lots.

Benefits

Outlying transit stations, when supplemented by car parks and "kiss-and-ride" facilities, produce important benefits, as follows.

1 They make it possible to reduce local transit services into the city center This allows a higher productivity of transit personnel and equipment, and a more simplified route structure.

2 They allow the automobile to provide secondary distribution. This has the potential advantages of (a) increasing the transit market, (b) reducing the extent of express transit services and the frequency of stations, and (c) reducing downtown parking requirements.

Realization of these benefits calls for providing fringe parking at least 5 to 8 miles from downtown Express transit service to the city center must travel these distances to offset the time lost in transferring. Total travel costs must be less than the comparable costs to drive and park downtown.

BUS SERVICE INNOVATIONS

Many cities have introduced specialized bus services in an attempt to maintain or improve ridership. The more significant service experiments include: (1) combined freeway and arterial bus service, New York City and Washington, D.C , (2) expanded freeway bus service, as in Milwaukee and Los Angeles; and (3) express commuter service between specific employment centers, as between downtown Washington, D.C., and Reston, Va.

New York City Express Bus Service

New York City operates a network of 16 express bus lines between Manhattan and high-density residential areas not served by rapid transit Express services were first initiated in 1968 with lines to Manhattan from Fresh Meadows, Queens; Riverdale, Bronx; and Staten Island. Service has been progressively expanded

Buses operate on arterial streets and on the Long Island Expressway contra-flow lane, with Manhattan distribution along Third Avenue, Madison Avenue, Fifth Avenue, and Avenue of the Americas One-way fares are $1.00 Commuter tickets are available on six lines at $8.50 per 10 trips

The express bus program is reported as highly successful Patronage continues to grow, passenger acceptance has been good, and applications for additional franchises continue. On a typical 1971 day, 186 buses entered Manhattan between 7:00 and 9.00 AM, and 145 buses between 9:00 AM and 4:30 PM During the morning peak two hours, buses delivered some 8,000 people.

The service clearly demonstrates the potentials for express bus service—and bus priority treatments—in cities with major rail rapid transit systems. It also brings to focus the need for more effective allocation of downtown street space to public transport—the buses have added significantly to the traffic stream, and compete with local buses for preferred stop locations

Washington Capital Flyer Experiment

Special "Capital Flyer" express bus services between downtown Washington and neighboring Prince Georges and Montgomery Counties in Maryland and Fairfax County in Virginia were installed under an UMTA demonstration project in 1970 (*7*) Certain fares were reduced and free fringe parking was provided. The demonstration indicated that:

- The original special low ($0 25) fare (outbound only) was an inducement to those seeking new jobs in the suburbs. However, the incremental costs of operating reverse-commuter lines in a loop system, due to increased circuity and time lost in loading and unloading, raised costs high enough to justify a regular fare structure
- All suburban commuter lines were successful, including those serving high-income neighborhoods. Success resulted from providing direct service to downtown from free fringe parking lots and scheduling trips to fit work hours. Demands for the reverse commuter service were light.
- Optimum peak-period service was found to comprise four or five trips (AM or PM) The greater dispersal of riders in the afternoon made it more difficult to provide homeward service.
- Provision of free fringe parking was found to be essential. Regional shopping centers proved feasible as collection points for both kiss-and-ride patrons and those who drove and left their cars. Parking was maintained, cleaned, and lighted by the shopping centers, and there was no need for a guard system during the life of the project Because peak parking requirements for shopping occurred during evening hours, the regional centers afforded reserve parking capacity during working hours.

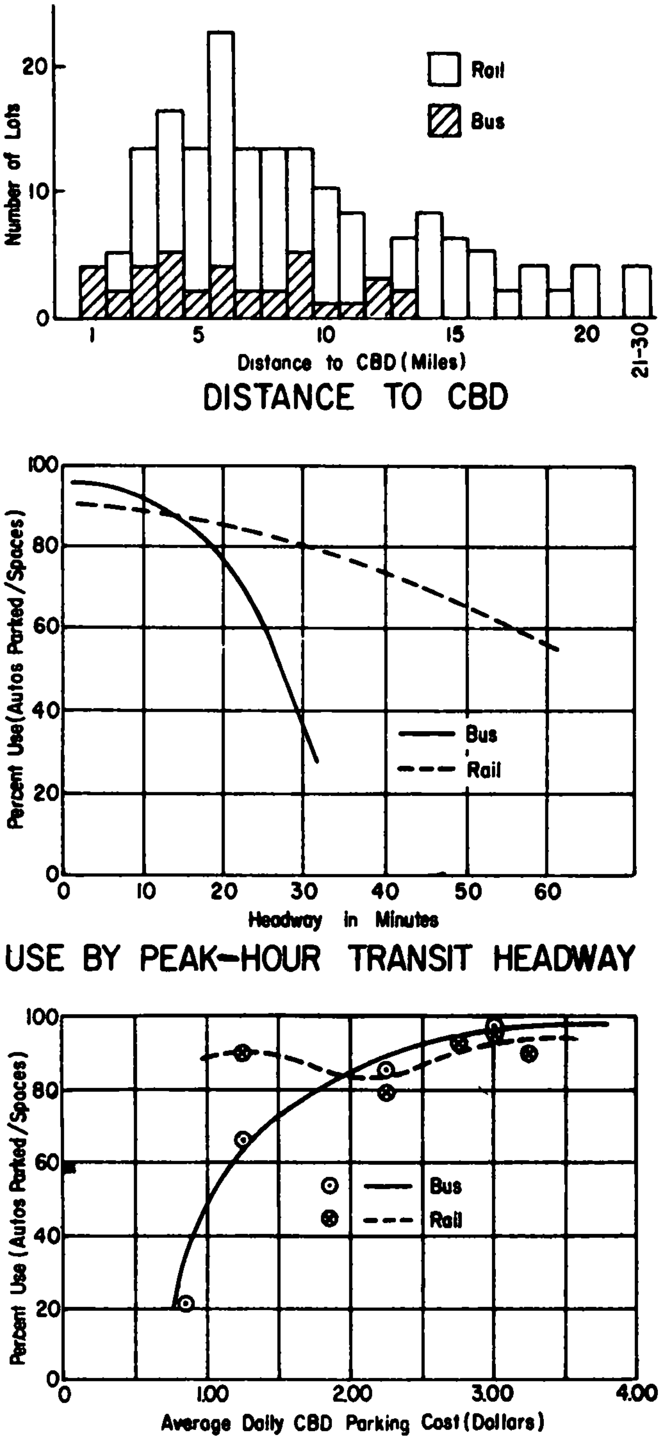


Figure 7 Summary of characteristics of outlying rail and bus parking lots (Source Ref. 6)

Reston Bus Service

The Reston, Va., bus service represents one of many specialized operations that link common origins and destinations. The Reston Commuter Bus Lines carry about 650 people each way daily on 18 buses.

Results of bus rider surveys conducted during 1971 (*8*)

TABLE 27

CHARACTERISTICS OF SELECTED BUS PARK-AND-RIDE FACILITIES

CITY AND LOCATION	DATE STARTED OR STATUS	HOURS OF BUS OPERATION	PARKING LOT CAPACITY	OVER THE ROAD MILES TO CBD	TERMINAL FACILITIES FOR PEDESTRIANS	EXPRESS BUS SERVICE	RELATED CBD OR LINE-HAUL BUS PRIORITIES	BUSES IN PEAK-HOUR HEAVY DIRECTION (AND ALL DAY)	PEAK-HOUR BUS SPEEDS (MPH)	BUS FARE	PASSENGERS PEAK-HOUR ONE-WAY (AND ALL DAY)	REMARKS
Atlanta Town Flyer Stadium	1970	7:30- 9:00 A.M. 4:30- 6:00 P.M.		1	No	No	No	6 (18)		$0.75/ (Car round trip)		
Atlanta Town Flyer Civic Center	1970	7:30- 9:00 A.M. 4:30- 6:00 P.M.		1	No	No	No	6		$0.75/ (Car round trip)		
Baltimore, Md. Metropolitan Flyer Towson to Baltimore CBD	1965	6:00 A.M. 6:00 P.M.		15.3	No	No	Yes	3	28	$0.50 one- way	(500)	
Hartford, Conn. Corbins Corner Corbins Corner S.C.	1972	7:00- 9:00 A.M. 4:00- 6:00 P.M.		7.0	No	No	Yes	4		$0.35 one- way	(572)	
Burr Corner	1972	7:00- 9:00 A.M 4:00- 6:00 P.M.		7.5	No	Yes	No	4		$0.35 one- way	(550)	
Louisville, Ky. Iroquois Park Rt. 4-Amphitheater	1971	6:40- 8:25 A.M. 3:50- 5:40 P.M.	170	8.5	No	Yes	Yes- partially	4	15			
Louisville, Ky. International Harvester Rt. 2		6:45- 8:30 A.M. 3:50- 5:40 P.M.		8.5	No	Yes	Yes- partially		22			
Louisville, Ky. Auburndale, Rt. 6		6:45- 8:25 A.M. 3:50- 5:40 P.M.		10	No	No	Yes- partially		15			
Milwaukee Mayfair S.C.	1968	6:20- 8:25 A.M. 4:15- 5:45 P.M.	300	10	No	No	Yes	8 (28)	30	$0.50 one- way	(1,000)	Trip would take about 25 minutes longer by regular service.
Milwaukee Bayshore S.C.	1965	6:45- 9:00 A.M. 4:15- 6:05 P.M.	150	7	No	No	Yes	5 (22)	42	$0.50 one- way	(600)	
Milwaukee Treasure Island South S.C.	1967	6:15- 8:20 A.M. 4:15- 5:35 P.M.	100	10	No	No	Yes	3 (9)	30	$0.50 one- way		
Milwaukee Treasure Island North S.C.	1968	6:40- 8:25 A.M. 4:00- 5:30 P.M.	100	12	No	No	Yes	2 (7)		$0.50 one- way		
Milwaukee Country Fair S.C.	1969	6:23- 8:27 A.M. 4:15- 5:30 P.M.	50	14	No	No	Yes	2 (4)	42	$0.55 one- way		

Spring Mall	1970	6:25- 8:25 A.M. 4:45- 5:35 P.M.	100	10	No	No	Yes	2 (7)	45	$0.50 one-way		
New York Metrop. North Bergen, N.J.	Exist	6:00 A.M.- 1:00 A.M.	1,500	3.3		Yes	Yes	15 (135)		$1.25 round trip including parking	1,900 cars parked daily	
New York Metrop. N. Brunswick, N.J. Suburban Transit Co.	Exist			35		Yes	Yes					
New York Metrop. E. Brunswick, N.J. N.J. Turnpike Int. #9	1971		400	35		Yes	Yes					$563,000 Cost.
New York Metrop. N.J. Turnpike Int. #8				45		Yes	Yes					
Seattle, Wash. Northgate S.C.	1970	7:00 A.M.- 7:00 P.M.	475	7	No	Yes	Yes		30	$0.70 round trip		Part of Blue Streak Proposal
Washington, D.C. Carter Baron Amphitheater	1955	7:10 A.M.- 6:10 P.M.	800		No	Yes	None	20		$0.30		Free Parking
Cincinnati, Ohio Mt. Washington Term. Sutton Avenue	Proposed	N.A.	230	9.5	Yes	No	Yes					Urban Corridor Proposal
Cincinnati, Ohio Fairfax Term.	Proposed	N.A.	175	8.5	Yes	No	Yes					Urban Corridor Proposal
Cincinnati, Ohio Milford Term.	Proposed	N.A.		17	Yes	No	No					Urban Corridor Proposal
Cincinnati, Ohio Terrace Park Term.	Proposed	N.A.	150	14	Yes	No	No					Urban Corridor Proposal
Cincinnati, Ohio Beechmont Mall Term.	Proposed	N.A.		11.5	Yes	No	No					Urban Corridor Proposal
Cincinnati, Ohio Hyde Park Term.	Proposed	N.A.		5.5	No	No	Yes					Urban Corridor Proposal
Detroit, Michigan State Fairground Parking Area Eight Mile Road and Woodward Ave.	1971	N.A.	5,000	11	No	No	Yes					Stopped. May continue for special events.
New York Metrop. Rutherford, N.J. Rt. 3 W. of Rt. 17	Proposed		1,090	8		Yes	Yes					3,000,000 Cost. Urban Corridor Proposal
New York Metrop. Clifton, N.J. Rt. 3, W. of Garden State Pkwy.	Proposed		650	13		Yes	Yes					$648,000 Cost. Urban Corridor Proposal
New York Metrop. Little Falls, N.J. Rt. 3 E. of Garden State Pkwy.	Proposed		1,040	15		Yes	Yes					$2,000,000 Cost. Urban Corridor Proposal
New York Metrop. Willowbrook, N.J. Rt. 3 and Rt. 23	Proposed		500	18		Yes	Yes					$811,000 Cost. Urban Corridor Proposal
New York Metrop. Leonia, N.J. Rt. 208 N. of I-80	Proposed		430	11		Yes	Yes					$482,000 Cost. Urban Corridor Proposal
New York Metrop. Delawanna, N.J. Rt. 3 and Rt. 21	Proposed		620	10		Yes	Yes					$1,500,000 Cost. Urban Corridor Proposal
New York Metrop. North Hackensack, N.J. Rt. 4 N. of I-80	Proposed		660	20		Yes	Yes					$1,500,000 Cost. Urban Corridor Proposal
New York Metrop. Ridgefield Park, N.J. New Jersey Turnpike	Proposed		1,500	8		Yes	Yes					$2,000,000 Cost. Urban Corridor Proposal

indicate the following. (1) Ridership increased from 180 in December 1968 to 1,030 in October 1971, and rides per 100 persons in Reston increased from 6.0 to 7 0; (2) 87 percent of the bus commuters rode the buses regularly, (3) the bus service reduced the number of automobiles in about 20 percent of the households of bus riders, and will probably reduce the autos another 8 percent; (4) if the service were not available, it would have resulted in increased car ownership in 50 percent of the bus riders' households, (5) 44 percent of the passengers stated that they would not have moved to Reston if the bus service had not been available; and (6) reduced travel times appeared to be the main concern of passengers, but not at the cost of reducing service, system performance, or passenger comfort.

The survey suggests that a specialized commuter bus service might, in the long run, help reduce peak highway travel demands

COMMUNITY IMPLICATIONS

Bus priority treatments reflect the growing public recognition of transit as an essential public service. Their installation, maintenance, and operation call for cooperative approaches among affected state, regional, and local governmental agencies and transit companies.

Legal Considerations

The ability of local government authorities to legislate, administer, and enforce bus priorities depends on state enabling legislation and judicial interpretation Municipal ordinances usually specify basic traffic control measures, and, more specifically, bus lanes The bus priority lanes in Baltimore, Washington, and many other cities were installed in this manner In other cases, such as in New Orleans, bus service merely used former streetcar rights-of-way.

Traditionally, streets and highways have been established as rights-of-way for general public use. Traffic management measures that differentiate among users should, therefore, show that the treatment is in the public interest.

In the only court case involving bus lanes, the Wisconsin Supreme Court ruled that the police power of a city could not discriminate against the use of the street, in the absence of specific state enabling legislation (*9*) Similar court decisions, in many states 25 or 30 years ago, required specific enabling legislation for restricted access on freeways Until that time, highway authorities were powerless to control access on a public highway, except through acquisition of an extremely wide right-of-way and construction of frontage roads on both sides of the highway

The legal status of busways is more elusive. Responses to a busway questionnaire denote a wide range of state laws and interpretations (Table 28). Legislation specifically authorizing busways exists in California and Virginia (where busways exist or are being built) and was proposed to the 1971 Wisconsin legislature

Impacts and Benefits—A Perspective

Bus priority treatments generally (a) reduce travel times, (b) achieve better service dependability, and (c) increase patronage. Maintaining transit patronage in turn can reduce the road and parking costs that otherwise might be incurred.

Highway Implications

In several cases, peak-hour bus riding has increased while auto riding has remained the same (i e., Bay Bridge, Shirley Highway). This is largely because the roads operate at capacity and are not able to accommodate additional motorists. Bus riding can, however, readily increase in the peak hour, subject to the availability of buses and demands. Thus, the bus operation begins to provide important capacity reserves—peak-hour motorists shift to buses; the highway capacity is absorbed by other motorists, the end result is a sharpening of peak-hour person-travel and a reduction in peak-period duration.

Transit Implications

Revisions in bus routing patterns and their operating cost consequences are important in planning for efficient bus utilization of highway facilities. The labor requirements and other costs associated with diverting motorists to buses during peak periods must be clearly identified. These costs —especially where duplicate bus services must be maintained—could increase transit operating costs. In these cases, the rationalization for bus priority treatments depends on the external benefits—the peak-hour bus service costs as they relate to the alternate cost impacts associated with providing comparable peak-hour road capacity for motorists

A feature permeating most bus priority treatments is their radial character. This results from the historic focus on the city center. Little emphasis has been placed on improving crosstown or suburb-to-suburb bus movements—a growing travel market with increased latent travel demand.

Community Impacts

The effects of bus priority treatments on urban development patterns are difficult to identify. Major changes in development usually occur with continued population growth and vastly improved accessibility—where new levels of accessibility are introduced into growing areas Consequently, bus treatments incorporated into existing freeways appear to have little impact on land use, although land development patterns were strongly influenced by freeway construction prior to busway development The Shirley Highway, for example, helped stimulate development in its corridor, but this largely occurred before busway operation began. Freeways located in "gores" between urban development corridors are not likely to affect corridor growth, and nonstop express bus runs on freeways do not impinge upon the areas between stations.

Busways on their own rights-of-way may help to shape urban development, in similar fashion to rail lines Stations on Milwaukee's proposed busway and regional express bus system will be coordinated with adjacent development potentials.

TABLE 28

STATUS OF BUSWAY LEGISLATION IN THE UNITED STATES, 1971

		NO SPECIFIC LEGISLATION						
STATE	No Reply	Interpret Present Code Negatively	Interpret Present Code Positively	Interpret Present Code to Require Project by Project Approval	Interpret Present Code to Allow Construction Only on State Highways	Interpret Present Code to Allow Construction Only in Incorporated Juristic-tion	No Opinion	Existing or Pending Legislation Specifically Authorizing Busways
Alabama					x			
Alaska							x	
Arizona		x						
Arkansas			x					
California								x
Colorado							x	
Connecticut			x					
Delaware			x					
Dist. of Columbia	x							
Florida			x					
Georgia	x							
Hawaii			x			x		
Idaho							x	
Illinois		x						
Indiana			x					
Iowa						x		
Kansas						x		
Kentucky	x							
Louisana			x					
Maine		x						
Maryland		x						
Massachusetts				x				
Michigan							x	
Minnesota			x					
Mississippi		x						
Missouri	x							
Montana	x							
Nebraska		x						
Nevada		x						
New Hampshire		x						
New Jersey	x							
New Mexico							x	
New York						x		
North Carolina	x							
North Dakota	x							
Ohio			x					
Oklahoma	x							
Oregon			x					
Pennsylvania		x						
Rhode Island				x				
South Carolina		x						
South Dakota		x						
Tennessee							x	
Texas			x					
Utah	x							
Vermont	x							
Virginia								x
Washington	x							
West Virginia							x	
Wisconsin								x

NOTE: Summary of response to Busway Legislation Questionnaire.
SOURCE: Busways, Final Report, Goodman, Joseph, ITE Committee 6RA Division of Planning Applications, August, 1971.

Development of busways on their own rights-of-way, however, may have social impacts similar to those encountered in new urban highway construction. These concerns have surfaced in Milwaukee and New Haven, where busways are proposed The New Haven Canal Line busway proposal was criticized by minority groups because major service benefits would accrue to suburban residents, rather than to the residents of impacted central city neighborhoods

The specific effects of incremental traffic and transportation improvements on commercial core vitality are difficult to isolate Population, purchasing power, and commercial locational patterns have significantly influenced downtown attractiveness and commercial activity. Advantages of bus priority treatments may be more readily evident in environmental and amenity terms (for example, the Nicollet Mall development in Minneapolis).

CHAPTER THREE

FINDINGS – EXISTING RESEARCH

Research efforts pertaining to bus use in relation to urban highways have accelerated in recent years A detailed review of ongoing and completed research is set forth in this chapter. Appendix F contains an annotated bibliography of relevant research.

Research efforts have focused on the following:

1. Studies of busway capacity.
2. More effective use of freeways for moving people, including priority (exclusive) lanes for buses and other high-occupancy vehicles
3. Preservation of steady flow on high-demand freeways through ramp metering, sometimes with preferential treatment for bus access
4. Alternative means of scheduling and operating buses through transit stops and stations to maximize flow (platooning, automatic vehicle control, etc).
5. Functional design of bus stops and stations (including stops for passenger transfer or pickup on busways and exclusive freeway lanes).
6. Ventilation needs of enclosed busways and stations (bus tunnels).
7. Busway design features.
8 Arterial street exclusive bus lanes and traffic management approaches.
9. Bus stop location and design in the CBD.
10 Bus priorities at signalized intersections (signal preemption).
11. Optimization of vehicle design for general and special applications
12. Innovative new vehicles and transportation systems.

BUS FLOW STUDIES

Work carried out at the General Motors Proving Ground illustrates the fundamental nature of many of the studies now in progress. In 1968 and 1969, Scheel and Foote studied bus platoons operating in exclusive busways, to ascertain the upper limits of bus lane capacity under specified sets of conditions (*10, 11*). These studies compared experimental and simulated single-lane bus flow through a series of stations along a private right-of-way. Six buses were driven as a convoy through a series of simulated passenger stations, stopping at each station to simulate the dwell time associated with passenger pickup and discharge. The capacities of the bus lane (in vehicles per hour) observed during these experiments exceeded those predicted by the computer programs that were prepared on theoretical bases to study bus motion through such a system. Buses in groups of six, at cruising speeds of 30 mph between stations placed 0.3 mile apart, with a 30-sec dwell time at each station, resulted in capacities ranging from 350 to 400 buses per hour, and system speeds ranging from 13 to 15 mph.

Further studies conducted by Herman et al. (*12*) identified the transient characteristics of a platoon of buses starting and stopping along an exclusive right-of-way. By using a six-bus platoon on a 2.5-mile test facility, the effects of factors such as platform length, station spacing, speed, delay, etc., on operating dynamics were investigated. The space-time trajectories of the first and last vehicles were examined in detail, and a number of bus platoon dynamics were described. Buses starting at one position and stopping at another were found to be highly predictable. Motion of the platoon through such a cycle was found describable in terms of a starting transient, a steady state, and a stopping transient Furthermore, the "smoothness" of the acceleration of a platoon to a steady state was found to be strongly dependent on starting delay, vehicle performance, and inter-vehicle spacing at the starting position. In addition, the experimental observations were compared with the theoretical results obtained from numerical solutions of the linear car-following model of single-lane traffic flow.

The foregoing studies represent idealized and largely theoretical approaches. They did not assess effects of variations in vehicle performance, roadway grades and curves, and passenger loading and off-loading procedures on predicted performance levels. They did not relate bus platoon capacities to the likely demand ranges in most cities

Problems of scheduling buses with common destinations proceeding through each bus queue in precisely the same position—an essential condition for effective passenger loading—were not considered. Neither were the problems that would be introduced by buses arriving at queue formation points either early or late (out of phase with other vehicles in the platoon). These problems are being evaluated in a pilot project in Rochester, N Y.

FREEWAY BUS AND HIGH-OCCUPANCY VEHICLE OPERATIONS

Theoretical research also has been undertaken on the allocation of freeway lanes to multiple-occupancy vehicles. The efficiency of such allocations depends on (a) the number of people using the lane and their time savings as compared with (b) the number using the remaining lanes and their time losses.

1. Early theoretical work was done by May et al. in 1967 (*13*). They indicated that inasmuch as severe congestion is usually confined to only a few critical sections of highway, priority schemes for these bottlenecks could significantly reduce total passenger delay. The tradeoffs between bus priority and mixed operations in these areas were identified.

2. Additional queuing models were developed by Russell (*14*). The models analyzed the consequences of converting freeway lanes to bus use under alternative highway demands and bus use levels. The effects of bus use on the San Francisco-Oakland Bay Bridge were analyzed in detail.

The model indicated that under most "normal" conditions, the proportion of buses in traffic would not warrant an exclusive lane, because delays to motorists in the remaining lanes would be increased significantly. The conversion of automobile travel lanes to bus travel would increase total person delay unless the proportion of peak-hour travel by bus increased substantially Implicit, therefore, is a necessary modal shift to buses to minimize person delay. It should be noted that no freeway-related bus priority treatments or proposals have actually removed lanes from car use in the heavy direction of flow.

The model did not directly address the consequences of providing exclusive bus lanes without reducing highway capacity in the flow direction. It can, however, be applied to this condition.

3. Further analysis based on the preceding models indicated that "it is not feasible to establish an exclusive lane for buses and car pools across the San Francisco Bay Bridge in either direction" (*15*)

4. A theoretical analysis by Stock, Wang, and May (*16*) tested various priority lane and vehicle configurations for buses and car pools in the bottlenecks at points of entry onto the San Francisco-Oakland Bay Bridge approaches. Four alternative plans were studied for handling traffic on the westbound approach to the bridge. Each plan was concerned with the allotment of certain toll booths for exclusive use by buses and high-occupancy passenger cars. (All other traffic would be excluded from the lanes leading to these booths to a point beyond the booths at which all lanes converge to five through lanes at the bridge abutment.) All plans offered benefits with a 10 percent occupancy shift. Only one plan was found to offer benefits over normal operations without requiring additional motorists to group-ride (develop more high-occupancy vehicles). This plan would provide two toll booths for priority traffic, plus an additional "skim" toll booth to meter nonpriority traffic into the reserved lane to better utilize the lane's excess capacity.

Ten alternative plans were analyzed for the eastbound traffic flow Unless a shift to high-occupancy vehicles occurred, none of the alternatives showed any potential benefits. It was found that an occupancy shift of more than 5 percent could not be expected from implementing the best of the alternatives.

Analysis of the normal operation of eastbound traffic showed that the existing exclusive bus ramp design allows buses to bypass most of the congestion on the bridge approaches.

The validity of the theoretical results of priority lanes for buses and car pools on the westbound toll plaza is being tested: (a) A "bus only" lane was opened to transit vehicles in April 1970, permitting nearly 500 buses to avoid congestion between 6:00 and 9.00 AM. Bus traffic was permitted to pass without stopping to pay tolls (payment is billed monthly on the basis of trans-bay bus operating schedules). Buses saved between 5 and 14 min during the peak hours on the bridge approach. (b) Early in December 1971, the experiment was expanded to three "priority" lanes at the toll plaza—one for buses and two for high-occupancy cars (three or more persons per car). The two lanes for car pools allowed ample reserve capacity for future increases in high-occupancy cars, thereby assuring free-flowing traffic in the reserved lanes Incentives to develop car pools were created by allowing cars with three or more occupants to use the bridge without paying the $0 50 toll; they are billed $1 00 per month. The number of high-occupancy cars increased from 1,100 to 2,300. This is an application of congestion-pricing in reverse.

5. Theoretical studies by Morin and Reagan (*17*) quantified the delays and benefits resulting from reserving a freeway lane for buses and car pools Analyses were applied to demands of 10,000 and 20,000 persons per hour (one-way) with a known proportion on buses for four conditions. (1) mixed flow on all lanes, (2) one lane reserved for buses only, (3) one lane reserved for all vehicles with two or more occupants, and (4) one lane reserved for all vehicles with three or more occupants. (The proportion of these person trips in buses must be known; also, the proportion of cars with two or more occupants (2+) and those with three or more (3+). Average car occupancies in peak-hour traffic commonly range between 1.3 and 1.5 persons per car. Cars with two or more occupants generally account for 20 to 30 percent of all cars, those carrying three or more persons generally range between 4 and 8 percent of all peak-hour vehicles. Thus, the number of 2+ and 3+ cars in a particular peak-hour flow of traffic can be approximated. Field surveys would, of course, refine the relationships in particular situations that show promise)

With four freeway lanes for one-way flow and a demand of 20,000 person-trips per hour, reserving one lane for buses only or for buses and cars with two or more occupants was found to yield greater total delays than under normal traffic flow. Buses and vehicles with two or more occupants amount to nearly one-third of all vehicles in traffic; assigning all of these to one lane (one-fourth of the roadway capacity) would create congestion and long delays in that lane

The least delay would occur if one lane were reserved for all vehicles containing three or more persons In this situation, only about one-eighth of all vehicles would be assigned to the priority lane and there would be no delay to persons in those vehicles. This solution would result in the least total person delay for the range of conditions where 15 to 40 percent of all persons used buses. However, persons in the unreserved lanes would experience more delay than if mixed traffic were permitted in all lanes.

On a 2-lane (one direction) freeway, with a 10,000 person-trip demand per hour and a known proportion in buses, the least total delay would occur if one lane were reserved for vehicles with two or more persons: in this particular case, one-third of the vehicles, carrying three-fourths of the persons, would be using one-half of the roadway. Long delays would be experienced by single-occupancy vehicles in the second lane.

When 30 percent of the people travel by bus, and the reservation of one lane of a 4-lane one-direction freeway for vehicles with three or more persons causes (a) 10 percent of people riding in cars with one or two persons to switch to vehicles with three or more occupants, and (b) another 10 percent to switch to buses, total delay to all persons would decline 75 percent, and average delay to persons in autos with less than three occupants would be reduced by 4 min (from about 12 to 8 min).

The feasibility of limiting any of the existing freeway lanes in the heavier direction of flow to high-occupancy vehicles depends on the extent to which motorists will actually shift to buses and multiple-occupancy cars This, then, is a restatement of the California queuing model analyses.

6 The basic concept of reserving freeway lanes for buses and car pools was analyzed by Voorhees (*18*) on Cleveland's 8-lane, I-90 Memorial Shoreway, which extends 12 miles eastward from the Inner Belt Freeway. The potential values resulting from reserving one lane for buses and car pools inbound in the weekday morning peak commuting period, and outbound in the evening peak period were analyzed The study found the following:

(a) The concept is basically sound Its objective should be to induce significant numbers of commuters to shift from low-occupancy cars into higher-occupancy buses and/or car pools. Feasibility depends on the unique characteristics of each specific freeway.

(b) On freeways with four or five lanes in each direction, reservation of one lane for buses and cars with three or more occupants was found to have good potentials under all conditions considered. The potential increase in person-carrying capacity approximated 13 percent.

(c) Reserving the left lane of the roadway for each direction of flow was recommended, as this would minimize lane changing to and from entrance and exit ramps.

(d) Distances of 5,400 to 7,500 ft would be required for smooth transition from "normal" to "reserved-lane" operation at the beginning and end points of the reserved-lane section

(e) A full-scale test is needed to determine whether accidents are likely to increase in the reserved-lane transition due to lane changing and weaving.

(f) Cities served by the freeway have the legal authority to enact reserved-lane legislation.

(g) Officials in the three affected cities believe that enforcement of the reserved-lane ordinance would be difficult Great reliance would be placed on voluntary cooperation through an effective public information program stressing the benefits of increased freeway capacity and peak-hour speeds.

The reserved-lane proposal for Cleveland was subsequently rejected by the municipalities involved, on grounds that enforcement could not be achieved.

RAMP CONTROLS

An important alternative to freeway lane controls is provision for ramp metering, with or without bus priority at freeway access ramps.

California Metering Study

The California Division of Highways began freeway ramp metering experiments in 1969 at three locations—two in Los Angeles and one in the San Diego area (*19*). The objective was to reduce over-all travel time in the total traffic stream—freeway and local street traffic. Priority access for buses was not provided initially, but was installed later at several locations By controlling the number of vehicles allowed to enter a freeway ramp at locations where mainline freeway volumes were approaching critical density, delays could be reduced Tests led to the following conclusions

- Capacity of a bottleneck does not increase with ramp control.
- Slight sacrifices to optimum freeway control sometimes must be made to ensure that local street operation does not become critical.
- Random merging of single vehicles or small platoons is satisfactory at most ramps Isolated merging problems seldom, if ever, affect over-all operation
- It is virtually impossible for the freeway to operate at capacity and still avoid shock waves
- Because of the frequency of incidents and difficulty in dissipating the resultant congestion, operation should be controlled to maintain volumes slightly below capacity if local street conditions permit. This slack allows a natural recovery capability.
- Sharp curtailment of the traffic allowed to enter a freeway at a high-demand ramp, to dissipate freeway congestion, is usually not possible because of the severe congestion that would result on feeder streets.
- Good information on freeway traffic conditions should be provided to drivers approaching metered ramps so they

will understand the need for such constraint—especially if wide traffic fluctuations occur on the freeway. Alternative arterial street routings are essential.

Texas A & M Study

Glennon and Stover (*20*) analyzed the feasibility of priority operations for buses on urban freeways by freeway surveillance and control. Under this "bus-freeway system," buses are given priority access to the freeway via exclusive bus ramps; automobiles are metered to utilize excess capacity, but short of the volume that jeopardizes the desired level of transit service.

Preliminary designs and cost estimates were prepared for four existing freeways to evaluate the technical feasibility of this system. These were:

1. The John C. Lodge Freeway, Detroit, Mich.
2. The Gulf Freeway, Houston, Tex.
3. Interstate 35W, Minneapolis, Minn.
4. The Penn-Lincoln Parkway (east), Pittsburgh, Pa.

Preliminary designs identified necessary modifications of physical facilities, including (a) the location and type of each surveillance and control element, (b) the location and design of bus ramps, and (c) the location of bus terminals.

The estimated costs to modify the four freeways were considered representative of the costs that might be encountered in converting existing freeways or in constructing a bus-freeway system on a new location. Cost estimates included (a) bus ramp construction costs, (b) bus terminal construction and right-of-way costs, and (c) capital costs of a surveillance and control system. Cost estimates for all surveillance and control elements represented 1967 prices, based on the cost of equipment and installation of the John C. Lodge and Gulf Freeway facilities (the latter operated by the Texas Transportation Institute).

Capital costs needed to modify the four study freeways ranged from $519,000 to $785,000 ($35,300 to $53,700 per mile of system or coverage), including the costs of bus ramps, terminals, and surveillance and control elements, but not bus interest and amortization. Annual operating costs varied between $226,000 and $288,000, including the costs of equipment and manpower for the control center and surveillance points, but not bus operating and maintenance costs. Costs were less than alternative busway or rail transit options, because ramp metering involves less physical construction.

The study indicated that there must be a certain minimum passenger diversion from freeway autos to buses for the bus-freeway system to improve peak-hour corridor operations Each freeway tested was found to meet this requirement. Therefore, the installation and operation of the bus-freeway system was believed to be technically feasible and practical at each location

BUS PRIORITIES AND TRAFFIC MANAGEMENT

A variety of research efforts has been undertaken to optimize bus use in urban areas

Buses in Baltimore, Maryland

A pilot study in Baltimore, Md. (*21*) concluded that the bus system has the potential to become an acceptable and economical alternative to the additional highway construction. The location and magnitudes of the forecast-year peak-hour vehicular overloads on the existing and committed highway systems were determined. Two alternative transportation systems were defined that would reduce or eliminate future overloads—one automobile-oriented, the other bus-oriented. The ability of each system to relieve highway traffic overloads was evaluated and system costs were estimated. Bus transit was found to offer a viable alternative to increased urban freeway construction The study indicated that:

1. Buses are capable of alleviating peak-hour overloads on radial freeways in the densest part of the city where additional street capacity cannot be provided. However, buses could not compete effectively in less-dense areas where transit demands are widely dispersed, nor could buses sufficiently relieve overloads on highways that are heavily used by externally oriented cars or trucks.
2. Exclusive or privileged rights-of-way are advantageous for buses if they are to maintain a competitive position. This may call for busways, preferential freeway entry (metered ramps), or reserved freeway lanes during peak hours.
3. In view of the relatively light bus volumes observed on typical urban freeways, it appears that other vehicles, including high-occupancy automobiles, could be allowed to use special busways or reserved freeway lanes during peak periods to better utilize reserved lane capacity.
4. The existing and committed arterial highway and freeway network developed for most cities is a basic element for viable bus transit.
5. Direct and rapid access between suburban areas and the CBD is important. Where no direct paths exist, or where the bus is severely disadvantaged by having to operate in peak-period forced-flow conditions, buses cannot compete successfully with private cars.
6. The costs to individual trip makers using either alternate system—bus-oriented and automobile-oriented—were nearly equal The bus system, however, offers special social and community benefits by providing mobility to persons without access to cars and by minimizing community disruption.

The research has some limitations: (a) it used forecasts of future travel that were predicated on assumptions as to travel demand, trip distribution, and peak travel concentrations, (b) it is sensitive to modal split procedures to the extent to which improved bus service would attract travelers, particularly those who can go by car.

Buses in Camden, England

The British approach in Camden, a part of Central London, relates more directly to current conditions (*22*). Engineering and economic analyses show the consequences of various bus segregation schemes.

Analyses demonstrated the feasibility of separate bus facilities on major streets. These bus lanes would be part of an over-all area traffic control scheme that also incorporates traffic signal and other changes

It was believed possible to increase bus operating speeds between 40 and 50 percent and reduce over-all bus journey times by about one-third throughout the study area The regularity of bus service would be substantially improved Reductions in the number of buses operated would be particularly important to London Transport in realizing labor savings at a time when financial problems are increasingly difficult

Although there would be a net over-all gain, losses to other traffic resulting from reduced street space would be substantial These losses could be reduced or eliminated by stricter parking control, including reductions of available parking spaces and increases in on-street parking charges

The difficulties of servicing business premises fronting on bus lanes were recognized, and arrangements would be necessary to ameliorate them. Loading bays should be provided close to the affected premises.

Costs of implementing the bus segregation scheme are small even if physical separation is provided. The total scheme is estimated to be equivalent to the construction and land costs for about 35 ft of the North Cross Route, a planned freeway link across the north side of Central London. In terms of transport investment the amount is small, whereas the net quantified benefit of the bus segregation scheme probably would be substantial. The estimated benefits were believed to be conservative

To maximize benefits of bus segregation, such schemes should be applied to a much larger area, including all of London's Central Area. The report suggests that further areawide studies should be made to test and evaluate bus segregation, but that the desirability of such tests should not delay initiating the bus segregation scheme proposed for Camden

Effects of bus segregation on non-bus traffic were computed. If the segregation scheme were applied only in Camden, car traffic in Camden would be reduced by slightly more than 6 percent; however, if improvements were applied throughout Central London, reductions in car travel might exceed 10 percent Some of this traffic would be diverted to buses, other trips probably would choose off-peak times, whereas still others would either divert to routes outside the restricted areas, find alternative destinations, or be eliminated.

Other studies have shown that, on average, people could travel faster by bus than by car in the Central Area of London if all persons traveled by bus as opposed to the existing modal split of 75 percent by bus and 25 percent by car. One of these studies (*23*) came to the following conclusion, after considering the possibility of transferring all existing Central Area private car trips to buses:

> The calculations suggest that any of the systems of buses within the range of 20-70 seaters could adequately cope with the present passenger traffic during peak hours and could reduce the average journey time for all travelers combined by up to one-third. Fares could be reduced with some of the systems, which could at the same time provide a better service. Economically, the system applied in Central London could result in a saving in vehicle operating costs and passengers' time costs of up to 20 million pounds per annum

The Camden study, however, assumed no basic changes in modal split in computing over-all benefits and impacts

"Test Track" for Buses, Great Britain

In 1970, the British Transport and Road Research Laboratory (TRRL) conducted controlled-track experiments to relate various parameters at a signal-controlled intersection with a curbside bus lane under saturated-flow conditions These experiments were conducted using 160 cars and 40 buses under a variety of saturated-flow conditions (*24*) Variables tested included cycle length, number of buses in traffic, and proportions of right and left turns.

The effect on capacity was measured for variations in the distance from the stopline at which the bus lane was discontinued. Other variables included the length of the signal green-time phase; proportions of left, right, and cross-flow traffic; number of buses per minute, and application of various priority rules in respect to turning vehicles The interim studies indicate that for a 30-sec green time, intersection capacity is marginally reduced in the bus lane if it is discontinued 200 ft before the signal stopline (Fig 8). Buses are thereby guaranteed clearance of the intersection within one signal cycle, whereas there is practically no capacity reduction for general traffic.

A small number of "bus only" tests were made using (a) unladen buses, and (b) buses loaded with sandbags to simulate 60 percent occupancy. Later in the test program "car only" tests were conducted so that the saturation flows of cars and buses separately could be compared. The tests were designed to measure (1) the benefits of a bus lane to public transport, and (2) possible hindrance of a bus lane to other traffic.

In the "bus only" tests, an hourly saturation flow of 1,100 to 1,300 buses per lane was found, which compares with a "car only" saturation flow of 1,900 vehicles per hour In the experiments testing mixed traffic conditions, equivalent passenger car units (pcu's) ranging from 2.5 to 3.0 were found for the standard British double-decker buses

TRAFFIC SIGNAL PREEMPTION

Research shows that traffic signal preemption by buses is a valid means of reducing total person delay under certain conditions. Signals represent one of the three major causes of bus delays, the other two are terminal delays and stops for loading and unloading. Signals can account for two-thirds to three-fourths of bus delay time in downtown areas.

Los Angeles Research

A pilot test in Los Angeles (*25*) suggests that savings in person travel time could be achieved through bus preemption of signals. Application of the experiment to other downtown sections would result in a 5 to 7 percent reduction in portal-to-portal times and in 15 to 20 percent reduction of riding time in Los Angeles. The bus occupancy level at which preemption is justified is largely a function of side-street auto volumes and main-street bus volumes

Kent State Research

A study at Kent State University (*26*) tested the effect of alternative traffic signal control strategies on bus and car travel times through three intersections on Main Street. The major travel time savings resulted from coordination and actuation of the three signals Additional gains resulted from on-vehicle bus preemption. Bus travel times were reduced by about 10 percent as a result of the signal improvements. Equally as significant, the study demonstrated the ability of on-vehicle signal preemption.

Washington, D.C., Research

A computerized traffic signal system with provisions for special bus preemption is being installed in downtown Washington. This system will test the feasibility of bus preemption in a downtown signal network. A combined urban traffic control and bus priority system will enable the bus operator to indicate when he intends to stop near an intersection, after which the system's computer logic will determine if (and how much) extension of green time is warranted, taking into account traffic flow and time savings to bus and auto passengers. Average occupancy rates are being used in calculating over-all average time savings and losses to persons passing through the intersections. These computations will provide a basis for adjusting the green signal phase.

Bus preemption schemes for central city conditions must be coordinated with downtown traffic signal networks. This fact constrains the extent of preemption and the benefits that are possible under actual city conditions It underlies the Washington, D.C., experiment.

DESIGN AND PLANNING STUDIES

The concept of joint use of freeway right-of-way for rapid transit and motor vehicles dates back nearly 50 years. At the International City and Regional Planning Conference held in New York City in 1925, Daniel L. Turner, consulting engineer to the New York Transit Commission, proposed a "parkway-rapid transit line" in the form of a superhighway that would accommodate rapid transit and automobile traffic, as well as space for a park and a playground along the same right-of-way. In 1947, the American Transit Association, in conjunction with the American Institute of Planners, developed a report on *Urban Freeways* which suggested that freeway designs make provision for both bus and rail rapid transit.

Bus Rapid Transit

Bus rapid transit was proposed in Chicago, 1937; Washington, D.C., 1956-62; and St. Louis, 1959. These early plans focused on regional system development and downtown distribution (Fig 9).

1937 Chicago Plan

The first bus rapid transit system was set forth in the 1937 Comprehensive Local Transportation Plan for the City of Chicago (*27*) as an alternate to rail rapid transit. This plan proposed conversion of three West Side rail rapid transit lines to express bus operations on superhighways with on-street distribution in outlying areas and downtown.

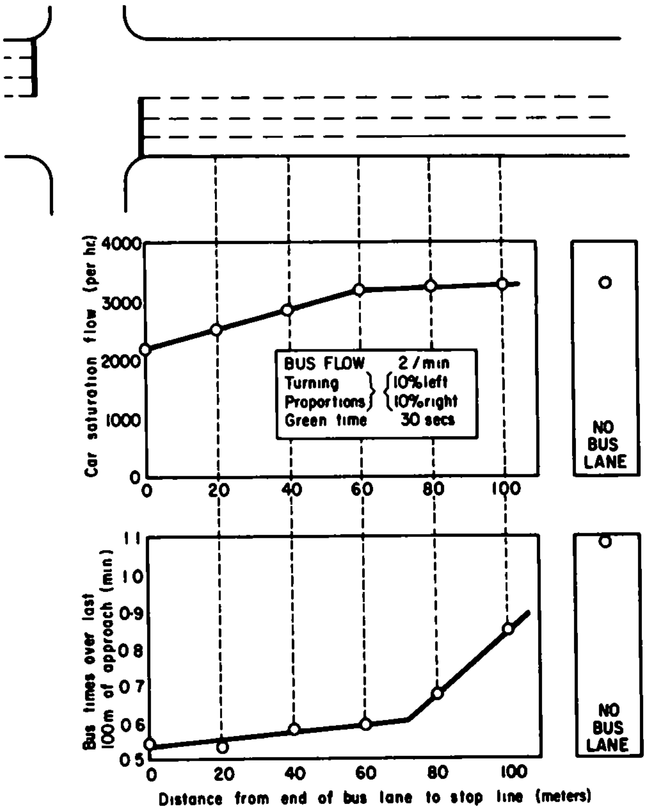


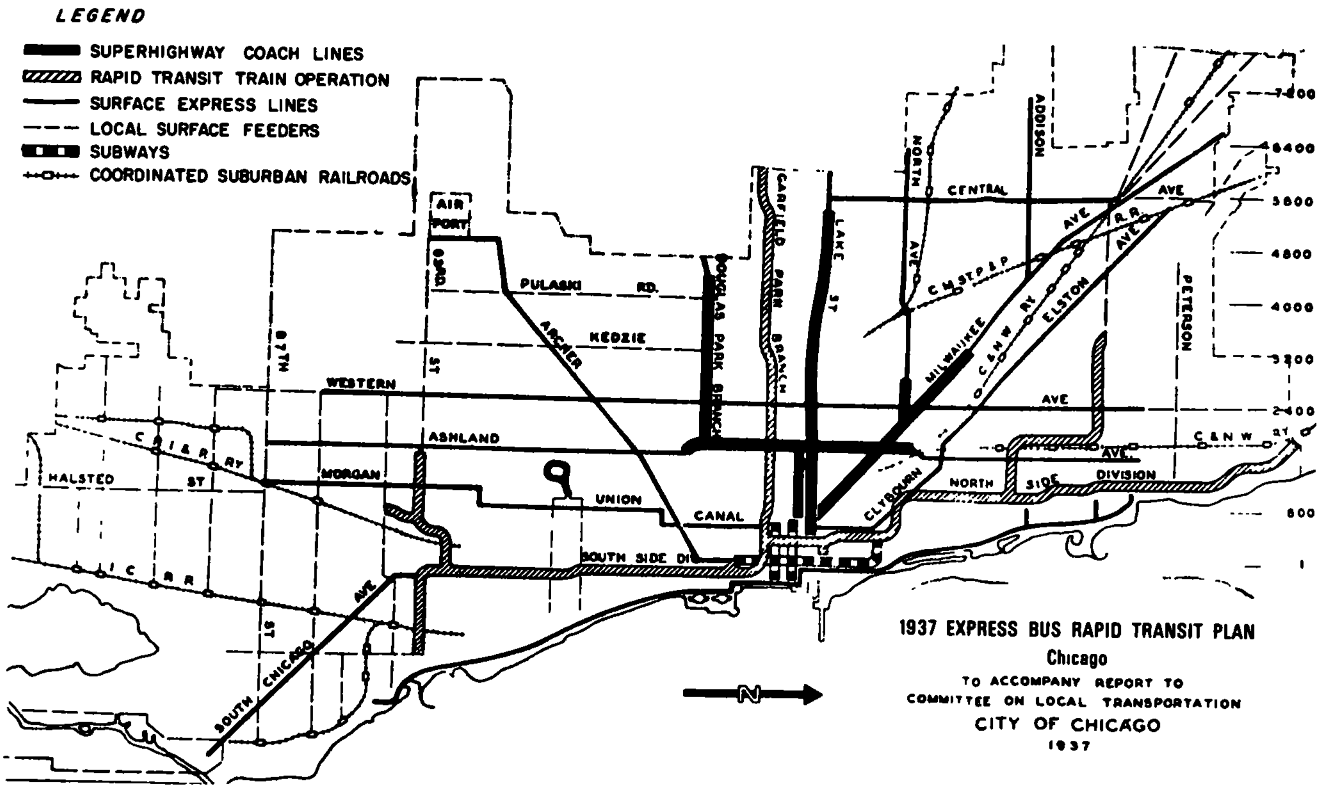
Figure 8 Effect of end of bus lane position on car saturation flows and bus journey times, Great Britain

Washington, D C., 1956-1959

Design studies for bus rapid transit within a freeway median were developed as part of the 1956-1959 Transportation Survey for the National Capital Region (*28*). It was recommended that "in planning of future radial freeways a cross section . . be provided to afford maximum flexibility and reserve capacity for vehicles as well as for the mass movement of people Under this plan there would be a three- or four-lane roadway for traffic in each direction. These roadways would be separated by a 64-foot mall with 51 feet from center-to-center of the columns supporting cross-street bridges. In the first stage, this wide mall would be landscaped and held available for future developments Public transportation at this stage would consist of express buses operating in the general traffic lanes. They would make stops at appropriate intervals on the parallel service roads without special station facilities or at simple stations within the end span of the cross-street bridges." Express bus service eventually would be converted to rail.

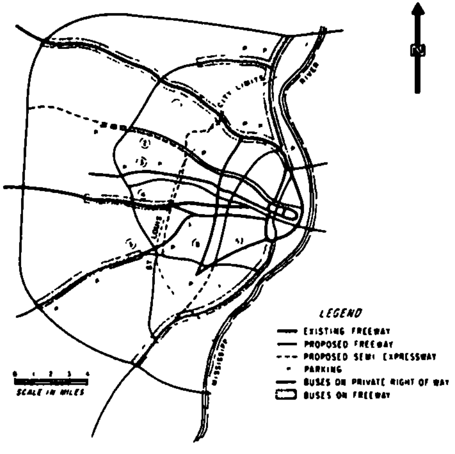
St. Louis Busway Plan

The 1959 Transportation Plan for the St Louis Area included an 86-mile bus rapid transit system, of which 42 miles were to be on special grade-separated bus roadways.

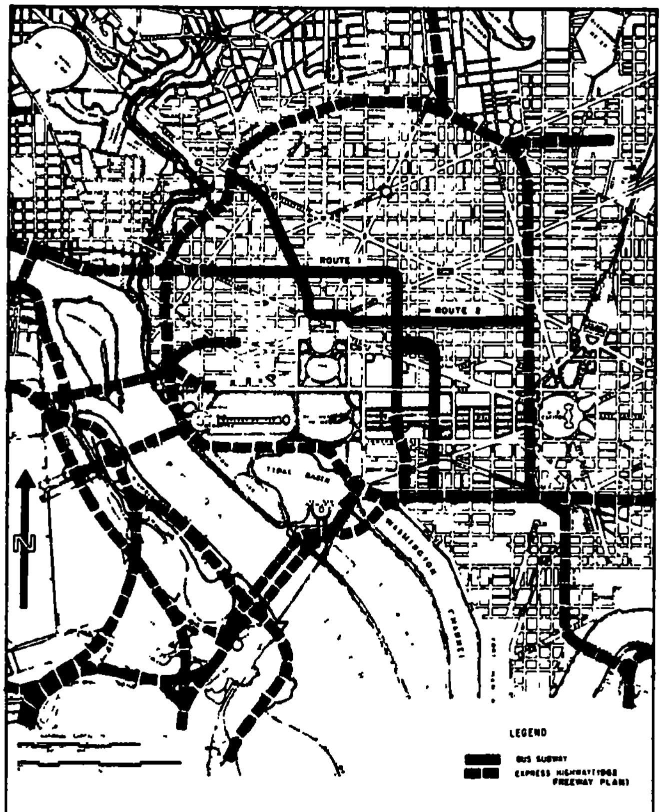


1937 EXPRESS BUS RAPID TRANSIT PLAN
Chicago
TO ACCOMPANY REPORT TO
COMMITTEE ON LOCAL TRANSPORTATION
CITY OF CHICAGO
1937

		INBOUND MAXIMUM HOUR PASSENGER LOADS			
		AT ROUTE MAXIMUM LOAD POINTS		AT CENTRAL BUSINESS DISTRICT LOOP	
	RAPID TRANSIT ROUTE	1957	1980	1957	1980
1	MARK TWAIN	5 215	7 232	5,215	7 232
2	PAGE	4 774	4 514	4 731	4 436
3	LINDELL	5 543	5,651	4,649	4 334
4	DANIEL BOONE	1 087	1,805	664	1 136
5	FRISCO	3,928	6,293	3,236	5 211
6	GRAVOIS	4,039	4 615	3,525	3 954
7	OZARK	1,870	2,957	1,301	2,686
	RADIAL ROUTE TOTAL	26,256	33,067	23,521	28,989
8	CROSSTOWN	935	1,917	-	-
	TOTAL	27 191	34 984	23 521	28 989
	PER CENT INCREASE 1957 TO 1980		28 7		23 2



1959 REGIONAL BUS RAPID TRANSIT PLAN
St Louis



1962 SCHEMATIC BUS SUBWAYS
Washington D C

Figure 9 Pilot bus rapid transit concepts

Costs for the busway system, including an elevated downtown bus loop, were estimated at $165 million (*29*).

The focus of the St Louis bus rapid transit proposal was an elevated loop road encircling part of downtown St. Louis, measuring six blocks north and south and five blocks east and west. The loop contained a 60-ft-wide operating deck that included a sidewalk or passenger loading platform located on the inner side of the deck to mesh with one-way clockwise operation of buses. It provided a three-lane bus roadway approximately 37 ft wide.

Washington, D.C., Bus Subway Concept, 1962

Bus subway concepts were analyzed by the National Capital Transportation Agency as an alternative to rail transit (*30*). Bus tunnels would connect with the 14th Street and Key Bridges to provide continuity of movement through the downtown areas. Functional plans were prepared for typical downtown stations. Ventilation requirements of bus subways were found to substantially increase over-all costs, with tunnel construction costs likely to exceed the costs to develop electrified rail tunnels by as much as 25 percent. Ventilation studies (*31*) noted that: "The odor of diesel exhaust will be the limiting factor in using diesels in an underground transit system because public use will depend on public acceptance Odor is a more severe limit than irritation or hazard from toxic gases. The ventilation volumes used are based on air volumes required to dilute diesel exhaust to the odor threshold with a reasonable allowance for incomplete mixing of air and exhaust in each of the . . . sections of the system."

Recent Design Studies

Bus design standards were translated into design policies in the various AASHO manuals. Subsequent bus design criteria were prepared by several large transit operators; most of this work relates to the design of bus terminals and bus-rail interchange points. This is illustrated by the *Massachusetts Bay Area Transportation Authority, Manual of Guidelines and Standards.* Part X summarizes site planning and new stations and includes sections on site selection, site analyses, and station design criteria.

Preliminary studies of transit designs in freeway corridors were conducted by the Ontario Department of Highways (now Department of Transport and Communications) in 1971 (*32*). Most concepts related to wide freeway medians; however, considerable attention was given to special bus ramp design and stations at interchanges.

More recently, the Southern California Rapid Transit District (SCRTD) in Los Angeles simulated busway lane width requirements. Tests were conducted to evaluate driver behavior at 60-mph speeds. These tests indicated that bus drivers feel no restriction with the following lane widths:

No barrier—13 ft

New Jersey-type barrier on one side—15 ft minimum; 17 ft desirable.

These tests provided the basis for establishing cross-section designs for the San Bernardino Busway.

CHAPTER FOUR

PLANNING AND POLICY IMPLICATIONS

The state-of-the-art review provides important direction for planning guidelines and policy formulation. This chapter presents an evaluative overview of bus priority treatments, identifies relevant planning considerations, sets forth associated policy implications, and suggests additional research directions.

AN EVALUATIVE OVERVIEW

An overview of contemporary practice disclosed many factors that are essential to guideline formulation. These include. (a) the ability to construct busways in stages, allowing service improvements to be inaugurated while parts of the facility are still being built; (b) the value of clearly identifiable busways (the "transit image"), (c) the development of busways at costs that are less than those for rail transit; (d) the importance of parking at fringe transit stations; (e) the suitability (or unsuitability) of specific freeways for bus service, (f) the limited number of existing arterial street bus lanes, although the number is increasing; (g) the need for, and enforcement problems associated with curbside bus lanes, (h) the relatively small number of bus priority treatments that have been discontinued; and (i) the problems of operating costs associated with providing peak-hour bus services.

Planning and Design Standards

Bus priority treatments vary widely in their planning philosophies; their design concepts; their operating policies; and their documentation of costs, patronage, and impacts. The most striking variabilities are found when busways and contra-flow lanes are compared Standards for starting anew are viewed differently from those that optimize existing facilities

Variabilities in design standards reflect ranges in operating speeds, characteristics of existing freeways, and local design preferences The highest bus volumes reported (nearly 500 buses per hour) use an 11-ft contra-flow lane on I-495 at speeds of 35 to 40 mph, there are no shoulders for bus breakdowns. This is in striking contrast to the California practice, which designs for 70-mph speeds, uses one-lane-wide buffer strips on the US 101 contra-flow bus operations, and provides 17-ft-wide lanes in the San Bernardino busway with off-roadway provisions for bus breakdowns. The operating experiences in the New York metropolitan area suggest that economies can be achieved by accepting lower speed levels without unduly sacrificing performance efficiency.

Shoulders are provided along the Shirley Busway (in anticipation of future use by other high-occupancy vehicles) and are proposed together with complex off-line stations in several busway designs (e g, Milwaukee). Because, in most cases, peak-hour one-way bus flows would be less than 2 to 3 per minute, this raises questions regarding the cost-effectiveness of many proposed designs.

Implicit in the application of higher design standards is the key issue. Will overdesign escalate costs and diminish or preclude feasibility? Design standards should consider the driving skills of professional bus drivers, high levels of vehicle maintenance, and the relatively light bus volumes needed to accommodate heavy passenger flows

It is significant to note that most existing express bus priority treatments represent either contra-flow operations on existing radial freeways or special treatments to bypass queues. Most major proposals, however, call for exclusive bus roadways Yet, measured in capital costs per person-minute saved, busways are far less cost-effective than these alternative operational treatments. (The bus priority, ramp metering scheme being implemented on I-35W in Minneapolis is a significant exception.)

Intermediate stations do not play a significant role along most existing freeway-related facilities. This is because facilities either represent contra-flow operations where stations are not possible (New York, San Francisco, Boston), or are located within or adjacent to freeway medians (Los Angeles, Washington). Freeways usually are removed from high-density residential areas; pedestrian access is difficult, bus transfer facilities are limited; and park-and-ride lots are not provided.

Use of existing rail rights-of-way (as proposed in Dayton) can often reduce costs of busway development, but may delay implementation because of protracted negotiation periods. The feasibility of bus and train operations on the same right-of-way has yet to be demonstrated.

Downtown Distribution

Distribution of buses in central areas remains an important challenge. Downtown, and its approaches, are among the few areas where transit can afford a time advantage over automobiles. Yet, in several planned installations (Pittsburgh, Los Angeles) line-haul routes have been established while the downtown bus priority treatments need development

Most current busway proposals (as well as many existing treatments) provide good access to the CBD perimeter but do not substantially improve service within the downtown core. Many treatments rely on terminals or on-street distribution systems, which in large measure duplicate service patterns and inefficiencies of former interurban railway lines

Terminals are not always located near major employment concentrations, and may (as in Midtown New York) rely on secondary distribution systems, curb bus lanes do not appear to provide desired service levels; and downtown contra-flow bus lanes have received limited use Elevated busways where proposed (i.e, Memphis, St Louis) have not been accepted, and underground busways have not been incorporated because of construction complexity and costs.

Buses using the Shirley Busway, for example, experience their greatest delays in downtown Washington. The peak-hour bus travel times between downtown Washington and the Shirley Busway equal the travel times from downtown to the outer limits of rail transit lines in Boston, Chicago, and Cleveland (15 min).

The Runcorn New Town Busway (England) is a significant exception to this generalization. The busway is elevated through the downtown area and is on the surface, often with signal-controlled intersections, in outlying areas

Factors Conducive to Success

Successful major freeway-related treatments—those implemented to date—have served real, demonstrated needs. Implementation and operating costs were low relative to actual and perceived problems They have attracted considerable use and save 5 to 30 min travel time during peak hours. These are substantial savings, and they compare favorably with time savings resulting from many rail transit improvements and extensions.

Successful treatments are usually characterized by: (1) an intensively developed downtown area with limited street capacity and high all-day parking costs, (2) a long-term reliance on public transport; (3) highway capacity limitations on approaches to downtown; (4) major water barriers that limit road access to the CBD and channel bus flows; (5) fast non-stop bus runs for considerable distances, (6) priority treatments on approaches to or across water barriers; (7) special bus distribution within the CBD (often off-street terminals); and (8) active traffic management and operations programs A major factor contributing to the success of the New York and San Francisco treatments has been their avoidance of on-street operations downtown, and their coordination of systems of priority treatments.

Successful operation of bus priority facilities calls for more than planning, design, and construction. Traffic management policies are a key part of bus priority treatments, particularly contra-flow bus lanes Provisions for maintenance, monitoring, policing, and emergency services are essential, costs for these provisions must be taken into consideration. State highway departments, as well as regional transportation agencies and municipalities, play important roles in both planning and operating major treatments

Other treatments have not been as successful from an implementation standpoint Some plans are too grandiose and are out of scale with need; the New Haven and Kansas City busways are clear examples. Imbalances between existing demands, future demands, and costs have probably precluded their implementation.

Most arterial bus priority treatments represent bus lanes in the downtown area They are too localized in extent and too sensitive to enforcement practices to produce major benefits to users and achieve substantial operating economies for bus companies. Moreover, most systematic measures of bus lane effectiveness are found in Europe Before-and-after studies in the United States have limited statistical significance

PLANNING PRINCIPLES AND OBJECTIVES

Planning bus priority facilities calls for realistic assessment of demands, costs, and impacts The basic objective is to select and apply the appropriate types of treatment for specific urban situations. This calls for a clear understanding of the bus transit market and the interrelationship of bus priority facilities and highway service deficiencies.

The Bus Transit Market

The downtown-oriented public transport market has three potential components:

1. Trip-making that takes place within the core area, and also between the core and the transitional areas immediately on the fringe Often, such trips are made as pedestrians or by downtown shuttle bus.

2 Trips between CBD and the older, intensively developed central city areas that surround the core (the apartment districts and traditional city neighborhoods, which, in a typical, symmetrically developed metropolis, include one-half or more of the urbanized area population within a radius of 3 to 5 miles of downtown) These trips are largely oriented to arterial street local and express bus services.

3. Trips between CBD and suburban communities beyond the central city. These trips are mainly potential to express operations along freeways or on special bus roadways.

The traditional market for transit service lies almost entirely within the central city ring. The CBD has long been regarded as the pedestrian's domain, because transit fares and intermittent availability (the headways between consecutive buses) combine with the mixed routing pattern of vehicles in the CBD to discourage use of mass carriers for any but the longest intra-CBD travel in all but the very large cities. At the other extreme, relatively low population densities and the low per capita rates of CBD attraction in the suburban population support only minimum service.

Major bus priority treatments in the United States have focused mainly on the suburb-to-CBD trip component. They provide little benefit to the majority of bus riders, who generally live within 4 to 5 miles of downtown. Arterial bus priorities, bus streets, and grade-separated busways in the CBD and/or its immediate environs could benefit these central-city-to-CBD trips The two types of services are largely complementary, thereby permitting bus priority lanes on freeways and arterials in the same corridors where traffic density warrants

Bus Priority Objectives

Efficient use of urban highways calls for maximum person flow with minimum net person delay over the long run This can be achieved by (1) optimizing total person flow, and (2) in some cases optimizing bus flow The latter may be desirable in anticipation of a long-term shift to bus transit or in response to CBD development policies. Both objectives may contrast with the goal of maximizing vehicle flow. Both call for a system of bus priority improvements

A bus priority treatment generally reflects one of the two basic forms shown in Figure 10, as follows:

1 Treatments involving new facilities through a high travel intensity corridor generally produce a strong sense of transit identity and can help achieve desired land-use impacts They usually involve substantial capital investments Most busways fall into this category (for example, the Runcorn and Shirley Busways, Pittsburgh's proposed PATways, and Dayton's proposed multi-modal busway). Arterial street bus lanes (such as proposed for Houston, St. Louis, and Washington) also reflect this objective, but do not involve major costs

2. Treatments involving development of bus priority upstream of and/or through bottleneck areas usually produce a high level of service efficiency with relatively small investment. They are designed to improve operations through a major delay area. Most reserved bus lanes on freeways and special bus bypass ramps reflect this concept (for example, the contra-flow bus lanes on approaches to the Midtown and Lincoln Tunnels, in New York; Seattle's Blue Streak bus operations; and the bus bypass lane on the San Francisco-Oakland Bay Bridge approach) They generally are provided upstream of the actual bottleneck point.

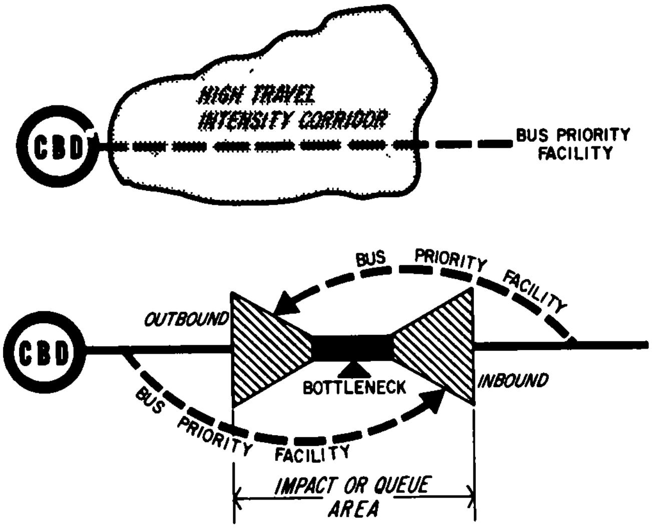


Figure 10. Bus priority concepts.

The bus terminal or transportation center can be an integral part of both concepts.

Bus priority planning should clearly differentiate between facilities that (1) add a bus lane to existing highway capacity in the flow direction of travel and (2) preempt a highway lane in the heavy direction of travel for bus use (Fig. 11). Freeway bus priority treatments mainly apply the former; arterial treatments, the latter.

Relating Improvements to Demands

Measures that achieve shared operations and maximize person-flow efficiency by bus and car can have widespread application—i.e., metering of freeway ramps, effective enforcement of curb parking regulations, and traffic engineering improvements along bus routes Treatments that optimize bus flow, per se, will be limited to larger urban areas—and will closely relate to downtown employment intensities. The existing and potential proportions of CBD travel by bus in specific corridors will influence the extent to which buses should be given priority over cars.

In most urban areas, justification of capital-intensive bus priority improvements appears contingent on aggregating a sufficient volume of transit passengers to sustain the capital investments required in a particular corridor It is more an issue of identifying sufficient transit potentials than one of overcoming capacity deficiencies This suggests major emphasis on operation treatments rather than physical construction wherever conditions permit

The sequence of bus priority treatments, in order of ascending travel demands, should be as follows:

1. Existing highway use should be optimized through traffic operational improvements, including construction Where increases in highway and downtown parking capacity are not feasible for economic, environmental, or other reasons, emphasis should be placed on bus priority improvements.

2 Freeway ramps should be metered, with bypass lanes provided for buses.

3 Contra-flow bus lanes should be installed on freeways wherever sufficient bus volumes are aggregated, roadway conditions permit, and traffic volume imbalances exist. Similarly, bus lanes could be installed along downtown and arterial streets.

4 Short busways that serve as "queue jumpers" should be developed to link contra-flow lanes with off-street bus terminals

5. Busways should be constructed where location and design conditions preclude contra-flow operations on freeways—for example, where stations are required to serve adjacent areas, or where freeways bypass tributary traffic areas.

An important advantage of busways is their "incrementability." A busway could be built in stages, with the bus routes assigned to existing streets and highways in sections where busway construction is delayed. To a large extent, the Shirley Busway has been developed in this manner

Busways could be conceived as an integral part of urban transportation corridor planning. Sufficient right-of-way could be acquired to accommodate projected freeways, to establish control of access, and to provide special turnouts for bus stops. The facility would operate initially as an expressway at grade. The second step could be conversion to a freeway, with preferential metering of buses into the freeway when peak volumes approach freeway capacities Exclusive bus lanes, special busways, and other improvements would follow when conditions warrant. Initiation of bus rapid transit service would come when customer demand was still below the level needed to sustain rail service. Conversion of busways to rail transit would be carried out when (or if) corridor transit demands approached levels justifying installation of rail transit

SOME FREEWAY GUIDELINES

Planning and design of bus services in relation to urban freeways suggests the following broad guidelines:

1. Existing bus volumes in freeway corridors are not necessarily a true measure of potentials. It is not likely that the existing Shirley Busway, or the proposed Milwaukee, Chicago, and Los Angeles busways, would be justified if existing bus volumes on the freeways or in their service corridors were used as the only basis for their justification. Consideration also should be given to the potential induced and diverted bus riders. A realistic appraisal of both existing and projected bus demands is essential.

2. Identification of major overload points on existing freeways, and anticipated overloads on proposed freeways, provide important guides as to where special bus priority facilities should be built This approach is valid to the extent that the future road network has been committed and forecasted highway loads are realistic.

3. It is not feasible to remove existing freeway lanes

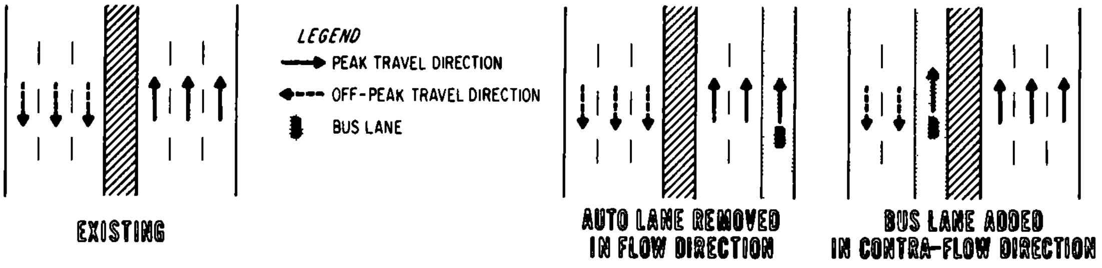


Figure 11 Bus lane options.

from auto use in the heavy (flow) direction and to give these lanes to buses. If the freeway is already congested, reducing the lanes available to cars will further increase delay. The over-all loss in person-time to motorists will exceed the time savings achieved by bus patrons.

4 When a bus lane is added in the existing flow direction, it is reasonable to expect a gain in peak-hour auto flows equal to the auto equivalents of the buses removed. A bus free-flowing in mixed traffic on level grades (0 to 4 percent) occupies space equivalent to 1 6 automobiles On steeper grades higher bus equivalents are found (*33*). Optimum use of bus lanes in freeways or busways might be achieved by allowing buses and other vehicles (viz , car pools or trucks) to share the exclusive lane or lanes up to the point where bus service is impeded. It would give buses a time advantage via a reserved lane that might otherwise not be available. This approach, however, calls for a very high level of control and enforcement; it would be unlikely to maximize the benefits of bus travel over auto travel, nor would it give buses a sufficient time advantage over all cars.

5. Right-hand freeway lanes are not usually desirable for exclusive bus use, because of frequent conflicts with entering and existing cars, which would have to weave across the bus lane on their way to and from ramps.

6 Standardization of freeway entrance and exit ramps to the right of the through traffic lanes will permit use of median lanes by buses, either in normal or contra-flow operations (Fig. 12). Special bus entry and exit to and from the median lanes can be provided in many cases without interfering with normal auto traffic on the right-hand ramps

7. Effective downtown passenger distribution facilities are an essential complement to regional bus rapid transit services. Downtown distribution may take place in terminals, tunnels, bus lanes, and bus streets. The cost/service implication of off-street distribution should be effectively explored.

8. Busways should be of economical design. They should be built at lower per-mile capital costs than the higher standards and costs for rail transit lines. This not only will offset the higher operating costs normally associated with buses as compared with trains, but also is a realistic approach to the provision of bus facilities that may serve interim functions The need for shoulders along busways should be carefully assessed in light of low bus volumes, infrequent bus breakdowns, and low probabilities of delays to opposing bus traffic when stalled buses are passed.

9. Busways should be designed to allow for possible future conversion to rail or fixed guideway transit with built-in features that will permit service to be maintained during the transition period. A 40- to 60-ft right-of-way would generally provide sufficient width for stations and permit continuity of service during the conversion period.

10 There may be merit in redirecting "busway emphasis" to developing facilities within the CBD, and on the close-in miles of radial corridors adjacent to it. This could allow buses to serve the areas of heaviest demand, a subject largely avoided in busway proposals. The heaviest transit demands in most cities are within a 4- to 5-mile radius of the center. This, in effect, would duplicate the service patterns afforded by "limited tramlines" in the United States and Europe

11. Metering of freeway ramps with bus bypass lanes should be introduced only where the technique will improve mainline through-flow Metering may not alleviate freeway congestion resulting from lane-use imbalances at freeway-to-freeway interchanges. Metering usually requires available alternate arterial street routes.

12 Street-level bus stops are generally preferable to turnouts from freeway lanes Most bus stops along existing freeways are lightly patronized. Street-level stops, where buses leave the freeway for passenger pickup and delivery, can provide added convenience to patrons at minimum cost. Use of bus bypass lanes on metered ramps entering freeways will result in minimum delay to buses.

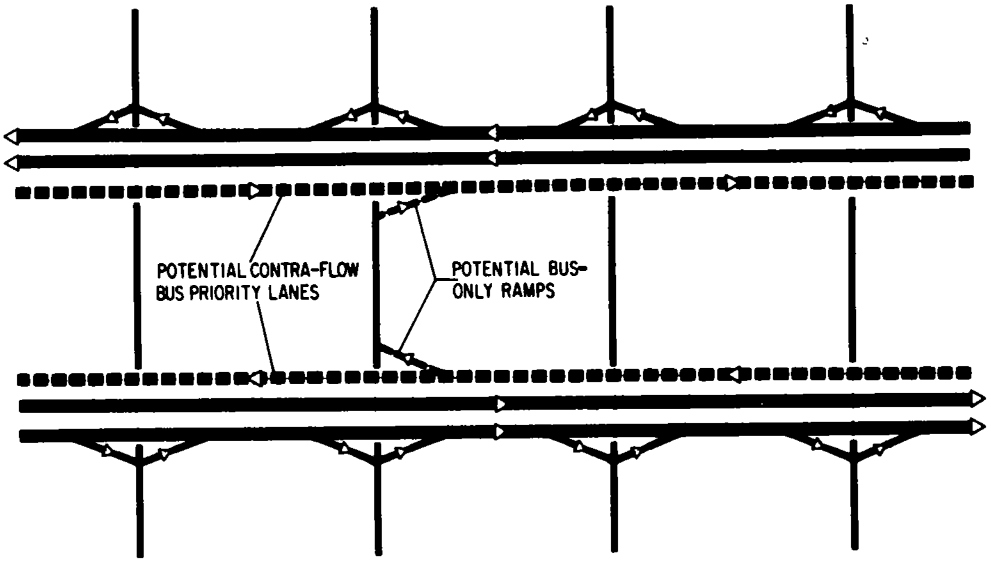


Figure 12 Bus lanes in relation to standardized right-hand ramps

13. Current operating experiences indicate that exclusive bus lanes (on freeways or in busways) can effectively carry up to 120 buses (6,000 people) per hour with stops in the lane Higher line-haul capacities can be achieved by using larger vehicles and removing bus stop areas from the through travel lanes, provided downtown distribution capacity is adequate to absorb the additional loads.

14. There is a pressing need to increase peak-hour driver productivity, as most existing expressway bus services operate only in the peak periods. This suggests larger, higher-capacity vehicles, perhaps articulated buses, provided this would not result in unacceptably large bus headways. It also calls for improved institutional arrangements that allow drivers to work elsewhere during off-peak periods.

15. Bus technology should be directed toward improving propulsion systems that minimize or eliminate the need for costly ventilation systems in tunnels. This may involve technologies that relate to gas turbine or dual-propulsion (internal combustion/electric) vehicles with low exhaust emission rates, or with no exhaust at all Catalytic converters in diesel exhaust systems can also reduce bus emissions. Improvements in bus loading capabilities (e.g, platform-height loading and additional or wider doors) are also desirable.

SOME ARTERIAL GUIDELINES

Most urban bus services operate along city streets. Even in cities with extensive freeway mileage, express bus patronage usually represents about 10 to 15 percent of the peak-hour bus travel. Moreover, many freeway configurations bypass rather than penetrate the city center and thereby offer little opportunity for use by CBD-destined bus users. Radial expressways are often poorly located for bus service and are only lightly used by buses. Chicago's Stevenson Expressway, for example, is used far less by buses than parallel Archer Avenue. The former traverses industrial areas, the latter, residential neighborhoods The heavy transit corridor in San Francisco is along Market Street, not the Bayshore Freeway. These factors underscore the need for arterial-related bus priorities

1. Effective enforcement of arterial bus lanes is essential. Many cities report major problems of curb lane availability. These sometimes can be solved by contra-flow bus lanes, which not only are self-enforcing, but also produce a sense of transit identity.

2. A much wider application of bus lanes is necessary before schedule speeds can increase sufficiently to produce operating economies and/or encourage additional riding. Although bus lanes can improve speed and reduce delays, they are often comparatively short segments of over-all bus routes.

3. Extended bus lanes on radial arterial streets could produce important benefits in service dependability These lanes could often be provided without reducing lanes for cars in the heavy travel direction. On six-lane streets, four lanes could be designated in the heavy travel direction, with the curb lane giving priority to buses, a similar arrangement could apply on five-lane streets. Arterial curb bus lanes proposed in St. Louis in 1955 (*34*) called for (a) use of two reversible center lanes on six-lane arteries for inbound morning and outbound evening traffic flow, (b) exclusive use by buses and right-turning cars of a curb lane in the flow direction during morning and evening peak hours on three major transit routes, (c) closing of certain side or "feed in" streets during rush hours on the flow side only; and (d) at certain signal-controlled intersections, 10-ft curb setbacks for a distance of 150 ft ahead of intersections to provide "reservoirs" for right-turning vehicles, eliminating use of the reserved transit lane for right turns.

4. Right turns by non-bus traffic can be allowed in curb bus lanes wherever it is not feasible to eliminate such turns. Right-turning cars could be allowed in the block preceding their turns, or alternatively in the 250 ft approaching the intersection

5. The high proportions of peak-hour urban travelers using buses in downtown areas suggest that increased consideration be given to (a) bus streets and (b) bus priorities in auto-free zones. Where land-use conditions permit, the extent and time limits of these treatments should be adjusted to allow for essential services. One variant might be to allow local car access in bus lanes, but prohibit through traffic (as in Johannesburg, South Africa).

6. Segregation of bus and auto traffic should be actively pursued in new town developments, as well as in existing urban areas. The Runcorn (England) New Town Busway is an important step toward this objective.

MODIFYING BUS PRIORITY CRITERIA

Existing criteria for bus priority treatments should be reevaluated in relation to the role that buses play in meeting peak-hour demands, in reducing congestion, and in reflecting specified urban design or environmental objectives The underlying principle should be whether an exclusive bus lane or busway will carry more people than when it is used by cars during peak travel periods. The number of bus riders in the exclusive lane should at least equal the number of auto occupants in the adjacent lane. (In the case of freeway and arterial bus lanes, the principle should apply during the hours that the lanes are in effect) Criteria for removing lanes from auto use in the heavy-travel direction must be more stringent than those for adding bus lanes or creating new bus facilities.

Freeway Criteria

Criteria should differentiate among (1) busway development, (2) provision of an additional (contra-flow) lane for buses in the heavy-flow direction on freeways, (3) reserving an existing lane exclusively for buses, and (4) ramp metering.

1. Volumes of 120 to 180 buses per hour (6,400 to 9,600 bus seats)—once suggested as conditions for designating a freeway lane as an exclusive busway—are rarely found in cities without rail transit. This volume exceeds the total bus fleet in many medium-to-large urban areas.

2. From the standpoint of person capacity, 50 to 60 buses per hour (2,500 to 3,000 bus seats) can generally

accommodate the number of persons carried in cars in a freeway lane (2,250 to 2,700 persons). This level of corridor volume also occurs mainly in larger cities. If a minimum warrant of at least 3,000 existing and divertible bus passengers per hour were rigidly applied, several existing bus priority treatments would not have been implemented

3. A somewhat lower volume may be appropriate to achieve wider application of freeway bus priority treatments, especially where low-cost measures (such as queue bypass lanes or preferential ramp metering) are involved. A special ramp used by 10 to 15 buses in the peak hour may be justified by transit user time savings, especially where it improves bus service and driver productivity. Moreover, warrants should also reflect (1) projected bus flows, (2) downtown employment intensity, and (3) downtown parking space costs

Federal Highway Administration policies should be appraised in this context (*35*). In adapting these policies, it should be clearly recognized that express transit is essentially a peak-hour service. The policies suggest·

> that the general warrant for an exclusive bus lane is whether such a lane will accommodate more people than when used by general traffic. For an exclusive bus highway (as against a lane reserved for peak-period use), the analysis should consider not only the peak period, but the off-peak period as well Analyses should examine the alternative of exclusive bus use in the peak period and mixed use in other hours
>
> For preferential treatment of buses, the warrant should be applied when the number of persons served would be insufficient to consider exclusive bus use Such treatment includes freeway metering with bus bypass ramps, closing certain ramps to all vehicles except buses and emergency vehicles, reserving curb lanes for buses and right-turning vehicles, and bus-actuated traffic signals.

Arterial Criteria

Warrants for reserved bus lanes in city streets, as developed by the Institute of Traffic Engineers, provide some general guidance (*36*). They specify that:

1. A curb transit lane is practical, under normal circumstances, only during peak traffic periods when curb parking and stopping regulations can be implemented.
2. A minimum of 60 transit vehicles per peak hour should use the transit lane to justify the lane's exclusive use.
3. The width of roadway must be sufficient for at least two lanes of travel in addition to the transit lane in the direction of travel of the transit lane.
4. The number of transit patrons using the transit vehicles in the subject street should equal or exceed 1 5 times the number of drivers plus passengers carried by other vehicles during the peak hour.

The Baltimore warrant (*37*) is somewhat more flexible and represents a more realistic approach to arterial bus lane development. It states: "When the number of transit riders carried in one lane in a particular artery equals the number of occupants in automobiles in an adjoining traffic lane, then the bus (or transit rider) is entitled to the exclusive use of the first lane."

Contemporary practice suggests that warrants should be broadened. The number of buses per hour necessary to justify arterial bus priority treatments should be influenced by planning, as well as traffic considerations

- Bus priority lanes on a main shopping street should be installed to improve transit visibility and might be justified by a lower number of buses per hour than median bus lanes or bus lanes on other streets.
- A bus mall that penetrates the heart of a commercial area may be desirable for lower volumes of peak bus flow than are normally considered for arterial bus lanes.

Accordingly, it appears desirable to establish specific criteria for. (a) main street bus malls; (b) main street curb bus lanes, (c) curb bus lanes, (d) median bus lanes; and (e) contra-flow bus lanes The following factors should be considered in refining warrants.

- From the standpoint of person capacity, 20 to 30 buses per hour (1,000 to 1,500 seats) can accommodate more people than are carried in cars in an equivalent arterial street lane (600 to 750 persons per hour).
- From the standpoint of enforceability, volumes of 40 to 60 buses per hour (resulting in approximately one bus in each block at any time) are desirable. At, or above these volumes, buses will tend to preempt the curb lane when "no stopping" controls are implemented.
- When bus volumes are less than 60 in the peak hour, taxis may be allowed in bus lanes.

POLICY IMPLICATIONS

Bus priority treatments should be complemented with appropriate policies that encourage and reinforce transit use In this context, there is need for reappraisal of many current standards, approaches, and actions.

There is strong interdependence between public transport and the city center. Public transport makes possible high land-use and employment concentrations. Simultaneously, the existence of these concentrations makes capital investments in public transport feasible. Continued downtown office building developments will increase employment densities and increase peak-hour travel demands, which can be met best by improved public transit Therefore, the extent and feasibility of bus priority treatments must relate to and reflect downtown growth objectives and policies.

Consistent with CBD employment growth, bus-pedestrian streets should be encouraged downtown—at least during peak hours. Even more significant, CBD parking policies should be compatible with efforts and investments designed to improve bus service Bus travel to the CBD should cost less than the costs to drive and park. Travel times are an important element of CBD access costs, whereas transit fares and parking costs represent the principal direct out-of-pocket expenditures by persons traveling to the CBD. Ideally, bus transit service should match or improve on the door-to-door time of the driver. Similarly, transit fares should be less than average costs to drive and park; ideally, motorists should pay the true costs of the parking spaces they occupy downtown

Arrangements of land uses in suburban areas should be conducive to bus operations Linear concentrations of dwellings along bus routes and high-density development near focal points on the transit system should be encouraged

Greater community recognition and support of metropolitan bus services is essential Public support, particularly by the automobile user, will be necessary for adoption and strict enforcement of preferential treatment of buses. Institutional changes that permit greater driver productivity also will become increasingly essential.

RESEARCH DIRECTIONS

A review of bus priority applications and on-going research has identified several significant data gaps, as follows·

1. There is a significant need for detailed information on downtown employment and peak-hour cordon crossing changes in many cities as they relate to bus priority proposals Consistent peak-hour bus and passenger volume data for most proposals are lacking There is little correspondence in many cities between existing and proposed corridor volumes as they relate to downtown development trends and intensities Simultaneously, there is need for greater clarity in downtown distribution proposals, because they will have important bearing on costs, operational viability, and community acceptance of proposed systems.

2 Estimating the patronage impacts of improved bus service remains difficult. Many plans are predicated on attracting an increased proportion of peak-hour travelers to the city center, yet available experiences show relatively small increases Accurate demand forecasting, including modal allocations, is essential to freeway-related bus priority treatments, especially where substantial capital investments are involved.

3. There have been few scientific studies of the impacts of bus priority facilities in the United States, and data on the external impacts of bus priority facilities have not been fully developed. Systematic measurements of the actual and perceived effectiveness of most treatments are not available—especially "before" and "after" measurements pertaining to arterial bus priority treatments.

4 Much research has been theoretical, in that high-occupancy vehicle priority lanes are not found in actual practice Queuing models should more fully analyze the consequences of high-occupancy vehicle priority lane operation as an alternative to mixed travel in reversible (contra-flow) highway lanes.

5 Operating and service consequences associated with new or improved bus technologies. viz, articulated (or double-decked) buses should be explored.

6. Additional research is needed on the underground operation of buses Emphasis should be given to the ventilation requirements associated with alternative power systems. Cost-effectiveness and capacities of alternative underground station configurations related to various vehicle types and operating patterns should be explored.

7. More information is needed on (a) the cost allocations of bus service between peak and off-peak services for various peak-to-base service ratios, and (b) the cost-service implications of bus and rail line-haul systems and alternative downtown distribution systems.

8 Additional design studies and field tests should identify (a) optimal widths of various normal and contra-flow bus lanes, (b) optimal lane widths for busways (If intercity buses operate safely at 70 mph on two-lane roads against oncoming cars, why are median barriers necessary on urban busways?); (c) driver reactions and behavior on normal versus contra-flow busways, (d) means of maintaining bus operations as busways are converted to rail services (and the associated design implications); and (e) rail-bus interchange and bus terminal design.

REFERENCES

1. "Freeway Lanes for High-Occupancy Vehicles—First Annual Progress Report." Calif Dept. of Public Works (Dec. 1971).
2 GRAHAM, E. F., "Use of Freeway Bus Stops in California" *Traffic Bull. No. 12,* Calif. Dept. of Public Works (June 1964).
3. GOODMAN, J. M., "Operation of a Freeway Priority System for Buses and Car Pools." *Traffic Eng* (Apr. 1970) pp. 30-37.
4. VUCHIC, V R., "Optimum Bus Stop Locations on a Street with Coordinated Signalization." Presented at ORSA, Miami, Fla. (Nov. 1969).
5. "Parking Principles." *HRB Spec. Rept. 125* (1971) 217 pp.
6. "Change of Mode Parking—A State of the Art." Inst. of Traffic Engineers (draft 1972).
7. "The Capital Flyer Bus Service Between the District of Columbia and Maryland and Virginia Counties in the Washington Metropolitan Area—Final Report" (Demonstration project in center city and suburban employee transportation facilitation). Prepared for UMTA by Metropolitan Washington Council of Governments (Nov. 1971).
8. MORIN, D. A., LINDSEY, L. C., and RIEMER, R., "A

Report on the Reston Bus Passenger Survey." Fed. Hwy Admin (Jan 1972)

9. MADRZAK, R, "Successful Bus Lanes in Madison, Wisconsin" Fed. Hwy. Admin. (Nov. 1970); also, "Success for Bus Lane in Madison, Wisconsin—Illegal" Fed Hwy. Admin. (1971).
10 SCHEEL, J W., and FOOTE, J. E, "Bus Operation in Single-Lane Platoons and Their Ventilation Needs for Operation in Tunnels" *Res. Publ GMR-808,* G M Research Labs., Warren, Mich. (Sept 1968).
11. SCHEEL, J W., and FOOTE, J E, "Comparison of Experimental Results with Estimated Single-Lane Bus Flow Through a Series of Stations Along a Private Busway" *Res. Publ. GMR-888,* G.M. Research Labs, Warren, Mich (May 1969).
12. HERMAN, R, LAM, T., and ROTHERY, R., "Further Studies on Single-Lane Bus Flow, Transient Characteristics." *Transp. Sci.,* Vol. 4, No. 2, pp 187-216 (May 1970).
13. MAY, A. G., NEWELL, G F, OLIVER, R. M., and POTTS, R. B., "Q's and Q's" *Bull Oper. Res Soc of Amer.,* Vol. 15, Suppl. 3 (1967)
14. RUSSELL, G. L, "Exclusive Bus Lanes." Calif. Dept. of Public Works (Nov. 1969).
15. "Feasibility Study on an Exclusive Lane for Buses and Car Pools on the San Francisco-Oakland Bay Bridge." Calif. Dept of Public Works (Apr 1971).
16. STOCK, W. A, WANG, J. J., and MAY, A. D., "Priority Lane Operations on the San Francisco-Oakland Bay Bridge" Inst of Traffic and Transp. Eng, Univ. of California (Apr 1971) Also see SPARKS, G. A, and MAY, A D., "A Mathematical Model for Evaluating Priority Lane Operations on Freeways." (Prepared for Fed Hwy. Admin., June 1970).
17. MORIN, D A., and REAGAN, C. D., "Reserved Lanes for Buses and Car Pools." *Traffic Eng,* Vol. 39 (July 1969) pp. 24-28.
18. Voorhees, Alan M., & Associates, "Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Car Pools." Prepared for Fed. Hwy. Admin., U.S. Dept. of Transportation, in association with Northwestern Univ. Traffic Institute and Daniel J. Edelman, Inc. (Nov. 1970).
19. NEWMAN, L., DUNNET, A., and MEIS, G. J., "Freeway Ramp Control—What It Can and Cannot Do" *Traffic Eng.,* Vol. 19, No. 7, pp. 14-21 (June 1969)
20 GLENNON, J. C, and STOVER, V. G., "A System to Facilitate Bus Rapid Transit on Urban Freeways" Prepared by Texas Transportation Inst. for UMTA, U.S. Dept. of Transportation (Dec. 1968) p. 95.
21. GOODMAN, J. C., MACDORMAN, L. C., and WEINER, E., "Evaluation of a Bus Transit System in a Selected Urban Area." *Hwy Res Record No. 314* (1970) pp. 114-122.
22. "Buses in Camden A Study of Bus Segregation in the Central Area of London" Dept. of Planning and Communications, Borough of Camden, London (Nov. 1971).
23 WEBSTER, F V., "A Theoretical Estimate of the Effect of London Car Commuters Transferring to Bus Travel" Brit. Road Res. Lab. (1968)
24 COBURN, T. H, "Bus Priority Experiment on Test Track" *Bus Priority Symposium,* Brit Transp. and Road Res. Lab (Feb. 1972).
25 EVANS, H K, and SKILES, G. W., "Improving Public Transit Through Bus Preemption of Traffic Signals." *Traffic Quart,* Vol. 24, No 4 (Oct. 1970) pp. 531-543.
26. "A Bus Priority System for Traffic Signals." Joint project between Kent State University Campus Bus Service, the Center for Urban and Regional Studies, and the City of Kent, Ohio. Prepared for UMTA (Project Ohio MTD-4) (Summer 1971).
27 HARRINGTON, P., KELKER, R F, DE LEUW, C. E., "A Comprehensive Local Transportation Plan for the City of Chicago." (1937).
28. "Mass Transportation Survey, National Capital Region, Civil Engineering Report." Prepared for the National Capital Planning Commission and the National Capital Regional Planning Council by De Leuw, Cather & Co. (Jan. 1959). See Ch. XI, pp. 34-35.
29 Gilman, W. C., and Company, "St. Louis Metropolitan Area Transportation Study." Prepared for the City of St. Louis and St Louis County (Aug. 1959)
30. Smith, Wilbur, and Associates, "Volume-Capacity Implications for Bus Transportation—Central Business District—Washington, D C., Appendix IV, NCTA Technical Report" Prepared for National Capital Transportation Agency (1963).
31. Kaiser Engineers, "Ventilation for an Underground Transit System Using Diesel Buses. Appendix II. NCTA Technical Report· A Study of Bus Rapid Transit Operations for the National Capital Region." Prepared for National Capital Transportation Agency (July 1963).
32. "Transit Design on Freeway Corridors." Vol. 1, Functional Planning Office, Planning Branch, Ontario Dept. of Highways (Mar. 1971).
33. "Highway Capacity Manual, 1965." *HRB Spec. Rept 87* (1965) p. 260.
34. "A Plan for the Improvement of Traffic and Mass Transportation in St. Louis." St. Louis Public Service Co. (Sept. 1955)
35. MARPLE, G. E., "Warrants for Exclusive Bus Facilities." *Instr Memo.,* FHWA (July 17, 1970).
36. "Reserved Transit Lanes." *Traffic Eng.,* Vol. 29, No. 10 (July 1959) pp. 37, 39, 40.
37. "Baltimore City Traffic Codes." (1957)
38. RAINVILLE, W. S., JR., "Expressway Bus Operations" Amer Transit Assn (1963).
39. "Tentative ITE Recommended Practice, Bus Stops for Freeway Operation." *Traffic Eng.,* Vol 40, No. 4 (Jan 1970) pp 14-22.

APPENDIX A

USE OF FREEWAYS BY URBAN TRANSIT BUSES

TABLE A-1

USE OF FREEWAYS BY URBAN TRANSIT BUSES, SELECTED CITIES

CITY	BUS ROUTE	LENGTH OF ROUTE Terminal to Terminal	Part of Route on Freeway Miles	Part of Route on Freeway Per Cent	NO. OF STOPS ON FREEWAY	RUSH HOUR INTERVAL (MINUTES)	RUSH HOUR SERVICE-BUS SPEEDS IN MILES PER HOUR On Freeway	Terminal to Terminal	On Local Streets
Atlanta - (1967)$^{(1)}$									
	I-20 E								
	7 - Glenwood-Columbia	14.8	3.2	21.4	0	10	N.A.	16.5	N.A.
	10 - Belvedere-Peachcrest	15.3	3.2	20.8	0	20	N.A.	19.0	N.A.
	18 - South Decatur-Glenwood	9.5	3.2	33.2	0	7	N.A.	15.6	N.A.
	65 - Northwoods-Oakcliff	20.7	6.3	30.4	0	60	N.A.	19.3	N.A.
	I-20 W								
	56 - Adamsville	10.4	2.9	27.8	0	10	N.A.	15.2	N.A.
	57 - Collier Heights	14.9	4.5	29.9	0	6	N.A.	16.9	N.A.
	75-85N								
	28 - Northwest Limited	11.4	3.0	26.6	0	10	N.A.	15.1	N.A.
	29 - Lenox Limited	11.5	5.0	43.0	0	20	N.A.	16.3	N.A.
	30 - LaVista Limited	10.8	3.6	33.0	0	12	N.A.	16.8	N.A.
	33 - Howell Mill Argonne	15.1	3.3	22.1	0	10	N.A.	17.2	N.A.
	41 - Piedmont	7.4	3.9	53.3	0	20	N.A.	16.3	N.A.
Baltimore - (1971)									
	Jones Falls Expressway								
	Towson-Metro Flyer	15.3	11.0	72.0	0	20	35	26	8
Chicago - (1971)									
	Calumet Expressway								
	4A - Pullman - Altgeld	6.5	1.8	28	N.A.	12	N.A.	N.A.	N.A.
	Kennedy Expressway								
	40 - International Towers	6.7	6.3	95	N.A.	20	N.A.	N.A.	N.A.
	40 - O'Hare Express	8.5	8.1	95	N.A.	30	N.A.	N.A.	N.A.
	North Lake Shore Drive								
	151 - Sheridan	9.8	6.8	69	N.A.	3	N.A.	N.A.	N.A.
	Outer Drive Limited								
	152 - Addison Express	N.A.	N.A.	N.A.	N.A.	6	N.A.	N.A.	N.A.
	153 - Wilson - Michigan Express	8.1	4.8	59	N.A.	4.5	N.A.	N.A.	N.A.
	156 - Wilson - LaSalle Express	8.1	3.9	48	N.A.	4	N.A.	N.A.	N.A.
	South Lake Shore Drive								
	2A - Hyde Park Express	7.5	4.6	61	0	9	(36)	(23)	(16)
	5A - Jeffery Express	12.8	4.6	36	0	3	(36)	(13)	(10)
	Stevenson Expressway								
	62A - Archer	11.1	5.5	50	N.A.	4	N.A.	N.A.	N.A.
Cleveland - (1972)									
	I-71								
	51 - Pearl	20.0	14.0	70	0	20	N.A.	N.A.	N.A.
	79 - Ridge	10.5	3.7	35	0	3	N.A.	17	N.A.
	81 - Scranton	6.5	0.9	14	-	10	N.A.	19	N.A.
	86 - Berea	19.5 to 24.0	12.8	53 to 66	0	10	N.A.	19 to 23	N.A.
	Memorial Shoreway East (I-90)								
	39 - Lake Shore	12.0	8.0	68	0	2.5	30	26	15
	43 - Willowick	18.5	13.7	74	0	8	N.A.	N.A.	N.A.
	49 - Wickliffe	19.5	14.0	72	0	N.A.	33	26	8
	Memorial Shoreway West								
	31 - Avon Lake	21.0	3.2	15	0	15	30	21	19
	55 - Clifton	5.5 to 17.0	3.1	18 to 56	0	1	N.A.	N.A.	N.A.
Dallas - (1972)									
	Dallas North Tollway								
	Number 72	11.5	4.8	41.7	0	N.A.	30.5	21.5	17.6
	North Central Expressway								
	Number 21	6.6	1.6	24.2	0	12	21.3	13.2	11.9
	Number 31	10.2	1.1	10.7	0	10	21.8	15.3	14.7
	Number 32	10.3	3.8	36.8	0	N.A.	20.9	16.3	14.4
	Number 33	7.9	1.6	20.2	0	10	21.3	15.7	14.7
	Number 36	11.7	0.9	7.6	0	N.A.	22.5	18.4	18.2
	Number 51	9.9	1.1	11.1	0	N.A.	21.8	15.6	15.0
	Number 67	9.2	3.8	41.3	0	N.A.	20.9	15.7	13.3
	Number 69	11.1	3.8	34.2	0	11	21.7	16.6	14.8
	Number 73	14.7	6.5	44.2	0	N.A.	22.8	20.5	19.0
	Thornton Freeway East								
	Number 60	10.5	2.3	21.9	0	N.A.	22.1	14.3	13.0
	Number 64	11.1	4.1	36.9	0	11	26.4	19.6	17.0
	Thornton Freeway South								
	Number 55	10.5	2.2	20.9	0	12	23.5	15.7	14.4
	Number 61	10.5	6.9	65.7	0	12	25.7	21.0	15.5

TABLE A-1 *(Continued)*

		LENGTH OF ROUTE					RUSH HOUR SERVICE - BUS SPEEDS IN MILES PER HOUR		
		Terminal to Terminal (Miles)	Part of Route on Freeway		NO. OF STOPS ON FREEWAY	RUSH HOUR INTERVAL (MINUTES)	On Freeway	Terminal to Terminal	Local Streets
CITY (DATE)	BUS ROUTE		Miles	Per Cent					
Detroit - (1972)									
	Chrysler Freeway								
	John R-Oakland Exp.	11.1	3.5	32	0	25	35	23.6	20.5
	Second Ave. Express	16.1	3.5	32	0	30	35	18.5	16.4
	John Lodge Freeway								
	Fenkell Express	18.6	5.3	28	0	7	35	18.1	15.1
	Hamilton Express	12.4	4.0	32	0	10	35	19.1	15.6
	Imperial Express	19.6	8.0	41	0	3	35	18.7	14.1
	Plymouth Express	16.2	2.6	16	0	11	35	12.3	10.9
Houston - (1972)									
	I-10 East								
	21 - Northshore	14.1	10.3	73.0	--	30	36.3	24.2	12.6
	I-10 West								
	48 - Spring Branch	13.5	2.8	20.4	--	7.5	33.0	19.5	17.6
	I-45 North								
	44 - Studewood	13.9	4.6	33.1	--	5.5	27.8	18.3	15.7
	50 - Heights	13.7	6.0	43.8	--	8	30.0	16.8	12.4
	I-45 South								
	40 - Park Place	13.0	4.8	37.1	--	7	29.0	15.0	10.9
	41 - Garden Villas	13.4	5.6	42.2	--	30	34.0	17.0	13.4
	Memorial Drive								
	16 - Memorial Drive	20.4	6.6	32.4	--	12.2	35.2	19.9	12.7
	16M - W. Memorial Drive	19.5	11.4	58.5	--	20	34.0	23.4	17.7
	17 - Tanglewood	9.9	6.2	63.2	--	20	37.2	19.7	11.0
	U.S. 59								
	65 - Bissonet	9.5	2.4	25.6	--	8	29.2	13.7	11.7
	88 - Beachnut	12.6	8.6	68.3	--	9.5	36.8	16.3	15.4
Kansas City - (1972)									
	I-29								
	KCI - Express	N.A.	N.A.	N.A.	0		45 to 50	N.A.	N.A.
	I-70								
	Rayton-Ruskin	22.2	4.7	21	0	30	45 to 50	N.A.	N.A.
	Prospect	N.A.	N.A.	N.A.	0	8	40 to 45	N.A.	N.A.
	SW Trafficway								
	Broadway-Ward Parkway	N.A.	N.A.	N.A.	0	15	40 to 45	N.A.	N.A.
Los Angeles - (1971)(2)									
	Harbor Freeway								
	5 - Hawthorne-Union Station	18.0	4.5	25	3	7	(29.0)	15.0	N.A.
	7 - Eagle Rock-South Broadway	17.1	3.5	21	N.A.	7	(15.4)	(12.7)	N.A.
	37 - Harbor Fwy. Flyer	26.5	15.5	59	3	60	(27.1)	21.2	N.A.
	120 - Russmore-Los Angeles Fwy. Flyer	31.4	22.3	71	N.A.	60	N.A.	N.A.	N.A.
	125 - Los Angeles-Marineland Fwy. Flyer	35.1	20.3	58	3	30	N.A.	28.0	N.A.
	Hollywood Freeway								
	35 - W. Valley Fwy. Flyer	24.0	9.6	40	3	15	(29.6)	21.0	N.A.
	42 - Sunset Blvd.-El Paso Drive	10.6	5.2	49	1	15	N.A.	N.A.	N.A.
	44 - Beverly Blvd. - West Adams Blvd.	18.3	3.6	20	N.A.	10	(16.5)	(12.6)	N.A.
	91 - Hollywood Blvd.	16.2	5.3	33	2	4	(24.5)	14.0	N.A.
	93 - Los Angeles-Pacoima	30.3	14.7	49	N.A.	10	(27.2)	(18.8)	N.A.
	Pasadena-Golden State Freeway								
	39 - Los Angeles-Burbank	13.8	5.6	41	N.A.	60	N.A.	N.A.	N.A.
	56 - Los Angeles-Sunland	21.3	4.0	19	N.A.	10	(16.4)	(16.1)	N.A.
	86 - Los Angeles-Canoga Pk.	38.1	11.4	30	N.A.	20	(33.8)	(22.0)	N.A.
	121 - San Pernando Valley Fwy. Flyer	23.2	15.6	67	N.A.	30	N.A.	23.2	N.A.
	122 - Los Angeles-Burbank Fwy. Flyer	24.7	9.8	40	N.A.	N.A.	N.A.	N.A.	N.A.
	Riverside Freeway								
	59 - Los Angeles-Riverside	63.3	16.6	26	N.A.	60	(48.0)	26.1	N.A.
	Santa Ana Freeway								
	45 - Santa Ana Fwy. Flyer	16.5	13.9	84	0	45	N.A.	N.A.	N.A.
	55 - Los Angeles-Balboa	44.5	3.9	88	0	30	(26.1)	24.6	N.A.
	58 - Los Angeles-Disneyland (also Riverside Fwy.)	41.1	32.2	78	N.A.	8	(22.7)	N.A.	N.A.

TABLE A-1 (*Continued*)

CITY (DATE)	BUS ROUTE	LENGTH OF ROUTE			NO. OF STOPS ON FREEWAY	RUSH HOUR INTERVAL (MINUTES)	RUSH HOUR SERVICE-BUS SPEEDS IN MILES PER HOUR		
		Terminal to Terminal	Part of Route on Freeway Miles	Per Cent			On Freeway	Terminal to Terminal	Local Streets
Los Angeles - (1971)(3) (Cont.)									
	Santa Ana-Long Beach Freeways								
	34 - Los Angeles-Bellflower	18.1	11.2	62	0	60	(27.5)	18.0	N.A.
	36 - Long Beach Fwy. Flyer	23.7	19.9	84	0	15	(28.4)	23.5	N.A.
	Santa Monica Freeway								
	75 - Venice Blvd.-Echo Park Ave.	21.5	6.5	30	N.A.	12	(25)	(15.3)	N.A.
	128 - Marina Del Rey Fwy. Flyer	20.2	7.1	35	2	30	N.A.	20.5	N.A.
	176 - Pacific Palisades Fwy. Flyer	34.7	4.7	14	0	30	N.A.	17.5	N.A.
	San Bernardino Freeway								
	53 - Los Angeles-Pomona	35.5	14.8	42	N.A.	20	N.A.	N.A.	N.A.
	60 - Los Angeles-Yucaipa	91.8	51.8	56	N.A.	20	(25.9)	N.A.	N.A.
	63 - Los Angeles-Garvey	15.7	3.4	22	N.A.	15	(24.9)	N.A.	N.A.
	69 - San Bernardino	12.8	4.4	34	N.A.	10	(20.1)	N.A.	N.A.
	San Diego Freeway								
	88 - Van Nuys - International Airport	24.7	12.1	49	N.A.	60	N.A.	24.5	N.A.
Milwaukee - (1970)									
	East-West - Zoo Freeways								
	41 - Mayfair	10	8	80	--	5-10	N.A.	28.5	N.A.
	44 - Treasure Island South	10	8	80	--	20-30	N.A.	30	N.A.
	45 - Treasure Island North	12	10	83	--	30	N.A.	32.8	N.A.
	North-South-Airport Freeways								
	43 - Country Fair	14	10	72	--	30	N.A.	42	N.A.
	46 - Spring Mall	10	8	80	--	30	N.A.	40	N.A.
	North-South (US 141) Freeway								
	42 - Bayshore	7	5.5	79	--	10-15	N.A.	42	N.A.
Minneapolis-St. Paul-(1971)									
	1 - Har-Mar (I-94)	8.4	3.0	36	0	30	43.0	18.0	13.5
	5 - Portland Red Ball Express (I-35W)	17.4	10.1	58	1	35	36.1	29.0	26.0
	6 - Southdale Red Ball Express (I-35W)	10.2	7.7	75	1	35	36.6	22.7	10.8
	18 - Nicollet (I-35W)	14.0	5.3	38	1	9	31.2	20.6	16.7
	50 - Minneapolis Airport (I-494 and I-35W)	18.7	10.8	58	1	30	38.5	23.3	15.4
	50 - St. Paul Airport (I-494)	10.5	4.7	45	0	30	47.0	22.8	16.1
New York (See Table A-2)									
Philadelphia - (1971)									
	Ben Franklin Bridge - I-295, North-South Freeway, and Atlantic City Expressway								
	Public Transport of New Jersey								
	21/31 - Williamstown	22.4	8.6	38.3	--	3	N.A.	N.A.	N.A.
	27 - Woodbury	11.9	4.6	38.7	--	10	N.A.	N.A.	N.A.
	47 - Pennsville	30.6	4.8	15.7	--	20	N.A.	N.A.	N.A.
	51 - Erial	20.0	8.4	42.0	--	30	N.A.	N.A.	N.A.
	101 - Atlantic City	63.3	60.0	94.7	--	30	N.A.	N.A.	N.A.
	103 - Bridgeton	42.8	3.5	8.2	--	N.A.	N.A.	N.A.	N.A.
	105 - Millville	41.5	8.2	19.8	--	15	N.A.	N.A.	N.A.
	111 - Ocean City	65.3	51.7	79.2	--	N.A.	N.A.	N.A.	N.A.
	113/115 - Cape May	97.2	81.9	84.3	--	60	N.A.	N.A.	N.A.
	Schuylkill Expressway								
	A	12.0	5.5	45.8	0	1	35-40	24	11
	38	8.0	2.0	25.0	0	8	35-40	17	11
	44	12.1	5.0	41.3	0	7	35-40	23	10
	45	23.0	15.9	69.1	0	20	35-40	29	12
	E	10.0	2.0	20.0	0	--	35-40	17	12
	G	11.1	3.0	27.0	0	--	35-40	18	12
	I-95								
	Route 20 Express	13.0	5.0	38.4	0	5	35-40	23	13
St. Louis - (1972)									
	Daniel Boone								
	52X - Brentwood Express	12.26	3.92	32.0	1	20	25.4	13.6	--
	55X - Kirkwood Express	16.22	5.65	34.8	1	15	26.1	16.0	--
	56X - Manchester Road Express	16.52	5.14	31.1	2	18	23.8	15.5	--
	152X - Clayton Rd. Express	16.4	4.66	37.0	2	19	23.3	16.4	--
	608X - Big Bend Express	19.45	5.14	26.4	2	25	26.1	17.70	--

TABLE A-1 (*Continued*)

		LENGTH OF ROUTE					RUSH HOUR SERVICE-BUS SPEEDS IN MILES PER HOUR		
		Terminal to Terminal	Part of Route on Freeway		NO. OF STOPS ON FREEWAY	RUSH HOUR INTERVAL (MINUTES)	On Freeway	Terminal to Terminal	Local Streets
CITY (DATE)	BUS ROUTE		Miles	Per Cent					
St. Louis - (1972) (Cont.)									
	Mark Twain								
	16R - Ramona Rapid	13.35	8.99	67.3	4	34	31.7	19.6	--
	30R - Jennings Rapid	10.99	6.13	55.8	3	28	30.7	17.8	--
	40R - Bissell Hills Rapid	10.85	3.39	31.2	0	21	29.1	15.48	--
	41R - Northside Rapid	15.05	4.91	32.6	0	11	29.5	15.8	--
	74R - Berkeley Rapid	18.07	6.71	37.1	2	14	31.0	16.9	--
	132R - Ashby Rapid	18.56	11.50	62.0	3	26	31.4	19.9	--
	174R - Florissant Rapid	20.49	9.12	44.5	3	14	30.4	19.8	--
	274R - Paddock Hills Rapid	20.92	7.84	37.5	--	16	29.4	19.0	--
	530X - Pontoon Express	13.27	1.58	11.9	0	20	20.9	15.9	--
	635X - Riverview Gardens Rapid	13.92	3.12	22.4	0	19	29.1	16.1	--
San Francisco - Oakland - (1970) - Bay Bridge									
	A.C. Transit Transbay								
	A	10.5	5.5	52.4	--	10.0	36	27	15
	B	10.2	8.7	85.0	--	15.0	36	28	16
	C	11.5	7.7	67.0	--	3.5	35	28	15
	E	10.3	5.5	53.3	--	4.5	36	25	14
	F	12.7	7.8	61.3	--	2.5	33	21	13
	G	15.3	8.5	55.5	--	6.5	N.A.	N.A.	N.A.
	H	14.7	8.5	57.8	--	5.0	33	25	17
	K	16.0	10.7	67.0	--	3.5	N.A.	N.A.	N.A.
	L	19.5	12.3	63.0	--	1.8	37	26	17
	N	16.7	8.5	50.8	--	2.5	N.A.	N.A.	N.A.
	O	16.5	11.5	69.8	--	5.0	N.A.	N.A.	N.A.
	R	25.2	13.6	54.0	--	2.5	33	24	18
	RCY	22.1	15.3	69.3	--	7.5	35	29	15
	S	22.2	16.2	73.0	--	5.5	36	32	17
	V	19.0	8.9	46.8	--	8.5	N.A.	N.A.	N.A.
	W	13.6	8.7	64.0	--	6.8	35	28	15
Seattle - (1971)									
	Blue Streak - I-5								
	5 - Phinney	14.7	5.8	39.4	0	10	N.A.	25	N.A.
	7 - 15th Avenue	12.1	5.6	46.3	0	8	N.A.	16	N.A.
	7 - Lake City	11.8	5.6	47.5	0	15	N.A.	16	N.A.
	7 - View Ridge	11.6	5.0	43.0	0	8	N.A.	17	N.A.
	8 - Ravenna	14.5	3.7	25.5	0	10	N.A.	20	N.A.
	16 - Meridian	12.2	5.0	41.0	0	15	N.A.	18	N.A.
	22 - Roosevelt	10.5	3.7	35.1	0	20	N.A.	17	N.A.
	41 - Blue Streak	14.0	6.6	47.0	0	20	N.A.	N.A.	N.A.
Washington, D.C. - (1971) - Shirley Busway									
	A.B. and W. and NVTC on (Approx. 10 lines)	10.4 to 20.8	--	--	--	Varies	35 to 40 on Busway	--	Approx. 9 to 10 in D.C.

---

(1) Selected Routes from total of 35 Routes on freeways.
(2) Numbers in parentheses from 1962 data.

TABLE A-2

USE OF FREEWAYS BY URBAN TRANSIT BUSES, BETWEEN NEW YORK AND NEW JERSEY (1971)

	LENGTH OF ROUTE					RUSH HOUR SERVICE-BUS SPEEDS IN MILES PER HOUR		
		Part of Route on Freeway						
BUS ROUTE	Terminal to Terminal (Miles)	Miles	Per Cent	NO.OF STOPS ON FREEWAY	RUSH HOUR INTERVAL (MINUTES)	On Freeway	Terminal to Terminal	On Local Streets
Short Haul Bus Lines								
DeCamp								
32	12	8	66.6	--	7	32.0	18.0	9.6
33	23	11	50.5	--	7	31.4	27.6	24.5
44	14.4	8	55.0	--	7	26.7	19.2	14.2
55	14.0	8	57.0	--	7	26.7	21.0	16.4
66	24.0	12.5	52.0	--	7	32.6	24.8	19.7
77	36.8	18.7	50.0	--	7	33.0	27.6	23.6
88	18.4	11	59.6	--	25	31.4	22.0	19.4
Domenico (To Bayonne)	30	18	30.9	--	7	36.0	27.7	20.6
Hudson								
99	8	1	12.5	--	10	12.0	12.0	12.0
99S	39	12	30.8	--	10	24.0	17.3	15.4
Intercity								
30	16.5	10.5	63.5	--	5	25.2	19.8	15.6
35	21	6	28.6	--	5	18.0	16.5	16.0
40	21	9	42.8	--	6	20.6	18.0	13.3
41	22	9	40.9	--	5	32.2	24.0	15.6
45	20	15	75.0	--	5-10			
Lakeland L	42	--	--	13	5-10	30.6	30.6	
Manhattan								
50	16.5	--	--	--	15			
51	16.5	9.5	61	--	60	25.8	21.0	16.8
52	18	9	50	--	--	30.0	24.0	20.0
53	18	--	--	--	30	--	18.0	18.0
54	13.5	--	--	--	5-20	--	13.5	13.5
55	14	9	64	--	10-20	25.8	21.0	15.8
North Boulevard								
4	10.5	--	--	--	7	--	16.5	16.5
5	6	--	--	--	7	--	12.0	12.0
Orange & Black								
6	9	--	--	--	8	--	18.6	18.6
7	7	--	--	--		--	12.2	12.2
8	7	--	--	--		--	12.2	12.2
9	9	--	--	--	7	--	18.6	18.6
10	11	--	--	--	60	--	14.7	14.7
11	5	--	--					
Public Service								
61	5	--	--	--	5	--	11.7	11.7
63	5	--	--	--	6	--	11.2	11.2
67	6	--	--	--	5-10	--	11.2	11.2
107	18	12	67	--	5-10	36.0	27.0	18.0
108	12	--	--	--	30	--	11.1	11.1
118	12	--	--	--	2-3	--	24.0	24.0
118	13	9	69					
135	33	15	46	--	5-10	34.6	23.0	18.0
135	45	33	79	--	20	45.0	31.8	17.5
165	18	9	50	--	4	27.0	20.0	15.9
165	18	--	--	--	4	--	14.2	14.2
167	18	9	50	--	3	27.0	19.3	15.0
167	18	--	--	--	3	--	14.3	14.3
168	12	9	75	--	7-10	27.0	18.9	10.0
168	12	--	--	--	7-10	--	15.0	10.5
200	4	4	--	--	4	--	--	--
Rockland								
9	30	2	7	--	--	--	--	--
11	30	9		--	5-10	27.0	22.5	21.0
20	18	12	67	--	10	21.8	20.0	17.2
21	18	9	50	--	12	22.5	20.4	18.6
45	30	24	80	--	5	30.0	24.7	14.4
47	27	19	72	--	5	27.2	25.0	20.5
49	33	27	82	--	5	32.5	30.5	23.9
Somerset								
15	27	12	45	--	30	24.0	21.6	20.0
111	18	10.5	59	--	30	25.2	24.0	22.5
143	27	10.5	39	--	25	25.2	25.8	24.6
148	40.5	27	67	--		27.0	29.5	23.2
222	31.5	16.5	53	--	25	39.6	27.0	20.0
333	32	20	63					
444	36	20	55					
Westwood								
W-54	13.5	2	15	--	--	---	--	--
W-55	14.0	9	13	--	--	--	--	--

TABLE A-2 (*Continued*)

	LENGTH OF ROUTE					RUSH HOUR SERVICE-BUS SPEEDS IN MILES PER HOUR		
		Part of Route on Freeway						
BUS ROUTE	Terminal to Terminal (Miles)	Miles	Per Cent	NO.OF STOPS ON FREEWAY	RUSH HOUR INTERVAL (MINUTES)	On Freeway	Terminal to Terminal	On Local Streets
Medium Haul Bus Lines								
HUDSON TRANSIT CORP. (Short Line)								
Monroe-Mahwah	46	8	17	0	--	--	33	--
Oakland (Local)	27	8	30	--	--	--	--	--
Oakland (Express)	27	8	30	--	--	--	--	--
Suffern	29	8	27	0	--	--	32	--
Mahwah (Aumont Rd.)	27	8	30	0	--	--	31	--
Franklin Turnpike - Saddle River Road - Allendale	24	8	33	0	--	--	34	--
SUBURBAN TRANSIT CORP.								
Princeton-Trenton via Hightstown	81	47	56	0	--	--	--	--
Kendall Park - Princeton - Trenton	60	27	45	0	--	--	--	--
New Brunswick - Trenton - Princeton	62	32	52	0	--	--	--	--
South Plainfield - Metuchen	32	26	81	0	--	--	--	--
NORTHEAST COACH LINES								
New Foundland (local)	36	4	11	0	--	--	24	--
New Foundland (express) Sussex Hwy Express. Smoke Rise Special	36	4	11	0	--	--	31	--
REAL TRANSIT CO.								
Stanhope - Andover - Newtown - Blairstown	42	19	45	0	--	--	21	--
WARWICK-GREENWOOD LAKE AND NEW YORK TRANSIT INC.								
Warwick - Paterson	59	9	15	--	--	--	--	--
W. HUNTERDON TRANSIT CO., INC.								
Flemington-Milford	67	50	75	--	--	--	--	--
NEW YORK KEANSBURG LONG BRANCH BUS LINE, INC.								
Hazlet - Long Branch	55	24	44	--	--	--	--	--
LINCOLN TRANSIT CO.								
Woodbridge - Lakewood	68	29	43	--	--	--	--	--
PUBLIC SERVICE COORDINATED TRANSPORT								
Perth Amboy	29	20	69	--	--	--	--	--
Old Bridge	45	8	18	--	--	--	--	--
Freehold	47	14	30	--	--	--	--	--
Lakewood-Toms River	61	14	23	--	--	--	--	--
New Brunswick-Milltown	36	14	39	--	--	--	--	--
135 - Manville Bound Brook S. Bound Brook	33	14	42	--	--	--	--	--
Matawan - Browntown	40	33	82	--	--	--	--	--
ASBURY PARK - NEW YORK TRANSIT CORP.								
Asbury Park - Ocean Grove	70	37	53	--	--	--	--	32
Red Bank Express	45	24	54	--	--	--	--	
Red Bank Local	45	24	54	--	--	--	--	39

APPENDIX B

CASE STUDIES OF FREEWAY BUS PRIORITY TREATMENTS

This appendix describes and interprets examples of bus priority treatments along freeways. United States and Canadian experiences are discussed first, followed by significant experiences in other countries. Case studies are arranged alphabetically by city or metropolitan area.

1. ATLANTA BUSWAY FEEDER SYSTEM

Atlanta, Ga., has had three busway proposals within the last decade. The first was set forth by the Atlanta Transit System in 1967 as an alternative to a rail rapid transit network The second, developed in 1969-70 as part of the

Atlanta Area Transportation Study, called for a combined busway-rail system serving the city center. The third, developed in 1971 as part of the Metropolitan Area Rapid Transit Authority (MARTA) program, recommended outlying busway feeders to rail lines.

The 1967 proposal is significant in that it achieved a grade-separated downtown bus distribution roadway through an existing railroad cut. The over-all regional busway system along existing rail lines was estimated to cost $52 million. The system did not, however, directly serve the Peachtree corridor, an area of heavy bus use and major land development.

The current MARTA proposal, approved by the voters in 1971, is shown in Figure B-1 The plan (*B-1*) calls for 14.4 miles of busways at a capital cost of $25.9 million (Table B-1)

Three busways will provide high-speed feeder bus service to the rail rapid transit stations, have intermediate stops, and circulate through residential neighborhoods. Preliminary design concepts indicate that the busways would provide normal-flow operations with turnouts at stations The North Atlanta and East Atlanta Busways are proposed in median strips of future highways planned by the Georgia State Highway Department. The Tucker-North DeKalb Busway will be built alongside the Seaboard Coast Line Railroad right-of-way. Thirty-eight routes would use the three busways.

Brief descriptions of these facilities are as follows:

The 4.7-mile North Atlanta Busway will serve the Northeast Line of the rail rapid system, connecting with it at the Lenox Road station From there the busway will extend north in the median of the proposed North Atlanta Toll Road to the Atlanta Beltway (I-285), where it will terminate. Bus service will continue to the Sandy Springs station (1,600 parking spaces) in the normal traffic lanes of the North Fulton Expressway. Intermediate access ramps will be provided along the busway at Wieuca and Trimble Roads. This project is scheduled for completion by mid-1977 MARTA estimates that 1,200 persons would use the facility in the peak hour by 1983 and about 2,000 by 1995

The 3.3-mile East Atlanta Busway will provide service to the East Line of the rail rapid transit system, joining it at the Moreland Avenue station. It will be located in the median of the proposed East Atlanta Toll Road, with intermediate bus access at Glenwood and East Confederate Avenues. Parking for about 1,000 automobiles will be provided at the Thomasville station. The busway is scheduled for completion by 1976. About 2,300 persons are expected to use the busway during the peak hour by 1983 and 3,500 by 1991.

The 6 4-mile Tucker-North DeKalb Busway will also serve the East Line of the rapid rail system. It will be located along the Seaboard Coast Line Railroad and will serve the LaVista Road and Lawrenceville Road corridors north of the city. Two stations will be provided at North Decatur and North Druid Hills Roads, plus a station where the busway and rail facilities meet at East Lake Drive Intermediate bus access will be provided at Clairmont, North Druid Hills, and Montreal Roads, with parking for 600 cars planned at the latter facility. The busway is scheduled for completion in 1976. About 1,500 passengers will use the busway in the peak hour by 1983 and 2,500 by 1995.

TABLE B-1

CAPITAL COSTS FOR BUSWAYS, ATLANTA[a]

LINE	LENGTH (MI)	COSTS ($1,000)		
		CONSTR	ROW	TOTAL
North Atlanta	4.7	$ 6,090	$1,600	$ 7,690
East Atlanta	3 3	5,300	2,950	8,250
Tucker-North DeKalb	6 4	7,650	2,320	9,970
Total	14.4	$19,040	$6,870	$25,910

Source Ref (*B-1*)

[a] Design and contingency costs not included

2. BOSTON SOUTHEAST EXPRESSWAY CONTRA-FLOW BUS LANE

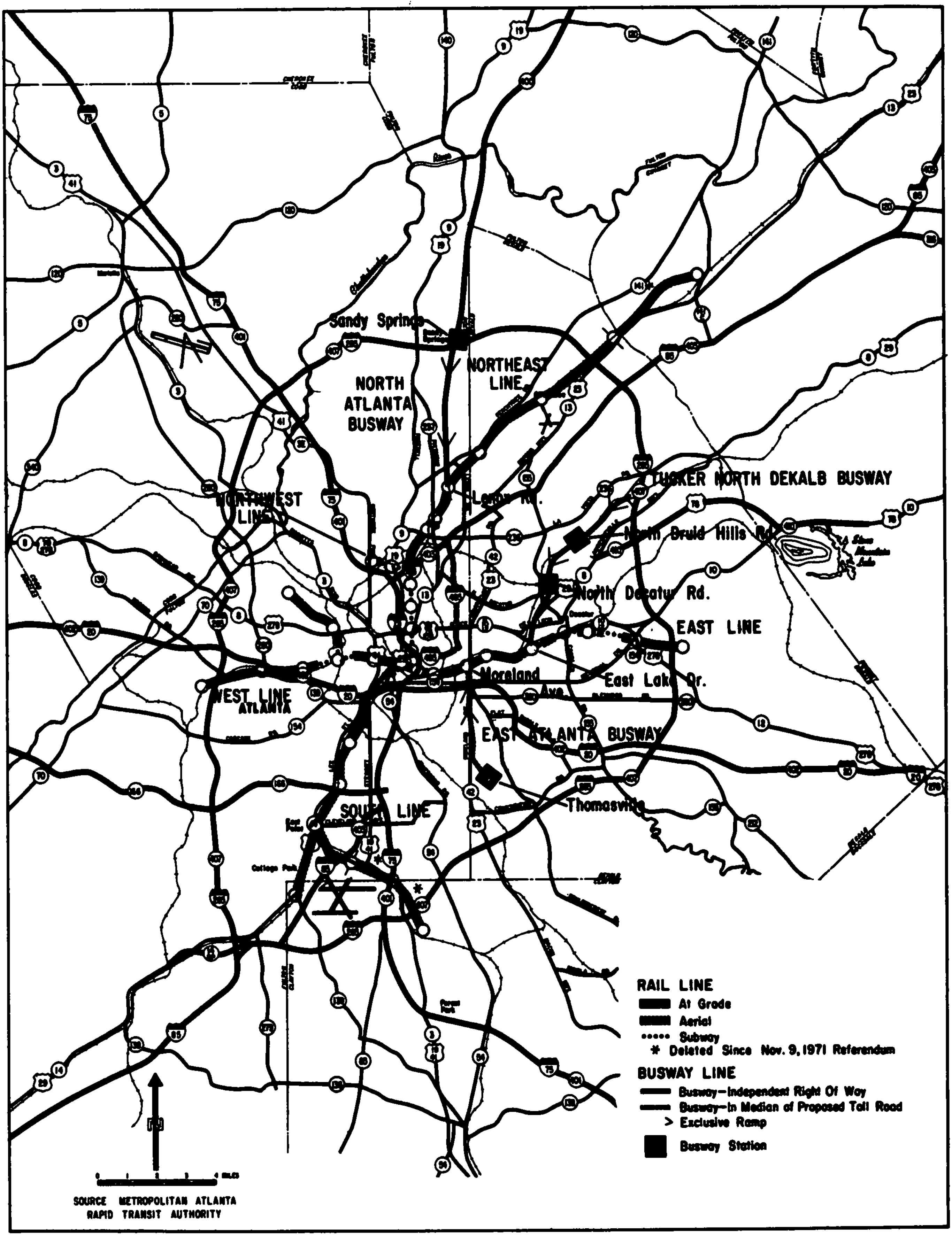
Greater Boston (Mass) has a population of approximately 2.7 million and a CBD employment of more than 250,000 The Massachusetts Bay Area Transit Authority (MBTA), the primary transit carrier, operates a 50-mile rail rapid transit system, of which 17 miles use multiple-unit street cars. It also operates approximately 1,300 buses, almost exclusively in local service (*B-2*). The notable exceptions are the express buses operating over the uncongested Massachusetts Turnpike from central Boston to Newton and Watertown. Other express bus service within the area is provided by more than 25 smaller companies, some under contract with the MBTA for operating subsidies.

An 8.4-mile contra-flow bus lane currently operates on Boston's Southeast Expressway (S.R 3) during the morning peak hours. This lane extends from Route 128 in Quincy to the periphery of the central business district and is the longest contra-flow bus lane in the United States. Contra-flow bus lanes operated during both morning and evening peak periods from May 24 to October 15, 1971. The bus lane was re-instituted during the morning peak period (7 00-9 30 AM) in May 1972. The evening peak operation (4·00-6:00 PM) was abandoned because the benefits derived were not found to be significant and because the manual placing and collecting of traffic cones became hazardous during the hours of darkness The expressway is not illuminated between interchanges.

Studies of the initial bus lane operations were conducted by the Massachusetts Department of Public Works during 1971 (*B-3*). The results are summarized in Table B-2 and are discussed in detail in the following.

Planning Considerations

Installation of the contra-flow bus lanes reflected the needs to (1) increase person-capacity during peak hours in Boston's southeast corridor, and (2) relieve highway pressures. The Southeast Expressway—the major route in this corridor—was designed in the early 1950's. Two roadways, each 52 ft wide, extend over most of its length; three 12-ft



SOURCE METROPOLITAN ATLANTA RAPID TRANSIT AUTHORITY

Figure B-1 Proposed rapid transit system, Atlanta, Ga.

TABLE B-2

SUMMARY OF CONTRA-FLOW BUS LANE IMPACTS, 1971, SOUTHEAST EXPRESSWAY, BOSTON

ITEM	AM PEAK HOUR		CHANGE		
	BEFORE	AFTER	IN-CREASE	DE-CREASE	(%)
Vehicles, Quincy	4,997	5,003	6		0
Vehicles, Boston	4,554	4,201		353	−8
Buses [a]	57	65	8		+14
Bus passengers [a]	2,152	2,454	302		+14
Travel time, car (min)	22:00	17:28		4·32	−21
Travel time, bus (min)	24 00	10.00		14:00	−58
Vehicle occupancy:					
Quincy	1 35	1.32		0.03	−2
Boston	1.48	1 43		0 05	−3

Source Ref (*B-3*)

[a] Of the four lines using the bus lane, only three are represented in these totals They are primarily suburban lines carrying commuters into central Boston The fourth line (Bonanza) connects Boston with Fall River and Providence by nonstop buses It therefore carries intercity traffic rather than commuters Although Bonanza's traffic decreased during 1971, this is ascribable to depressed economic conditions or to competition from AMTRAK's Boston-Providence train service

travel lanes and a 6-ft median shoulder are provided in each direction. The roadways are separated by a raised median of varying width and by a steel-beam guardrail barrier.

The expressway was initially designed for an average daily volume of 60,000 vehicles. Current daily volumes average 106,000 vehicles, and volumes as high as 136,000 vehicles per day have been recorded. As a consequence, the expressway operates at or beyond capacity during peak hours. Congestion is common, and drivers often use the shoulders as travel lanes. Travel is highly directional toward and from central Boston, with excess capacity available outbound in the morning and inbound during the evening. Removal of one lane was found to yield a level of service "C" in the off-peak travel direction. Thus, reduced capacity in the off-peak direction—required to implement the contra-flow bus lanes—would not adversely affect vehicle travel

Description and Operations

The initial demonstration project reversed the innermost lane on the opposite side of the median for bus use. The bus lanes extended 8.4 miles from Route 128 to a point just north of the terminal interchange of the Massachusetts Avenue Interchange in the South End of Boston. The southbound median lane was allocated to northbound bus use from 7.00 to 9 30 AM and the northbound median lane was used by southbound buses from 4:00 to 7:00 PM Monday through Friday, except when weather or other conditions made operations inadvisable (Fig. B-2).

Both the morning and afternoon bus crossovers at the southern end of the bus lane were located immediately north of State Routes 128 and 3. Northbound buses crossed over to normal-flow operation near the former Berkeley Street exit immediately south of the Massachusetts Turnpike and north of connecting ramps to Massachusetts Avenue and the planned I-95 Southwest Expressway. These crossovers allowed buses to bypass the congestion caused by heavy traffic volumes entering the expressway from the South End and Roxbury areas of Boston.

Southbound buses could not cross over to reverse flow until south of Massachusetts Avenue at Southampton Street because of conflicts with northbound traffic entering from the Massachusetts Avenue ramps. As a result, the southbound bus lane was about one-half mile shorter, and buses were delayed by congestion at the interchange resulting from traffic entering from the southbound Massachusetts Avenue on-ramp.

All buses using the reserved lanes entered at the first crossover, no other access was provided. The operation, therefore, served only bus trips beginning or ending south of Route 128. It did not serve shorter trips to or from Boston, Milton, or Quincy, although some of these trips are accommodated by the MBTA Quincy rapid transit extension. Four companies (Almeida; Bonanza; Hudson, Plymouth and Brockton) used the bus lane.

Traffic Control Features

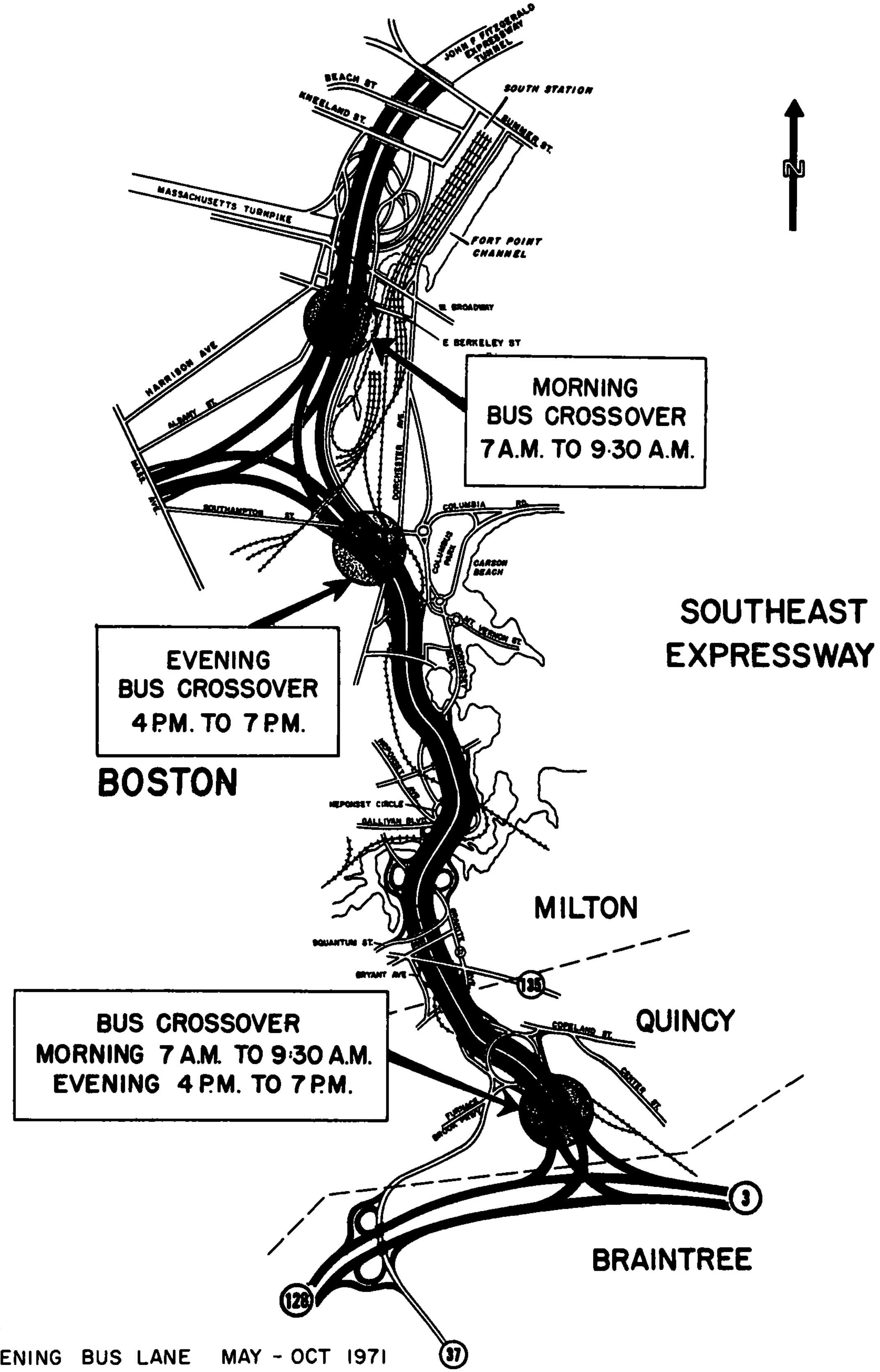
Rubber traffic cones, placed manually by state maintenance crews, separated the bus lanes from the general traffic flow Initially, the cones were placed at 40-ft intervals; later, this distance was increased to 80 ft. Twenty-eight-inch, 9-lb cones, designed to withstand wind pressure associated with vehicles traveling at 60 mph, were used. The 35 percent cone knockdown initially experienced throughout the length of the busway was largely attributed to backdrafts from heavy trucks. This problem was corrected by truncating the cones, cutting approximately 12 in. from their tops.

At the end of the bus lane, cones were tapered for 800 ft to preclude vehicles from entering the bus lane. Transitions to normal flow were accomplished well within this distance. A flashing yellow arrow directed traffic around the bus lane A maintenance truck fitted with a large sign indicating the closure of the lane to traffic other than buses was parked inside.

Overhead signs mounted on several expressway overpasses indicated to auto traffic (which may have entered the expressway between crossovers) that the bus lane was in operation. In addition, small ground-mounted signs in the median indicated the lane closure; these were of the folding type and were closed when the bus lane was not being operated. The signs that directed the buses into the lane also could be folded. When the lanes were not in operation, reflectorized abutment warning panels were placed horizontally in the median crossover openings.

State police were required initially at both ends of the bus lane. Subsequently they were only stationed at the southern end, because severe speed conflicts and a higher probability for serious accidents existed there. (Buses at 40 mph or less were crossing over to the fast lane with traffic averaging 50 mph.) A State Police helicopter provided visual surveillance and reported traffic incidents promptly. A wrecker, paid for by the bus companies, was also provided.

Each bus lane was 12 ft wide (effectively somewhat



NOTE
EVENING BUS LANE MAY - OCT 1971
MORNING BUS LANE { MAY - OCT 1971
MAY 1972- PRESENT

Figure B-2. Contra-flow bus lane, Southeast Expressway, Boston, Mass.

TABLE B-3

AVERAGE NUMBER OF BUSES AND PASSENGERS, MORNING PEAK-HOUR CONTRA-FLOW BUS LANE, SOUTHEAST EXPRESSWAY, BOSTON

	BUSES			PASSENGERS		
CARRIER	BEFORE	AFTER	INCREASE (%)	BEFORE	AFTER	INCREASE (%)
Plymouth and Brockton	43	48	11	1,790	1,980	16
Almeida	10	11	29	242	313	10
Hudson	4	6	34	120	161	50
Total	57	65	14	2,152	2,454	14

Source Ref (*B-3*)

narrower because of the need to clear the traffic cones) and had a 6-ft shoulder on the median side.

Bus Operating Procedures

Buses were required to keep emergency flashers on while operating in the bus lane. A speed limit of 40 mph and a spacing of 400 ft between buses was recommended, giving a time interval of about 7 sec. Buses were prohibited from overtaking and passing. After exiting from the bus lane, buses were restricted to the left lane until their speeds matched other traffic, at which time they could proceed to the right lane

Use Comparisons

The general impacts of the initial bus lanes are summarized in Tables B-3 and B-4.

Bus Patronage

The number of morning peak-hour buses increased from 57 to 65 and peak-hour bus passengers increased from about 2,150 to 2,450 The 14 percent increase in bus passengers (about 300 commuters) contrasts with the normal seasonal decrease in riding of 5 to 15 percent during the summer months as previously experienced by the participating companies.

TABLE B-4

PEAK-HOUR VEHICLE VOLUMES, BEFORE AND AFTER CONTRA-FLOW BUS LANE INSTALLATION,[a] SOUTHEAST EXPRESSWAY, BOSTON

	INBOUND (AM) PEAK-HOUR VOLUME			OUTBOUND (PM) PEAK-HOUR VOLUME		
AREA	TIME	BEFORE	AFTER	TIME	BEFORE	AFTER
Quincy[b]	7–8	5,392	5,232	4–5	6,333	6,594
	8–9	4,601	4,774	5–6	6,108	6,032
	7–9	4,997[c]	5,003[c]	4–6	6,221[c]	6,313[c]
Boston[d]	7–8	4,662	4,218	4–5	6,217	5,518
	8–9	4,445	4,183	5–6	5,589	4,840
	7–9	4,554[c]	4,201[c]	4–6	5,903[c]	5,179[c]

Source Ref (*B-3*)

[a] Volumes in the contra-flow bus direction were not reported Based on 1964 volumes at the Boston end, the outbound AM peak-hour volume was between 2,000 and 2,500 vehicles and the inbound PM peak-hour flow was between 3,000 and 3,500 vehicles

[b] Southerly end [c] Hourly average [d] Northerly end

Relationships between bus service and patronage growth varied among specific carriers For example, an increase of 50 percent in Hudson Bus Lines' service in the corridor led to a 34 percent increase in passengers. Almeida's 29 percent growth in patronage corresponded to an increase of only 10 percent in buses operated

Auto Traffic

No significant traffic volume changes were reported. It may be assumed that the busway arrested traffic growth on the roadway, typically about 2.5 to 3.5 percent per year. However, the effect of daily and seasonal variations and capacity constraints also influenced traffic change patterns Moreover, the MBTA South Shore Rail Rapid Transit extension to Quincy was opened late in the demonstration and parallels portions of the Southeast Expressway. Although it extends to Quincy Square and serves a different area (an older medium-density residential area colonized by a now-abandoned rail commuter service) the rapid transit line may have diverted some peak-hour motorists

Vehicle Occupancy

Passenger car occupancy declined from 1.48 to 1.43 persons per vehicle at the Boston terminus. Car occupancy at the southern terminus declined from 1.35 to 1.32 persons per vehicle. However, the statistical significance of these differences was not identified.

Costs

Costs incurred by the Massachusetts Department of Public Works for implementation, operation, and evaluation during the 106 days that the project was in service during 1971 totaled $97,000 (Table B-5). About $33,700 represented investment in fixed plant, including the crossovers and traffic cones The project cost the Department $542 per day to operate, covering both morning and evening operations—an equivalent annual maintenance cost of $136,000, or $16,000 per mile. Police enforcement costs were not included, and helicopter costs were considered part of the normal area-wide traffic surveillance program. The bus operators contributed to the cost of a tow truck, which was on call during bus lane hours. Study and evaluation costs approximated $6,100.

Benefits and Impacts

The bus lane substantially reduced person travel times in the corridor In addition to quantifiable benefits, it improved bus utilization and efficiency, achieved better schedule reliability, increased driver productivity, and reduced air pollution.

Bus Time Savings

Buses experienced substantial travel time savings as a result of bus lane operations. During the morning peak periods, bus travel times averaged 10 min as compared to 24 min before, a time saving of 14 min. During the afternoon, it took buses about 10.5 min to travel a distance that previously had taken 14.5 min, a time saving of 4 min per trip.

Auto Time Savings

Northbound automobile travel times during the morning peak hour were reported to be reduced from 22 to 17.5 min. Southbound automobile travel times remained relatively constant—14 min 54 sec before, and 14 min 54 sec after.

Auto Delays

Average delays caused to traffic in the direction opposite to the buses was estimated at 25 sec per vehicle in the morning and 35 sec per vehicle in the evening peak period. Outbound morning peak-hour volumes were about 2,000 vehicles and the inbound evening peak-hour flow was 3,100 vehicles. The evening inbound auto volume, therefore, was in the range of 1,500 to 1,800 vehicles per hour per lane—near level of service "D" according to *Highway Capacity Manual* definitions.

Safety

No major accidents were reported during the periods of bus lane operation. One minor accident occurred during evening operating hours when a bus, after merging with traffic, collided with a passenger vehicle.

Net Benefits

The net benefits of the 1971 contra-flow bus lane, expressed in daily and annual terms, are summarized in Table B-6. The morning contra-flow bus lane saved 2,450 passengers 14 min each morning. Based on a time savings of $3.00 per hour, this represents a daily savings of more than $1,700 and an annual time savings of $429,000. The annual value of the time lost by southbound traffic in the morning peak hour approximated $15,000.

The annual monetary value of time savings by buses in the PM peak hour totaled $122,400, as compared with $32,400 in time loss accrued by northbound motorists.

TABLE B-5

DEMONSTRATION COSTS, CONTRA-FLOW BUS LANE, SOUTHEAST EXPRESSWAY, BOSTON, MARCH 29 TO MAY 23, 1971

ITEM	COST ($)
Materials·	
Traffic cones	4,380 00
Expressway bus signs	9,799 65
Materials for crossovers	611 68
Contract	
Crossover at Braintree	6,800 00
Equipment·	
District 8	784 95
Labor:	
District 8	10,538.11
Design (Boston)	
Design of crossovers	700 00
Subtotal	33,674 39
Study and Evaluation Costs	
Planning (Boston).	
Studies and vehicle counts	5,400.00
Traffic (Boston)·	
Engineering costs	692 00
Subtotal	6,092 00
Operational costs	
Average cost of operation=$542/day	
Bus lane in operation 106 days	57,452 00
Total costs	97,218.39

Source Ref (*B-3*)

Significance

The contra-flow lane has provided substantial improvements for long-distance bus travel An initial investment of less than $35,000 and an equivalent annual operating cost of $136,000 produced equivalent annual benefits to bus passengers of more than $400,000 in the morning and $120,000 in the evening peak hour. There were no significant increases in delays to auto traffic as a result of the bus lane operations.

The bus lane in 1972 operated only during the weekday morning peak period. The present AM contra-flow bus lane does not delay auto users, as outbound traffic flows in the morning peak hour are well below the capacity of two freeway lanes. In effect, it provides an additional free-flowing lane for buses only while simultaneously removing 65 buses (each equivalent to 2 or 3 passenger car units) from the northbound traffic stream.

When outbound AM peak-hour traffic on the Southeast Expressway exceeds 3,000 vehicles in the morning peak, delays to southbound motorists may offset the benefits to bus users and northbound motorists. The contra-flow bus lane operation, therefore, must be monitored in terms of its over-all traffic impacts.

TABLE B-6

NET USER BENEFITS FROM CONTRA-FLOW BUS LANE, SOUTHEAST EXPRESSWAY, BOSTON

		TIME SAVINGS			
ITEM	PEOPLE CARRIED	PER TRIP	TOTAL DAILY	TOTAL ANNUAL[a]	MONETARY VALUE[b] ($)
AM peak hour:					
Northbound buses	2,450	14 min	34,300	143,000	429,000
Northbound cars[c, d]	6,000	4.5 min	27,000	112,500	337,500
Southbound cars[c]	2,900	−25 sec	−1,200	−5,000	−15,000
Total					751,500
PM peak hour:					
Southbound buses	2,450	4 min	9,800	40,800	122,400
Southbound cars[c, d]	7,400	0	0		0
Northbound cars	4,400	−35 sec	−2,600	−10,800	−32,400
Total					90,000

Source Ref (*B-3*)
[a] 250 days per year [b] At $3 00 per hour [c] At Boston end [d] Occupancy 1 43 persons per vehicle

3. CHICAGO CROSSTOWN BUSWAY AND O'HARE AIRORT BUS RAMP

Chicago, Ill., has a long history of freeway bus operations and successful bus priority measures. The city has pioneered in rapid transit developments in freeway medians, and busway development concepts date back some 30 years (*B-4*). Freeway-related bus priority treatments are planned for (1) Chicago's proposed Crosstown Expressway and (2) the Kennedy Expressway at O'Hare Field.

CROSSTOWN BUSWAY

Starting at the intersection of the Kennedy and Edens Expressways, the 20-mile proposed Crosstown Expressway runs south along Cicero Avenue past Midway Airport and then turns eastward to follow 75th Street to the Dan Ryan Expressway.

A contra-flow busway will be included in portions of the expressway median and alongside the northbound roadway in sections where the expressway has a split design. The location of the proposed busway is shown in Figure B-3

Planning Considerations and Design Criteria

Right-of-way requirements were designed to allow future conversion to rail operations. The following planning criteria were adopted.

1. The minimum right-of-way requirements for a two-track Chicago Transit Authority (CTA) rail rapid transit system are:

- 11 ft 9 in. clearance of train (northbound)
- 11 ft 9 in. clearance of train (southbound)
- 19 ft 6 in. required platform width to accommodate a free collection area capable of handling a maximum boarding traffic of 10,000 passengers per day; 24 ft minimum platform width at major transfer stations.
- 43 ft total width at stations.

2. Express bus facilities were based on the following criteria:

- 12 ft bus lane width.
- 5 ft minimum platform width; 6 to 8 ft desirable.
- 43 ft 6 in. minimum bus turning radius.
- 8 ft 6 in. nominal bus width.

The conventional two-track rail line requires a minimum clear width of 43 to 47 5 ft. Other possible future systems have roadway and car widths in the range of those for existing buses and trains. Therefore, general requirements for future systems were considered compatible with those of present bus and rail systems.

Design Options

Two basic alternatives were analyzed for both conventional and contra (reverse) bus flow, as follows.

1. Buses operating in their own right-of-way, in exactly the same manner as a rail system, with no access from the local street system.

2. Buses operating in their own right-of-way with access to and from the local street system and the ability to operate on the local street system.

Provision of intermediate access points substantially increases cross-section requirements, as summarized in Table B-7. Accordingly, initial planning recommended that no intermediate access be provided and that buses operate in a reverse-flow manner (alternative 2). This decision recognized the busway as a facility that would primarily collect passengers traveling by all modes within or alongside the corridor and distribute them to destinations within the corridor or to radial transit lines The Federal Highway Administration has subsequently questioned the validity of the concept for local bus operations and has suggested further study to determine where additional access points should be provided, including additional land-taking and cost implications.

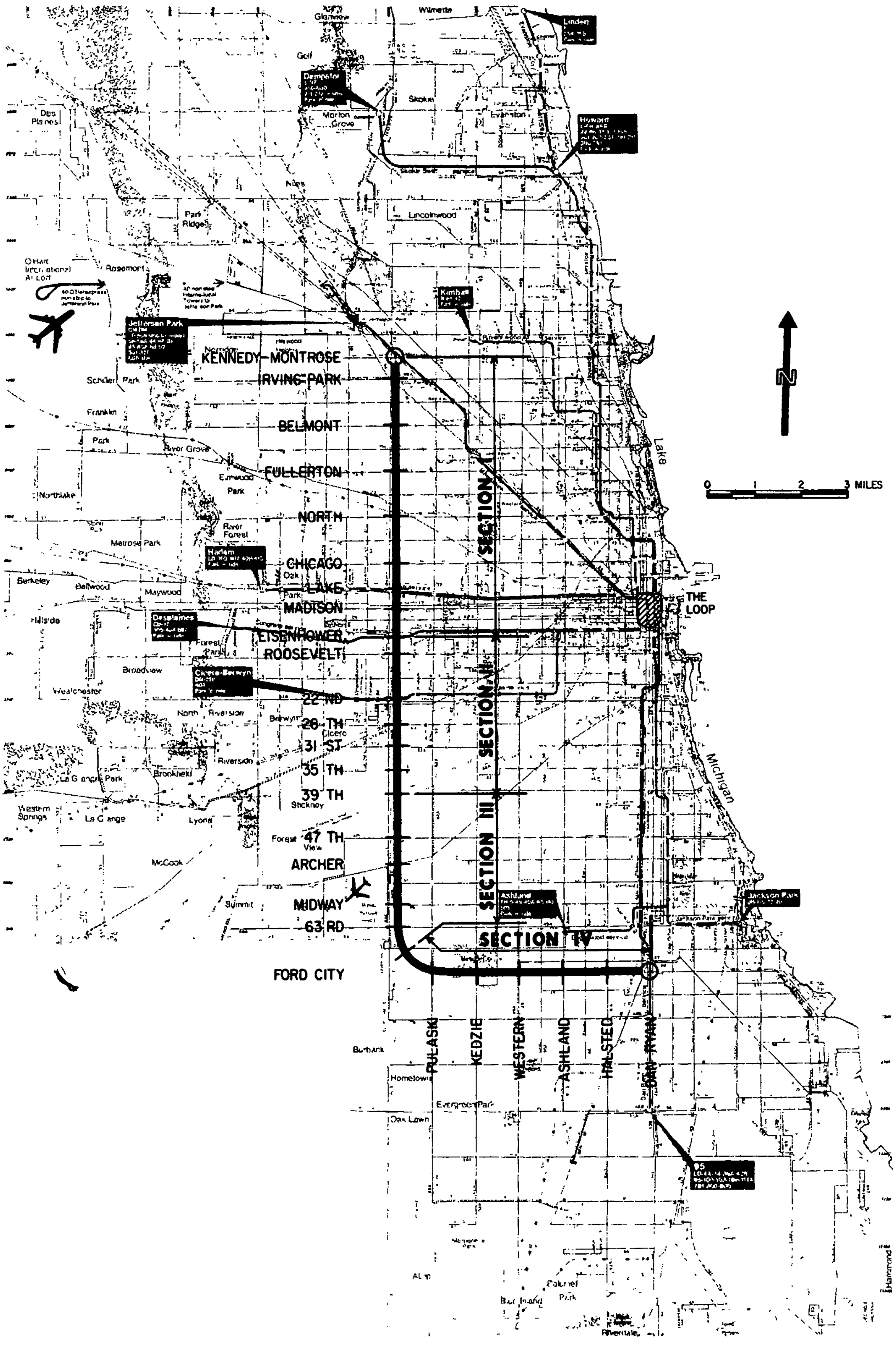


Figure B-3 Proposed Crosstown Busway, Chicago, Ill

TABLE B-7

ALTERNATIVE BUS OPERATING CONCEPTS, CROSSTOWN BUSWAY, CHICAGO

ALTERNATIVE	MIN WIDTH REQ AT STATION (FT)
1 No ramps, normal flow	43
2 No ramps, reverse flow	43
3 Single ramps, normal flow	56
4 Single ramps, inside, normal flow	48
5. Double ramps, inside, normal flow	64
6 Double ramps, outside, reverse flow	64

Source Ref (*B-5*)

Initial Busway Design Concept

The initial design concept called for contra-flow operations with single island station platforms. This design allowed simple future conversion to rail, required minimum right-of-way, and involved minimum costs. Approximately 28 major and 7 minor stations would be located along the 20-mile route

The suggested design standards are shown in Figure B-4. The busway would be separated from the four-lane, one-way expressway roadway by a continuous barrier; there would be no connection between the two roadways The cross-sectional width of the bus roadway would vary, depending on its location Within the split expressway portions, the dimensions require 45 ft to allow for arterial street bridge piers between the expressway and the busway. The 16½-ft center area between roadways serves as a shoulder for disabled vehicles, as a passing lane, and/or as a 9-in high platform area at the stations.

For the combined expressway portions, the bus roadway requires a 43-ft cross section. Bridge piers at stations are in the center of the platform, so it is not necessary to increase the width When the bus roadway is on structure, and no station is required, the width would be reduced to 29 ft.

TABLE B-8

PRELIMINARY COST ESTIMATES, CROSSTOWN BUSWAY, CHICAGO

ITEM	COST ($ MIL)
Right-of-way	$20 15
Clearing	1.05
Utilities	4.95
Grading	8 56
Roadway	8 90
Structures	12.07
Walls	19.38
Traffic control	2 14
Stations	5.20
Buses	7.50
Engineering and contingencies	7 29
Total	$97.19

Source Ref (*B-5*)

All crossroads over the expressway and all public transportation right-of-way would be grade separated. The vertical clearance for the bus roadway would be the same as for the highway—14 ft 6 in. Clearances at crossroads would be set with respect to both roadways, and the grades of the expressway and transit roadway would remain in the same relationship. Traffic control devices would not be required on the busway, because only buses would traverse it

Station Design Concept

The reverse-flow system permits use of a single common platform serving standard CTA buses (Figure B-5) Major stations would be located at intersecting expressways, at Midway Airport, and at approximately 1-mile intervals. They would include a platform 9 in. high and 150 ft long extending below the intersecting arterial street bridge, with a stair and escalator providing vertical access on one or both sides of that bridge. Minor stations would employ a platform 9 in high and 50 ft long, and would be designed to allow the express buses to bypass local buses stopped alongside the platform. From the platform, a single stair connects to either a pedestrian bridge or an intersecting arterial street bridge. Buses would always load or unload parallel to the platforms.

Anticipated Use

Travel assignments to the proposed busway were based on 1965 travel patterns. Traffic potentials along the route ranged from 23,000 passengers per day at the northern extremity to 60,000 passengers per day in the central portion. Volumes along much of the route would range from 30,000 to 40,000 persons per day. The peak-hour demand was estimated at 15 percent of the daily total for the north-south leg and 13 percent for the east-west leg. Peak one-way volumes would range from 3,000 to 9,000 passengers per hour, averaging 6,000 over most of the route. In comparison, the adjacent Cicero Avenue bus line carries an estimated 1,000 to 1,500 persons in the peak hour.

Costs

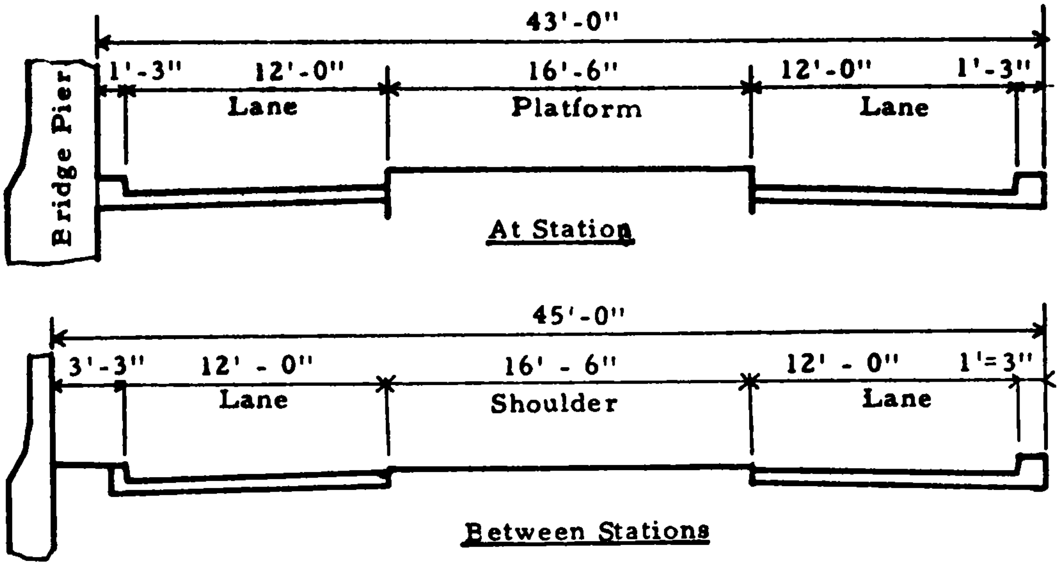
Preliminary costs for the Crosstown Busway, as compiled for the 1970 Interstate estimate, are summarized in Table B-8 Total cost of the 20-mile system, using standard CTA buses, was estimated at $97 million.

Significance

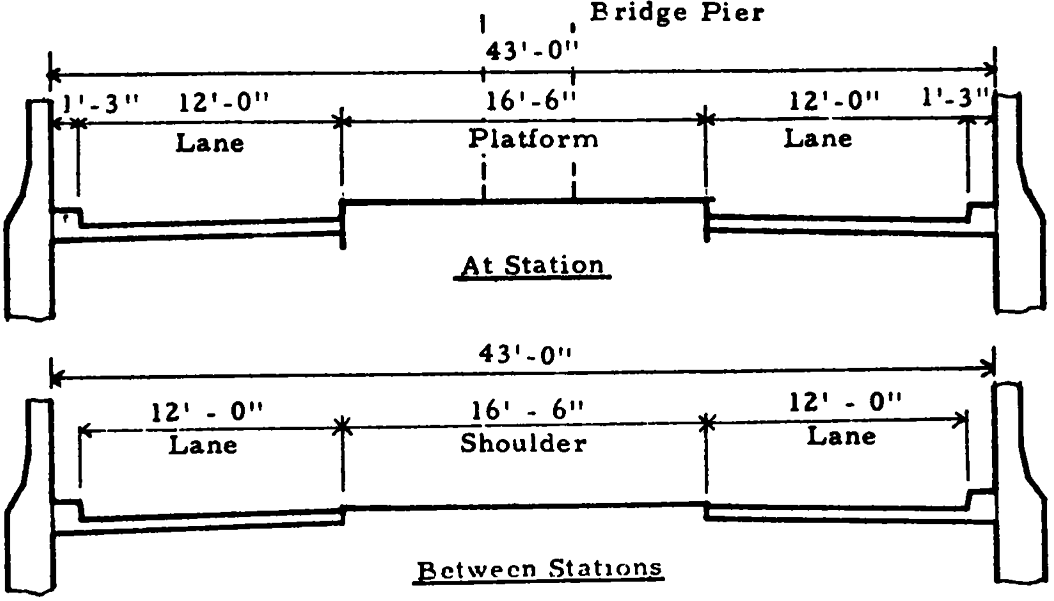
The proposed Crosstown Busway is unique in several respects. First, it is a crosstown, rather than a radial route. It would intersect seven commuter rail lines, five CTA rapid transit lines, and five suburban bus lines. Second, it is designed as a reverse-flow operation to facilitate future conversion to fixed-guideway transit. Third, the suggested manner of operation is similar to that of a rail system; neither branches nor intermediate bus access ramps were initially contemplated.

The 1965 patronage forecasts produce peak volumes that are similar to those experienced on major crosstown street-

SPLIT ROADWAY



COMBINED ROADWAY



ELEVATED ROADWAY

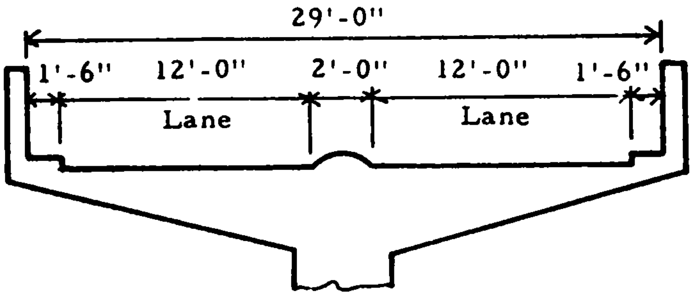


Figure B-4 Typical cross sections, Crosstown Busway, Chicago, Ill.

car lines in Chicago some three decades ago, but are considerably less than existing transit levels in the corridor. Thus, the busway plan assumes major shifts in transit riding patterns and considerable diversion of automobile travelers to transit.

BUS RAMP AT O'HARE AIRPORT

A ramp has been proposed at O'Hare Field for exclusive use by CTA buses. This treatment is shown in Figure B-6.

The ramp would enter the eastbound expressway approximately 1,500 ft west of the relocated Mannheim Road

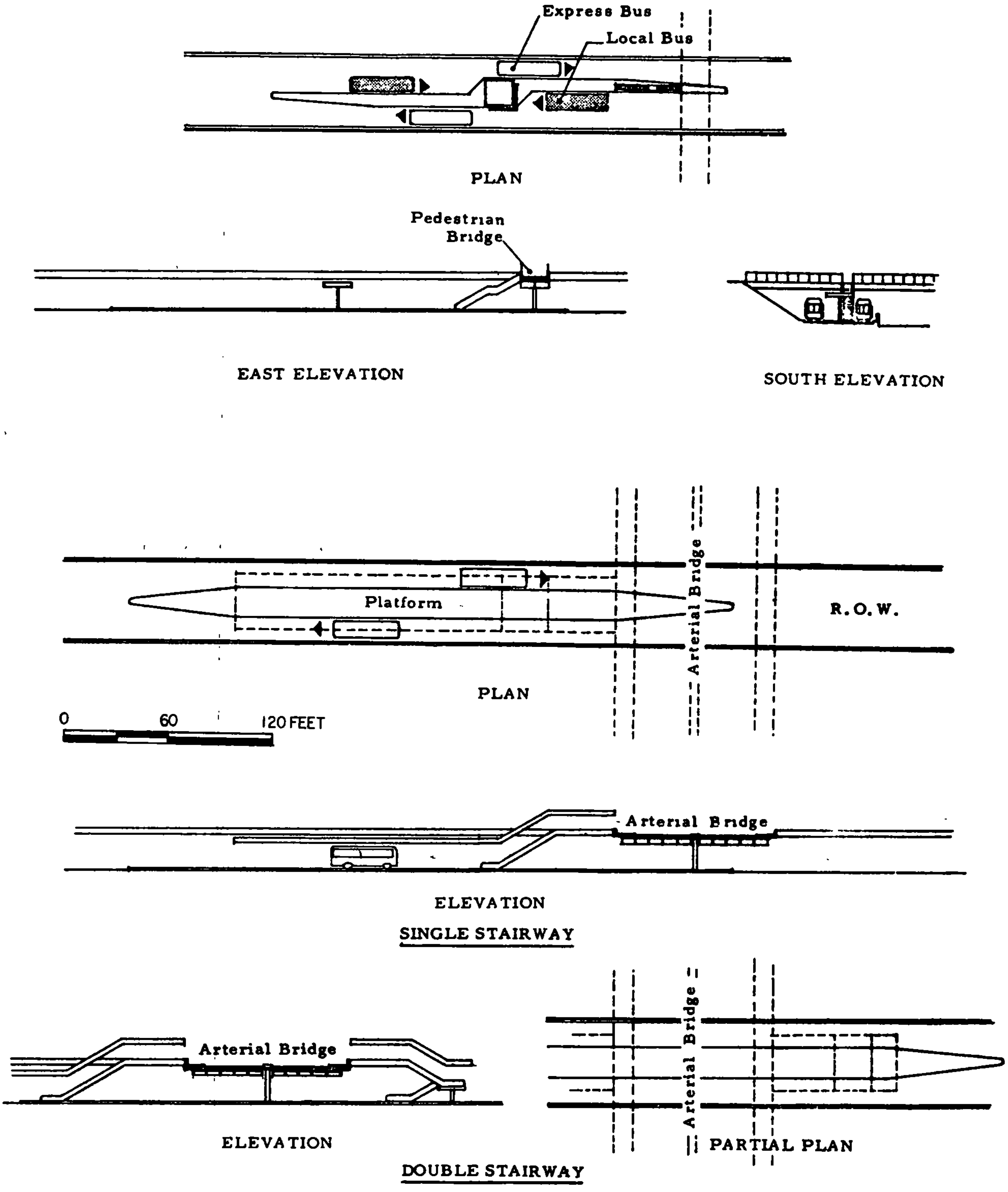


Figure B-5. Typical station designs, Crosstown Busway, Chicago, Ill.

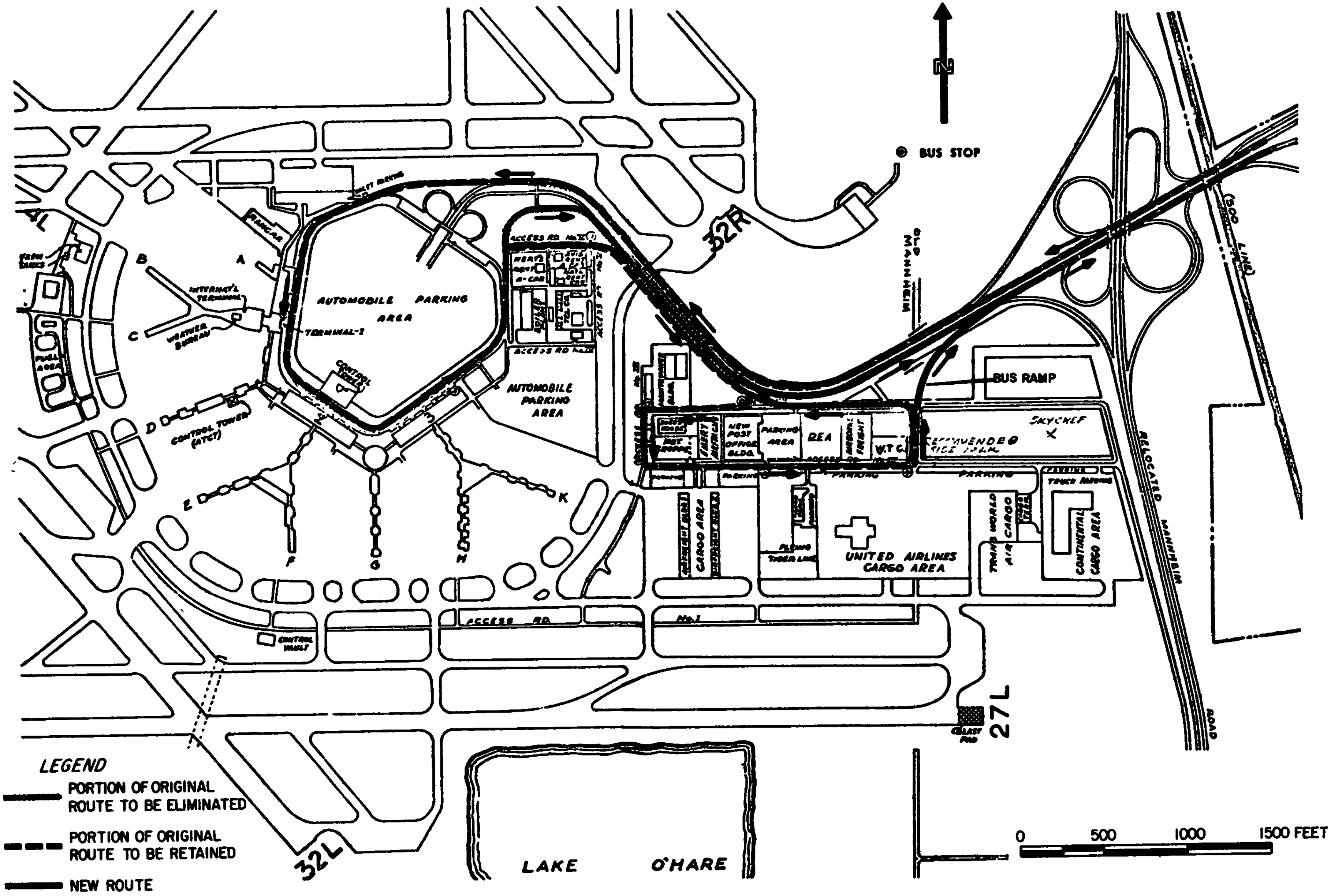


Figure B-6 Proposed bus ramp at O'Hare Field, Chicago, Ill interchange. It would eliminate backtracking movement of buses, thereby reducing over-all running times and operating costs. Because of the relatively low volume of bus movements (45 to 90 buses per day), no major weaving problems are anticipated at the entry to the expressway. Daily traffic volumes on the eastbound expressway are 22,000 vehicles, of which 3,100 use the ramp exit to southbound Mannheim Road. The cost was estimated at $81,000 based on 1971 data.

Construction of the ramp would reduce inconvenience for bus passengers, as well as backtracking of buses within the airport cargo and service areas. It would benefit the entire bus service by reducing the bus running time from 30 min to 20 min. These features should reduce operation costs, make the bus service more attractive to the public, and possibly reduce airport vehicular traffic volumes on the connecting road from the Kennedy Expressway.

The improvement clearly shows how minor adjustments in freeway access and interchange designs could expedite bus flow.

4. DALLAS PROPOSED NORTH CENTRAL BUSWAY

The improvement program proposed for the North Central Corridor in Dallas, Tex., recommends a busway, preferential bus ramps, and traffic signal preemption along major bus routes. The busway was developed to link a rapidly expanding downtown core with a low-density area.

Corridor Characteristics

The North Central Corridor had a 1970 population of 152,700, or 18 percent of the city's total. Corridor residents owned 75,775 cars—one for every two persons, and 21 percent of the city's total.

Each day, there are 281,000 person trips into the CBD, of which 123,000 are from the corridor. There are approximately 45,000 CBD trips between 7.30 and 8.30 AM, of which 20,000 come from this corridor (Table B-9). Thus, the corridor contributes nearly one-half the peak-hour travel to the city center. Work trips account for about 90 percent of all peak-hour trips in the CBD.

TABLE B-9

DAILY CAR AND BUS TRIPS INTO DALLAS CBD FROM NORTH CENTRAL CORRIDOR

		ALL TRIPS INTO CBD		CORRIDOR INTO CBD	
PERIOD	VEH TYPE	PERSONS	VEHICLES	PERSONS	VEHICLES
6 30 AM-6 30 PM	Auto	179,329	123,882	78,487	54,136
	Bus	52,535	2,162	22,383	921
	All	231,864	126,044	100,870	55,057
7.30 AM-8·30 AM[a]	Auto	33,569	23,633	14,703	10,328
	Bus	11,846	269	5,046	115
	All	45,415	23,902	19,749	10,443
24-hr	Auto	217,632	157,410	95,323	68,788
	Bus	63,756	2,747	27,160	1,170
	All	281,388	160,157	122,483	69,958

Source. Ref. (*B-6*)

The corridor is served by 16 of the 58 basic routes of the Dallas Transit System and extends over five transit fare zones Approximately 16,700 outbound passengers board corridor bus lines on a typical weekday, with almost 80 percent boarding within the CBD. Another 13 percent board in Fare Zone 1; 5 percent in Zone 2; and 2.5 percent in Zone 3. Less than 1 percent of the outbound passengers board in the last two fare zones.

Inbound buses in the corridor carry approximately 14,000 passengers on weekdays. Nearly one-half (47.7 percent) board in Fare Zone 1; 38 percent in Zone 2; and 12 percent in Zone 3. Less than 2 percent of inbound passengers board in Zones 4 or 5.

Peak-hour bus speeds in the corridor range from 14 to 21 mph, compared with 20 to 60 mph for autos.

Proposed Corridor Improvements

A system of proposed freeway and arterial improvements was designed to improve bus as well as auto flow. The estimated costs and benefits are summarized in Table B-10

Restriction of certain ramps to buses, metering of other ramps, and provision of bus bypass lanes around ramps, would cost $102,000. This compares with $245,000 to $619,000 in annual benefits, depending on the specific option that is implemented. Bus preemption of traffic signals at 37 intersections on 14 bus routes would cost nearly $1 million but would produce an estimated $3.5 million in annual benefits.

Bus turnouts at arterials at about 20 locations, increased radii at 45 locations, and reversal of STOP signs to favor buses would cost $365,000.

TABLE B-10

SUMMARY OF URBAN CORRIDOR PROPOSALS, DALLAS

PROPOSAL	DEVELOPMENT COSTS ($)	ANNUAL OPERATING COSTS ($)	ANNUAL BENEFITS ($)
Freeway bus priority (Bus priority ramps, metered ramps; coordinated frontage road signals)	101,900	16,000	245,000–619,000
Bus preferential treatment at 57 signalized intersections (Signals, 11 bus routes)	93,800	35,100	3,450,310
Bus turnouts on arterials (20 potential locations; increased turning radii, 45 locations, reversal of STOP signs to favor buses, 15 locations)	364,550	—	—

Source Ref (*B-7*)

Proposed North Central Busway

Analysis of various operational alternatives indicated that construction of a special roadway for exclusive use by transit buses offers the greatest opportunity for obtaining major transit service improvements in the North Central Corridor. The busway would extend approximately 10 miles from the Dallas CBD to a proposed 2,000-car park-and-ride terminal at the junctions of Lyndon B. Johnson (LBJ) Freeway and Coit Road. A second park-and-ride terminal, for 1,000 cars, would be constructed at Park Lane, near the Northpark Shopping Center, linked to the busway by either a special roadway or an elevated moving-walkway (Fig. B-7).

The busway would have 9 stations, and would allow intermediate bus access at four locations. Downtown distribution would be by means of bus priority lanes along Elm, Commerce, and Main Streets.

The recommended busway would be mainly elevated;

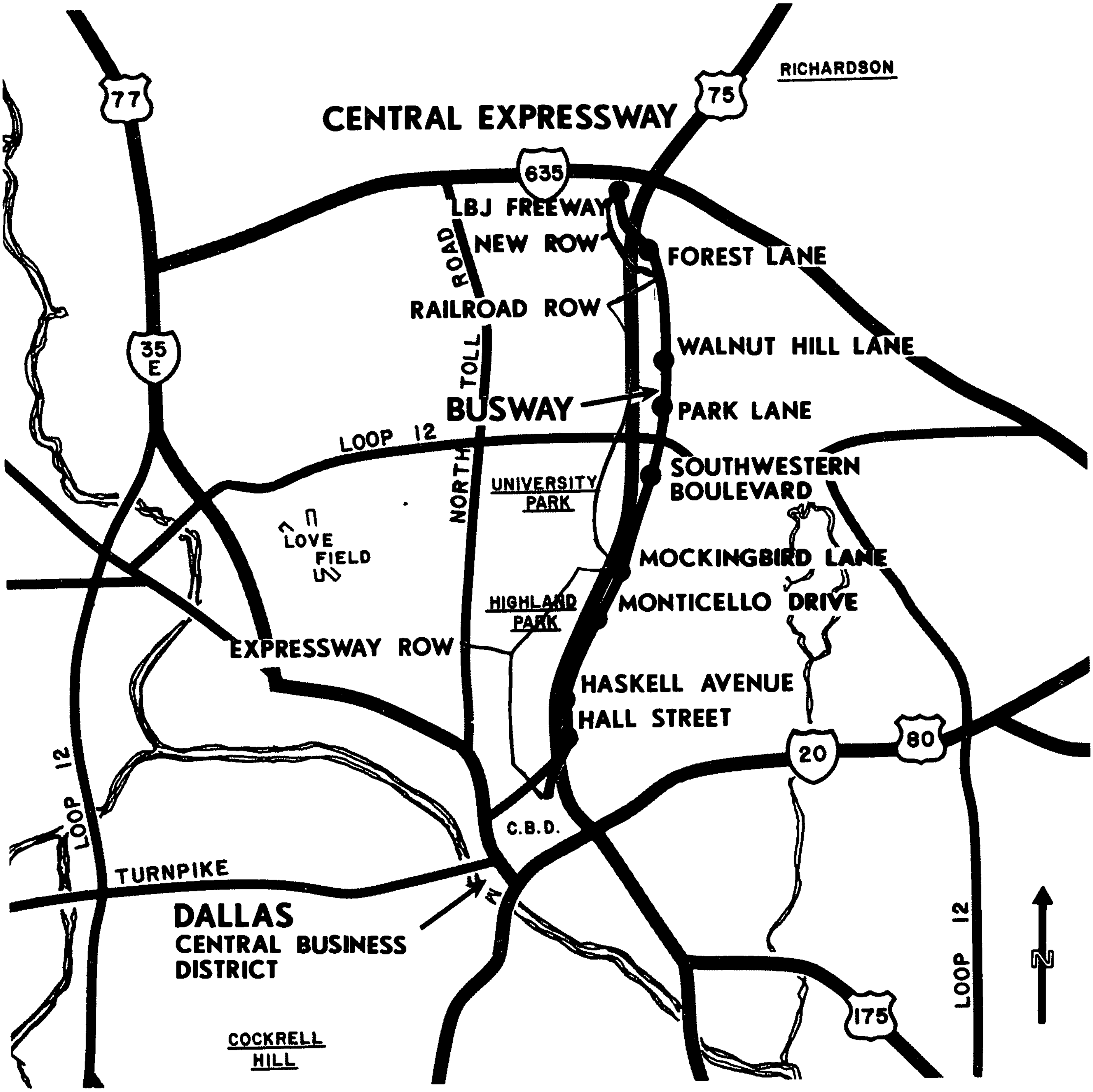


Figure B-7 Proposed North Central Busway, Dallas, Tex.

short sections might be on the surface or underground, depending on detailed design studies. Most of the route utilizes air-rights over 5 miles of the Southern Pacific Railroad right-of-way and over portions of the frontage roads of the North Central Expressway Initial discussions with railroad officials indicate that the busway involves no operational problems with the railroad, which plans no major movements of the tracks.

Design Standards

The busway would provide two travel lanes, each 12 ft wide, with a 3.5-ft lateral clearance space and a 1-ft railing on each side of the traveled way (Fig. B-8). It would be 33 ft wide from parapet to parapet and would be designed to the H20-S16-44 bridge standard used for the Interstate Highway System. The design would allow future conversion to fixed-guideway transit.

Bus Operations

Buses would operate express along the busway and distribute to arterial streets. This will allow certain bus lines now operating in the corridor to use the busway to reach selected cross-street locations and to travel along these streets to reach their normal neighborhood service areas. Ten existing bus lines would use the busway, as well as two new routes added to provide special service to the proposed Park Lane and LBJ Freeway park-and-ride stations.

About 400 daily trips (37 percent of all busway trips) would occur solely on the busway, with 700 other trips operating both on and off this facility. About 3,650 bus-miles of daily service would operate wholly on the busway (71 percent of all corridor bus-miles), while 1,470 bus-miles of service on the busway would involve lines that primarily operate on surface streets.

Nineteen buses would be used for exclusive busway operation if it existed now. They would make 121 daily nonstop trips between the LBJ Freeway terminal and the CBD, and 118 daily nonstop trips between the Park Lane station and the CBD. All peak-hour peak-direction bus service on these lines would be nonstop between the downtown area and the Park Lane and LBJ Freeway stations.

Anticipated Use

Busway patronage forecasts for 1975 are summarized in Table B-11. If downtown employment growth continues, daily patronage might reach 20,000 riders There would be about 8,000 one-way peak-period work trips, of which 4,000 would occur in the peak hour. This is substantially more than the 1,200 persons currently carried in buses on the North Central Expressway during the morning peak hour.

Costs

Estimated costs for the two-phase busway program are summarized in Table B-12. Development costs for the busway and related parking facilities would approximate $32 million. Costs for new buses, project administration,

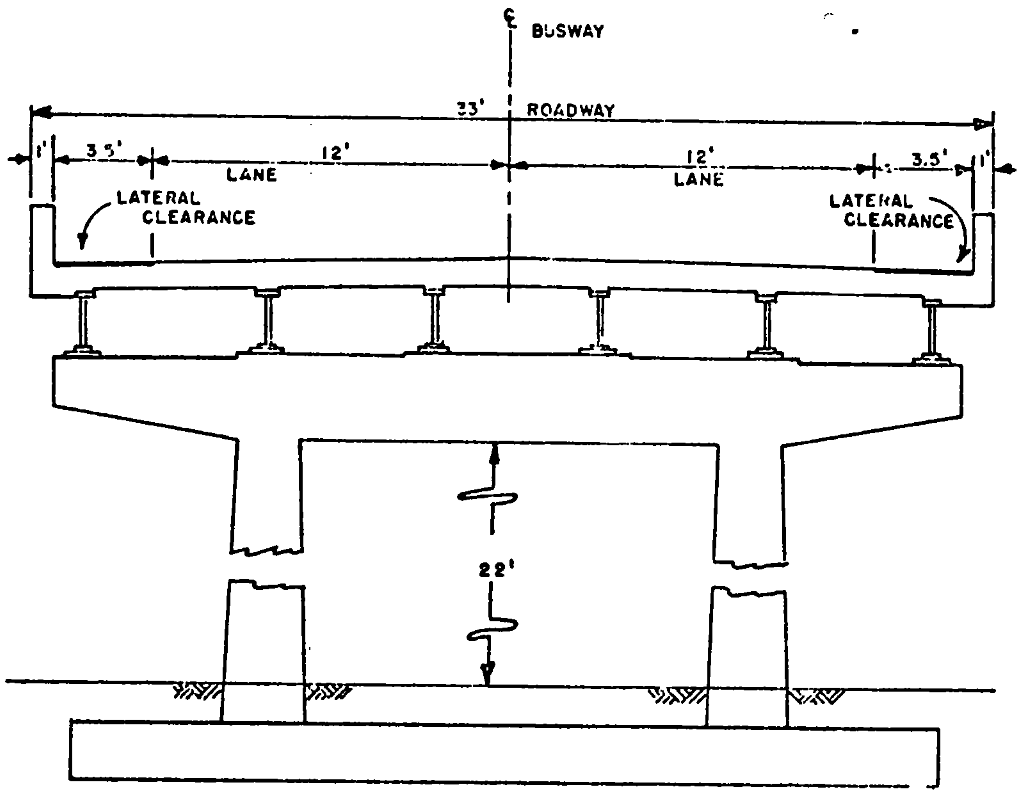


Figure B-8. Typical cross section, North Central Busway, Dallas, Tex.

TABLE B-11

PROJECTED 1975 PERSON-TRIPS TO DALLAS, ON NORTH CENTRAL BUSWAY

ITEM	PERSON TRIPS
1 Work trips to CBD [a]	175,900
2. Corridor-to-CBD work trips [b]	70,400
3 Corridor-to-CBD work trips between 7 and 9 AM [c]	42,200
4 Nondivertible peak-period corridor-to-CBD work trips [d]	3,700
5. Divertible peak-period trips [e]	38,500
6 Percentage of peak-period work trips diverted to busway [f]	(20)
7. Peak-period person-trips diverted to busway [g]	7,700
8 Estimated total 24-hr person-trips on busway [h]	19,300

[a] CBD employment projections for 1975 from Ref (*B-8*)

[b] 40 percent of CBD work trips from corridor

[c] 60 percent of CBD work trips in AM peak period

[d] 60 percent of (a) 3,700 CBD work trips by auto from locations within 3 miles north of CBD, and (b) 2,500 "captive" bus rider CBD work trips in corridor No future increase in these trips is anticipated, with CBD work trip growth offset by rising per capita auto ownership

[e] Item 3 minus Item 4

[f] Based on Ref (*B-9*)

[g] Item 6 percentage applied to Item 5

[h] Item 7 doubled to cover two-way peak-period trips (7 to 9 AM and 4 to 6 PM), based on Ref (*B-6*) Total peak-period trips estimated at 80 percent of 24-hr trips to and from CBD, based on commuter-type transit system experience in New York City, Chicago, and Philadelphia

and an interim one-year operating subsidy would total another $2 million.

Benefits

Revenue-cost comparisons for 1975 were based on a $0.51 average fare, 5,783,500 annual person trips, 2,534,180 annual bus-miles, and an annual operating cost of $1.15 per bus-mile. These figures would produce $2,914,307 in annual expenses and $2,914,585 in annual revenues, resulting in a 1975 operating ratio of 0.988. Other benefits related to the busway were not identified in the analysis.

Significance

The proposed busway appears to achieve a reasonable balance between costs ($32,000,000) and patronage (19,300 riders per day) provided patronage forecasts are achieved. Implicit in the patronage forecasts are the continued growth of commercial floor space in downtown Dallas, limited road capacity, and a relatively constant downtown parking supply; all must continue in order to favor transit development

5. DAYTON PENN-CENTRAL BUSWAY

The Dayton (Ohio) Urban Corridor Program, one of eleven UMTA demonstration programs, outlines a CBD-oriented corridor plan that can be used to demonstrate methods for moving persons and vehicles efficiently. Significant goals were (a) to minimize disruption of existing residential, commercial, and public areas; (b) to reduce congestion in the region's most rapidly urbanizing corridor; and (c) to provide higher speeds, lower costs, and shorter travel times than can be obtained with the present transit system

Corridor Characteristics

The "Urban Corridor" includes portions of the municipalities of Dayton, Oakwood, Kettering, Moraine, and Centerville in Montgomery County. The Dayton central business district is located near the northwest corner of the corridor. The corridor's 1970 population of 181,000 comprised 25 percent of the 731,200 people living in the Montgomery-Greene County area.

The corridor is an area of high-income, single-family homes. Auto ownership rates are high, transit patronage is low, and highway capacity is generally adequate. Three interrelated area factors and one assumption underlie the recommended corridor program: The three factors are: (1) extremely high peak-period travel, (2) rapid growth that will require additional capacity, and (3) a seldom-used railroad spur right-of-way. The assumption is that any significant shift away from single-occupant auto use will be achieved only when these users are provided with an attractive alternative (*B-10*).

Corridor Improvement Concept

The proposed corridor transit system would include three types of coordinated bus systems, as follows·

1. A neighborhood collection and distribution component would serve 15 neighborhood areas, each with three subareas, operating as a demand-actuated system over

TABLE B-12

DEVELOPMENT COSTS, NORTH CENTRAL BUSWAY, DALLAS

	COSTS ($1,000)		
ITEM	PHASE 1	PHASE 2	TOTAL
Parking terminal·			
Land purchase	1,500	—	1,500
Construction	500	—	500
Engineering design	15	—	15
Busway construction, right-of-way and air rights	—	300	300
Roads and lighting (9.5 mi)	—	25,118	25,118
Ramps and passenger loading areas	—	1,843	1,843
Passenger stations	—	1,050	1,050
Engineering design	—	1,870	1,870
Subtotal, development costs	2,015	30,181	32,196
Purchase of 40 buses	—	1,920	1,920
Project administration	10	370	380
Operating subsidy (12 mo) until busway is completed	150	—	150
Evaluation of busway	—	40	40
Total	2,175	32,511	34,686

Source Ref (*B-7*)

flexible routes. The service would operate from suburban terminals, through the neighborhood areas, picking up patrons and terminating runs at the suburban terminals

2. A line-haul component would operate in main arterials and a planned busway using the right-of-way of a Penn-Central Railroad branch line. Ultimately it would terminate at a transportation center proposed for the Dayton CBD.

3. A CBD shuttle component on two routes would provide service to the major activity centers in the core area

Initially, the busway would be used by buses only. After this is amply tested, car pools would be permitted to use the facility during peak periods If the mixed-mode concept does not adversely affect the bus service, it would be continued. Only cars with three or more occupants would be permitted.

The improvements were recommended for development in three phases plus a fourth monitoring, long-range-potential phase. Phase I would include development of the busway and inauguration of neighborhood transit services. Phase II would involve busway operation, extension of the busway, reorientation of bus service to coordinate with the busway, initiation of control systems, and testing busway use by car pools during peak hours Phase III would include extension of the busway, addition of five neighborhood routes, and initiation of cross-town bus service between the Frigidaire complex in Moraine and the Wright-Patterson Air Force Base-Wright State University area

Design and Operating Features

The proposed busway would be approximately 7.5 miles long. It would extend from Alexandersville-Bellbrook Road on the south to Alberta and Caldwell Street near South Main Street, 1 mile south of the CBD. Distribution to the downtown terminal would be via Main Street.

The proposed busway design is shown in Figure B-9. The southern 2.7 miles would have a 6-ft shoulder, a 16-ft roadway, and a 10-ft separation of the pavement edge from the center line of a relocated rail track. The rest of the roadway would be 26 ft wide with the same shoulder and clearance widths. There would be about 15 cross streets, of which three are currently grade-separated. Three stations are planned along the route; each would provide bus and auto parking, and turnouts for line-haul buses. Busway design and operating criteria are summarized in Table B-13. Intersections along the busway would be controlled by coordinated traffic signals and variable-matrix signs.

Buses would preempt signals at cross streets so that they can continue to move along the busway at maximum possible speed. Each driver would actuate an electronic impulse that would initiate appropriate programmed action for the approaching signal and others interconnected with it

Buses would use most of the busway in both directions However, reversible-lane operation is anticipated on the southern part of the busway

Initially, one lane in each direction would meet travel demands from buses and car pools However, ultimately it may be necessary to operate the facility one-way north-

TABLE B-13

INTERSECTION DESIGN CRITERIA, PENN CENTRAL BUSWAY, DAYTON

		PHYSICAL CONSTRUCTION REQUIREMENTS				PROPOSED OPERATING CHARACTERISTICS	
		PAVEMENT WIDTH (FT)					
CROSSROAD	AT LINE HAUL STATION	CROSS-ROAD	BUSWAY	CURBS	R R TRACK ACTION REQUIRED	SIGN & SIGNAL CONTROL REQD [a]	VEHICLE ACCESS PERMITTED [b]
Alexandersville-Bellbrook Road [c]	56+75	19	16	None	Realigned	Signalized	Bus only
Whipp Road [c]	118+00	28	16	None	Realigned	Signalized	Bus only
Rahn Road	152+00	24	16	None	Realigned	Signalized	Bus only
Hempstead Road	200+20	28	16–26	None	Realigned	Signalized	Bus, auto pools
Stroop Road	228+80	50	26	None	Realigned	Signalized	Bus, auto pools
Berwin Avenue	243+00	20	26	None	Realigned	STOP signs	Bus, auto pools
Marshall Road [c]	263+00	—[d]	26	None	Realigned	Signalized	Bus, auto pools
Devon Avenue	276+50	22	26	None	Realigned	STOP signs	Bus, auto pools
Dorothy Lane [c]	291+35	55	26	None	Realigned	Signalized	Bus, auto pools
Wiltshire Blvd	333+40	30	26	Roll	Removed	STOP signs	Bus, auto pools
Shroyer Road	362+00	36	26	Roll	Removed	Signalized	Bus, auto pools
Patterson Road	381+05	22	—[e]	None	Removed	—	—
Irving Avenue [c]	414+40	30	26	Roll	Removed	Signalized	Bus, auto pools
Acacia Drive	421±00	20	26	Roll	Removed	STOP signs	Bus, auto pools
Alberta Street	454+55	30	26	Roll	Removed	Signalized	Bus, auto pools
Brown Street	459+80	40	26	Roll	Removed	Signalized	Bus, auto pools
South Main St.[c]	472+00	60	26	Roll	Removed	Signalized	Bus, auto pools

Source Ref (*B-10*)

[a] All intersections, whether sign or signal controlled, will be equipped with variable-matrix control signs

[b] Bus and auto pools include emergency vehicles and taxis, auto pools limited to peak-period use, other vehicles permitted throughout the day

[c] Bus access point proposed for use.

[d] To be rebuilt, existing Marshall Avenue 58 ft wide south of the intersection

[e] Bridge over tracks, 23 ft face to face of piers

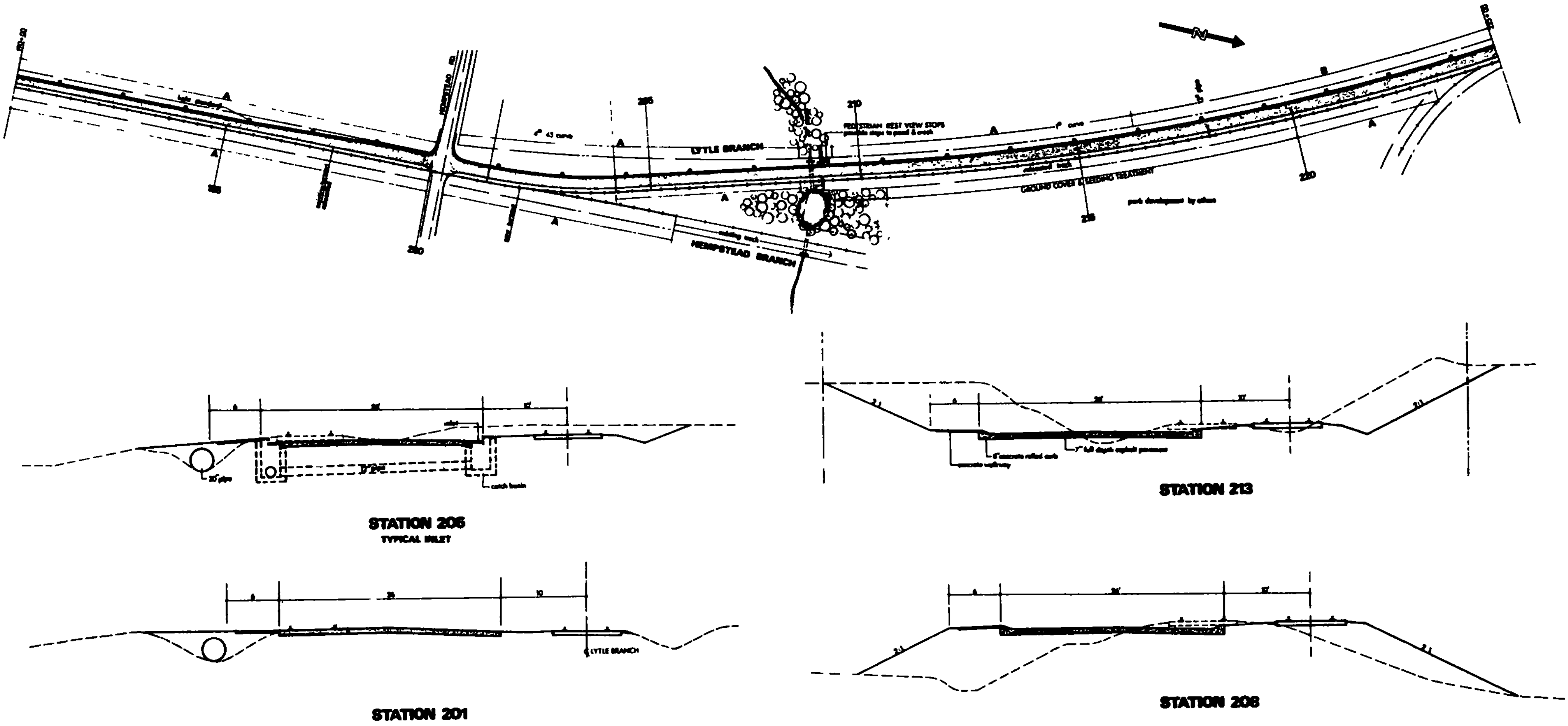


Figure B-9. Typical cross section, Penn Central Busway, Dayton, Ohio bound during AM peak periods and one-way southbound during PM peak periods This would require special signal systems along the busway and at its terminals.

Anticipated Use

After development of the second phase, about 92,000 persons would use the neighborhood collection and distribution system each week and 81,000 persons would ride the line-haul express buses After Phase III, the neighborhood system was estimated to carry 143,000 weekly passengers, of which 117,000 were line-haul passengers This corresponds to about 20,000 passengers per day on the line-haul system.

Patronage on the busway (6 AM-6 PM) would range from about 3,000 persons on the southern end to about 15,000 persons on the approach to the Dayton CBD Anticipated peak-period patronage with and without car pools is given in Table B-14. Maximum directional 3-hr volumes would approach 4,500 persons; or an estimated 2,200 persons per hour, if it is assumed that one-half of all travel is in the peak hour. Car pools would reduce the peak-period one-way bus ridership at the maximum load point by about 2,000 persons.

TABLE B-14

ANTICIPATED PATRONAGE, PENN CENTRAL BUSWAY, DAYTON[a]

	6–9 AM		3–6 PM	
SECTION	IN	OUT	IN	OUT
North	4,500 (1,810)	370	810	4,075 (2,190)
Central	3,950 (1,220)	550	1,050	3,700 (1,720)
South	725 (170)	300	310	810 (255)

Source Ref *(B-10)*

[a] Net reduction in transit riding for car pools given in parentheses

Costs

Estimated costs to develop the busway and related facilities total $4 8 million (Table B-15). Costs for the entire program, including bus operations, equipment purchase and lease, monitoring and evaluation, and marketing, would total $3,944,160 for Phase I, $2,712,720 for Phase II, and $1,641,400 for Phase III. Thus, total program costs would approximate $8 3 million.

Annual system costs and revenues based on anticipated gains in patronage are given in Table B-16. These figures imply an increase in patronage and an expansion of service.

Benefits

Benefits were computed for both users and nonusers.

Travel Time Savings

Computations assumed $3 00 per hour as the value of time and 250 days per year

1. Some 850 car pool drivers who would use the busway would save $0 02 per vehicle-mile and 3 min per trip. This corresponds to an annual savings of $114,750 based on a 3-mile trip.

2. About 450 car drivers who would make their trip in autos each carrying 1.2 occupants would save time, operating costs, and parking charges as a result of faster travel and car pooling. These annual savings were estimated at $265,000.

3 About 30,000 auto trips from 6 to 9 AM and 3 to 6 PM would save about 1 min, or the equivalent of $450,000. (This type of saving is, perhaps, questionable, as there is little evidence that express rapid transit improvements substantially reduce peak-hour road congestion.)

Corridor Land Development Potentials

There are 1,600 acres of vacant land and 80 acres of developable land within one-half mile of the proposed busway. This land could be developed more intensively if the

TABLE B-15

COST SUMMARY, PENN CENTRAL BUSWAY AND RELATED IMPROVEMENTS, DAYTON

	TOTAL COSTS ($)			
WORK ELEMENT	PHASE I	PHASE II	PHASE III	ALL PHASES
Construction	$2,575,600	$ 863,900	—	$3,439,500
Right-of-way acquisition	415,000	—	—	415,000
Other property acquisition	277,500	62,500	—	340,000
Operating equipment	54,100	539,800	—	593,900
Subtotal, physical development	$3,322,200	$1,466,200	—	$4,788,400
Operation, excluding buses	284,400	725,300	1,146,200	2,155,900
Buses	51,000	151,700	270,200	472,900
Administration	122,000	130,000	150,000	402,000
Monitoring and evaluation	150,560	189,520	25,000	365,080
Marketing	14,000	50,000	50,000	114,000
Total	$3,944,160	$2,712,720	$1,641,400	$8,298,280

Source Ref *(B-10)*

corridor projects were carried out Value of land and property was estimated at $268.5 million, and with the busway, $350 million. This represents a potential increase of $81 5 million in land value

Significance

The project has many innovative concepts. It was approved in concept by federal and local agencies as a demonstration project dealing with the conversion of a rail freight line to urban bus services. Design standards fulfill the area's specific needs, and the coordination of complementary transportation services is an integral part of the program

As with other busways, the detailed distribution of buses downtown is on-street. Costs of a proposed downtown transportation terminal are not included in the corridor program.

The concept of terminating express buses on the perimeter of downtown and requiring a transfer to local distribution facilities seems to conflict with the principles of (a) transit penetration of the core and (b) minimization of unnecessary transfers. Downtown Dayton has several wide streets; bus priority lanes, curbside or median, could afford a viable alternative.

The feasibility and benefit analyses are sensitive to patronage forecasts. Existing daily bus flows in the influence area of the proposed busway (Routes 5, 7, 12, A, B, C, and Kettering) approximate 10,000 persons adjacent to the CBD; most daily corridor bus passenger volumes are less than 5,000. Thus, the busway is predicated on attracting a large proportion of existing bus riders, as well as diverting motorists.

6. KANSAS CITY RAPID TRANSITWAY

The Kansas City (Mo.) Rapid Transitway is an outgrowth of a report (*B-12*) prepared for the Kansas City Area Transportation Authority in March 1968. This report explored ways of providing rapid public transportation for air passengers and airport employees from downtown Kansas City and from other important centers throughout the metropolitan area to the new Kansas City International (KCI) Airport. It investigated and analyzed the general suitability and economic aspects of various types of rapid transit facilities (bus, rail, monorail, etc), recommended a bus Rapid Transitway, and suggested a general corridor location.

The concept report was followed in 1969 by a preliminary engineering design report (*B-12*) for a Rapid Transitway, a two-lane express bus roadway that would extend from the CBD of Kansas City, Mo., to the Kansas City International Airport in Platte County.

Description

The proposed facility would be approximately 19 miles long (Fig. B-10). Its southern terminus would be at 12th Street in downtown Kansas City, where a temporary connection would be provided to 12th Street midway between Central Street and Broadway. Ultimately, a transit terminal building is contemplated in one of the blocks north of the Auditorium Plaza Garage. From the temporary terminal at 12th Street the route would extend due north, at midblock or alley locations, crossing the 6th Street Expressway at May Street, and continuing northerly across the CB&Q Railroad yards and Broadway. (Tentative alignment studies south of Tenth Street were developed It was recognized that the final location of the Transitway in this area depends on detailed location studies of a downtown terminal building; accordingly, a temporary terminal was analyzed for cost purposes. It was further recognized that a tunnel section might be required in the downtown area on the same alignment or under existing streets, depending on the location of the terminal building.) The Transitway would cross the Missouri River on a new bridge about 150 ft east of the existing Hannibal (CB&Q) Bridge It would follow the general alignment of an existing road from the northerly end of the existing Municipal Airport Terminal Building to the north end of the airfield. The Transitway would then continue northerly adjacent to US 169, crossing I-29 immediately west of the major interchange between US 169 and I-29.

TABLE B-16

ANNUAL SYSTEM COSTS AND REVENUES, URBAN CORRIDOR IMPROVEMENT PROGRAM, DAYTON

ITEM	PHASE I	PHASE II	PHASE III
Cost	$228,700	$1,199,604	$1,651,724
Revenue	$110,760	$1,478,880	$2,160,080
Ratio	0 48	1 23	1 31

Source Ref (*B-10*)

The route would veer northwesterly, entering Platte County near N.W. 56th Street, and follow the Line Creek valley. Continuing northwesterly along or parallel to the former Kansas City-St. Joseph Interurban rail line, the route would veer westerly as it nears the US 71 bypass. Continuing due westerly, the Transitway would cross I-29 and then parallel the entrance roadways to the KCI terminal complex.

The preliminary designs allow for interim access as demands for transportation to downtown Kansas City, Municipal Airport, and the future Kansas City International Airport increase. Intermediate access points to the Transitway could be provided at five locations on Harlem Road, US 71 in Riverside, Mo. 152 (Barry Road), and at a point immediately southeast of the I-29 and US 71 bypass interchange. No stations were contemplated along the route.

Design Standards

Recommended design standards conform to criteria established by the American Association of State Highway Officials and the Missouri Highway Department. Principal geometric design criteria are summarized in Table B-17. Functional plans utilized the "desirable" standards where

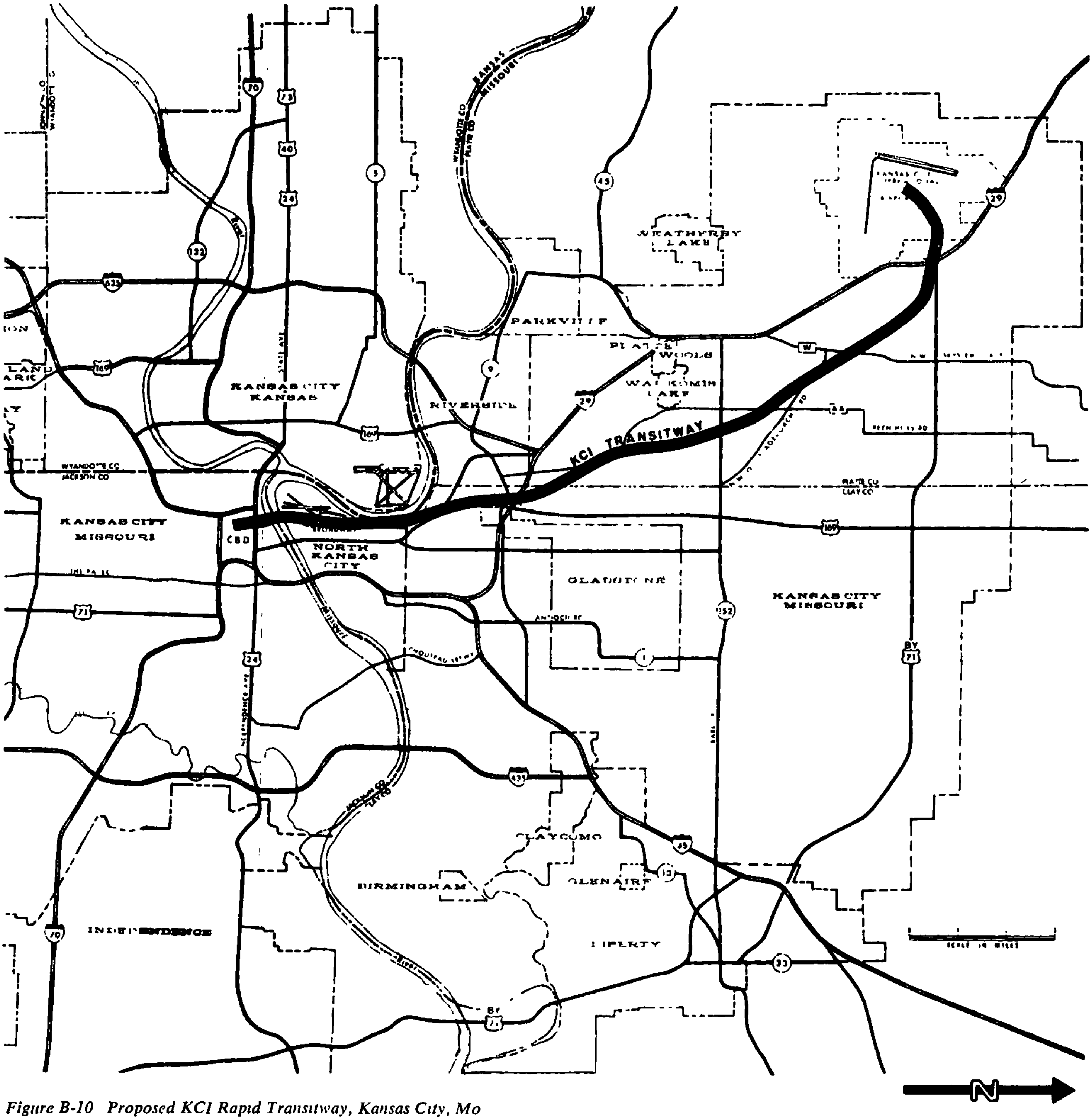


Figure B-10 Proposed KCI Rapid Transitway, Kansas City, Mo

economically feasible A 24-ft-wide road, with 6-ft shoulders on each side, was recommended.

Anticipated Use

Estimates of potential users were based on projections of air passengers. Air passenger origins and destinations in the Kansas City area were assumed as 89 percent of enplanements and deplanements. A factor of 1.26/365 was used to convert air passengers to daily passengers for a “busy day during a busy month”

Air passengers were divided into residents and nonresidents or transients. Nonresidents with origins and destinations in the CBD were considered the greatest potential users. Other nonresidents and residents were considered as potential transit passengers at different percentages depending on their Kansas City origins or destinations relative to the CBD.

The resulting passenger forecasts are given in Table B-18. It was estimated that 7,000 passengers would use the Transitway on a typical 1975 day, and 17,000 in 1990.

Projections considered only the use of the Rapid Transitway by air passengers. The roadway also has potential for use by a regular transit bus operation that serves employees at the airport and the TWA overhaul and administration facilities. (The Chicago O'Hare express bus provides a similar service over the Kennedy Expressway, operating on a basic 30-min headway.)

Cost Estimates

Cost estimates, summarized in Table B-19, were based on 1969 price levels. The initial development phase would cover the portion of the project from 12th Street to the airport perimeter; the ultimate phase would include a Transitway structure around the KCI Airport Entrance Loop Road and the terminal satellites. The initial phase would cost about $23.6 million, or about $1.5 million per mile; the "ultimate" phase would add another $5.8 million.

Significance

The concept is inactive (October 1972). The problems of maintaining the existing bus service appear to have taken precedence over the development of a largely single-purpose 19-mile busway through suburban and rural areas.

TABLE B-17

DESIGN CRITERIA, KCI RAPID TRANSITWAY, KANSAS CITY

ITEM	URBAN	RURAL
Design speed		
(a) Desirable	50 mph	70 mph
(b) Minimum	35 mph [a]	50 mph
Horizontal alignment·		
(a) Desirable max	7°30′	3°
(b) Absolute max.	18°	7°30′
Vertical alignment.		
(a) Desirable max	5 0%	3 0%
(b) Absolute max	7.0%	5.0%
(c) Desirable *K*, crest	85	255
(d) Minimum *K*, crest	42	85
(e) Desirable *K*, sag	75	145
(f) Minimum *K*, sag	20	75
(g) Desirable min. grade	0 5% [b]	0.0%
(h) Absolute min grade	0.35% [b]	0 0%
Superelevation.		
(a) Maximum	0 08 ft/ft	0 08 ft/ft
Vertical clearance.		
(a) Over Interstate	16′–6″	16′–6″
(b) Over local and state rts.	14′–6″	14′–6″
(c) Over railroads	23′–0″	23′–0″
Horizontal clearance		
Interstate	30′ [c]	30′ [c]
Ramps	6′ rt –4′ lt [d]	6′ rt –4′ lt. [d]
Road width·		
Pavement	24′	24′
Shoulders	6′	6′

Source Ref (*B-12*)

[a] At terminals [b] Curbed [c] State roads, current state standards

[d] City streets, current city standards

7. LOS ANGELES BUSWAY AND RAMP METERING

The Southern California Rapid Transit District (SCRTD) operates a fleet of about 1,500 buses. Daily patronage remained constant over the last five years at about 180 million, or approximately 720,000 riders per day. Of this total, 24,000 passengers (about 3 percent) use buses operating on the Harbor, Hollywood, San Diego, Golden State, San Bernardino, Santa Ana, Riverside, and Long Beach Freeways Service frequencies of freeway buses during rush hours generally range from 10 to 60 min, compared to 1 to 3 min on downtown streets.

Major freeways carry more than 200,000 vehicles per day In an attempt to increase freeway person-capacity and movement efficiency, the California Division of Highways has collaborated closely with the City of Los Angeles and the Southern California Rapid Transit District (and its predecessors, the Los Angeles Metropolitan Transit Authority and Pacific Electric) for many years in providing express bus operations on freeways. Bus turnouts were incorporated into the original design of the Hollywood Freeway in 1946; bus bypasses were subsequently provided at metered on-ramps along the Harbor Freeway; and con-

TABLE B-18

PASSENGER FORECASTS, KCI RAPID TRANSITWAY, KANSAS CITY

ITEM	1975	1980	1985	1990
Annual KCI air passengers.				
Enplanements and deplanements	7,586,000	12,804,000	17,000,000	20,000,000
Origin and destination	6,800,000	11,400,000	15,100,000	17,800,000
Daily KCI air passengers				
Origin and destination [a]	23,500	39,400	52,200	61,500
Transitway passengers:				
Daily	7,000	11,500	14,500	71,000
Annual	2,020,000	3,318,000	4,184,000	4,905,000

Source Ref (*B-12*)

[a] Busy day

TABLE B-19

COST ESTIMATES, KCI RAPID TRANSITWAY, KANSAS CITY

	ESTIMATED COST ($1,000)		
ITEM	INITIAL PHASE	ULTIMATE PHASE	TOTAL
Roadway construction	6,354	555	6,909
Bridges	11,589	4,460	16,049
Engineering and contingencies	2,700	800	3,500
Total construction cost	20,643	5,815	26,458
Right-of-way, including acquisition [a]	2,992	—	2,992
Total estimated project cost [a]	$23,635	$5,815	$29,450

Source Ref *(B-12)*

[a] Public right-of-way valued at $1,600,000 not included

struction was initiated on the 11-mile San Bernardino Busway in January 1972 Additional freeway ramps will be metered as part of an areawide surveillance-control system, and extensive improvement proposals are recommended for the Santa Ana Freeway corridor. Characteristics of principal freeway-related bus priority treatments are summarized in Table B-20.

The transportation corridor concept is not new in California Joint use of rights-of-way for freeways and rapid transit was tried after World War II in the Cahuenga Pass section of the Hollywood Freeway An attempt to extend the rail facility in the median southeasterly to connect with the subway line at Glendale Boulevard failed because the Division of Highways was legally prohibited from acquiring land for rail facilities, and Pacific Electric could not afford the additional investment. Progressive abandonment of rail services followed, culminating in closure of the 20-mile Long Beach Line in 1961.

SAN BERNARDINO BUSWAY

The San Bernardino Freeway Busway, under construction, is being coordinated with widening of the freeway from six to ten lanes. It occupies the Pacific Electric interurban right-of-way for its entire 11-mile length from El Monte to Covina, Pomona, San Bernardino, and Los Angeles. It follows the easterly segment of the "Backbone" rapid transit route, recommended by the LAMTA in 1958. The former interurban rail service was discontinued when the freeway was built, and express bus service was introduced with bus stops on the shoulder of the freeway at several points, plus a bus turnout at Eastern Avenue (near California State College at Los Angeles). Although both transit buses and private cars benefited from the freeway, the relative advantages of the rail service (its private right-of-way with priority at most grade crossings) were lost. This event, combined with growth in car ownership and income, and dispersal of employment and commercial activities, led to reductions in transit use in the corridor.

Description

The location of the San Bernardino Busway in the metropolitan area is shown in Figure B-11. The busway extends on its own right-of-way for 11 miles westerly from El Monte. A further 1½-mile length uses the Santa Ana Freeway (a short 10-lane section crossing the Los Angeles River), and the balance traverses local streets. Consideration is being given to the exclusive use of curb lanes on these streets for buses (and right turns for cars) where applicable, but the plans have not been finalized. About 6 miles of the 17-mile bus operation will traverse surface streets

The general plan of the busway and illustrative cross-sections are shown in Figure B-12.

1. A 6.6-mile section of busway is being located in the median between the Long Beach Freeway and El Monte. In this section, a 20-ft railroad opening will be maintained in the median, flanked on each side by a barrier wall, a

TABLE B-20

FREEWAY-RELATED BUS PRIORITY TREATMENTS, LOS ANGELES

TREATMENT	STATUS	DESCRIPTION	EVALUATION
San Bernardino Freeway Busway	Under construction, 1972	11-mile exclusive bus roadway, partly in freeway median	Does not penetrate CBD, parallels portion of freeway being widened. Effectiveness in improving bus speeds unknown at present. Increase from 18 mph to 36 mph in peaks is predicted for El Monte-L.A run.
Bus lanes at metered ramps, Harbor and Hollywood Freeways	In operation	Striped lanes for buses only bypassing queues at on-ramps	Successful in alleviating adverse impact of ramp metering on bus operations. Otherwise buses, which leave freeway to make intermediate stops, would be seriously delayed in queues at each metered ramp No discernable over-all improvement in bus speeds as a result of ramp metering.
Bus turnouts on freeways	In operation	Special bus-only ramps with loading bays and platforms at freeway level, acceleration and deceleration lanes.	One bus turnout, in median of Hollywood Freeway at Vermont, for buses entering the fast lane, is to be rebuilt Few passengers board at the turnouts relative to the number riding through on the bus. Comparison of passenger benefits and costs could lead to their elimination.

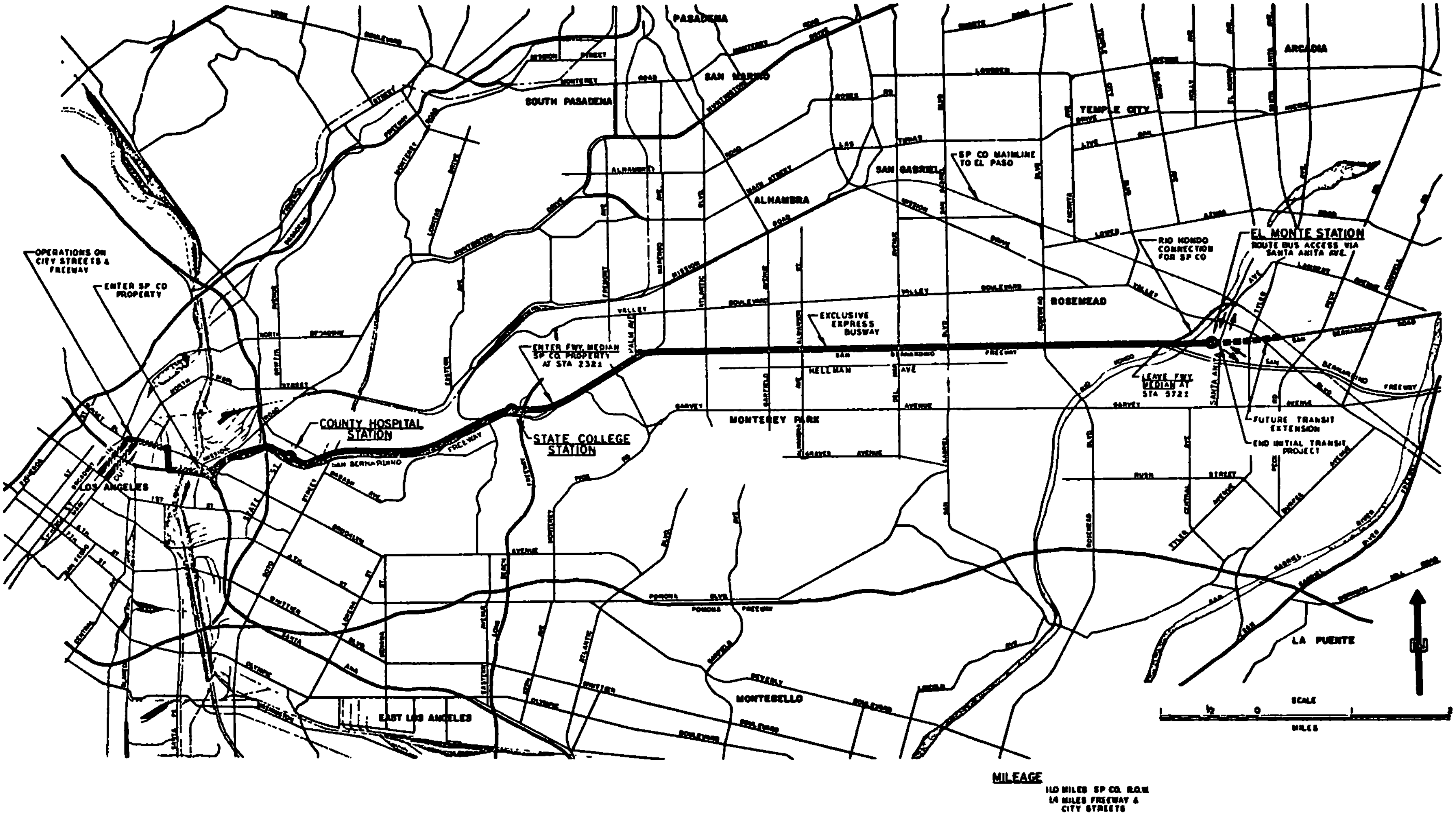


Figure B-11 Location of San Bernardino Busway, Los Angeles, Calif.

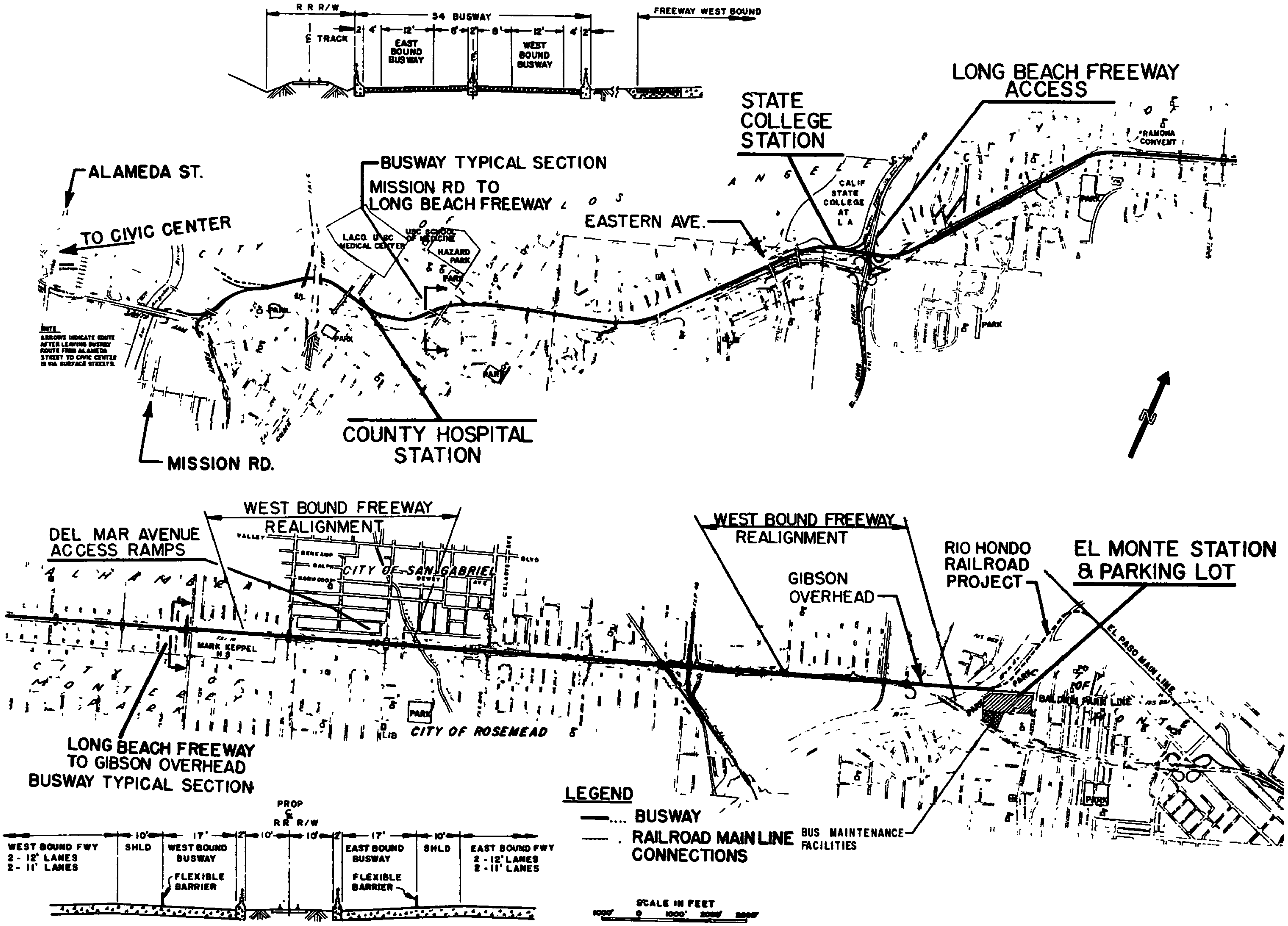


Figure B-12. Functional plan, San Bernardino Busway, Los Angeles, Calif.

17-ft busway, a 3-ft flexible post spaced every 50 ft, a 10-ft common shoulder, and then the four freeway lanes.

2. A 3 8-mile section adjacent to the freeway between Mission Road and the Long Beach Freeway will consist of a 54-ft two-way busway with 12-ft lanes, an 8-ft right shoulder, and a 4-ft left shoulder in each direction separated by a barrier.

From Mission Road, just north of the Santa Ana/San Bernardino Freeway interchange, the busway runs easterly to California State University at Los Angeles, located between the freeway and the freight line of the Southern Pacific. Contra-flow operations will prevail in this section. This transposed operation provides for a slip ramp from the westbound busway onto the ramp from the westbound San Bernardino Freeway to the southbound Santa Ana Freeway, thereby permitting buses to reach downtown Los Angeles via the First Street or Fourth Street Bridges, as well as the freeway. Also, the westbound busway exits into Mission Road directly across from the westbound Mission Road on-ramp on the Santa Ana Freeway. One 12-ft lane is provided in each direction, with a 4-ft shoulder to the left and an 8-ft shoulder on the right These shoulders are separated by a median barrier.

A station with an island platform is being provided at Kingston Avenue near the Los Angeles County/USC Medical Center. Stairs and an elevator (for infirm or disabled persons) will connect the platform with an overhead mezzanine, and a minibus service will connect the station with County Hospital and the University of Southern California School of Medicine No parking facilities are being provided at this station.

Just west of California State College, the westbound bus roadway overcrosses both the Southern Pacific track and the eastbound bus roadways (Fig B-13) A split-level station is being built at "Cal State L.A." The westbound platform is considerably above the eastbound platform, which is at track level From the overbridge connecting both platforms, a walkway leads further up the bank to the College campus. No parking is being provided at this station; however, there may be a feeder bus connection.

From the College easterly to Gibson, overhead, normal right-hand operation of buses will prevail The railroad track will occupy the center of the median, with a 17-ft bus lane on either side, A 10-ft paved shoulder on the inside of the freeway will be used by buses in an emergency by crossing a flexible barrier strip (see Fig. B-14).

Ramps are provided to and from the Long Beach Freeway so that Valley Boulevard buses from such locations as El Sereno and Alhambra can enter and leave the busway at that point. Additional access ramps are being provided at Del Mar Avenue for use by buses serving San Gabriel, Rosemead, San Marino, Temple City, and South San Gabriel; up to 4,000 riders a day are expected to use this point. The westbound freeway lanes will be relocated and the existing bridge over the Southern Pacific tracks will be rebuilt to allow the bus lanes to exit from the median. A further grade separation will take the track under the westbound busway onto the easterly bank of the Rio Hondo River, whence it will join the Los Angeles-El Paso main line. The busway then continues straight east to El Monte Station.

A circular island platform at the El Monte Station will provide for easy transfer between feeder lines, as well as trunk line express buses using the busway (Fig. B-15). Buses will gain access to the station via Santa Anita Boulevard, from the freeway, and from surrounding areas. This portion of the busway will serve not only El Monte, but also West Covina, La Puente, Arcadia, Pomona, and San Bernardino As at the County-USC Medical Center and "Cal State L.A.," elevators will be provided for the infirm or handicapped to reach platform level About 400 parking spaces are being provided at El Monte initially, with future expansion to 1,200-1,400 spaces.

The buses using the Mission Road ramps of the Santa Ana Freeway will benefit from the fact that the freeway adds and drops a lane at this point, giving it five lanes each way over the Los Angeles River. The fifth lane is added eastbound and dropped westbound at Vignes Street, and the fourth lane is added and dropped at Alameda Street. Because of circuitous connections to downtown from Vignes Street, it is planned to have buses use the Alameda Street ramps to enter and leave the Santa Ana Freeway west of the Los Angeles River. From the Alameda Street off-ramp near Union Station, buses would use First and Temple Streets, the Main/Spring one-way couplet, Seventh Street and (probably) Hope Street to reach Wilshire Boulevard as far as Western Avenue, thus serving the mid-Wilshire employment center as well as downtown Los Angeles. Bus lanes (presumably shared with right turns) would be provided on these streets to expedite operations.

Railroad Relocation

To enable proper functioning of the El Monte Terminal, to minimize delays, and to increase passenger safety on buses passing through El Monte, a new railroad connection is being constructed between the SPTC's existing Baldwin Park Line and its existing El Paso main line. This new connection is being constructed along the easterly bank of the Rio Hondo River.

This location was selected as the best route for this new connection because it entails approximately $0.5 million less right-of-way and construction cost. It uses mostly existing railroad and existing flood control (public) property, and requires less private property, all commercial; no residential units are involved A minor portion will be alongside Pioneer Park (devoted primarily to baseball fields), but the railroad track will be on a viaduct, about 20 to 30 ft above grade and outside the playing field fence. This will have less adverse effect on the environment than a mainline track along the present at-grade location, which passes through the heart of the city.

North of the park, the relocation continues along the east bank of the Rio Hondo River, crossing over Valley Boulevard and Santa Anita Avenue before connecting to the Southern Pacific El Paso main line.

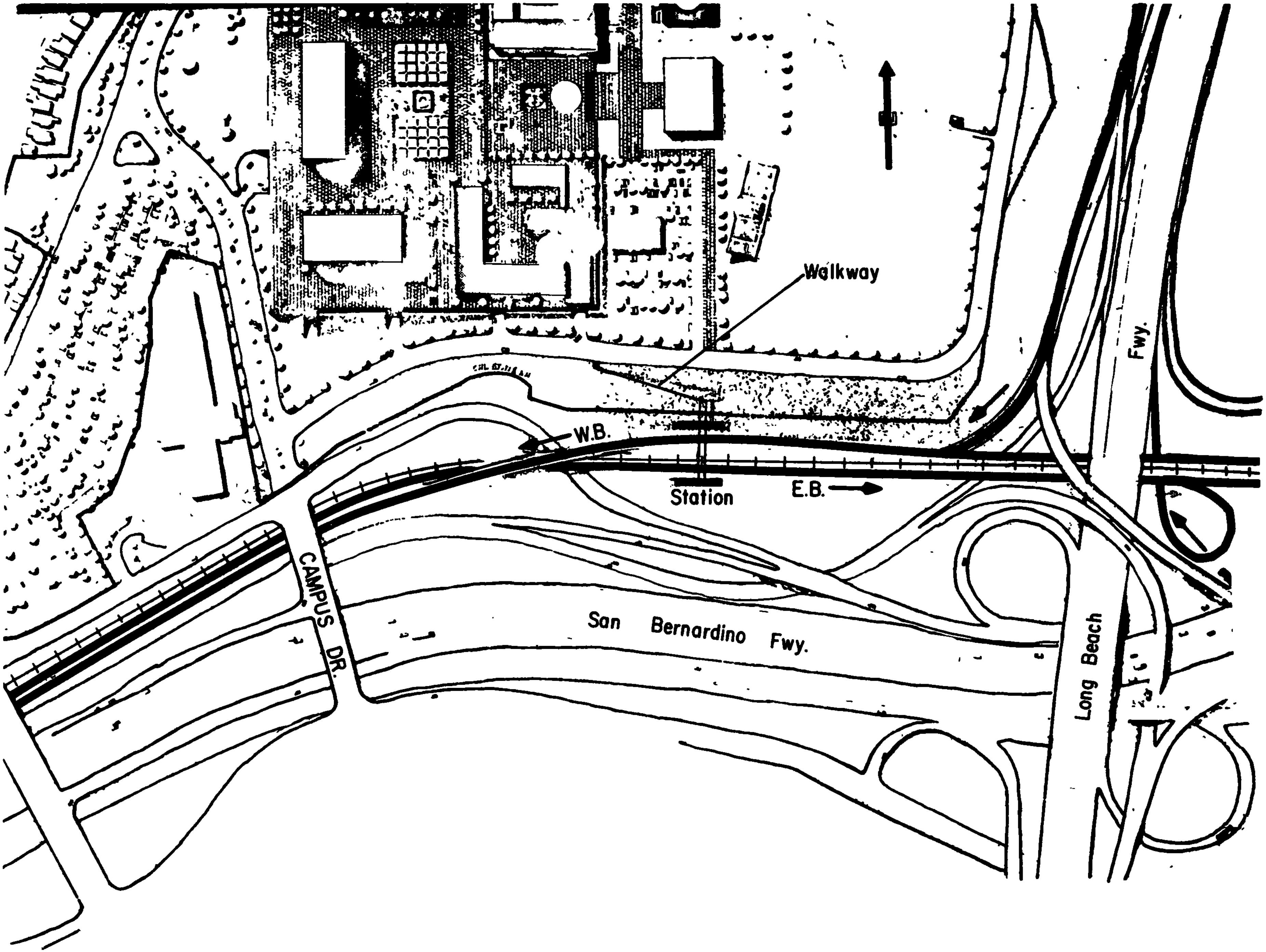


Figure B-13 California State College bus station, San Bernardino Busway, Los Angeles, Calif

Operations and Use

Phase 1 of the demonstration (the first two years) will involve exclusive bus use of the busway Phase 2 will attempt to incorporate car pool automobiles, as well as buses, for at least a year thereafter In the third year, automobiles may be metered into the bus lanes at the El Monte end, at the midpoint station, and just easterly of the Long Beach Freeway up to the point where the autos fill the gaps between buses but not to the extent where they cause any significant reduction in bus speeds. (Prior to the end of the third year, federal and state agencies will reach a decision as to the method of operation during the last two years of the five-year demonstration period.)

Service on seven bus lines will be improved in the San Gabriel Valley-Pomona area. Three lines will be routed into the busway for a portion of their trips. Nine new "Busway Flyer" lines will be added, originating in El Monte, West Covina, La Puente, Arcadia, Temple City, and San Marino. A seat is planned for every passenger "Super Flyer" buses from Pomona and San Bernardino, and similar expresses, will bypass all intermediate stations, and possibly El Monte. Other routes will stop at El Monte, Cal State L.A., and County-USC Medical Center.

Buses will reach maximum speeds of 65 mph in the section east of the Long Beach Freeway and 60 mph west of the Cal State L A overcrossing. Headways are planned at about 45 sec in peak periods (80 buses per hour). A reduction in scheduled times between El Monte and downtown Los Angeles of 19 to 24 min or more is anticipated; present peak-hour schedules are 37 min in the morning and 42 min in the evening. The busway is expected to reduce these to 18 min. Average speeds would be increased from 18 mph present evening peak schedule to 42 mph, with accompanying improvements in user service and driver and vehicle productivity. These improvements apply for trips using the whole length of the busway between downtown Los Angeles (RTD Terminal) and El Monte Station. Proportionately smaller time savings would be experienced by buses using the Del Mar and Long Beach Freeway ramps

Street operation would also be accelerated by exclusive bus lanes. Bus stops will be at about two-block intervals through the central area, and at key cross streets on Wilshire Boulevard. Assuming adequate road capacity, these bus lanes could assure an average speed of 10 to 12 mph This speed will be limited by the need (1) to make stops with long dwell times at intensively used downtown locations and (2) to negotiate signal-controlled at-grade intersections. At several of these, left-turn movements will require buses to weave across traffic from the right to left curbs. Even with bus preemption of traffic signals, interference between buses and other traffic is expected.

Anticipated Traffic

The busway is expected to increase public transit use in the corridor from 7,000 passenger trips per day (3,500 round-trip riders) to 17,000 (8,500 round trips), with the additional 5,000 riders (10,000 bus passenger trips) being diverted from private cars. Of the 8,500 trips in each direction, 4,000 are expected to occur during the peak

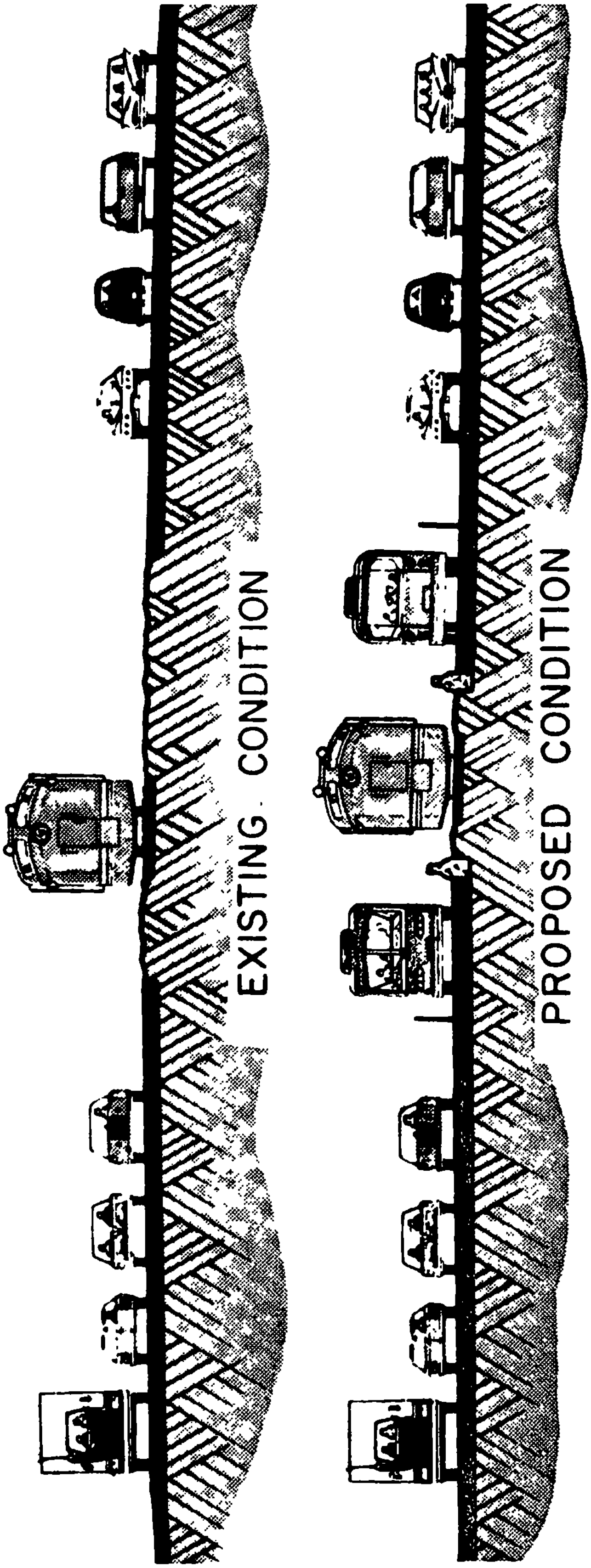


Figure B-14. Typical section straddling railroad, San Bernardino Busway between Long Beach Freeway and El Monte Station, Los Angeles, Calif.

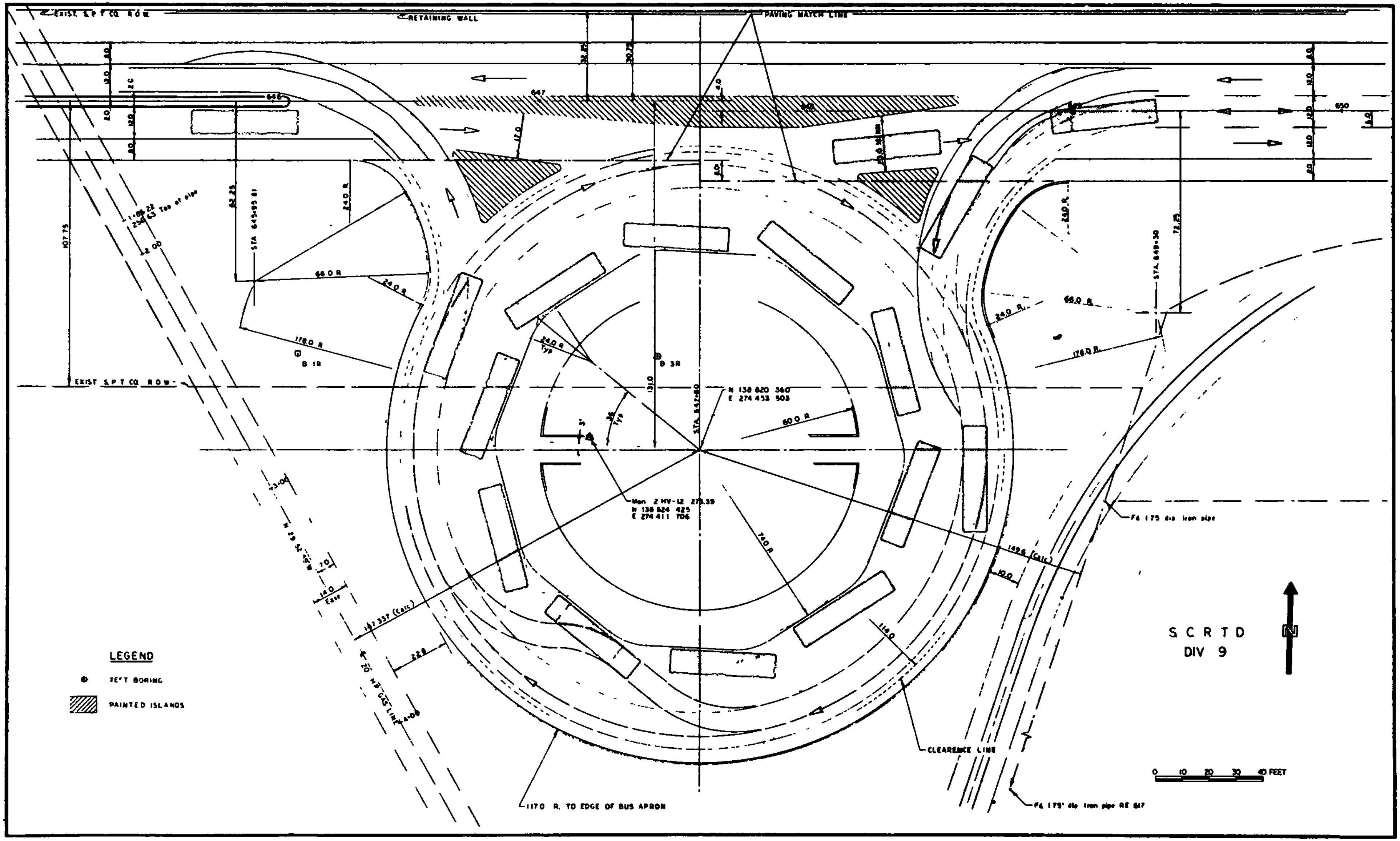


Figure B-15. El Monte Station, San Bernardino Busway, Los Angeles, Calif.

hour. (Thus, one bus lane would carry as many people as two lanes of cars.) Considering the projected growth of downtown Los Angeles and potential population shifts stimulated by the busway, these forecasts appear reasonable, although they may not be achieved immediately after opening.

Capacity Implications

The busway should be able to accommodate predicted volumes, because about 80 buses per hour will use the busway in the direction of maximum flow (perhaps 50 during the peak 20 min). With some buses bypassing stations, this volume can be achieved without delay. Without such bypassing, congestion and queues might occur at stations, although this is unlikely. However, problems may be experienced in bus operation on surface streets, particularly on Main and Spring Streets, which both already carry more than 100 buses per hour in the peak hour. (It may be desirable to reroute certain busway lines via Olive Street instead of Spring and Main, or use "back" streets to reach the RTD station, as did the Pacific Electric Interurban cars.) No capacity problems are anticipated on Seventh Street or Wilshire Boulevard, assuming that bus lanes are provided.

Parallel Freeway Improvements

Concurrently with the busway construction, the San Bernardino Freeway is being widened to about 10 lanes between I-5 (Golden State Freeway) and the Long Beach Freeway. This widening will alleviate some of the congestion now experienced in this area. However, capacity limitations on the San Bernardino Freeway west of I-5, and on the Los Angeles River Bridges (First, Fourth, and Whittier Boulevard) will limit the number of downtown-oriented trips that can be accommodated without queuing in peak hours. Queuing can also be expected eastbound where the freeway reduces to eight lanes east of the Long Beach Freeway interchange.

Costs

Costs of the busway are estimated at $53 million for right-of-way, construction, and equipment, including the purchase of 100 new buses Cost participation is expected to entail (a) Federal Highway Administration and state highway funds, $40.5 million; (b) Urban Mass Transportation capital grant funds, $8.6 million; (c) Southern California Rapid Transit District, $3.6 million; and (d) Southern Pacific Transportation Company, $0 3 million.

Benefits

Buses using the busway will make the trip from El Monte to downtown in 18 min, as compared with 35 to 45 min at present. Accordingly, 8,000 peak-hour persons using the busway each day probably will save an average of 10 min each. This results in annual time savings to users of approximately $1 million In addition, the buses will provide direct delivery to the downtown core without requiring parking This is an important consideration, as the city expects downtown floor space to increase from about 65 to 85 million square feet in the next decade.

Significance

The project, of which 8 miles are scheduled for opening by late 1972, will provide an important test of busway operation in an ultimate rail corridor All prior Southern California Rapid Transit District plans called for the use of this corridor for transit purposes because (1) there is a demand for transit service between the San Gabriel Valley and the Los Angeles central district and the Wilshire area; (2) it is the only corridor in the metropolitan region where there is sufficient grade-separated right-of-way that can be converted to transit use at minimum cost. Travel pattern studies, however, indicate that this corridor generates fewer CBD trips than other corridors. Conceivably, successful operation could encourage more CBD workers to locate in this corridor.

The busway is designed to high standards, it will be the widest busway in the United States. The standards were established by the California Division of Highways to allow for 70-mph operations by buses and multiple-occupancy vehicles. They also result from the busways' proximity to an active railway track.

RAMP METERING

The California Department of Public Works uses a lane density of 40 to 50 vehicles per mile as a basis for ramp metering. As of December 1971, Los Angeles metering projects were mainly limited to ramps on the Hollywood and Harbor Freeways. Additional metering projects have been proposed on the Santa Ana Freeway. An areawide electronic surveillance and traffic-responsive ramp control measure is also proposed for 42 miles and 56 freeway interchanges along the Santa Monica, San Diego, and Harbor Freeways

Existing Bus Priority Ramps

Ramp metering along the Harbor and Hollywood Freeways was initially installed to counteract effects of grade changes and lane drop-offs. Metering is by means of fixed-time traffic signals, ramps are painted for a single lane of cars, and buses are allowed to bypass the car lanes over the paint markings (Fig B-16) Peak-hour use of the ramps ranges from 15 to 18 buses per hour (Table B-21).

At the metered ramps, "queue-jumping" by the buses is accepted by motorists. There are no enforcement problems, and no significant protest has materialized. If the queues build up beyond the striping, buses are blocked by cars On the Harbor Freeway, express buses leave the freeway, make a stop, and return at each major street interchange. It is these buses that use the special lanes at the metered ramps.

Although ramp metering is reported to have raised freeway speeds to 40 mph during the peak, SCRTD has not observed any resulting improvement in the over-all speeds of freeway buses. Either the time is lost in congestion elsewhere on the freeway or speed improvements from metering have been offset by increased traffic. It has not been possible to reduce the number of buses to meet scheduled

Figure B-16. Example of bus priority treatment at metered freeway ramps, Los Angeles, Calif.

requirements. This is largely because many buses make only one trip during the peak and cannot return in time for a second trip, even with improved freeway speeds.

SCRTD did not observe any bus patronage increases that can be ascribed to ramp metering. They have noticed an increase in traffic on Cal 37 to Carson, but this may result from changed development patterns.

Santa Ana Corridor

A study of ramp metering along the Santa Ana Freeway was completed as part of the Urban Corridor Project (*B-13*) This radial freeway corridor is a strip approximately 35 miles long and 6 miles wide from the Los Angeles CBD to the Newport Freeway. Ten of 71 projects are on freeways and attempt to increase capacity through widening, restriping, and ramp controls. The arterial street improvements would provide alternate routes that would then make freeway ramp controls feasible. Preferential treatments would be provided for buses at metered freeway ramps (Fig. B-17). Two projects involve fringe parking and new freeway bus stops, a third calls for new peak-hour commuter service from Buena Park-Norwalk to the Los Angeles central district.

The 71 projects were estimated to cost $17.8 million. They would be implemented between 1971 and 1973. It was anticipated that the improvements could reduce typical morning inbound and evening outbound peak-hour travel time between the San Gabriel River Freeway (I-605) and the Los Angeles CBD from 45 to 20 min.

BUS TURNOUTS ON FREEWAYS

Bus turnouts were provided at three locations on the Hollywood Freeway, at Eastern Avenue on the San Bernardino Freeway, and at two locations on the Harbor Freeway to facilitate bus operations on each route. In addition, shoulder bus stops were provided on the San Bernardino Freeway, and bus stops were constructed on the interchange ramps of the Harbor Freeway. Table B-22 summarizes information on the types and use of these stops. Only four stops, three of them on the Hollywood Freeway, accommodate more than 100 passengers per day. Patronage of freeway bus stops is generally light. In the Los Angeles area, considerable use is made of three stops on the Hollywood Freeway; but when their construction cost ($900,000) is considered, they appear difficult to justify Use of stops on the Harbor Freeway is reported to be poor, except at Vernon Avenue, a major transfer point. A 1960 survey showed that 5 percent of all bus passengers on the Hollywood Freeway and 7 percent on the Harbor Freeway actually used the stops.

Long walking distances to stops, and limited (or no) parking may contribute to light use. This suggests that street-level loading with bus priority at metered ramps has a more feasible option.

8. MILWAUKEE TRANSITWAY PLAN

Milwaukee's 1990 Bus Rapid Transit System-Transitway Plan is an outgrowth of a Mass Transportation Technical Study initiated in 1968.* The recommended 1990 plan includes 107 miles of express bus routes over the freeway system and an 8-mile east-west transitway

TABLE B-21

EXISTING FREEWAY RAMP METERING LOCATIONS, LOS ANGELES

FREEWAY	DIREC-TION	LOCATION	BUS BYPASS LANE	PEAK-HOUR USE BUS ROUTES	TRIPS
Hollywood	North	Wilton/Sunset	No	—	—
	South	Vermont Ave.	No	2	18
	South	Silverlake Blvd	No	—	—
	South	Glendale Blvd	No	—	—
Harbor	South	37th St	Yes	3	15
	South	Santa Barbara Ave.[a]	No	3	15
	South	Vernon Ave	Yes	3	15
	South	Slauson Ave	No	—	—
	South	Gage Ave	No	—	—
	South	Florence Ave.	No	—	—

Source Southern California Rapid Transit District, 1971

[a] Buses have exclusive use of on-ramp during metering period (4 00-6 00 PM)

Current Transit Operations and Travel Patterns

Local transit service in Milwaukee County is provided by the Milwaukee Suburban Transport Corporation (MSTC), a privately owned and operated company. The company employed about 1,500 people in 1969; owned approximately 590 vehicles, of which 540 were normally in service during peak periods, operated 935 round-trip route-miles; and carried 71.5 million revenue passengers. The average age of the bus fleet was 9 years.

Between 1950 and 1970, population in Milwaukee County increased 21 percent, from 871,000 to 1,054,000 persons. During this same period, transit fares increased from $0.10 to $0.40, and annual revenue passengers dropped from 215 to 63 million. Driver wage rates in 1971 approximated $5.73 per hour. Although the company provides better-than-average service, it has been caught in the cost-increase patronage-decline spiral.

In 1963 there were approximately 207,000 trips to or from the Milwaukee CBD, of which about one-half were for work purposes. About one-half of the work trips are made by transit (Table B-23). Trips to or from the Milwaukee CBD in 1990 were estimated at 263,000, of which 125,000 would be by transit. With the proposed bus rapid transit system, 121,000 trips would be by transit, of which 77,000 would be work trips.

Travel patterns of 1964 central area person-trips are shown in Figure B-18. Trips generally are oriented to the northwest and north and are less than 4 miles long. Central

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* The technical study includes specific technical reports, such as. *Milwaukee Central Area Transit Distribution System, East-West Transitway Location, Evaluation of Alternative Transit Equipment Systems for Milwaukee County, Analysis of Milwaukee's Transit Service, Urban Design Considerations in Transitway Development, Transit System Development Objectives, Principles and Standards;* and *General Criteria for Transitway Design* The summary report, *Milwaukee Area Transit Plan* (*B-15*) is the basic source document for the discussion herein

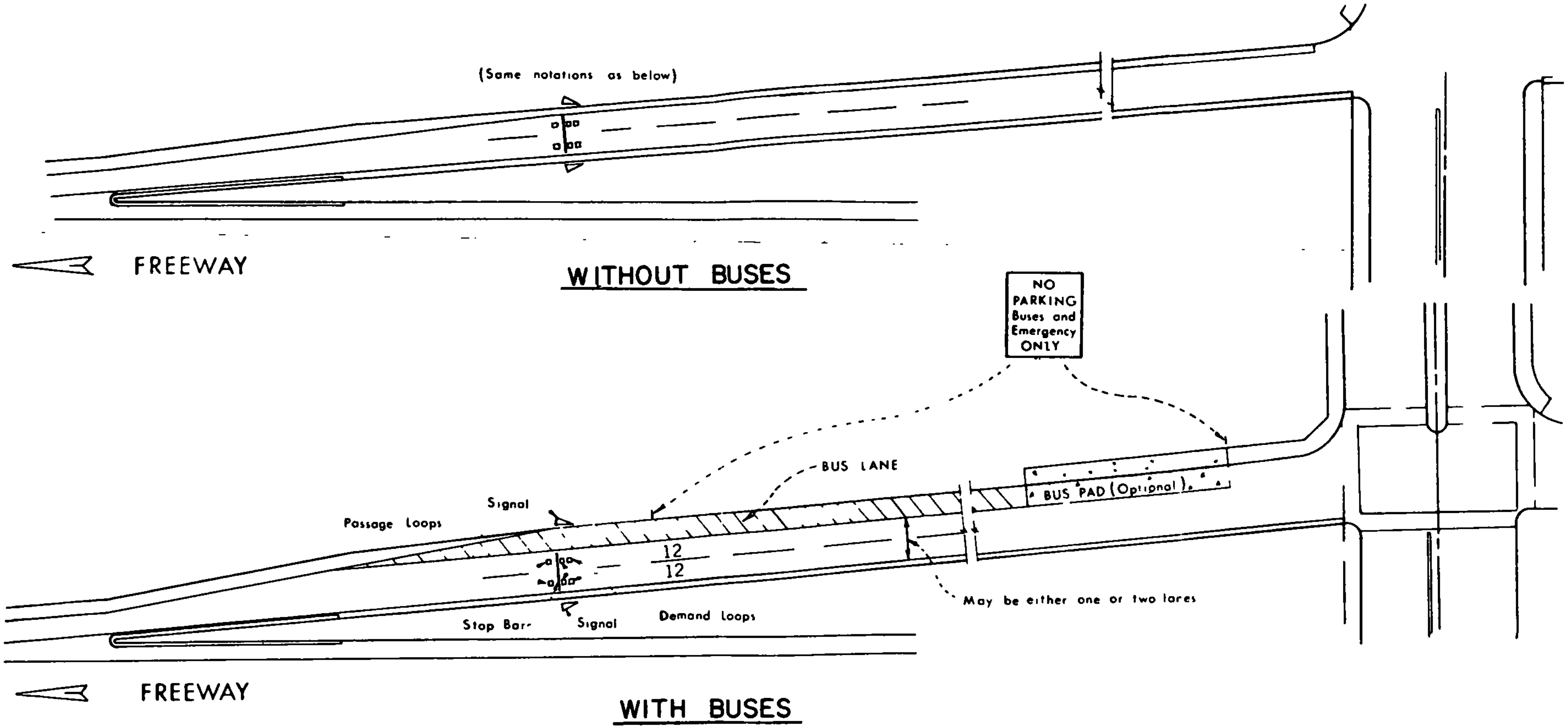


Figure B-17 Ramp metering concept, Santa Ana Freeway, Los Angeles, Calif

TABLE B-22

BUS STOPS ON FREEWAYS, LOS ANGELES

FREEWAY	LOCATION	TYPE	ESTIMATED DAILY BUS PASSENGERS [a]
Hollywood	Vermont Ave	Turnout [b]	300
Harbor	Vernon Ave	Ramp	275
Hollywood	Western Ave	Turnout	150
Hollywood	Alvarado St.	Turnout	120
Harbor	Jefferson Blvd	Ramp	75
San Bernardino	Vincent Ave	Shoulder	50
San Bernardino	Citrus Ave	Shoulder	50
San Bernardino	Azuza Ave.	Shoulder	35
Harbor	Santa Barbara Blvd	Ramp	35
San Bernardino	Eastern Ave	Turnout [c]	30
San Bernardino	Pacific Ave	Shoulder	30
San Bernardino	Puente Ave	Shoulder	25
Harbor	Slauson Ave	Ramp	5

[a] Estimated daily volumes based on peak-period counts cited by Wilson (*B-14*)

[b] Under reconstruction to eliminate exit into fast lane

[c] Demolished and replaced by station on busway (Fig B-13)

TABLE B-23

DAILY PERSON TRIPS TO OR FROM CENTRAL BUSINESS DISTRICT, MILWAUKEE

TRIP TYPE	1963	1990	INCREASE (%)
Home-based work	103,600	125,600	21
Home-based shopping	22,600	37,600	66
Home-based other	50,000	62,800	25
Nonhome-based	31,000	37,600	21
Total	207,200	263,600	27
Work trips by transit	52,000 [a]	77,400	49

Source Ref (*B-16*)

[a] Estimated at 50 percent of all work trips

area travel does, however, include a comparatively high proportion of relatively long trips that could benefit from fast transportation.

Alternative Technologies

Seven transit technologies potentially suitable for meeting the area's 1990 needs were considered. These were railbus, monorail, rail rapid transit, Skybus, Starrbus, conventional bus (on an exclusive right-of-way), and an advanced design bus (on an exclusive right-of-way, with electronic guidance) The last five were analyzed and compared (Table B-24). Analyses included operating speeds; acceleration; capacity; unit costs; construction costs for tracks, guideways, or roadways, service potentials and availability; vehicular dimensions, and guideway implications

Monorails were eliminated from detailed consideration after initial analysis because of their lack of adaptability to at-grade or underground use, their generally poor ride quality, the oscillation (sway) problem, their inability to perform collection/distribution functions, and switching problems The railbus was also eliminated because of its generally poor ride quality, high internal noise levels, and traction problems, especially on wet or icy tracks. Similarly, detailed investigations were not made of continuous-flow systems because: (1) their limited speed ranges made them unsuitable for the types of service desired; (2) their ability to handle peak-period loadings is unproven; and, (3) the enclosed guideways may make emergency escapes difficult.

Seven basic standards were specified for screening of candidate systems, as follows:

1. Peak-hour, peak-direction capacity of 22,500 seated passengers on line-haul sections.

2 Top operating speeds of 50 mph (minimum) and 70 mph (desirable)

3. A minimum acceleration rate of 2 5 mph per sec from 0 to 30 mph, and a maximum deceleration rate of 3 5 mph per sec.

4 Vehicle performance and passenger-related nonmechanical elements consistent with standards set by the National Academy of Engineering (*B-18*).

5 Air pollutant emissions below the levels set by the Clean Air Act and other legislation.

6. Cost-feasibility established, relative to other systems, with allowances for trade-offs between costs and service features.

7 Equipment and control systems operational by 1975

Within this context, the alternative systems were evaluated and ranked in terms of construction costs, right-of-way requirements, equipment costs, operating costs, levels of service (including travel time, transfer requirements, and modal compatibility), quality of service (including noise levels, ride quality, and vehicle aesthetics), transitway aesthetics (appearance of the facility and its compatibility with the local environment), system expansion potential (including disruption of service, land required, capacity increase, and switching), joint use of transitway, and reuse of existing maintenance facilities (if a new replacement technology were used).

Based on these factors, it was recommended that the turbine-powered bus (e.g., the General Motors RTX) should be the basic vehicle for Milwaukee's future transit service The major determining factor was the operational flexibility offered by the bus. The reports indicate: "The vehicle can operate both in mixed traffic and on exclusive rights-of-way and thus can be used for collection, line-haul and distribution functions This service can be readily adapted to a demand-bus service to improve collection of passengers in outlying suburban areas. The level of service or area of coverage can be improved or expanded by adding more vehicles to the system. The addition of vehicles to the system results in a potential increase in system capacity. This increased supply of vehicles can be accommodated by the line-haul facility A final element concerning the flexibility of the rubber-tired system is achieved

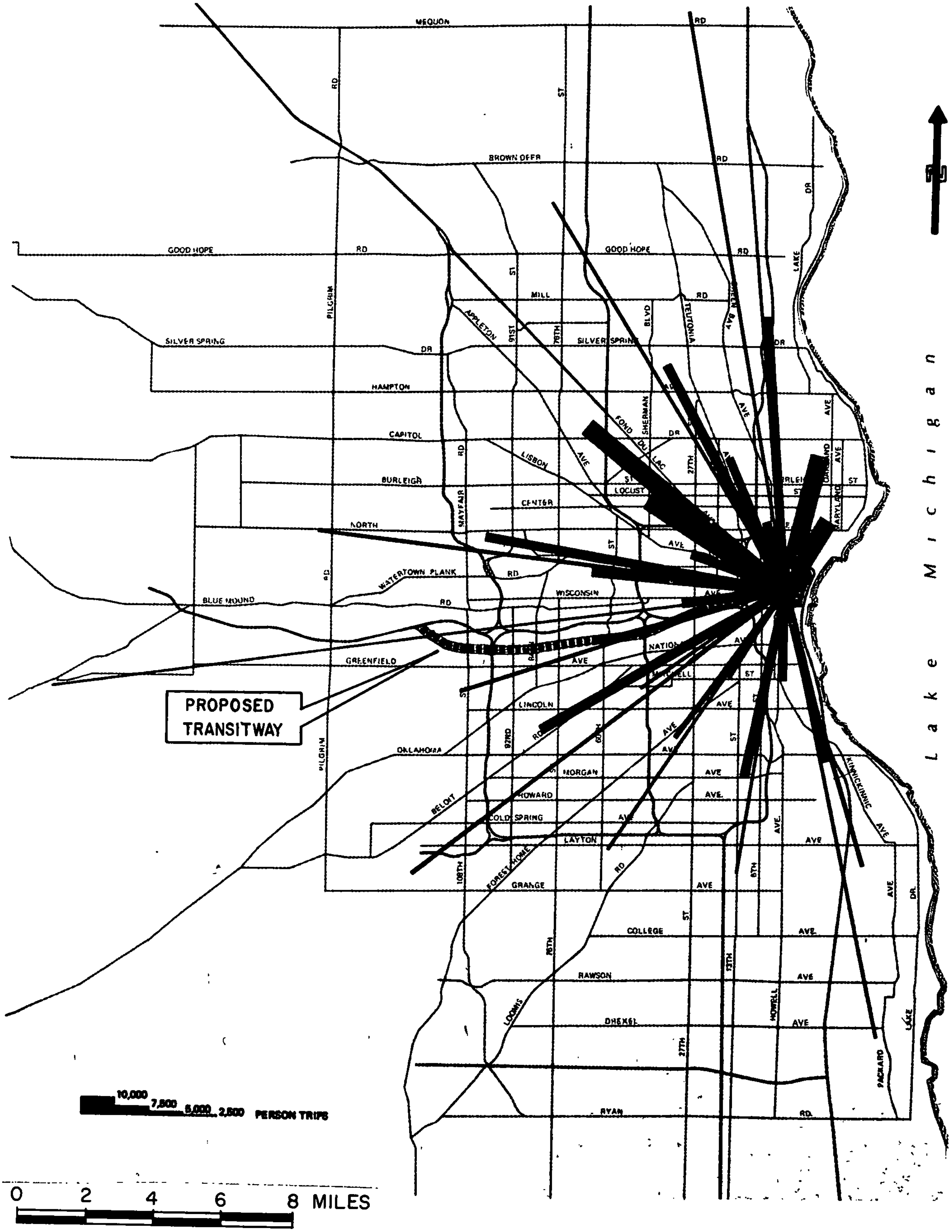


Figure B-18 1964 central area-oriented person trips, Milwaukee, Wis

TABLE B-24

COMPARISON OF ALTERNATIVE TRANSIT TECHNOLOGIES, MILWAUKEE

ITEM	CONVENTIONAL BUS	RTX BUS	SKYBUS	STARRBUS	RAIL RAPID TRANSIT (TYPICAL)
Vehicle dimensions					
Width	8′-0″-8′-6″	8′-0″	10′-0″	5′-6″	9′-4″-11′-4″
Height	10′-2″	8′-9″		7′-6″	11′-10″
Length	40′-0″	40′-0″	30′-6″	16′-0″	48′-0″-57′-2″
Wheelbase	23′-8″	23′-8″	17′-8″	NA	NA
Driver eye height	7′+	6′+	NA	NA	NA
Vehicle weight	28,700 lb [a]	28,700 lb [a]	19,000 lb [c]	4,800 lb [b]	117,300 lb [b]
Vehicle performance					
Attainable speed [c]	60 mph	70 mph	50 mph	60 mph	50 mph
Acceleration [d]	2 mph/sec	2.5-3.0 mph/sec	2 0-2 6 mph/sec	3 0 mph/sec	2.3-3 0 mph/sec.
Deceleration	2 5 mph/sec	2.5 mph/sec	2.5-3 5 mph/sec	(Comfort)	4 0 mph/sec
Maximum operating grade	10%	10%	10%	7%	5% +
Turning radius	42′-3″	42′-3″ ±	150′-0″	—	—
Capacity					
Seated pass [e]	30,000	30,000	10,000	50,000	50,000
Equipment cost/100 seats	$63,000	$142,000 [f]	$357,000	$84,000	$143,000
Operating cost/100 seat-miles	$1 48	$1.52	$1 25	$6 25	$0 85
Roadway:					
Elevated [g]	$1,000-1,200/lf [h]	$500-600/lf [f]	$400-520/lf	$320/lf	$800-900/lf
At-grade [g]	$100-200/lf	$110-200/lf	$240-340/lf	$200/lf	$500-600/lf
Open cut [g]	$200-300/lf	$200-300/lf	$360-460/lf	$300-350/lf	$600-700/lf
Transitway requirements					
Type	Road	Road	Elevated, at-grade, track/guide	Unrestricted + guideway	Track
Width	Variable	Variable	2 line, elevated, 19′-6″ 1 line, elevated, 8′-6″ 1 line, at-grade, 10′-0″	1 line, at-grade, 8′-0″ (ROW)	2 line, 27′-34″

Source Ref (*B-17*)
[a] Empty [b] Loaded [c] Line-haul [d] Measured between 0 and 30 mph [e] Approx seated passengers per hour in peak direction [f] Advanced design bus, exclusive right-of-way, guidance

by avoiding the development of a special, expensive guideway structure whereby the option is retained for re-use of the exclusive right-of-way by a wide range of future transit systems with no significant loss of initial investment."

Recommended Bus Rapid Transit Plan

The recommended 1990 transit system calls for 107 miles of express operations, 39 stations (excluding downtown), and 33,000 parking spaces An 8-mile east-west transitway roughly parallel to the East-West Freeway forms the heart of the plan Service would be provided by turbine-powered buses capable of maintaining 70 mph speeds. Feeder and local service would also be provided, especially in peak periods, between outlying residential, employment, and commercial centers. Some 1,450 round-trip route-miles of local bus service would include 887 miles of feeders to the rapid transit (bus) stations. General characteristics of the plan are summarized in Table B-25.

Corridor Locations

The initial bus rapid transit system recommended for completion by 1990 will consist of turbine-powered buses operating over the metropolitan freeway system (Fig B-19). Buses would use uncongested freeways, however, where 1990 freeway volumes would exceed design capacities, special bus rights-of-way would be provided.

The eight proposed routes assume the following configuration·

1 From Mequon Road in the north, following the North-South Freeway (US 141), to downtown Milwaukee.

2 From Thiensville to downtown Milwaukee along the Stadium and Park Freeways

3 From Germantown to the downtown area along the Zoo Freeway and the transitway.

4 From Waukesha to the downtown area via freeway and transitway.

5 From New Berlin to the downtown area along the Rock and Zoo Freeways and the transitway.

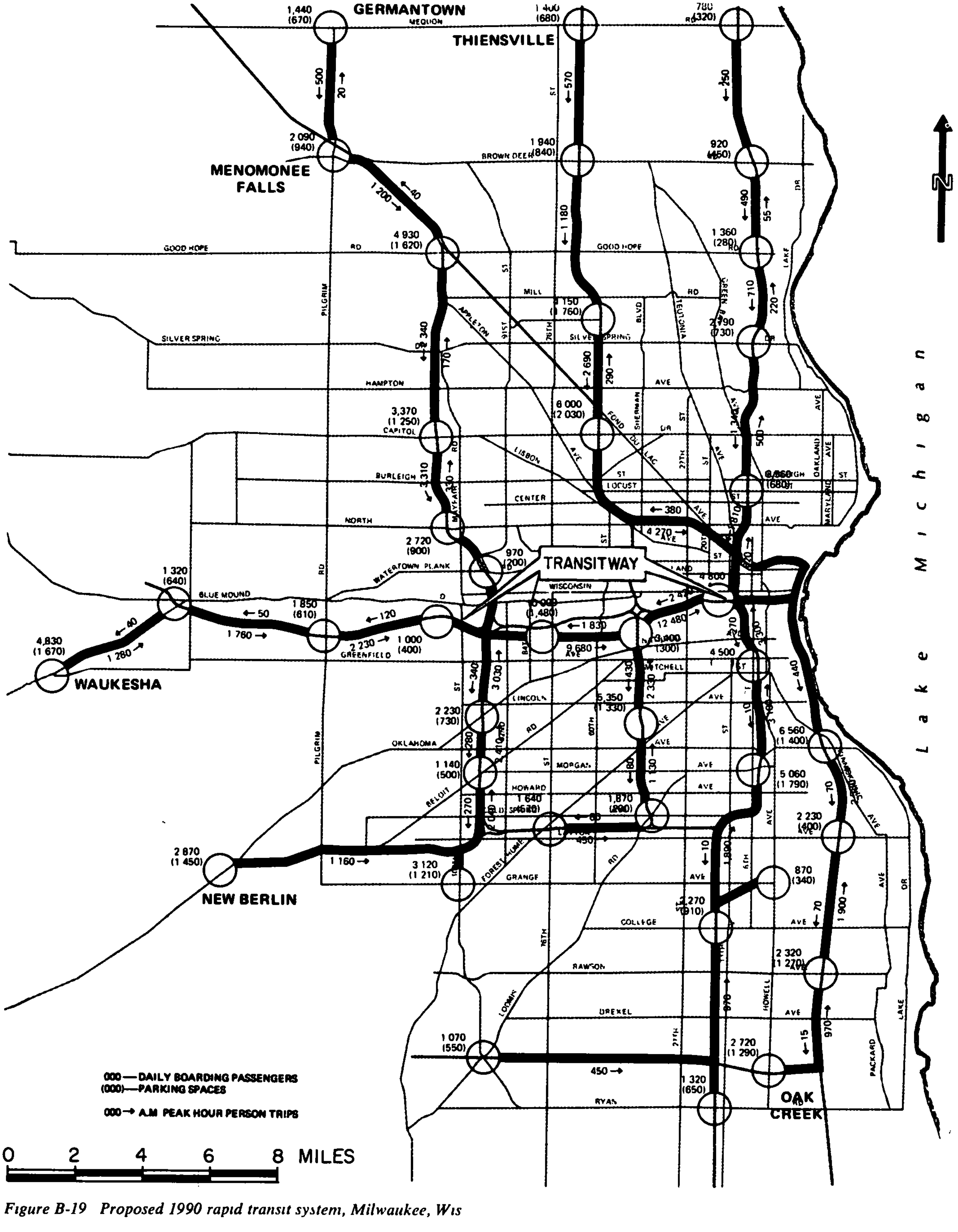


Figure B-19 Proposed 1990 rapid transit system, Milwaukee, Wis

6. From Loomis Road-Wis 100 on the Belt Freeway and Ryan Road, following the North-South Freeway to downtown

7. From Oak Street to downtown following the Lake Freeway.

8. From 76th Street and the Airport Freeway to downtown via the Airport and Stadium Freeway and transitway.

The East-West Freeway is currently congested during peak hours. It carries 125,000 cars per day at locations that were designed initially for 85,000 cars when the entire system is in operation Accordingly, the initial section of the two-lane transitway would extend parallel to the freeway from 13th Street near Marquette University to I-94 near 124th Street. Special ramps would connect the transitway with the Stadium and Zoo Freeways.

The recommended transitway alignment was chosen because of its ability to serve special travel generators, including downtown Milwaukee; its achievement of urban design objectives; and its minimal disruption to existing land uses. The preferred routing would require demolition of five dwelling units and 10 business establishments.

By about 1990, depending on the rate of urban growth, additional transitways may be required. One may run from the Airport Spur northward, generally paralleling the North-South Freeway, to Burleigh Street. The second would extend from downtown, in a location generally paralleling the Park and Stadium Freeways, to a point near the Capitol Court Shopping Center.

The right-of-way of the former Chicago North Shore and Milwaukee Railroad, currently owned by Milwaukee County, is in a location where it may be required as a route in the north-south corridor for an exclusive transitway. Accordingly, it was recommended that the county should retain ownership of this land, at least from Mitchell Field northward.

Downtown Distribution

Anticipated peak-hour bus design volumes entering the downtown area are given in Table B-26. The number of buses would increase from 134 in 1975 to more than 600 in 1990.

The proposed downtown bus distribution would be linear along Wisconsin Avenue, Michigan Avenue, and Wells Street (Fig. B-20) This routing configuration would deliver three-fourths of all passengers to within 800 ft (less than 0 2 mile) of their destinations The initial distribution system would accommodate bus flows ranging from 70 to 174 buses per hour—bus volumes comparable to those found on Michigan Avenue in Chicago, Euclid Avenue in Cleveland, and Hillside Avenue in New York

There appears to be no provision in the initial plan for exclusive transit streets, although they would likely evolve as transit patronage and bus volumes increase. A five-step evolutionary downtown distribution system was suggested.

TABLE B-25

SUMMARY CHARACTERISTICS, RECOMMENDED BUS RAPID TRANSIT SYSTEM, MILWAUKEE

1 Total length: 107 miles.
2. East-West Transitway 8 miles long, approximately parallel to East-West Freeway from 13th St to I-94, displaces 5 dwelling units and 10 businesses.
3 Stations (excluding CBD): 37 with parking, 2 without parking
4 Average speed· Recommended system, 28 2 mph, present local service, 11 4 mph.
5 Service Local lines, 5 00 AM to 12 PM;[a] express, all day
6 Recommended fares Rapid transit, $0 50; local, $0 30
7 Patronage forecast (1990) Local system, 133,000,000, rapid transit system, 80,000,000, total system, 213,000,000
8 Peaking Peak-to-base ratio, 1 95; local, 1 87, rapid transit, 2 09
9 Impacts. If busway plan implemented, could save $37 to $55 million for parking in CBD and adjacent area, tax base loss from recommended locations, $5 8 million

Source Ref (*B-15*)

[a] On related routes, hourly service from 12 00 PM to 6 00 AM

TABLE B-26

ESTIMATED DESIGN-HOUR BUS FLOWS APPROACHING CENTRAL BUSINESS DISTRICT, MILWAUKEE

TYPE OF SERVICE	1975	1980	1990
Transitway buses	0	174	250
Modified rapid system buses	73	173	262
Local buses [a]	61	75	104
Total buses	134	422	616

Source Ref (*B-15*)

[a] Wells Street, Wisconsin Avenue, and Michigan Street only

1 Existing conditions with general traffic and bus flows (Wisconsin Avenue currently handles 78 buses per hour one-way).

2. Initial ("start-up") rapid transit service-increased bus service operating in mixed traffic, plus the addition of service and marketing amenities.

3. Provision of exclusive bus lanes (center-of-street reversed-flow lane, for example) involving special passenger loading areas, shelters, and amenities Each lane would be capable of serving up to 120 buses per hour. (This could come about by 1975)

4 Provision of exclusive transit streets, involving elimination of all but transit vehicles from a major street (such as Wisconsin Avenue) and allowing a theoretical capacity of 600 buses to operate in four lanes in one hour, with appropriate station facilities and pedestrian amenities.

5 Provision of grade-separated transitways to be considered when transit service requirements exceed the capabilities of surface distribution and as new technology advances (after 1990).

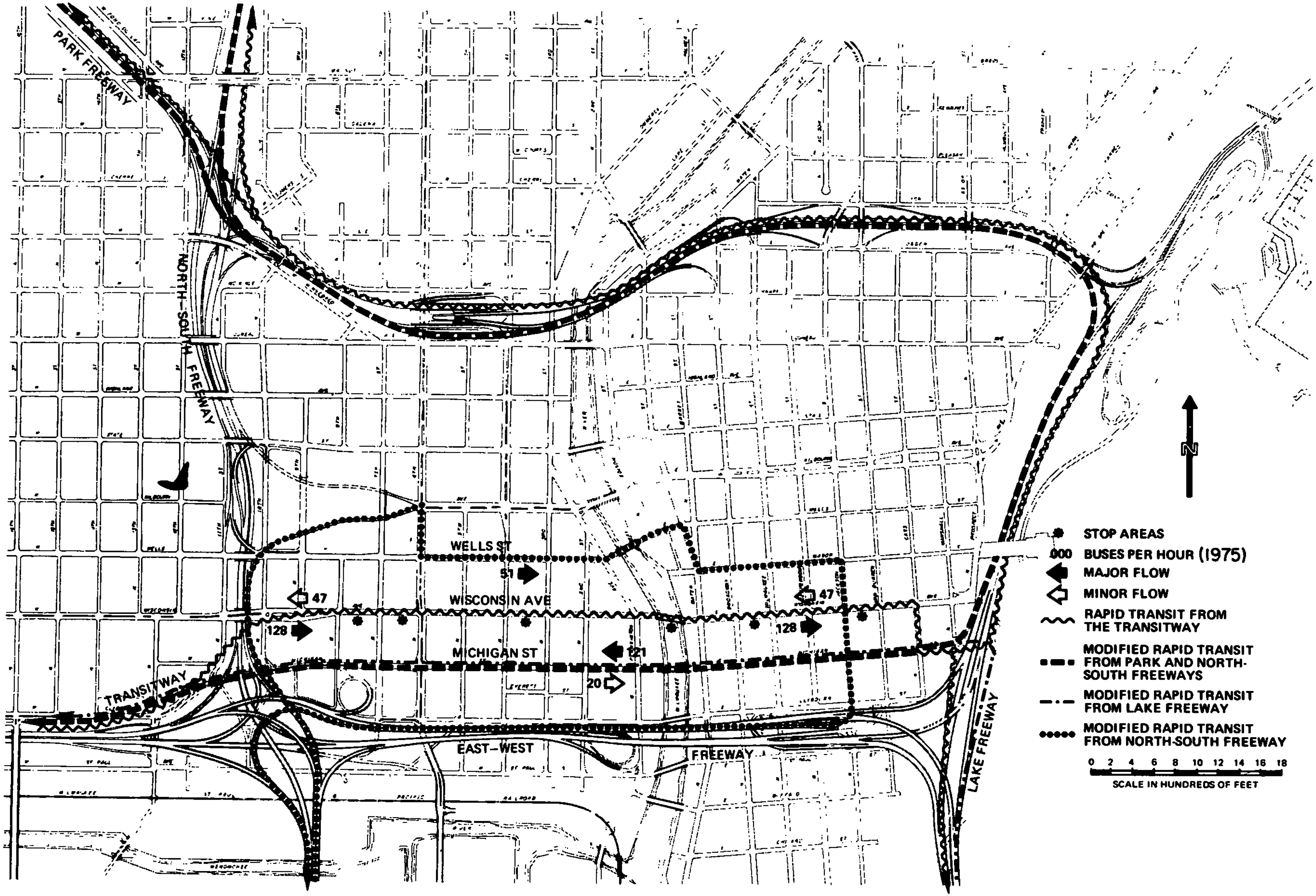


Figure B-20. Anticipated 1975 downtown AM *bus flows, Milwaukee, Wis.*

Transitway Design Criteria

The transitway would be designed to accommodate all potential fixed-guideway transit hardware, except intercity rail cars Pertinent design criteria are summarized in Table B-27 and typical cross-sections are shown in Figure B-21. Normal sections would be 36 ft wide to provide two 12-ft lanes plus some median and edge clearance. Sections at stations would be considerably wider.

The general urban design concept called for the transitway to enhance the present visual and physical structure of the corridor by. (1) creating new or reinforcing barriers; (2) separating incompatible land uses; (3) serving as an impetus for new development, where possible; and (4) harmonizing with existing development except where visual stimulation is necessary or desirable.

Anticipated Patronage

Patronage forecasts for the 1990 transit system are summarized in Table B-28.

1. Revenue passengers in 1990 would total 116 million, of which 49 million would be on the rapid transit system. This compares with 63 million on the existing system in 1990 without rapid transit facilities. Rapid transit patronage, therefore, would approximate 200,000 persons a day.
2. The east-west transitway would have a total 1990 ridership (all routes) of about 42 million, or 167,000 per day This is higher than on any existing rapid transit line in the United States outside of New York City.
3 Design-hour one-way passenger loads would approximate 12,500 persons at the maximum load point.

Costs and Staging

The staging sequence was based on 1980 and 1985 population and employment forecasts. It also considered programmed completion dates for freeway segments in Milwaukee County, and the desire to achieve a reasonably uniform rate of expenditures. The 1980-81 and 1990 systems are shown in Figure B-22.

During 1972 and 1973 it is anticipated that a number of transit system improvements will be achieved, including acquisition of 150 new buses, expansion of the Freeway Flyer service with four new park-ride lots, and inauguration of a new City Flyer service The new transitway paralleling the East-West Freeway is proposed for completion by 1977 or 1978. By 1980, 26 stations and facilities with parking space for 22,000 automobiles would be opened. During the ensuing decade, 13 more stations and 11,000 parking spaces would be completed. By about 1990, the second major phase of transit development would be undertaken; this is expected to include transitways paralleling a section of the North-South Freeway and a second extending northwesterly from downtown Milwaukee paralleling the Park and Stadium Freeways.

Capital Costs

The cost of developing the 1990 bus rapid system are estimated to total $151 million (1970), of which $40 million represent the costs for the transitway Of these costs, the potential nonfederal share was estimated at $35 million (Table B-29).

TABLE B-27

DESIGN CRITERIA, TRANSITWAY, MILWAUKEE

ITEM	CRITERION
Design speed	
Transitway	70 mph
Ramps	30 mph (min)
Lane width	
Transitway	13 ft (min.)
Ramp	
One lane, one way	15–18 ft [a]
One lane, one way with passing provision	21–29 ft [a]
Two-lane operation	26–35 ft [a]
Grade	
Transitway	5% (max)
Ramp	6% (max)
Vertical clearance·	
Transitway under highway or railroad, or over freeway	15'–0" (min)
Transitway over Interstate	16'–6" (min)
Transitway over railroad	23'–0" (min)
Horizontal clearance	
Left edge of pavement to vertical obstruction	30'–0" (des) 3'–6" (min.)
Right edge of pavement to vertical obstruction	30'–0" (des) 8'–0" (min)
Median	4'–0"
Sight distance: [b]	
70 mph	600 ft
60 mph	475 ft
50 mph	350 ft
45 mph	315 ft
35 mph	240 ft
Horizontal curves.	
Transitway	
Desirable max.	2°–00'
Maximum	3°–00'
Ramps:	
Maximum	18°–00'
Max rate of change	0 080 ft/ft
Transitway	1 200
Ramp	1·100
Runout location	
2/3 on tangent	(60–80%)
1/3 on curve	(20–40%)
Shoulders	
Desired	10'–0"
Minimum	8'–0"
Cross-slope	1/2" per foot
Side slope	
Fill	4.1 [c]
Cut	3.1 [c]
Bridge design	AASHO Standard Loading, Class HS20–44

Source Ref (*B-17*)

[a] Depending on radius of inner edge of pavement

[b] Minimum safe stopping sight distance for design speed

[c] Outside the 6 1 side slopes

Major contributions were anticipated from the Urban Mass Transportation Administration and the Federal Highway Administration (both agencies of the U.S. Department of Transportation), and from the Wisconsin Department of Transportation. The federal share was estimated within the constraints of existing funding limitations.

The annual capital expenditures from 1974 to 1982,

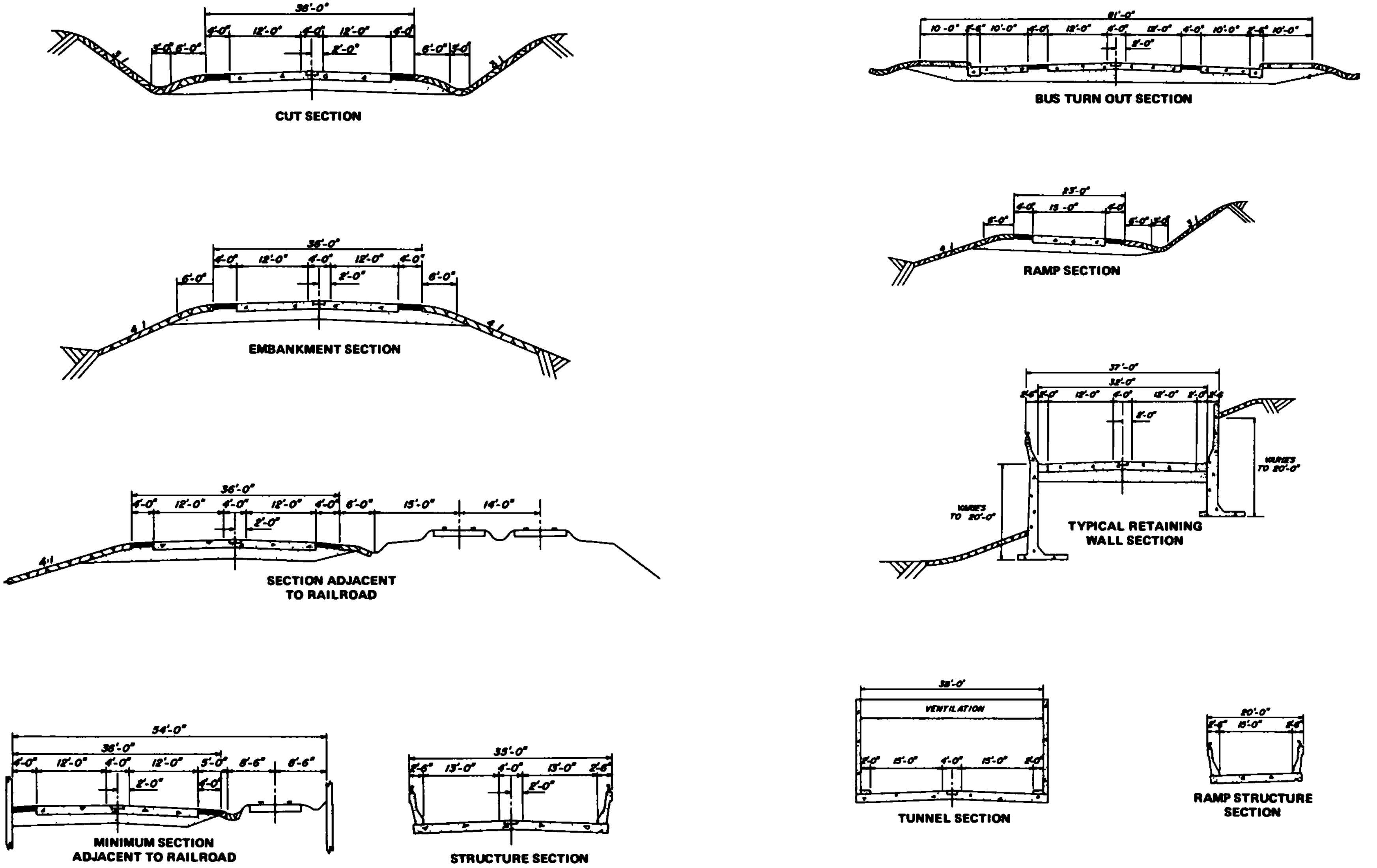


Figure B-21. Proposed Transitway cross sections, Milwaukee, Wis would vary between $10 and $20 million annually. By 1982, the transitway system would be largely completed and further expenditures would be mainly for buses and parking Annual expenditures from 1983 to 1990 would range from $1 million to $6 million

Operating Costs

Annual operating costs in 1970 dollars were estimated at $33.4 million for 1980, $37.8 million for 1985, and $43 5 million for 1990. These costs assume that the maintenance of public streets and freeways would continue to be paid by the highway user

Fare Structure

Several alternative fare structures were investigated to determine the annual revenues they would produce. It was recommended that a $0.50 fare be charged on the rapid transit lines and a $0 30 fare on the local service. These fares would result in a break-even operation based on the assumptions used in the analysis.

Benefits and Impacts

The proposed system would improve transit mobility throughout the region. The 35 highest noncentral employment zones in the study area contain approximately 144,000 jobs; the average distance from a proposed transit station to the edge of these zones would be 0.8 mile, with 1.5 mile being the maximum distance. Similarly, the 35 highest employment growth zones would be within 0.7 miles of a proposed station Of the 40 large employment centers in the metropolitan area, 37 would be within 40-min transit travel time of the Model Cities area using the proposed bus rapid transit system. Over-all travel speeds on the system, including station stops, would be 28 2 mph, as compared with an average speed on the existing local transit system of 11.4 mph.

In 1990, 13,300 more work trips per day to the central area would be made via transit than in 1963. Similarly, 8,500 more nonwork trips having a destination downtown would use transit If these transit travel increases were accommodated by private auto instead of transit, about 13,000 additional parking spaces would be needed within or immediately adjacent to the downtown area. Total cost of this new parking was estimated to range from $37 to $55 million.

If these increased central area trips were made by private auto, 11,200 more vehicles would have to be delivered into the downtown area during the 3-hour work-trip peaks This corresponds to a peak-hour volume of about 5,600 vehicles; the equivalent of four additional freeway lanes (or a new eight-lane freeway) would be required. Also, approximately 11 additional arterial street lanes would be required to handle vehicles entering the surface street system

By using existing freeway rights-of-way and other county lands, the private property that otherwise would have to be acquired for the stations was reduced by approximately 65 acres, with an equivalent value of $5.8 million.

TABLE B-28

ANTICIPATED 1990 PATRONAGE,
RAPID TRANSIT SYSTEM, MILWAUKEE

A. SUMMARY STATISTICS OF THE 1990 TRANSIT SYSTEM

ITEM	LOCAL SYSTEM	RAPID SYSTEM	TOTAL SYSTEM
Total annual passengers	133,000,000	80,000,000	213,000,000
Revenue annual passengers [a]	67,000,000	49,000,000	116,000,000
Annual vehicle-miles	32,200,000	39,600,000	71,800,000
Annual vehicle-hours	2,600,000	1,400,000	4,000,000
Max hourly scheduled vehicles	639	381	1,020

B ANNUAL RIDERSHIP BY ROUTE, 1990

CORRIDOR	ROUTE	ANNUAL RIDERSHIP
North	North-South Freeway	6,600,000
Northwest	Stadium-Park Freeway	10,100,000
	Zoo Freeway	11,600,000
West	East-West Freeway	6,600,000
	Transitway [b]	41,800,000
Southwest	Rock-Zoo Freeway	7,400,000
	Airport Stadium Freeway	7,000,000
South	North-South Freeway	11,200,000
	Lake Freeway	10,300,000

C DESIGN-HOUR PASSENGER LOADS BY ROUTE, 1990

CORRIDOR	ROUTE	DESIGN-HOUR PASSENGER LOAD (MAX)	(MIN)
North	North-South Freeway	1,810	250
Northwest	Stadium-Park Freeway	4,270	570
	Zoo Freeway	3,980	500
West	East-West Freeway	2,230	1,280
	Transitway	12,480	—
Southwest	Rock-Zoo Freeway	3,030	1,160
	Airport-Stadium Freeway	2,330	450
South	North-South Freeway	3,300	450
	Lake Freeway	3,730	970

Source Ref (*B-15*)

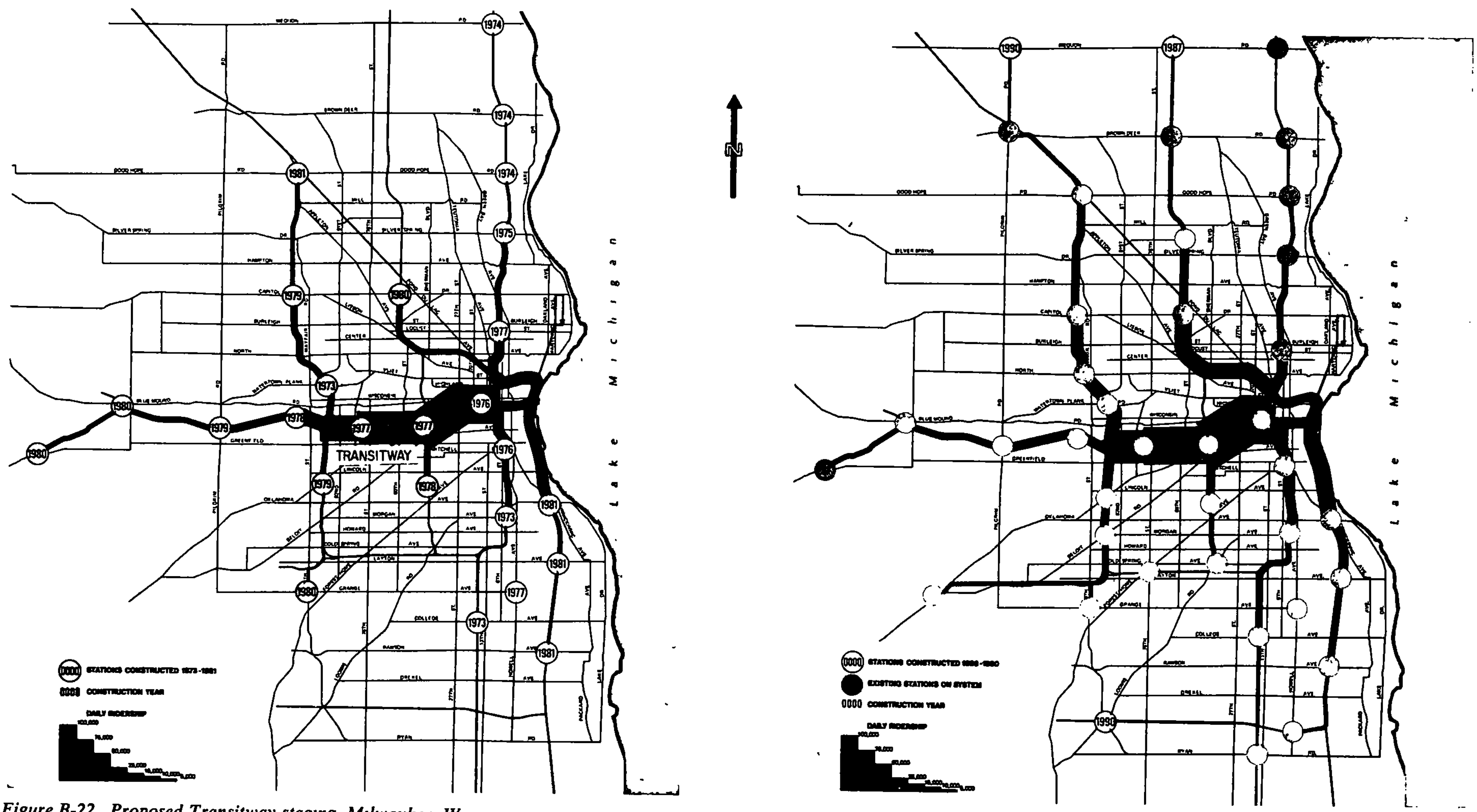
[a] Revenue passengers are those paying a full fare and exclude transfer and free passengers

[b] Transitway use includes ridership from four feeder freeways plus its own generated ridership

Construction of the recommended transitway and stations would require acquisition of about 30 dwelling units and some commercial buildings. It would reduce current annual taxes by about $780,000. Offsetting this loss in tax revenue is the potential for developing about 915 acres of vacant land within one-quarter mile of various rapid transit stations to higher densities.

Significance

The Milwaukee Bus Rapid Transit plan develops a busway as the integral element of a regional freeway-bus system. In this sense, it is a continuation of the bus rapid transit concept proposed for St Louis in 1959 (*B-19*). It is also



1980-81 SYSTEM PLAN

1990 SYSTEM PLAN

Figure B-22. Proposed Transitway staging, Milwaukee, Wis.

in contrast to those plans that utilize single-route busways as feeders to rail rapid transit or as the first stage of a future rail line

The plan builds on the existing and proposed regional freeway system. Thus, many components of the plan are contingent on availability of freeways—an increasingly difficult prerequisite in many urban areas

Patronage forecasts appear optimistic in view of the limited growth in downtown trips (about 30 percent), and transitway corridor demands. The transitway is located in a development gore, following the same general corridor as a former interurban rail line. It is removed from the heaviest existing CBD-oriented trip demands. Thus, it would have to rely on considerable distribution to north-south freeways, as well as local auto distribution At the same time, many basic elements of the system have important transferability to other urban areas

9. MINNEAPOLIS I-35W BUS-METERED FREEWAY SYSTEM

The Minneapolis Urban Corridor Demonstration Project—unlike other corridor projects—relates in total to a metered freeway system along I-35W (*B-20*).

Corridor Characteristics

The I-35W corridor extends due south of the Minneapolis Central Business District (Fig. B-23). The main section of freeway was constructed in the early 1960's, the final connection with the CBD was finished in 1967. The freeway varies from four lanes in Burnsville to eight lanes near the CBD. Parallel arterials flank the freeway on the east and west. Congestion occurs in the morning and evening peak periods. Pertinent corridor demographic and traffic characteristics are as follows:

- Approximately 375,000 people enter and leave the Minneapolis CBD on a typical 1970 day; 16 5 percent by bus.
- During the morning peak period (7:00-9.00 AM) 22,000 persons traveled into the Minneapolis CBD from the corridor. Approximately 6,000 were carried by bus transit, mainly on local routes.
- During the peak hours, 6,100 people entered the CBD on I-35W (Fig. B-24). Approximately 20 percent of the 27,000 cars entering I-35 inbound ramps in the morning 3-hr period on some 21 ramps had CBD destinations.
- Inbound ramp volumes during the 6:00-9.00 AM peak ranged from 500 to 3,100 vehicles, the equivalent of peak-hour flows of 250 to 1,500 vehicles.
- Approximately one-half of all I-35W freeway users were one-occupant cars; 30 percent had two persons; 20 percent were multiple-occupancy cars.
- Average 1971 daily traffic on I-35W increased from 45,000 per day at the Minnesota River to 104,000 at Lake Street. Peak-hour lane volumes ranged from about 1,400 to 1,900 vehicles. The highest lane densities and the lowest peak-hour speeds (25 to 30 mph) were found at Minnehaha Creek.

TABLE B-29

SHARED COSTS, BUS RAPID TRANSIT SYSTEM, MILWAUKEE (IN 1970 $MIL)

ITEM	POTENTIAL [a] FEDERAL SHARE	POTENTIAL [b] NONFEDERAL SHARE	TOTAL COSTS
Transitway [c]	36 14	4 01	40.15
Parking [d]	49 12	17.08	66.20
Stations [e]	5 23	2 58	7.81
Buses [f]	16 55	8 31	24.86
Other [g]	8 26	3 32	11 58
Total	115 30	35.30	150 60

Source Ref (*B-15*)

[a] Federal share based on formula applicable for the period beginning fiscal year 1974

[b] Nonfederal share assumed to be apportioned as follows Share under Interstate funding borne by state, share under FHWA and UMTA programs divided evenly by state and local agencies

[c] Transitway funded through FHWA at 90 percent federal and 10 percent nonfederal matching funds Costs of Transitway include right-of-way, utility relocation, main-line and ramp construction, and urban design costs

[d] Parking funded through FHWA Parking lots and access roads on the transitway appear eligible for 90 percent federal funding, as do parking lots adjacent to Interstate-designated highways Parking lots adjacent to Federal-Aid Primary, Federal-Aid Secondary, and Federal-Aid Urban systems can receive 70 percent federal funding after fiscal year 1973

[e] Station costs funded through UMTA Those elements of the station used strictly for passenger transport would be funded to two-thirds of the cost by UMTA

[f] Buses would be eligible for two-thirds federal financing by UMTA

[g] Includes physical plant and ramp access to parking and stations The physical plant would be two-thirds federally funded by UMTA The access ramps would be 90 percent federally funded if on Interstate-designated routes and 70 percent if on Federal-Aid Primary, Federal-Aid Secondary, or Federal Aid Urban systems Ramp funding would be through FHWA

Surveillance and Control System

The Urban Corridor Program recommended a surveillance and control system for I-35W. The system would monitor lower volumes and higher speeds than systems currently in operation throughout the U.S. In addition, it would be unique in (1) its combination of a digital-computer-controlled system (north of Minnesota River) with an isolated traffic-adjusted system (south of Minnesota River), and (2) its coordination with the City of Minneapolis computerized traffic signal system.

Design Concept

Functional objectives of the system were to:

1. Maintain a high level of freeway service This implies controlling ramp demands to operate the system at lower volumes and higher speeds than are prevalent on freeway surveillance and control systems currently in operation.
2. Provide express buses with priority access to the freeway over passenger vehicles. This would be accomplished with special slip ramps or widened ramp sections that permit buses to bypass the queues at ramp meter signals and enter the freeway without delay.
3. Quickly detect and react to incidents occurring on the freeway. Incident detection would be accomplished by the detector system and the proper response would be deter-

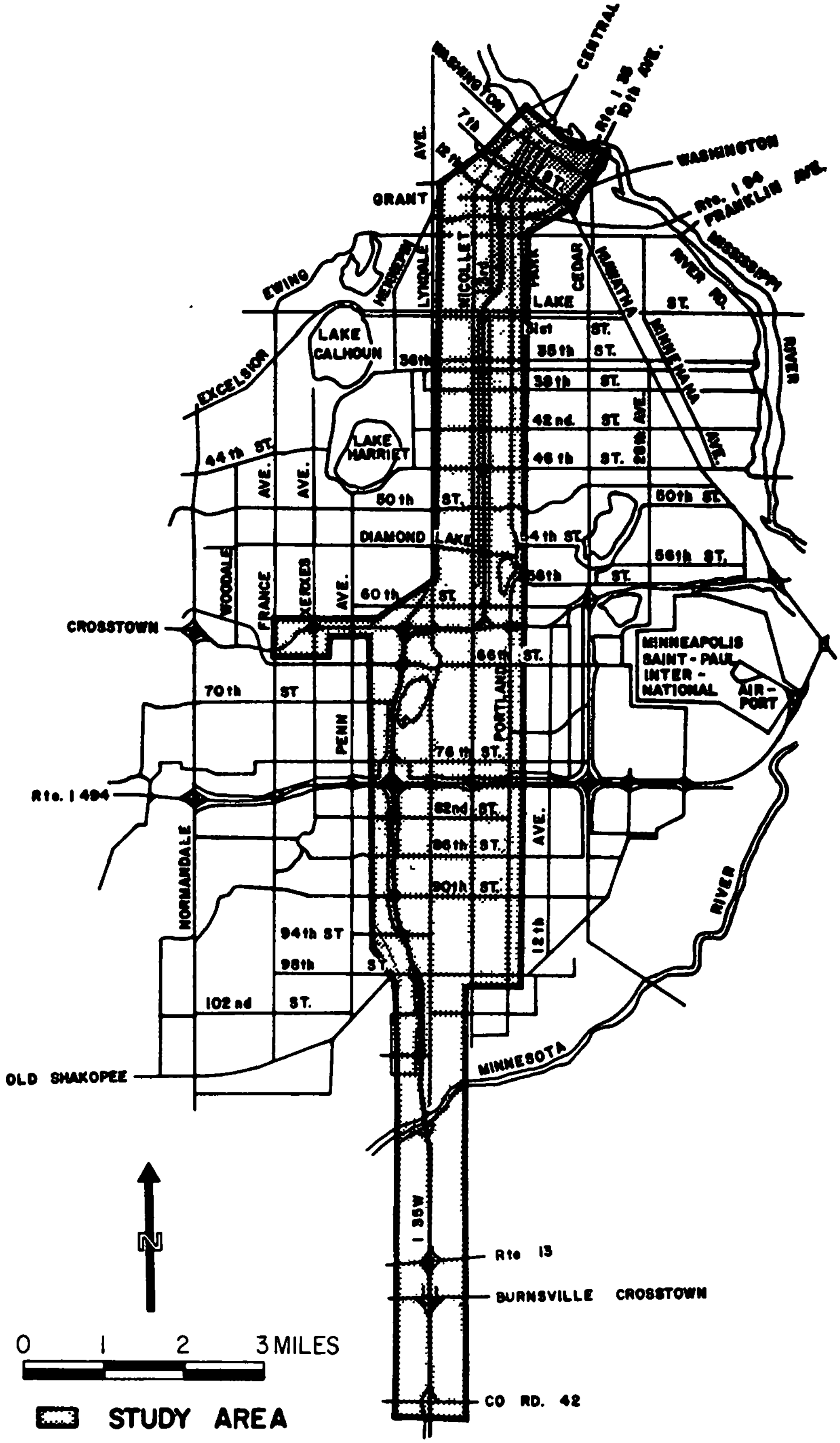


Figure B-23. Urban corridor, I-35W, Minneapolis, Minn

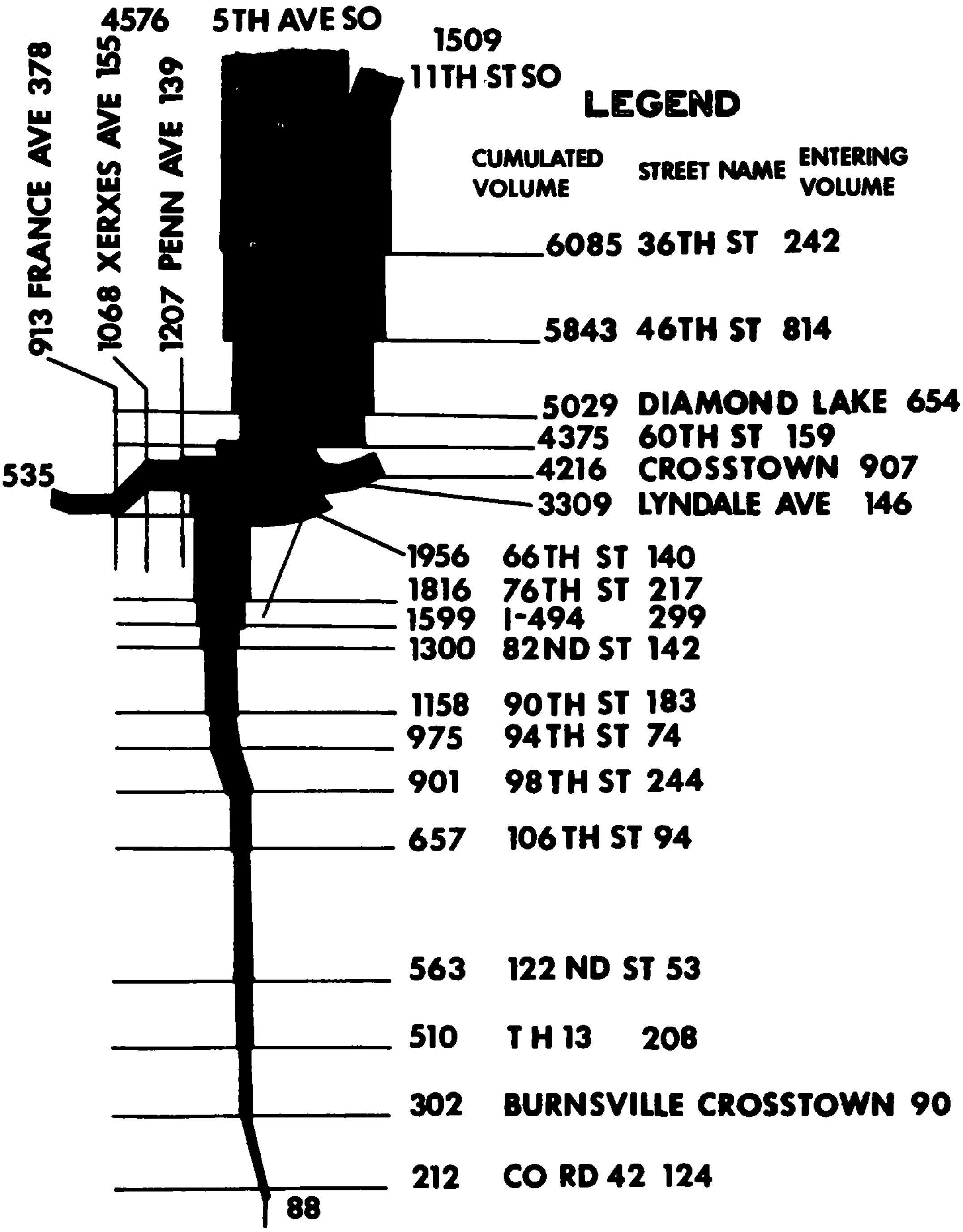


Figure B-24 Flow map of CBD-destined trips, I-35W, Minneapolis, Minn.

mined through the use of the closed-circuit television system.

4. Be sensitive to weather conditions This implies incorporating special control logic to reflect inclement weather conditions.

Virtually all inbound ramps would be metered except for freeway-to-freeway ramps. Ramps would also be metered on County Highway 62, a major multi-lane facility. Most outbound ramps also would be metered.

Bus priority ramp concepts are shown in Figures B-25 and B-26. Separate bus ramps would be provided wherever parallel frontage roads exist. This represents a basic design variant from the bus priority ramps found in other cities.

Bus Service

Extensive bus services are currently provided in the corridor. Twelve proposed routes were recommended in conjunction with revisions to five express routes that currently use I-35W.

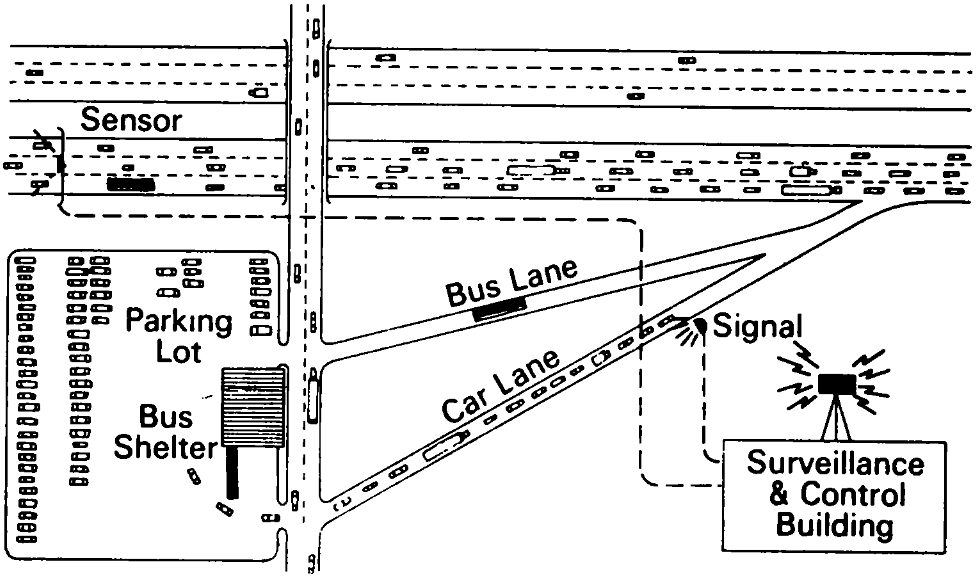


Figure B-25 Concept of bus priority ramp on metered freeway system, I-35W, Minneapolis, Minn

The 12 new routes and the revised existing express lines were estimated to carry about 6,000 passengers on a typical weekday Slightly more than one-third of these riders would be former travelers by automobile to and from downtown Minneapolis.

The recommended Plan B would require 48 vehicles to provide the proposed bus service. This includes 34 coaches for new routes and 14 for revised existing express bus lines. This service plan also would require special bus entrance ramps at seven interchanges along I-35W (Minn 13, 98th Street, 76th Street, 66th Street, Diamond Lake Road, 46th Street, and 35th Street) and one location on County Road 62 (Xerxes Avenue). Other necessary elements of the recommended transit service include three new park-ride facilities, 46 bus shelters (including five in the CBD), and 400 BUS STOP signs.

Downtown distribution would be by means of contraflow bus lanes on First and Second Streets.

TABLE B-30

SUMMARY OF CAPITAL EXPENDITURES, PLAN B, I-35W URBAN CORRIDOR DEMONSTRATION PROJECT, MINNEAPOLIS

ITEM	COST ($)
Bus ramps	486,000
Vehicles	2,064,000
Park-ride facilities	298,000
Shelters	160,500
Bus stop signs	20,000
Total	3,028,500

Source Ref (*B-20*)

Costs

Total capital costs for the recommended bus-metered freeway system were estimated at $4,731,000 (Table B-30) Costs for the surveillance and control system, consisting of the control center building, control center equipment, surveillance and control components, television system, and communication system, would total $1,703,000. The recommended transit service Plan B, consisting of exclusive bus ramps, transit vehicles, park-ride facilities, waiting shelters, and BUS STOP signs would cost $3,028,000.

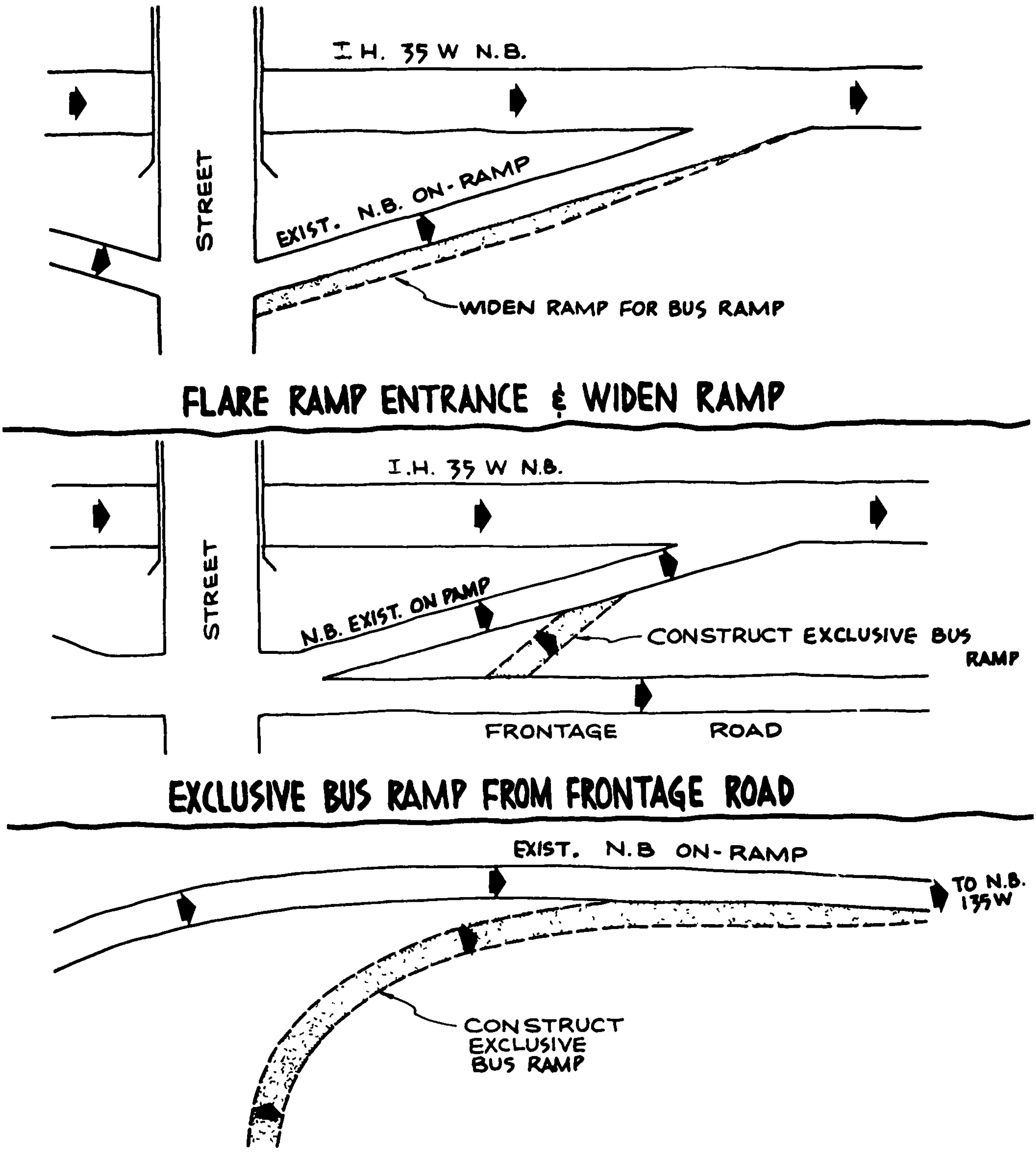
Proposed bus service costs are detailed in Table B-31. The operating costs were estimated at $558,800 However, a $272,000 savings would result from allowable reductions in existing local service, for a net cost of $286,800. Revenues from the transit service plan were estimated at $689,700; however, $360,600 in revenue would be lost from existing local services, yielding a net revenue of $329,100. This is an important consideration. The treatment of residual local transit services, and the marginal feasibility resulting from potential service duplication, are often overlooked in developing proposals The operating costs for the surveillance and control system were estimated at $148,000 The marketing costs, estimated at $102,150, include creative planning, advertising for metering and express bus service, and marketing coordination.

Benefits

Annual benefits were estimated at $578,500. These include $66,500 in accident reductions, $293,000 in travel time savings, and $219,000 in travel cost savings.

Significance

The I-35W project is designed to improve the efficiency of total person-flow through a heavily traveled radial corridor. It involves comparatively little investment relative to



FLARE RAMP ENTRANCE & WIDEN RAMP

EXCLUSIVE BUS RAMP FROM FRONTAGE ROAD

Figure B-26. Bus ramp design concepts, I-35W, Minneapolis, Minn

construction of busways or other more capital-intensive transit improvement systems. It does not preclude busway development if demands continue to rise. However, if transit demands fail to materialize, a smaller initial investment is lost, and bus routes could be adjusted accordingly. Downtown bus distribution facilities are an integral part of the over-all improvement concept.

10. NEW HAVEN CANAL LINE BUSWAY

The New Haven (Conn.) Canal Line Busway was recommended in 1971, as part of an Urban Corridor Demonstration Project (*B-21*). The proposal called for developing a two-lane busway on an existing single-track freight railroad. The line would extend some 8 miles initially—from

TABLE B-31

SUMMARY OF OPERATING RESULTS, PLAN B, I-35W, URBAN CORRIDOR DEMONSTRATION PROJECT, MINNEAPOLIS[a]

ITEM	AMOUNT ($)
Transit service plan costs	
Service plan operating costs	558,800
Savings resulting from local service reductions	—272,000
Cost differential	286,800
Transit service plan revenues	
Passenger revenues	689,700
Revenues lost to local service	—360,600
Cost differential	329,100
Transit service plan results	
Net revenue	329,100
Net operating costs	—286,800
Surplus	42,300
Surveillance and control system costs	
Personnel	100,000
Maintenance	46,000
Utilities	+ 2,000
Cost	148,000
Marketing costs	
Creative planning	23,150
Advertising for metering	15,500
Advertising for express bus service	58,500
Marketing coordination	+ 5,000
Cost	102,150

Source Ref (*B-20*)

[a] Initial year of operation.

downtown New Haven to Mount Carmel Avenue in Hamden. A second stage would extend 5.3 miles north to Cheshire, Conn. (Fig B-27).

Corridor Characteristics

The three communities served by the Canal Line had a 1970 population of 225,000 There were 900 work trips each day between New Haven and Cheshire in 1964, and about 12,000 between New Haven and Hamden.

The single-track Canal Line freight spur is owned and operated by the Penn-Central Railroad. Industrial and commercial operations mainly take place at night. Some 95,000 tons of freight are carried annually.

Design Concept

The proposed concept calls for express bus service operating on a 30-ft roadway paved *over* the tracks within a 50-ft right-of-way. Six tentative stations with turnouts and shelters would be provided Downtown distribution would be via city streets.

Many sections of the proposed busway route are already grade separated. At-grade intersections along other sections would be signalized to permit safe crossing of local streets. Busway signals would be coordinated with local traffic signal systems.

Buses would operate from 6:00 AM to 10:00 PM. Trains would operate only during late night time hours (1·00 AM to 6:00 AM.

Costs and Benefits

Detailed engineering plans were not prepared. Preliminary analyses indicate that Stage 1 would cost about $9 million and Stage 2 about $6 million. Annual revenues were estimated at $800,000; however, detailed patronage estimates were not prepared.

Significance

The project is innovative in its attempt to utilize a lightly used freight railroad line for bus rapid transit. At the same time, it appears out of scale in relation to existing and future needs. Peak-hour one-way 1972 bus volumes through most of the corridor average less than 10. Success of the project, therefore, would depend on substantially increasing both total population and the percentage of downtown New Haven workers living within the corridor. Yet, within the next 20 years, only modest population growth is anticipated for the service area (from about 225,000 to 260,000 persons).

The busway would mainly benefit suburban commuters. Several close-in neighborhoods along the route have questioned the busway's environmental impacts relative to the benefits derived. This concern is similar to questions of incidence of impacts and benefits associated with urban highway construction.

11. NEW YORK METROPOLITAN AREA CONTRA-FLOW BUS LANES

Two contra-flow bus lanes on key approaches to Manhattan provide important complementary services to rail transit lines These lanes are heavily used by buses, yet employ minimum design standards.

- The 2.5-mile exclusive contra-flow bus lane on the I-495 approach to the Lincoln Tunnel was placed in service in December 1970. It brings about 35,000 inbound commuters into the Port Authority Terminal each weekday from 7.30 to 9.30 AM.
- The 2-mile exclusive contra-flow bus lane on the Long Island Expressway approach to the Midtown Tunnel was placed in service in October 1971. It brings more than 180 buses with 7,500 inbound commuters into Manhattan each weekday from about 7.00 to 9.30 AM.

Both treatments apply the unbalanced-flow lane arrangement used along freeways in Chicago, St Louis, and Seattle to bus rather than automobile movements.

I-495 CONTRA-FLOW BUS LANE

Every workday morning nearly 100,000 commuters travel across the Hudson River into midtown Manhattan. Almost one-half arrive by bus, one-third by rail, and one-fifth by auto Buses and trains dominate commuter travel, even

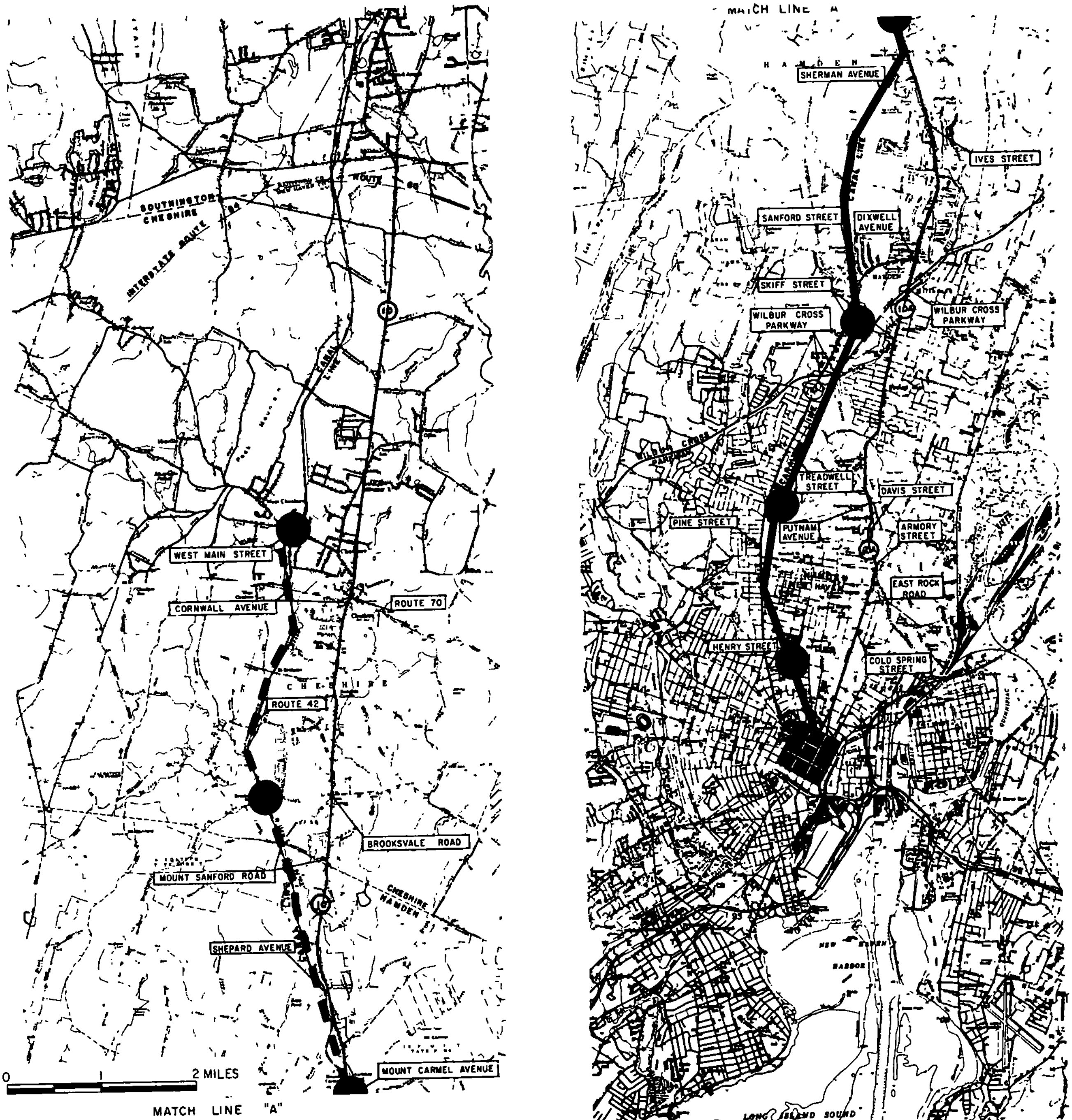


Figure B-27. Proposed Canal Line Busway, New Haven, Conn

though 86 percent of transit riders own autos and 25 percent own at least two.

Highways in the I-495 corridor leading toward Manhattan are chronically congested with both New Jersey and New York auto commuters. Delays of 5 to 15 min are encountered on several sections of US 46, N J. 3, and I-495 The New Jersey Turnpike flows freely since the new six-lane west spur opened in 1970 It was against this background that the I-495 eastbound contra-flow bus lane was opened on December 18, 1970

The bus lane allows some 35,000 daily commuters to reach their Manhattan jobs 10 to 25 min quicker than before In recognition of its satisfactory operating record and favorable public response, the one-year "experimental" project has become permanent (*B-22, B-23, B-24*).

Background

Studies of an exclusive bus lane on the New Jersey approaches to the Lincoln Tunnel date back to December 1963, when the Port of New York Authority prepared a report evaluating several bus lane schemes and recommending the basic plan that was subsequently implemented The report also suggested field tests to determine feasibility (*B-25*).

These field tests were conducted in 1964 and 1965. The first four-day experiment (September 1964) closed the "exclusive lane" to westbound traffic and determined that the remaining westbound lanes had sufficient capacity to function with the median lane closed. The second and most critical phase of testing (December 1965) involved a three-day test of actual roadway operations using maintenance trucks as "buses" It was found that the eastbound movement of the trucks in the "reversed" lane did not adversely affect westbound traffic. The findings were presented in a December 1965 report on both phases of the tests prepared by the Port Authority for the participating agencies.

Based on the results of these field tests, a January 1967 report recommended the exclusive bus lane plan. It was not immediately implemented, although studies of this and alternative bus lane plans continued. In late 1970, the New Jersey Department of Transportation, based on a July 1970 report by the Bureau of Research and Evaluation, determined that the exclusive bus lane should be implemented as soon as practicable

Prior to installation, some 30,000 advance notices were distributed to motorists Bus drivers received briefings from company representatives, who met with staff members of participating agencies.

Description

The 2½-mile contra-flow exclusive bus lane operates in the morning peak period (7.30 to 9 30 AM) Monday through Friday The lane extends from the New Jersey Turnpike to the Lincoln Tunnel (Fig B-28). The additional eastbound lane, for buses only, uses one of the three lanes that normally carry westbound traffic. Thus, the change provides four lanes for AM New York-bound traffic, three for cars and one for buses (Fig B-29)

The bus lane ties into the reversible lane operated through the Lincoln Tunnel. Thus, in effect, an extra lane is provided for buses directly into the ramp system leading to the Port of New York Authority Midtown Bus Terminal.

Approximately 60 percent of the buses that use the Port Authority Terminal use the exclusive bus lane. As these buses approach the Lincoln Tunnel Plaza, they are accommodated by two exclusive toll lanes and one priority lane to further speed their trip to the terminal On the New York side of the tunnel, the buses have direct access into the terminal. (In addition, the New York City Traffic Department set aside a lane on 41st Street for exclusive bus operation for some of the long-haul bus movements This lane does not function well because of lack of adequate patroling.)

Use of the bus lane is restricted to vehicles that meet Port Authority's definition of a bus—a vehicle that seats more than 16 people. Consequently, some of the airport limousines do not qualify, although Carey buses use the lane for their trips from Newark Airport. School buses are also restricted because of potentially inexperienced drivers The charter buses operated by regular bus lines are permitted to use the bus lane

The lane operates only during the morning peak hours; there is no corresponding treatment in the PM peak period This is because approaches on the Manhattan end of the tunnel are not susceptible to the same type of operation. Traffic is more balanced by direction three lanes are sometimes required for eastbound traffic during the evening peak hour; on occasions, the Lincoln Tunnel provides an equal number of lanes in each direction. Moreover, outbound traffic proceeds away from the point of constriction. In addition, many empty buses are stored in New Jersey and deadhead into the Port Authority terminal to pick up passengers.

For most of its length, I-495 from the New Jersey Turnpike to the Lincoln Tunnel Plaza consists of three lanes in each direction within a 32-ft-wide roadway. As the roadway approaches the Lincoln Tunnel Plaza in a hairpin turn, it widens to four lanes within a 44-ft-wide section. Most of this roadway was constructed in the 1930's and is considered substandard by current criteria. The bus lane is only 11 ft wide.

Traffic Operations and Controls

Detailed operating plans provide for changeover to and from the exclusive bus lane operation, police surveillance, and assistance to disabled vehicles. The lane operates on weekday mornings except when weather and traffic conditions make its use impracticable or unnecessary.

A specially constructed bus roadway at the New Jersey Turnpike facilitates entrance to the bus lane Buses entering the bus lane from Route 3 and the Turnpike use this special "teardrop" road to effectively bypass the normal highway queues (Fig. B-30). An "escape hatch" allows off-route vehicles to enter the regular eastbound flow

Under the initial operations plan, approximately 80 lane directional signals were installed on overpasses and sign bridges along the westbound side of I-495. These signals, placed over the center of each lane, show either a green arrow pointing downward when the lane is open for traffic or a red "X" to indicate that the lane is closed. The signals inform westbound motorists and eastbound buses of the prevailing operations. They were actuated in advance of the actual bus lane operations to familiarize drivers with the new traffic control devices.

In addition to the overhead lane signals, traffic posts and manually changeable signs are a vital part of the traffic control plan. Figure B-31 shows the types of traffic posts and lane directional signals used; Figure B-32 shows the type of hinged sign used. More than 350 cylindrical, 1½-foot-high, bright-yellow, plastic traffic posts are placed at 40-ft intervals in predrilled pavement holes for the entire 2.5-mile length of the bus lane. The traffic posts separate the eastbound bus lane from westbound traffic. They are manually placed before the lane is activated for buses and then removed at the conclusion of the morning peak-period operation. The posts are placed along the median-lane line except on horizontal curves on the helix roadway approaching the Lincoln Tunnel On the four-lane westbound helix roadway the posts are situated in the center of the second lane from the median, thus creating a closed buffer lane between the bus lane and the opposite (westbound) traffic flow.

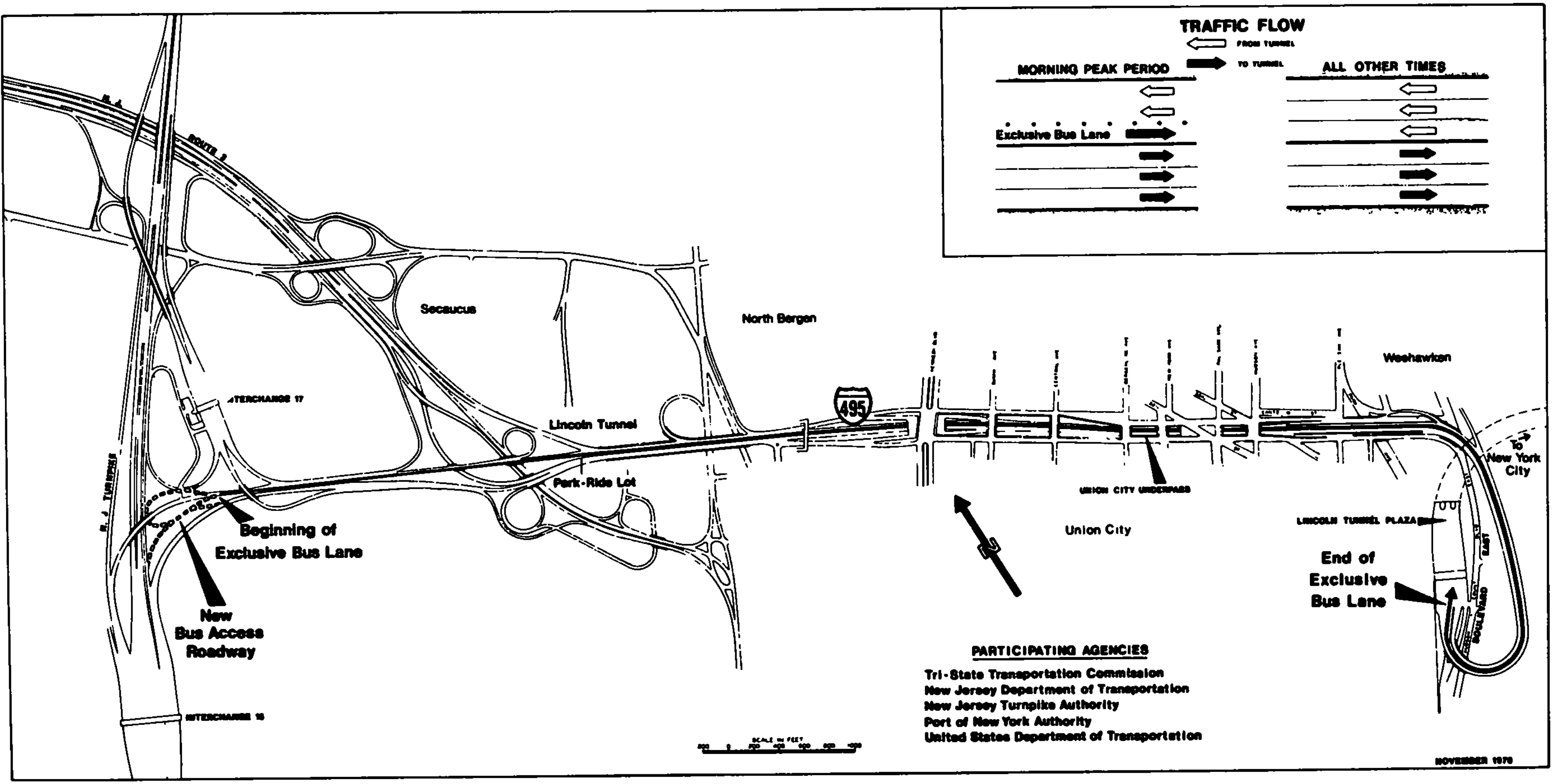


Figure B-28 Location map, I-495 exclusive (contra-flow) bus lane, New Jersey.

Figure B-29. Typical view, I-495 exclusive (contra-flow) bus lane, New Jersey.

An important element of the traffic posting system is the custom-modified posting vehicle, which allows placement of posts from either side and includes a special braking control to allow the post "placer" to control the vehicle's speed. The system allows completion of all post placement within 30 min.

Port Authority police activate about 50 traffic signs that display different messages depending on whether the lane is operating. The sign plan assumes that any vehicle may accidentally stray into the bus lane. The signs are designed to be read by the average motorists, not just the professional bus driver. New Jersey State Police assigned to the Turnpike assist in operating the lane along the Turnpike bus access road.

The lane is set up every morning with the installation of posts in holes in the pavement; five people are necessary for the installation, operation, and maintenance of the lane. Two are located on the specially designed tow truck to install the posts, two police are on station (one at each end of the lane), and one patrols the lane to check for breakdowns. Fairly quick response to breakdowns is achieved because emergency tow trucks are located at points along the route. The continuous patrolling enables breakdowns to be noticed soon after they occur and vehicles are removed as soon as possible. Average stoppage ranges from 8 to 9 min. Breakdowns occur approximately two times every three weeks, but significantly longer periods have elapsed without any breakdown.

The control plan incorporates detailed pavement markings for westbound I-495. A gate at the bus lane entrance

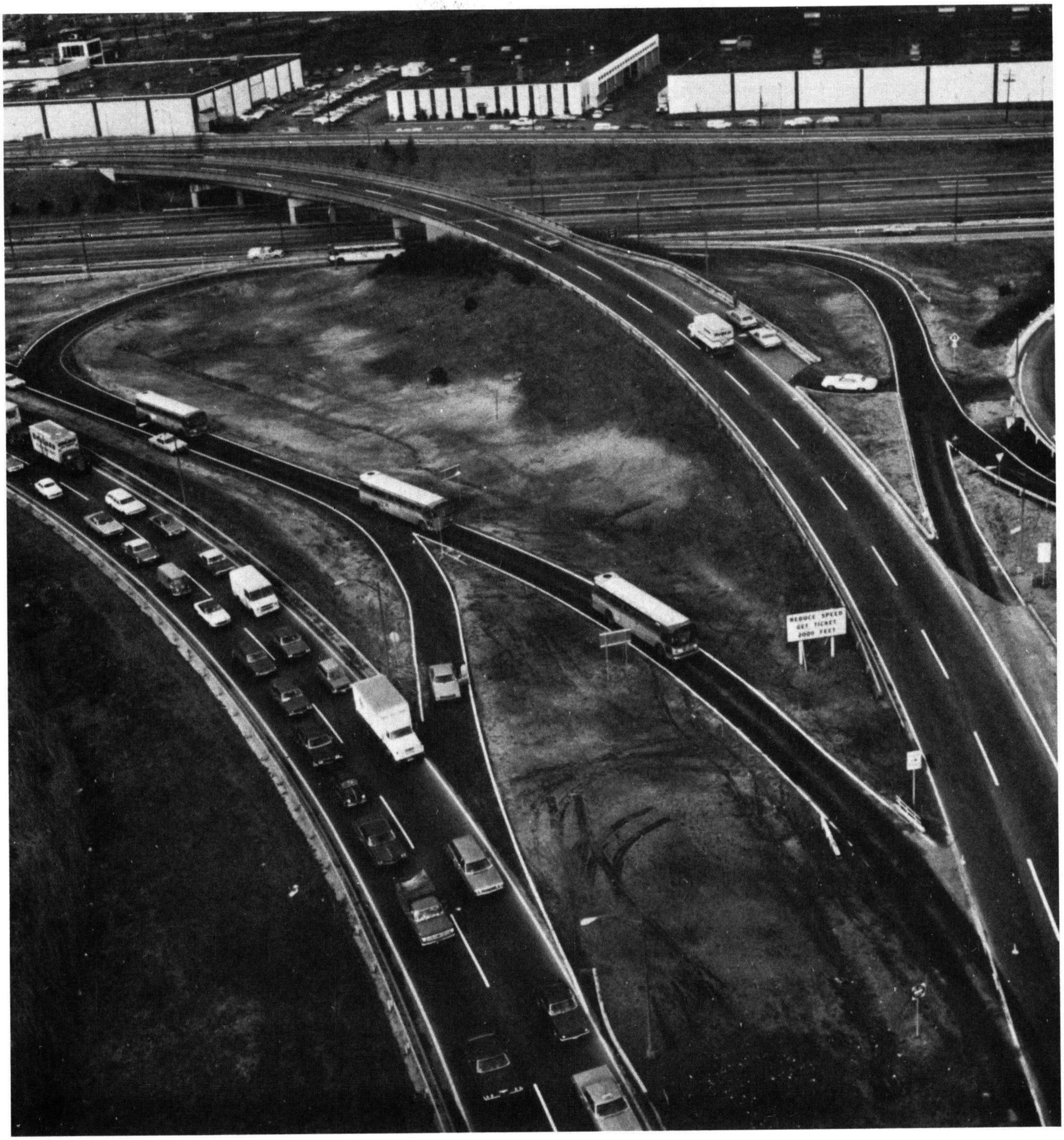


Figure B-30. Special bus entry road, I-495 exclusive (contra-flow) bus lane, New Jersey.

bars eastbound traffic from the lane during times when it is not in operation, allowing the lane to handle its normal complement of westbound traffic.

The control system has not experienced major operating problems. The manually operated sign changeover procedures, and the lack of remote control for the lane signals would be ameliorated by a Phase 2 control strategy. This phase would provide permanent signal installations that could be controlled from a single point. As part of this system, all lane indicators would be interconnected, and a television control monitor would be installed, together with electronic signing, at the point of entrance of buses to the bus lane. This automated surveillance system would extend along the entire length of the bus lane from the point off the New Jersey Turnpike to the Lincoln Tunnel.

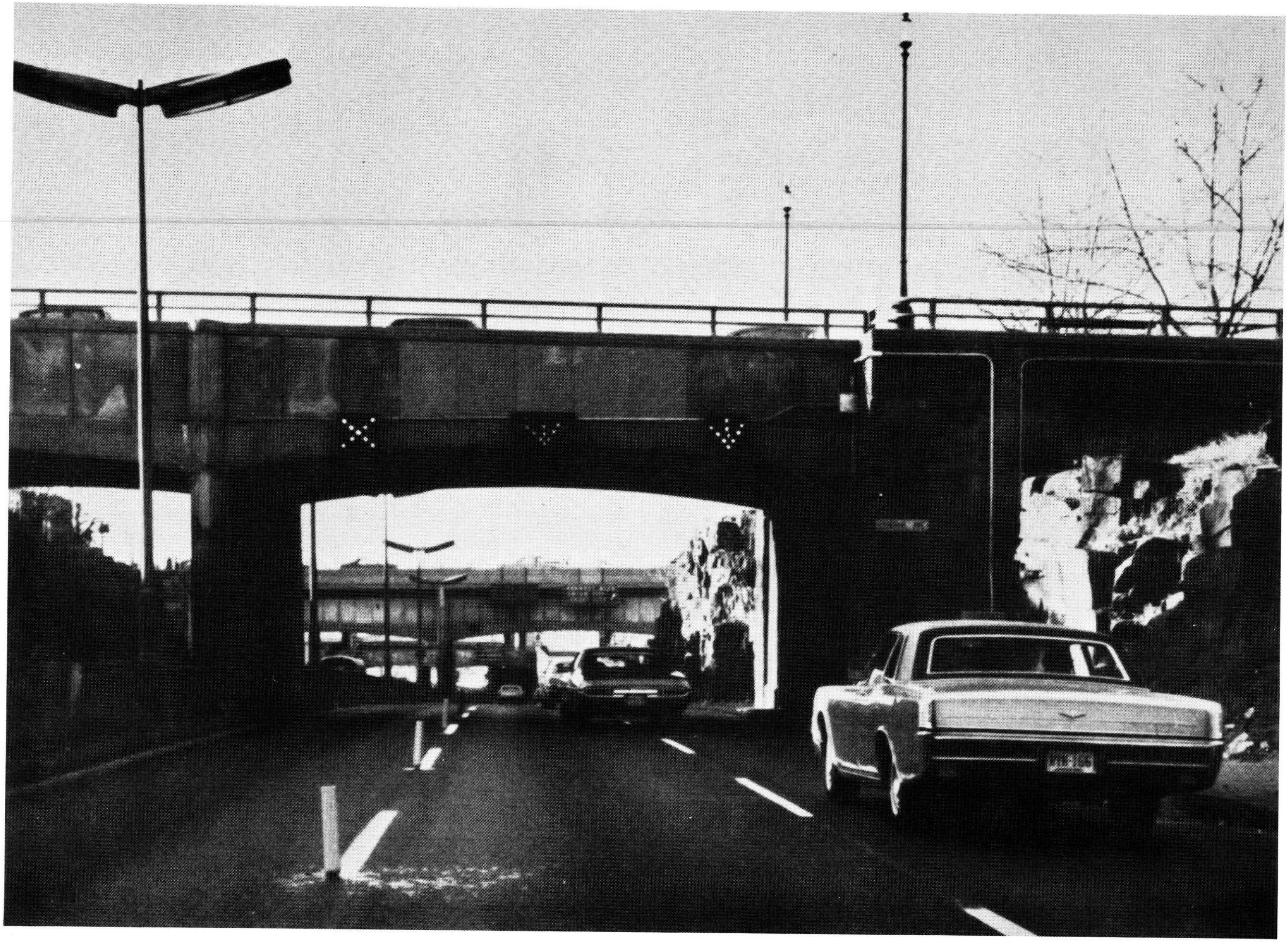


Figure B-31. Lane control signals, I-495 exclusive (contra-flow) bus lane, New Jersey.

Figure B-32. Typical hinged sign, I-495 exclusive (contra-flow) bus lane, New Jersey.

Use

The exclusive bus lane is used by 25 companies operating more than 70 routes, Public Service Coordinated Transport of New Jersey is the principal carrier. During the peak two-hour period, some 800 buses carry 34,000 to 35,000 passengers; during the 8:00 to 9.00 AM peak hour, 480 buses carry about 21,000 passengers along the exclusive lane. The highest average flows were recorded during the second quarter of 1971, when the peak-period figure reached 835 buses and 35,100 passengers. During the first three quarters of 1971, 154,000 buses carrying about 6,467,000 passengers used the exclusive bus lane (Table B-32).

Even higher flows were experienced during the transportation emergency created by the nationwide railroad strike on May 17 and 18, 1971. The bus lane handled the added loads easily with no stoppages or delays. Record flows were achieved on May 18, 1971, when almost 600 buses (25,800 passengers) in the 8.00-9.00 AM hour and 1,100 buses (47,800 passengers) in the peak period used the bus lane Media coverage of the bus lane's role in the rail strike was extremely favorable. one television commentary noted that, "The only thing moving into New York this morning was the express bus lane into the Lincoln Tunnel."

Bus Approach Volumes

During the total peak period, the highest volume of bus lane vehicles approach on the New Jersey Turnpike northbound, through Interchange 16E. This approach has the most direct routing to the exclusive bus lane (XBL), other approaches involve some backtracking to gain access. Buses from the Turnpike southbound through Interchange 17 constitute the second heaviest individual bus approach. Thus, the New Jersey Turnpike accounts for two-thirds of the total bus lane flow. Route 3 supplies about 24 percent of the buses, 6 percent come from Paterson Plank Road, and the remaining 3 percent originate in the Lincoln Tunnel park-ride lot There is little variation between peak-hour and total peak-period bus-volume distribution

Auto Volumes

The bus lane has increased the capacity of the substandard six-lane Union City underpass section of I-495 Removal of eastbound buses to their own exclusive lane increased morning peak-hour eastbound flow by 40 percent (from 3,287 vehicles in three lanes to 4,529 vehicles in four lanes). Concurrent with this eastbound traffic increase, the same number of westbound vehicles was accommodated.

TABLE B-32

USE OF THE I-495 EXCLUSIVE BUS LANE, NEW JERSEY

QUARTER	TOTAL		AVE , PEAK PERIOD		AVE , 8–9 AM	
	BUSES	PASS	BUSES	PASS	BUSES	PASS
1 [a]	48,921	2,054,700	785	33,000	464	20,400
2 [b]	53,425	2,243,900	835	35,100	491	21,600
3 [c]	51,640	2,168,900	807	33,900	484	21,300

Source Port Authority of New York and New Jersey (1971)

[a] January, February, March [b] April, May, June [c] July, August, September

Bus Patronage

Based on comparable spring survey data from 1968 through 1971, the bus lane has apparently arrested a mild downward trend in short-haul ridership, while it has increased medium-haul patronage. Peak-period ridership on short-haul routes was declining by 800 to 900 passengers per year until 1971, when it increased by 800, largely representing the lane's apparent inducement of 1,600 bus riders Middle-range bus routes were rising at an increasing rate over the past several years An expected increase during 1970-71 of about 500 bus riders, compares with an actual increase of 1,200, suggesting that about 700 were attracted by the exclusive bus lane.

Occupancy for routes using the bus lane was observed at 42 2 passengers per bus during the AM peak period and 44 1 passengers per bus during the 8 00 to 9:00 AM peak hour.

Operating Characteristics

Pertinent operating results are summarized in the following.

Stoppage

Exclusive bus lane stoppage caused by flat tires, brake problems, engine problems, and other factors occurred at the rate of less than three a month through the first three quarters of 1971. Two months (April and September) recorded no stoppages. The typical incident lasted about 7 min, a delay experience that is not unsatisfactory when compared with other transit operations in the Tri-State Region.

Safety

In the first three quarters of 1971, three accidents involving exclusive bus lane operations were reported, all occurred during March Only one of these involved personal injury (March 10, bus driver, leg lacerations)

The Port Authority reported no significant changes in the over-all accident records on the Lincoln Tunnel and its New York and New Jersey approaches during the first six months of 1971

Speeds

Ground observation surveys indicate that the exclusive bus lane saved the average bus 7.75 min during the morning peak period from the point where the bus approached the vicinity of the lane to the Lincoln Tunnel Plaza During the 8.15-9·15 AM hour of peak congestion, the bus lane saved each bus an average of more than 10 min travel time Although this average travel time saving varied widely by approach roadway and time period, the bus lane decreased the bus travel time from each tunnel approach during every 15-min time segment.

The exclusive bus lane, by removing a large volume of buses from the regular I-495 eastbound roadway, significantly increased eastbound peak-period auto and truck speeds on the I-495 approach section through the New Jersey Turnpike-Route 3 merge and over the North Bergen viaduct However, this improvement ended abruptly for eastbound vehicles beginning at the exit ramp for Kennedy Boulevard through the remaining 1.5-mile roadway to the Lincoln Tunnel Plaza, where speeds were no different from before No changes were discerned in westbound speeds.

Costs

Costs for implementing the exclusive bus lane approximated $700,000, of which $342,000 was for traffic control changes and $134,000 for the new bus access roadway (Table B-33).

Operating costs for the first year were estimated at $200,000, or about $80,000 per mile. This included daily Port Authority costs for exclusive bus lane set-up and take-down, police patrol and enforcement, emergency towing services, maintenance of traffic-control devices, and minor "housekeeping" such as roadway cleaning and snow removal. This figure did not include any major maintenance expenditures, as each operating agency retains basic operations and maintenance responsibilities within its own section.

Total operating expenses for the period January through August 31, 1971, were $130,668. At this rate, the first-year costs (December 18, 1970, through December 17, 1971) would amount to approximately $185,000, well within pre-opening estimates of $200,000 per year. Operating costs are shared by the New Jersey Department of Transportation and the Port of New York Authority. The former bears two-thirds of the expense; the latter, one-third.

Reported Benefits

An extensive series of traffic surveys identified the benefits of the exclusive bus lane. These showed major improvements for bus movement, as well as improved flow for other eastbound traffic in the morning peak period. During the morning peak hour, the exclusive bus lane saved each bus more than 10 min in average travel time. These average savings are based on hourly calculations and do not reflect the higher savings realized while regular traffic is delayed during short-term peaks or stoppages.

The vehicular capacity of the normal eastbound lanes increased by the shift of buses into their own, separate lane. Yet, the bus lane still carries more than ten times the number of people transported in any of the three other eastbound lanes at a much higher level of service. Based on 5-min counts, the short-term peak flows in the bus lane are running about 800 buses per hour, with indications that the hourly lane capacity is substantially higher than 800 buses

Removal of one westbound lane had little effect on westbound traffic Westbound volume remains unchanged, and speeds, although reduced, are in an acceptable 30- to 40-mph range

Analysis of bus-use trends indicates that the exclusive bus lane has induced an additional 2,300 daily morning peak-period riders (a 6 percent increase) onto routes using the bus lane Additional use of the Lincoln Tunnel park-ride lot was largely attributable to improved shuttle bus service to the Port Authority Bus Terminal via the bus lane. The number of parkers before 9 AM increased 11 percent during the first seven months of 1971.

TABLE B-33

ESTIMATED IMPLEMENTATION COSTS, I-495 EXCLUSIVE BUS LANE, NEW JERSEY[a]

ITEM	COST ($)
By Port Authority	
Preparation stage (development of operations and traffic control plans; design of traffic control device systems)	$60,325
Implementation stage (fabrication, purchases, installation, public information, training)	342,317
Project direction and coordination	25,400
Surveys and evaluation	38,100
Engineering for Part II	63,500
By Tri-State Transportation Commission	
Liaison and administrative	25,000
By N J Turnpike Authority	
Bus access roadway	134,000
Total	$688,642

Source Tri-State Regional Planning Commission

[a] Total federal reimbursement not to exceed $500,000

As a result of the bus lane, there is a reduction in driver overtime pay If a driver was previously delayed in traffic he was paid for this time if it increased his over-all time on duty. Reductions in driver overtime costs were reported by three-quarters of the companies, and many also reported improved equipment utilization. The companies also noted that their patrons and drivers were more satisfied and cooperative

Attitude surveys indicated positive responses from bus patrons After introduction of the bus lane, the proportion of bus patrons traveling four or more times a week increased substantially (from 82 to 92 percent).

Patrons and bus drivers indicated substantial time savings 54 percent in each group said the exclusive bus lane saved them 10 to 19 min. Some 95 percent of the patrons experienced more reliable travel and 86 percent indicated a more enjoyable trip

Following bus lane implementation, 88 percent of the bus drivers felt more relaxed and 75 percent felt safer while driving to Manhattan. Most eastbound motorists and many westbound motorists also felt that driving conditions had improved

Benefits were computed by the Port of New York Authority and the Tri-State Regional Planning Commission based on a monetary value of commuter time at $2 82 an hour, 225 working days each year, and 10 to 15 min of time saved The 35,000 commuters who use the lane save $3.7 to $5 5 million annually, or about $150 in time per commuter per year. These benefits compare to a first-year total project cost of $850,000.

Continuing Plans

Plans for continuing the program have been prepared Costs are estimated at about $1 4 million for this Phase II program, which includes: (1) several additional installations of overhead lane-control directional signals to provide coverage in areas presently covered only by sign and traffic-post control, (2) interconnection of all lane-control directional signals, (3) replacement of the present manually operated, locally controlled, changeable signs with electrically operated, remote-controlled, changeable-message signs, (4) installation of a television camera in the Secaucus interchange area, with monitors at a central control location, (5) installation of central remote control for all changeable-message signs and signals in the Lincoln Tunnel administration building, (6) installation of an automatic gate at the bus lane entrance, (7) additions and revisions to the fixed-message sign system, based on operating experience, and (8) a permanent police booth for use of the police officer on duty at the bus lane entrance.

Additional Urban Corridor recommendations call for 14,000 park-and-ride spaces to intercept autos in low-density areas; public acquisition of buses, installation of two-way radios on buses, testing of articulated buses to increase driver productivity, provision of automatic bus identification devices, and installation of 600 bus passenger shelters Four traffic management improvement programs were recommended for (1) I-495, (2) N J 3, (3) other key corridor arterials, and (4) completion of the permanent traffic control system for the I-495 exclusive bus lane Federal costs of these proposals were estimated at $86 8 million

Significance

The exclusive bus lane operation plan has actually improved the movement of all traffic approaching the Lincoln Tunnel. It typifies an important improvement approach toward maximizing the person-capacity of existing facilities It reflects changes in public and governmental attitudes toward public transport. It denotes cooperation of two toll-facility authorities, a state department of transportation, a tri-state regional planning agency, the federal government, local public agencies, and private bus carriers. It is an extension to buses of the "off-center" lane arrangements used in urban areas for more than three decades It shows how major benefits can be achieved through the use of minimum design standards.

The contra-flow bus lane alleviates a bottleneck condition as part of a *system* of express facilities. Its effectiveness clearly assists the high-speed express bus service along the New Jersey Turnpike or approaches to the Lincoln Tunnel and complements the off-street distribution in Manhattan in the Port of New York Authority Terminal.

The improvement is limited to the AM peak periods. In the PM peak period, buses receive preferential entry into the Lincoln Tunnel and then proceed at reasonable speed levels along I-495.

The bus lane shows how early action can be achieved within a heavily traveled corridor—a corridor with adequate demands for rail transit volumes. The AM peak-period bus volumes—nearly 800 buses—using the exclusive bus lane exceed the total bus fleets found in cities such as Seattle and Dallas. In fact, the peak-hour volumes handled exceed the per-track volumes of all U.S. commuter railroads and most rail rapid transit lines.

Until recently the two dozen companies using the bus lane provided good service entirely from fares Now, caught in the squeeze of rising costs, increasing fares, and diminishing returns, a number of companies (including the largest) are operating at a loss and are forced to curtail service. Thus, high driver productivity is essential.

LONG ISLAND EXPRESSWAY CONTRA-FLOW BUS LANE

The 2 2-mile Long Island Expressway contra-flow bus lane operates westbound between Greenpoint Avenue (just east of the Brooklyn-Queens Expressway) and the Queens Midtown Tunnel during morning peak hours (7 00 to 9:30 AM). During this period, eastbound traffic is restricted to two lanes along the six-lane expressway (Figs. B-33 and B-34). The bus lane was constructed and is operated by the New York City Department of Traffic

Like the I-495 exclusive bus lane, operations are limited to the morning peak hours Traffic during the afternoon peak hours is too balanced to permit use of a westbound lane by eastbound buses

Traffic Operations

Manhattan-bound buses move into the median westbound lane about 4 miles east of the Midtown Tunnel. At a point 2 miles east of the tunnel, the center divider is opened about 140 ft in the AM peak period to permit buses to move left into the median lane on the eastbound side of the highway. All eastbound traffic is barred from this lane, permitting westbound buses to bypass the daily backup of traffic from the tunnel entrance and toll plaza Once in the lane, buses operate with headlights on, with a maximum speed of 35 mph, and a 200-ft minimum spacing No passing is allowed Traffic tubes placed by maintenance crews separate buses from other cars during the peak period The bus lane is about 10 to 10½ ft wide, with the tubing placed on the outside of the reverse lane to allow full lane use by buses Manually changeable "clamshell" traffic signs guide traffic.

Westbound signs directing buses into the left lane begin two miles east of the crossover point The signs have an orange background with black letters. A quarter-mile series of signs guides buses into the express lane and directs other traffic to continue in the westbound lanes Eastbound signs repeat the warning "LEFT LANE CLOSED—ONCOMING BUSES" and the 35-mph speed limit throughout the 2-mile distance. Signing has been tripled over that initially designed.

Use

During the peak period, 13 express bus lines use the lane; 9 lines operate through the Queens-Midtown Tunnel, four others operate only in Queens. The starting points of Manhattan-bound express buses using the lane are given in Table B-34

The number of buses using the lane during the morning

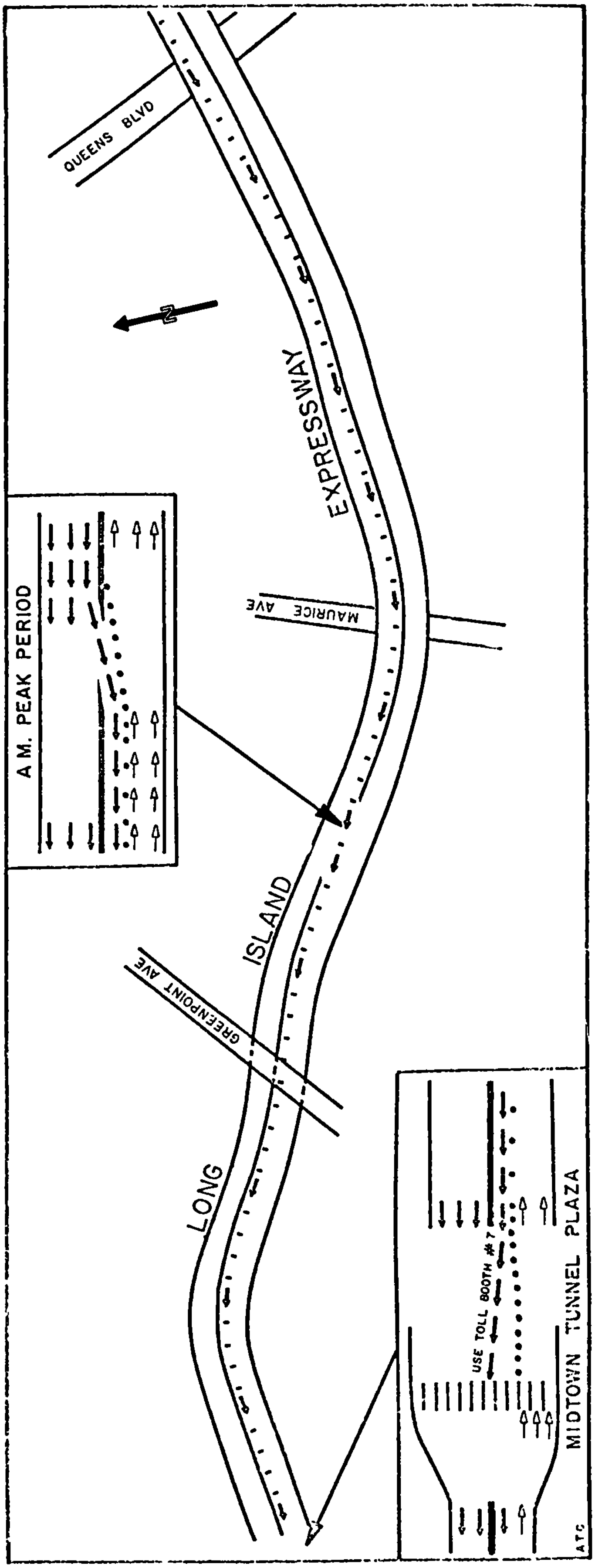


Figure B-33 Exclusive bus lane, Long Island Expressway, New York City.

peak hour (1971) is summarized in Table B-35. Up to 180 buses used the lanes during the morning peak period and 100 in the peak hour Weekly patronage averaged 25,000 for express buses and 12,500 for airport buses. In 1972, nearly 200 buses used the lane in the peak period and 120 in the peak hour Traffic volumes on the expressway approximated 3,400 westbound and 1,300 to 1,500 eastbound during the morning rush hour. The high directional imbalance allowed one eastbound lane to be removed from traffic without sacrificing speed or operating efficiency.

Costs

Costs to implement the lanes approximated $30,000 to $50,000 for signs, cones, and adjustment to median islands Approximately $20,000 additional was involved in

TABLE B-34

ORIGINS OF EXPRESS BUSES USING LONG ISLAND EXPRESSWAY BUS LANE, NEW YORK[a]

EXPRESS BUS LINE ORIGIN	TOTAL BUSES
Fresh Meadows	22
Glen Oaks	18
Flushing	8
Lindenwood	3
Rockaway	1
Lefrak City-Forest Hills	24
Douglaston	5
Clearview	8
Bayside	14
Total	103

Source New York City Department of Traffic, 1972

[a] Four other Queens express lines do not use the Queens Midtown Tunnel

TABLE B-35

NUMBER OF BUSES USING LONG ISLAND EXPRESSWAY BUS LANE, NEW YORK

TIME (AM)	MON. 11/22	TUES 11/23	WED 11/24	FRI. 11/26	TUES 12/7
7·15–7.30	3	9	8	11	5
30–45	12	19	19	22	16
45–8:00	10	19	15	25	10
8.00–8.15	34	32	41	29	32
15–30	25	30	31	23	28
30–45	(missed)	16	16	10	25
45–9 00	12	16	13	10	18
9 00–9 15	9	10	7	—	9
15–30	12	8	14	—	12
30–45	6	12	6	—	8
45–10 00	8	9	5	—	9
Total	131	180	176	130	172
Lane opened	7 15	7 15	7 15	7 15	7:15
Lane closed	9:45	10·00	10·15	9 00	10.00
Weather	Clear, cold	Clear, cold	Clear, cold	Clear, cold	Cloudy

Source New York City Department of Traffic, 1971

ENTRY POINT

ON APPROACH TO MIDTOWN TUNNEL

Figure B-34. Typical views, exclusive bus lane, Long Island Expressway, New York City.

the subsequent installation of traffic posts in drilled holes. Overhead lane signals, if provided, may ultimately cost $1 million.

Cost of a changeover crew (7 workers and a foreman) approximates $500 per day, or $125,000 annually.

Accidents

One accident was reported since inception of the bus lane in October 1971. In mid-July 1972, an eastbound taxicab skidded on wet pavement, made a 180° turn, and hit a bus traveling at 50 mph in the bus lane. No bus passengers were hurt, but the two occupants in the taxicab (the driver and a passenger) were hospitalized.

The accident brought to focus the effect of an incident on roadway operations when contra-flow facilities are used. Police quickly closed the bus lane, stopped traffic in the median lane on the reverse side, and permitted three buses in the bus lane to pass the accident scene. No provisions were made by the bus lines to exchange passengers, and the involved bus passengers were delayed nearly two hours.

Reported Benefits

Travel time studies are summarized in Table B-36. During the height of the AM peak hour, auto travel times from the point where the bus lane begins to the Queens Midtown Tunnel ranged from 16 to 23 min. Buses using the contra-flow lane took 3½ to 4 min to traverse the 2.2-mile length. Thus, up to 20 min were saved during certain time periods. Average travel times for eastbound motorists remained relatively unaffected at about 3 min.

The average time saved each passenger was estimated at 12 min daily, or 60 min each week. This corresponds to an aggregate weekly time savings of 37,500 passenger-hours.

Significance

The project provides improved bus service to areas with major transport capacity deficiencies because existing subways and highways leading from Queens to Manhattan are overloaded. This capacity relief is essential during the interim period until major subway improvements in Queens are completed.

Despite the success of the bus lane, additional buses are not being scheduled because of terminal capacity limitations in Manhattan. Improved distribution in Manhattan, therefore, becomes an essential part of long-range plans to expand the bus service. Efforts in this regard are reported under way.

12. PITTSBURGH PATWAYS

The Early Action Program, prepared by the Port Authority of Allegheny County Transit, is an integral part of the various planning efforts designed to meet changing urban travel patterns, as well as to stimulate downtown and regional growth It is a direct response to the need for improved transit access to the Golden Triangle, Pittsburgh's 0.5-square-mile central business district where some 100,000 persons work each day.

Pittsburgh has a long history of public transportation planning and development dating back to the 1850's. More than 16 transit studies and plans were prepared since 1906, an average of about one every four years. All plans developed before 1968 lacked community support and financing mechanisms necessary for implementation. As a result of the region's confining topography, virtually all studies located new transit facilities in common corridors extending south and east from the Golden Triangle.

The region's rugged terrain and major river valleys have shaped urban development, limited entry points to the Golden Triangle, and made it difficult to provide additional highways. Narrow downtown streets and an offset street grid along Liberty Avenue further complicate vehicular circulation. Streetcars still operate along Smithfield, Grant, Liberty, and Wood Streets These factors underscore the need to serve future downtown employment and peak-hour travel growths by improved public transport. They underlie the Early Action Program, which was adopted August 2, 1968.

PATway Description

The East and South PATways are key elements of the Early Action Program. In addition to these exclusive bus roadways (12 miles in total length), the program includes a 10-mile Transit Expressway Revenue Line, and retention of two private right-of-way streetcar routes. The over-all plan is shown in Figure B-35.

The city, the county, and the Pennsylvania Department of Transportation jointly proposed the busways as an economical and practical method of improving transit service to the CBD and simultaneously preserving rights-of-way in important travel corridors The two PATways, and the Transit Expressway (TERL) were endorsed and approved locally in 1968 and 1969. They were approved and funded by the Urban Mass Transportation Administration (UMTA) in June 1970. UMTA, however, required that PAT preserve and rehabilitate two existing streetcar services between the CBD and residential areas to the south and that they operate for three years after the Transit Expressway service begins. (The Library Line (Route 35) operates approximately 13 miles south of the CBD, and the Beechview Line (Route 43), approximately 2.25 miles.)

Final design and engineering of the PATways is nearing completion as of October 1972. However, the entire Early Action Program is being challenged legally, and several governments (including the City of Pittsburgh and some suburban communities) have formally expressed opposition to the program, primarily the Transit Expressway. Discussions are under way with the Penn-Central Railroad regarding the extent and cost of needed bus rights-of-way.

TABLE B-36

TYPICAL TRAVEL TIMES, LONG ISLAND EXPRESSWAY BUS LANE, NEW YORK

	WEEK OF 10/25/71		WEEK OF 11/4/71	
TIME (AM)	WB TRAVEL TIME (MIN)	NO OF BUSES	WB TRAVEL TIME (MIN)	NO OF BUSES
7·00– 7 30	3 25	5	3 20	10
7 30– 8.00	7 50	32	3 84	31
8:00– 8.30	14.22	56	11 23	44
8:30– 9 00	23 50	33	15 90	22
9 00– 9 30	21.00	20	8 08	22
9 30–10.00	8 50	16	3 20	14
Total		162		143

Source New York City Department of Traffic, 1971

East PATway

The East PATway will extend approximately 8 miles eastward from the Golden Triangle to a connection with the Penn-Lincoln Parkway (I-76) in Edgewood (Fig. B-36) It will follow the alignment and grade of the Penn-Central Railroad, will be essentially flat, and will permit high-speed bus operations. The railroad trackage on which the busway is being located is scheduled for abandonment.

The busway will serve several large residential neighborhoods and commercial areas (Shadyside, East Liberty, Point Breeze, Homewood, Brushton, Wilkinsburg, and Edgewood) via intermediate access points and stations However, it will not serve the major activity centers of the Oakland or Squirrel Hill areas, both of which have a strong orientation to the CBD

The facility will afford an effective shortcut for buses by providing service between the CBD and the eastern suburban areas, as well as intermediate areas. Buses will be able to avoid the congestion and resultant delays at the Squirrel Hill Tunnel during the morning and evening peak periods, thereby potentially saving up to 30 min on some trips, and reducing running times by as much as 50 percent (Table B-37) The PATway will also reduce travel times between the CBD and intermediate service areas by per-

TABLE B-37

ANTICIPATED PEAK-HOUR TIME SAVINGS, EAST PATWAY, PITTSBURGH

	TRAVEL TIME (MIN)		SAVINGS	
BETWEEN CBD AND	CURRENT SERVICE	PATWAY	(MIN)	(%)
Shadyside	24	9	15	62
East Liberty	29	11	18	62
Homewood	39	13	26	67
Edgewood	34	17	17	50
Penn Hills	44[a]	31	13	29
Penn Hills	58[b]	31	27	47
Rodi Road	53	23	30	57
Monroeville	62	32	30	48

Source Ref (*B-26*)

[a] Via Penn Lincoln Parkway

[b] Via East Liberty (surface streets)

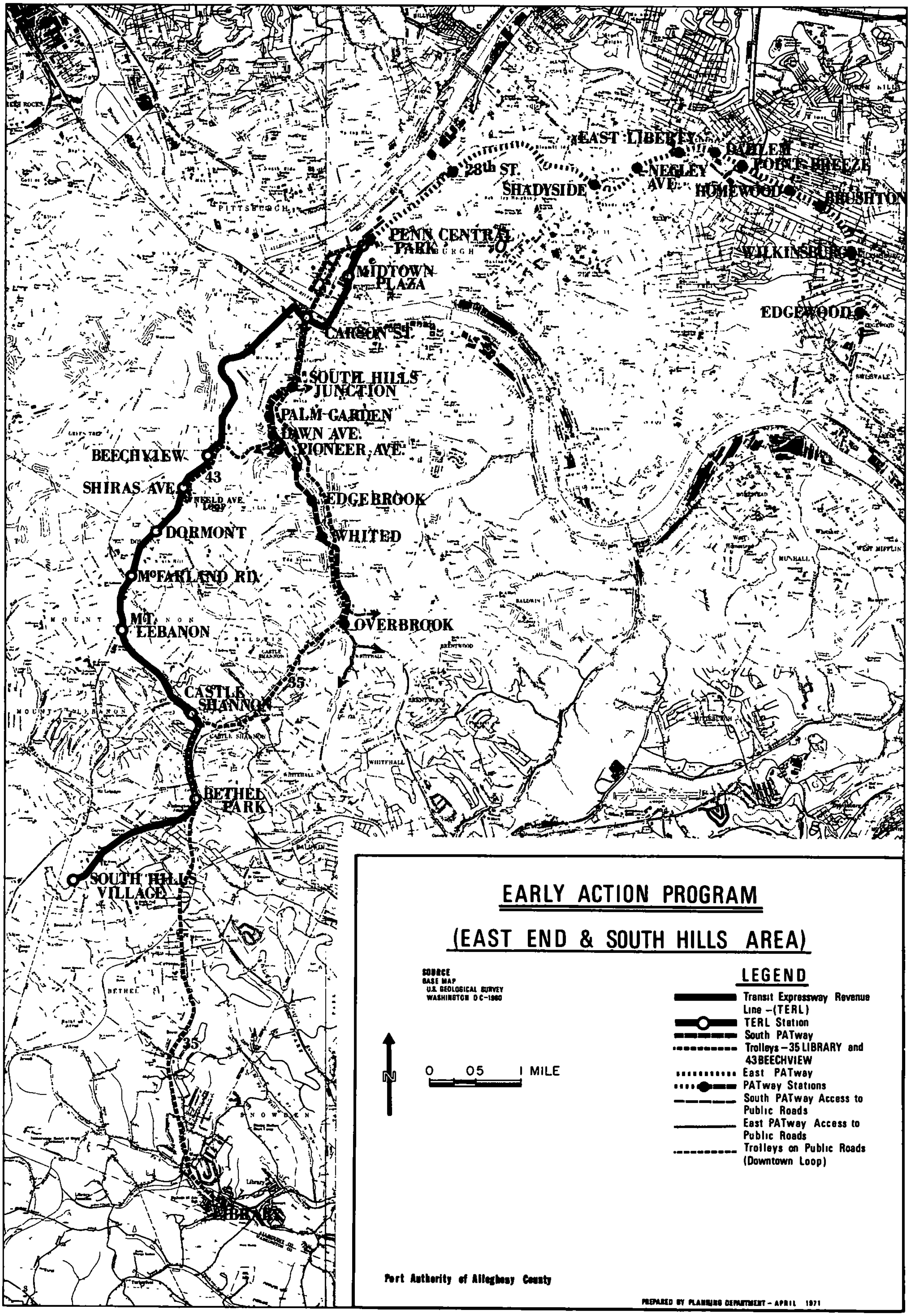


Figure B-35 Early action transit program, Pittsburgh, Pa

Figure B-36. Location map, East PATway, Pittsburgh, Pa.

mitting buses to operate on a congestion-free exclusive roadway for considerable portions of their trips.

South PATway

The South PATway will extend from the CBD on exclusive lanes (presently used only by streetcars) across the Smithfield Street Bridge, through the Mt Washington-Smithfield Street Tunnel, which it will share (temporarily) with streetcars, and then over a combination of new and existing exclusive rights-of-way southward to Overbrook, a total distance of about 4 miles (Figure B-37). The simultaneous operation of buses and streetcars in a single tunnel makes the PATway concept viable while the streetcars are still in regular use (Figure B-38).

The South PATway will have four intermediate access points that will provide improved bus service to residential neighborhoods and commercial areas along and near the Saw Mill Run Valley. It will permit buses to bypass the congested Liberty Tunnels and Bridge, thereby saving up to 6 min (35 percent) on running times and helping to assure on-time service (Table B-38).

TABLE B-38

ANTICIPATED PEAK-HOUR TIME SAVINGS, SOUTH PATWAY, PITTSBURGH

BETWEEN CBD AND	TRAVEL TIME (MIN) CURRENT SERVICE	PATWAYS	SAVINGS (MIN)	(%)
Whited Street	17	11	6	35
Overbrook	21	15	6	29

Source Ref (*B-26*)

TABLE B-39

DESIGN AND OPERATING CHARACTERISTICS, PATWAYS, PITTSBURGH

ITEM	EAST PATWAY	SOUTH PATWAY
Structure		
Length, approx	8 miles	4 miles
Cost	$21 382 million	$16 833 million
Avg cost per mile	$ 2 673 million	$ 4 208 million
Access control	Complete	Complete
Bus access points	7	6
Stations	11	8
No of lanes	2	2
Lane width	12–14′	12–14′
Median islands	None	None
Grades [a]	0–3 percent	0–5 percent
Design speed	60 mph	50 mph
Restricted speed [b]	50 mph	25 mph
Service		
Non-stop	40 8 mph	30 0 mph
Limited stops	32 6 mph	28 9 mph
All-stop	20 1 mph	20 0 mph
Avg. operating speed on parallel arterials	10 4 mph	12 3 mph
Special traffic controls	None	None

Source Ref (*B-26*)

[a] Except for short sections where steeper grades may be encountered, especially on the South PATway

[b] Usually due to curves

Emergency vehicles (police, fire, ambulance) and non-PAT buses will be able to use the PATways at all times. This will serve to increase their value to the general public.

Design Features and Control Methods

Major design features and characteristics of the two PATways are summarized in Table B-39; typical cross-sections are shown in Figure B-39. Each PATway will be designed with two 12- to 14-ft lanes with curbs Some sections will also incorporate 10-ft shoulders. There will be no median dividers. Acceleration and deceleration lanes will be provided at each entrance or exit point, and pull-out lanes will be built for passenger pick-up and discharge at stations along the PATways.

Each access point will be designed as a simple intersection to the extent practical, with appropriate acceleration and deceleration lanes. Where PATway ramps connect with arterial streets, traffic signals (perhaps with separate phases for buses), signs, and pavement markings will provide adequate control. Use of barrier gates or other special control methods is not anticipated. (Further design and operational analyses may recommend additional control devices at individual locations) Enforcement will be the responsibility of local police agencies.

The possible future conversion of PATways to fixed-guideway transit systems is of special significance The East PATway is designed to permit conversion to future TERL (Skybus) service. Its location makes it a logical extension of the presently proposed TERL line, which ends at the Penn-Central Station where the East PATway begins.

Downtown Distribution Concepts

PATway bus operations will require major modifications to the existing PAT routes and services

Peak-hour 1967 bus and streetcar volumes in the CBD, shown in Figure B-40, are largely depictive of current routing patterns (No major routing changes have occurred since then, except for a small reduction of service on Oliver Avenue due to its being vacated between Wood Street and Liberty Avenue.) The concentrations and movement patterns along Liberty Avenue result from the turning movements by buses looping in the CBD. Both in 1967 and in 1972, there was virtually no through-routing of buses, routes looped and returned via their entry corridors. During the typical weekday evening peak hour, 480 buses and streetcars left the Golden Triangle. 100 to the north, 225 south, and 150 easterly. They carried approximately one-half of the 50,000 people leaving the CBD in the peak hour

The two PATways will provide exclusive bus facilities up to the edges of the CBD (Grant Street from the east, Fort Pitt Boulevard from the south), but no (exclusive) bus streets are planned within the Golden Triangle The principal downtown distribution of PATway buses (and passengers) will probably be by means of priority bus lanes on Smithfield and Wood Streets (Fig B-41). (The overall concept shown in Figure B-41 was developed by Wilbur

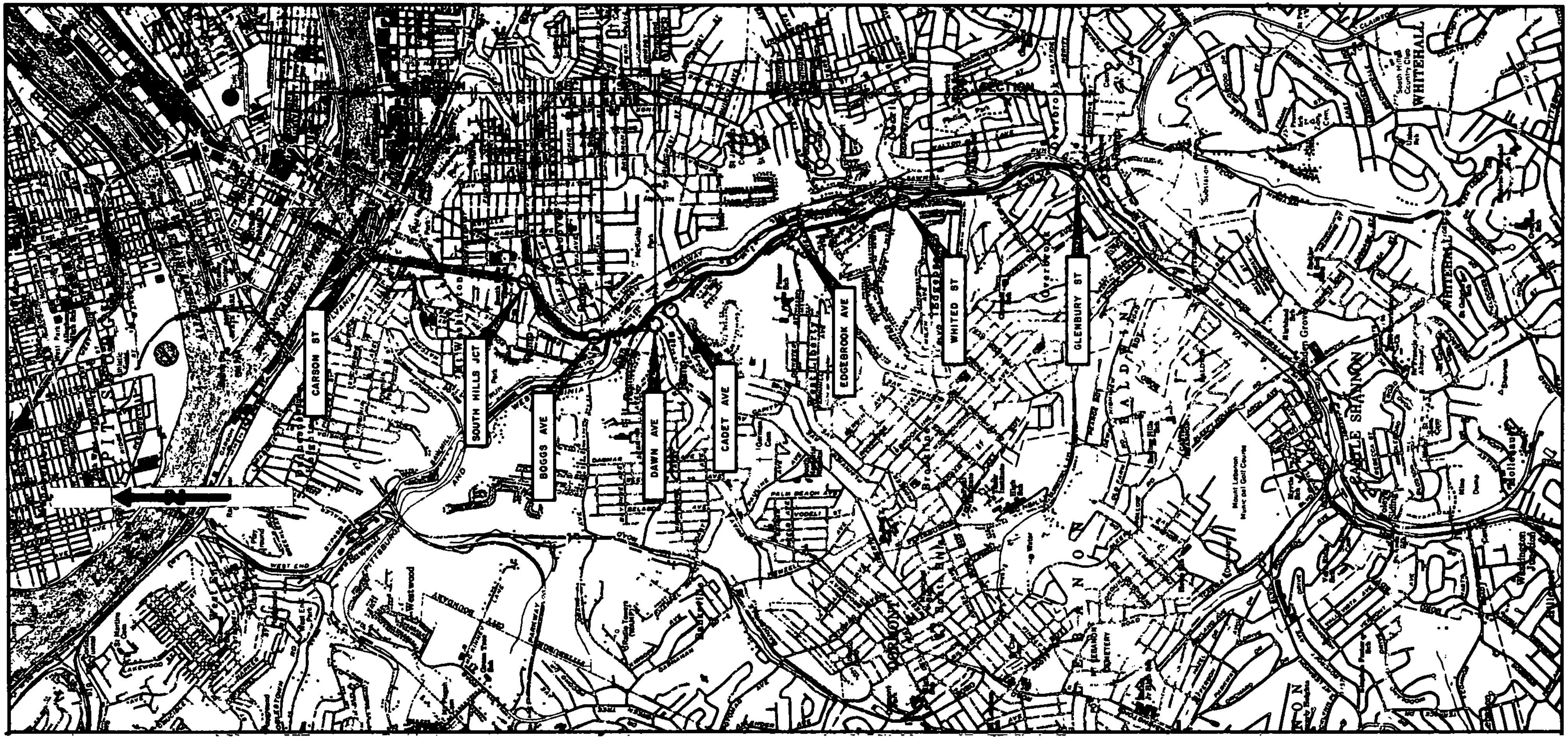


Figure B-37. Location map, South PATway, Pittsburgh, Pa

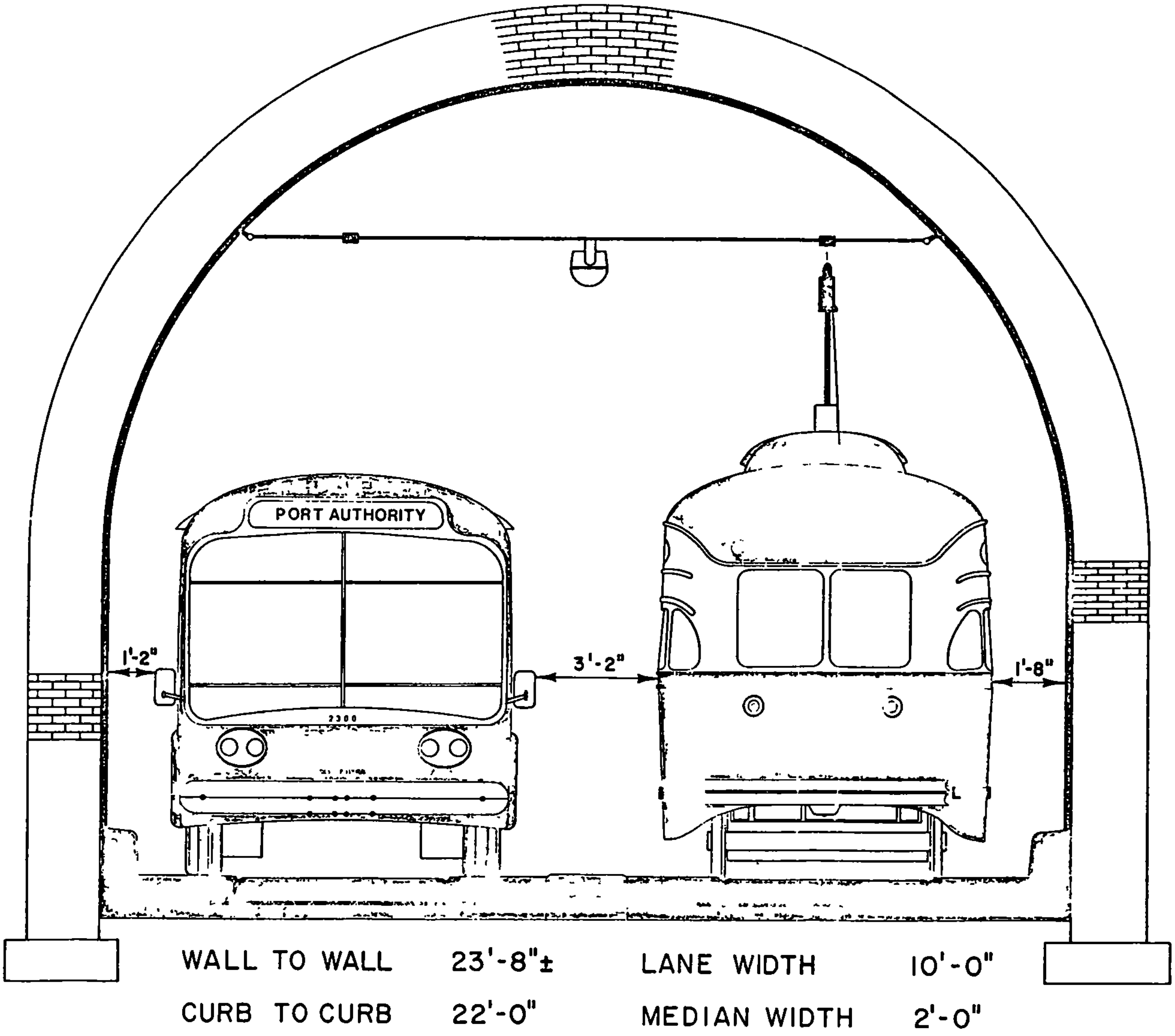


Figure B-38 Proposed Mt Washington Tunnel operations, South PATway, Pittsburgh, Pa

Smith and Associates for the Center City Transportation Project. Although not formally adopted by PAT, it represents a possible operational approach to downtown bus distribution.) Secondary service may be offered to the Gateway Center area near the Point (via a Commonwealth Place, Penn Avenue, and Stanwix Street loop), and along Grant Street and Liberty Avenue. The loop near Gateway Center could accommodate any unbalance in peak-hour PATway bus volumes. Bus routings along Smithfield and Wood Streets would penetrate the core area, serve to reinforce present employment and commercial patterns, and facilitate through routing.

The use of Smithfield and Wood Streets for primary PATway bus operations downtown would present few traffic operational problems. Neither street is used by through traffic; however, several parking garages along Smithfield Street make it impractical to convert it into a "transit only" street Thus, the bus priority lanes would represent a viable compromise.

The bus routing concept would require buses entering the East PATway to turn left across heavy rush-hour traffic on Grant Street, near Liberty Avenue. Traffic signal requirements, construction features, and other measures necessary to permit this heavy movement (95 peak-hour buses) remain to be more fully developed.

An alternative solution is the routing of buses down Smithfield Street, turning right into the middle lane on Seventh Avenue (a wide street in this section), and then left onto Grant Street at a signalized intersection (rather than proceeding via Smithfield and Liberty to Grant). The buses would then enter the East PATway by turning right, creating minimum traffic interference. Such a routing change might increase patronage by providing a stop directly opposite major office buildings along Grant Street.

The recently opened U.S. Steel Building, on a site bounded by Grant Street, Bigelow Boulevard, and Seventh Avenue, represents a major eastward shift in downtown employment concentrations. If that trend is accelerated by the proposed Transit Expressway service, it may be necessary to modify downtown PATway bus routings to better

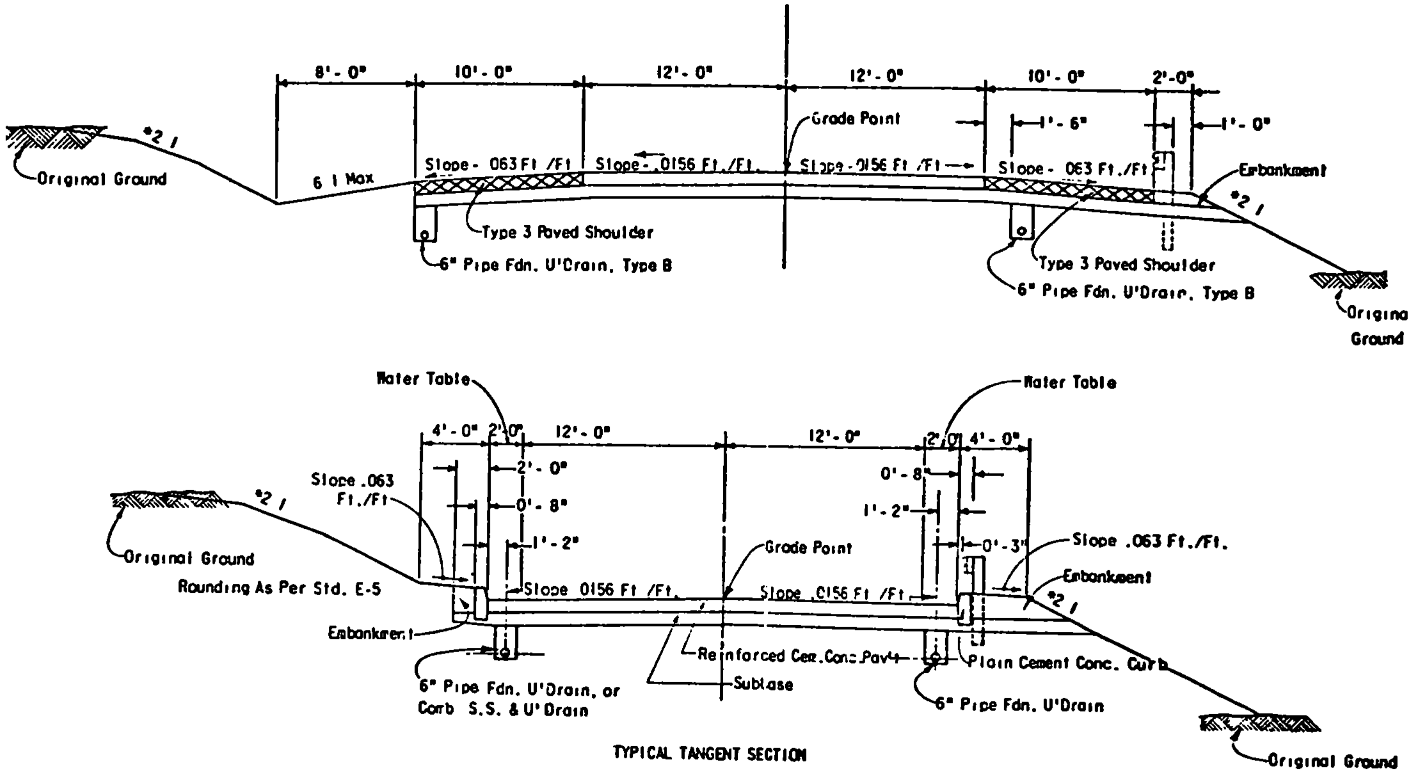


Figure B-39 Typical cross sections, PATways, Pittsburgh, Pa

serve the Grant Street corridor. This flexibility is a principal advantage of bus transit.

To maximize service benefits from the PATways, bus services to the east and south would have to be restructured. Similar changes also may be necessary on routes serving areas to the north and west to the extent that buses are through-routed or that the PATway and TERL (Skybus) downtown distribution services impact on remaining routes. Non-PATway buses would mainly operate on streets not used by PATway buses, and interline transfers would be made wherever the two bus services meet (Fig. B-42).

A comparison of the actual (1967) and anticipated peak-hour bus flows shows a greater concentration of future flows in the core area and a more even flow of buses along principal streets. The central area would accommodate about 60 percent of the total non-PATway volumes. These patterns would result from through-routing of buses and the minimization of turns in the CBD.

Final PATway and other bus routings will be established by PAT based on operational and administrative considerations. Detailed estimates of revised bus operating and maintenance costs are contingent on finalization of bus route and schedule changes.

Anticipated Use

Patronage forecasts for the initial year of service, 1973-4, are given in Table B-40. The East PATway would carry about 37,000 riders per day; the South PATway, 38,000. Weekday peak-period two-way patronage is estimated at about 20,000 for each route. On the assumption of 60 percent of peak-period travel in the peak hour and a 60 percent directional split, peak-hour one-way passenger volumes would range from 7,000 to 8,000 persons on each PATway. The anticipated peak-hour one-way PATway bus passenger volumes of 15,000 to 16,000 persons are the equivalent of about one-third of the total peak-hour outbound cordon person movement.

The patronage forecasts anticipate a heavy (approxi-

TABLE B-40

ANTICIPATED PATRONAGE, PATWAYS, PITTSBURGH [a]

ITEM	EAST PATWAY	SOUTH PATWAY
Average weekday patronage	37,400	27,700
Average weekday patronage, peak periods		
CBD	18,890	19,300
NonCBD	2,110	1,050
Average weekday off-peak patronage	16,300	7,350
CBD	5,700	2,600
NonCBD	10,600	4,750
Average weekly Saturday and Sunday	23,800	9,700
CBD	8,300	3,900
NonCBD	15,500	5,800

Source Ref (*B-26*)

[a] For initial year of operation East PATway expected to open late in 1974, South PATway, late in 1973

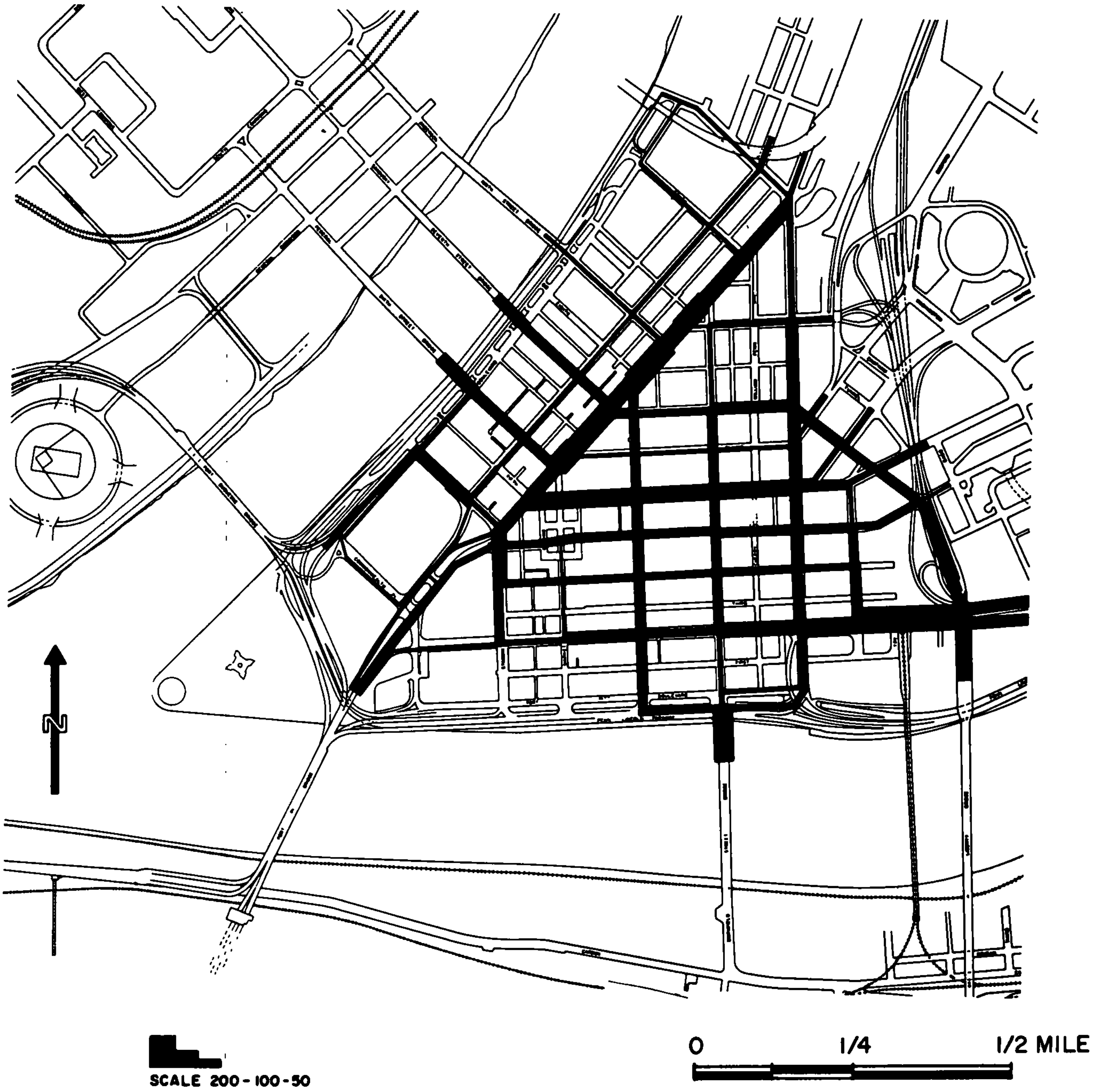


Figure B-40 1967 peak-hour downtown transit flows, Pittsburgh, Pa

mately 90 to 95 percent) CBD orientation during weekday peak periods, and a strong (approximately 66 percent) non-CBD movement during off-peak periods on both PATways. The peak-period pattern is to be expected; the off-peak movements suggest the degree to which the PATways will serve the communities and commercial areas through which they pass.

Costs

Current cost estimates for the two PATways are given in Table B-41. The East PATway is estimated to cost $21.4 million, or $2.7 million per mile; the South PATway is estimated to cost $11.7 million, an average of $4.2 million per mile. The 58 percent higher total cost per mile on the South PATway results from the need to construct three new bridegs, locate busways in hilly terrain, rehabilitate the present streetcar tunnel, and purchase new right-of-way.

Funding for the Early Action Program is two-thirds federal, one-sixth state, and one-sixth local. The arrangement has been assured by the respective agencies: UMTA, Penn DOT, Allegheny County, and the City of Pittsburgh.

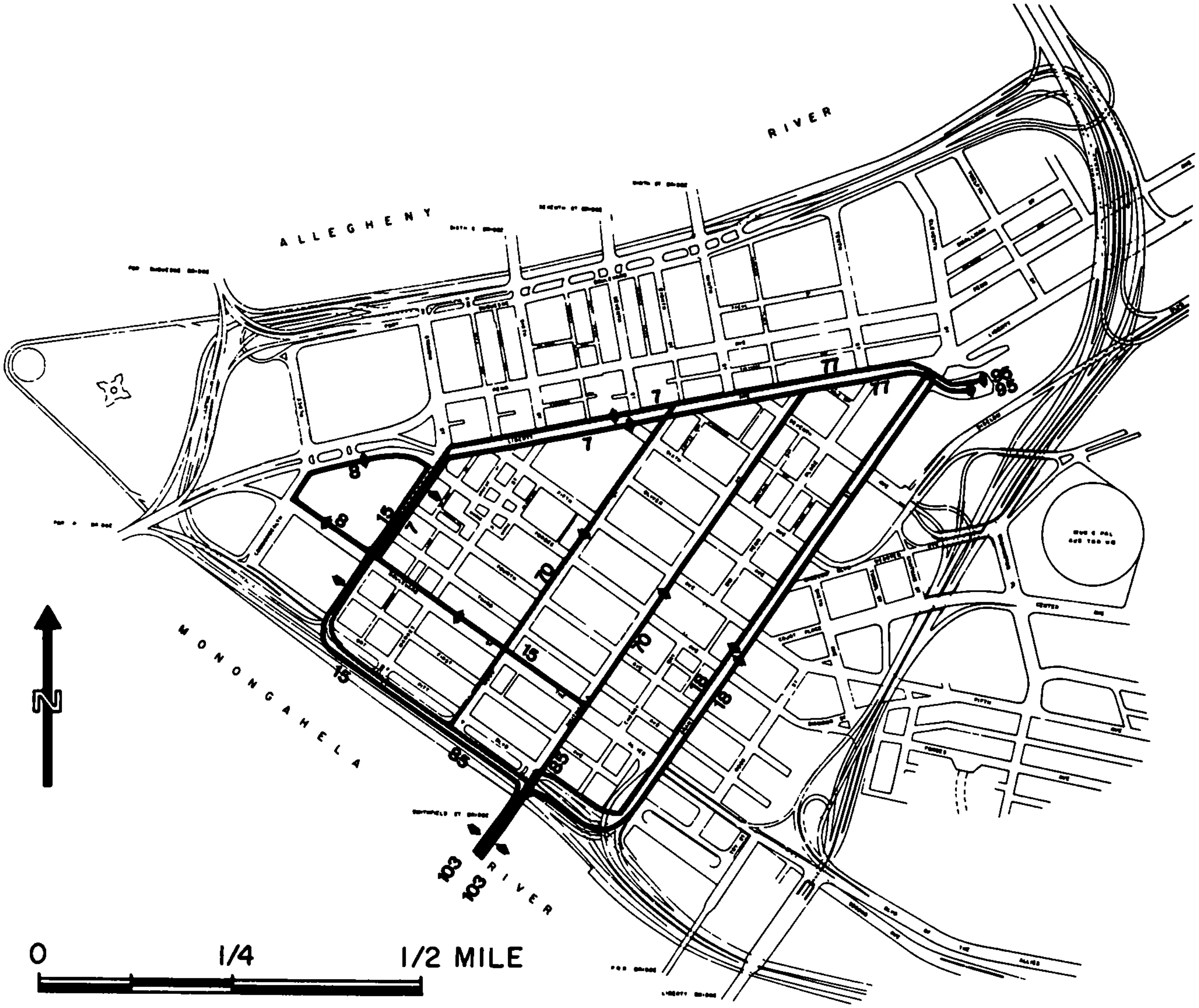


Figure B-41 PATway bus routing concept, Pittsburgh, Pa

Significance

The PATways represent an early action approach to express transit in a traditionally transit-oriented urban area. They will produce significant time savings (up to 50 percent for many patrons), and the exclusive nature of the facilities will help to assure commuters of on-time arrival in the CBD in the morning and at home in the evening. Scheduled operating speeds will be 66 to 100 percent faster than those on parallel streets.

They will also provide an important national test of the suitability of on-street downtown distribution of regional bus rapid transit. If on-street distribution of buses in the downtown core can maintain service reliability, it can help alleviate the need for more elaborate and costly distribution systems.

TABLE B-41

COST ESTIMATES, PATWAYS, PITTSBURGH

ITEM	EAST PATWAY[a]	SOUTH PATWAY[b]
Construction and right-of-way	$14,827,000	$11,673,000
Engineering and project administration	2,224,000	1,751,000
Excavation	2,387,000	1,879,000
Contingency @ 10%, rounded	1,944,000	1,530,000
Subtotal	$21,382,000	$16,833,000
Cost per mile	$ 2,673,000	$ 4,208,000

Source Ref (*B-26*)

[a] East PATway location utilizes existing high-speed railroad right-of-way, and is ideal in terms of topography

[b] South PATway is to be built in difficult terrain, requiring three new bridges and rehabilitation of existing trolley tunnel Cost estimates do not include new South Hills Division bus garage

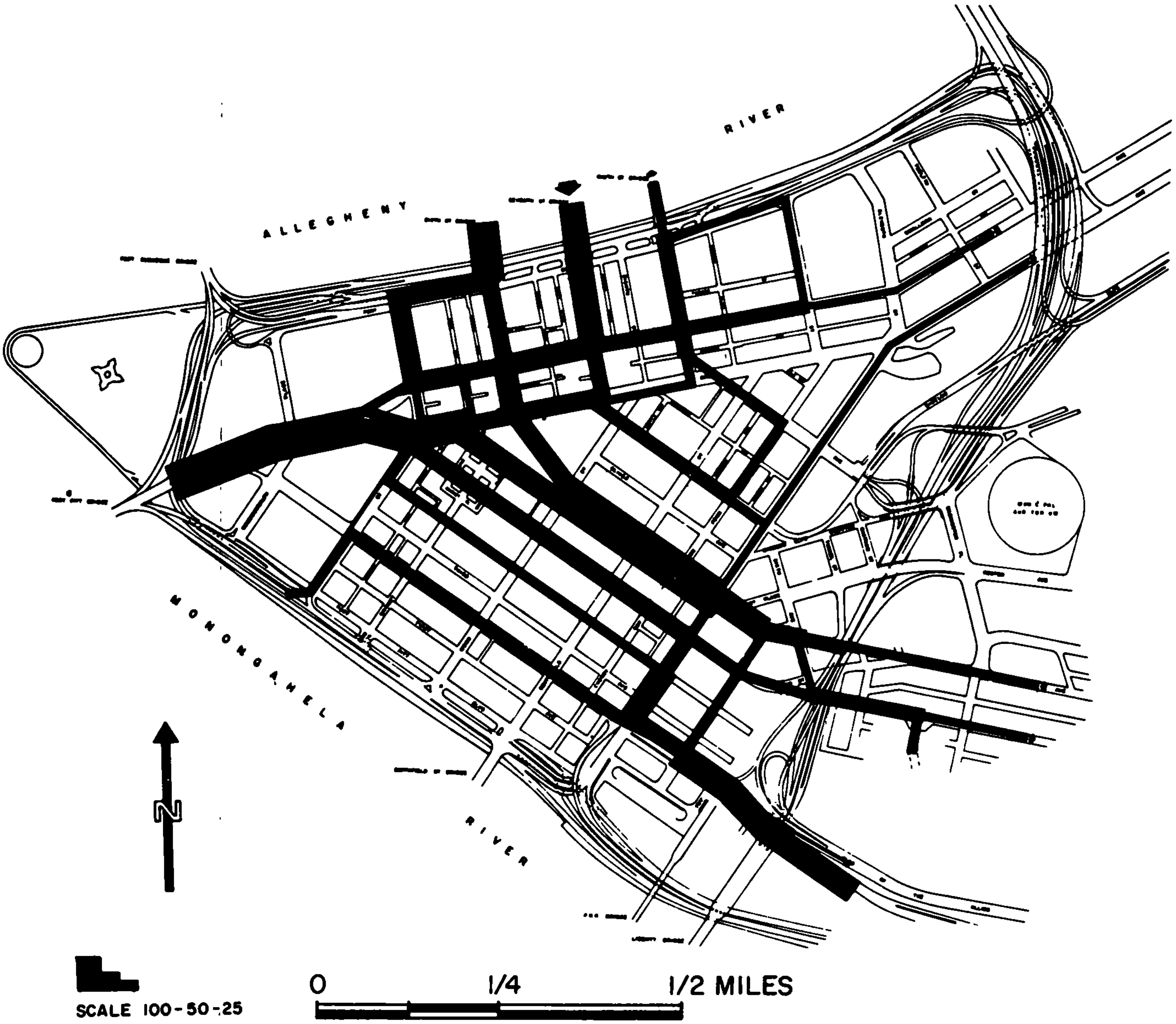


Figure B-42 Non-PATway bus flows, Pittsburgh, Pa

13. SAN FRANCISCO-OAKLAND BUS AND CAR POOL PRIORITY LANES

The San Francisco-Oakland Bay Bridge and the Golden Gate Bridge deliver heavy commuter bus passenger volumes into downtown San Francisco. To expedite these movements, a bus priority lane bypass of the Bay Bridge toll station was installed in April 1971, and a northbound contra-flow bus lane was initiated in Marin County during September 1972.

BUS AND CAR POOL PRIORITY LANES, SAN FRANCISCO-OAKLAND BAY BRIDGE

The San Francisco-Oakland Bay Bridge is a double-deck structure originally designed for two-way operation on each deck Six lanes (three in each direction) were initially provided on the top deck for automobiles; the lower deck provided three lanes for trucks and two tracks on the south side for Key System rail transit cars Although one or two rail lines used median reservations in major streets, the Key System was not grade-separated, the equipment was generally slow, and the service did not compete effectively with private autos. After the Bay Area Rapid Transit studies recommended a new tube rather than utilization of the bridge tracks, it was decided to convert the Key System to bus operation, thereby permitting the bridge to be modified for five lanes of one-way traffic on each deck.

Bus lanes were provided on the bridge during the reconstruction period in 1962. Studies initiated in 1968 indicated that an exclusive bus lane would increase total person-delay, but that further consideration and analysis should be given to preferential treatment in the toll plaza area. Accordingly, a morning peak-period exclusive bus lane was implemented in the toll plaza area in April 1970. Based on an exclusive bus lane model developed in 1970, bus and car pool priority lanes were implemented in December 1971 in the toll plaza area

Initial Bus Bypass Lane Experience (1962)

During reconstruction of the bridge, an exclusive lane was set aside for buses and government vehicles for a short period beginning in January 1962 (*B-27*). The construction bottleneck on the lower deck funneled eastbound traffic from three lanes down to two at the midbridge Yerba Buena Island tunnel signal. It was possible to queue vehicular traffic in two lanes, with the third lane being used exclusively by buses. Buses would then merge with other traffic at the bottleneck upstream from the signal, thereby providing an effective bypass lane through the queuing area

However, upon completion of bridge reconstruction the Division of Highways determined that there was not sufficient bus patronage for full utilization of a lane's capacity, and the exclusive lane was discontinued. The 6 percent growth in bus riding during 1962 was attributed to natural growth and to improved service, as well as to the exclusive lane operated for Alameda-Contra Costa Transit Authority buses.

Conditions Prior To Bus Bypass Lane

The location of the Bay Bridge in relation to major highways is shown in Figure B-43. The bridge follows a general east-west corridor between San Francisco and Oakland Near the center of the crossing is Yerba Buena Island, through which a double-decked tunnel section passes. The Island is served by right- and left-hand eastbound off-ramps and one left-hand westbound off-ramp. Return to the bridge is accomplished by one right-hand eastbound on-ramp and two right-hand westbound on-ramps There are no shoulders on the bridge.

Transbay commuter buses, which use the Transbay Transit Terminal in San Francisco, are served by an exclusive approach system to and from the bridge. Westbound buses leave the bridge with some automobile traffic in the right-hand lanes at the first exit in San Francisco. The buses then have an exclusive ramp to the terminal building without having to travel on city streets. Eastbound buses enter the bridge from the terminal building via their own left-hand entry ramp at the freeway approach to the bridge.

Road Pattern

Three major freeways converge at the east approach to the Bay Bridge—Route 80 (Sacramento) from the north, Route 580 (Stockton) from the east, and Route 17 (San Jose) from the south. During the weekday morning commuter hours, heavy local and regional traffic, in addition to other intrastate traffic, exceeded the bridge's capacity. Accordingly, motorists were forced to stagger their hours or encounter queues in the bridge approach area.

The toll plaza is located about midway in the 1.6-mile approach area; there is a 50-mph speed restriction in the vicinity. Nine westbound lanes on the three converging freeways merge into 6 lanes in the bridge approach area

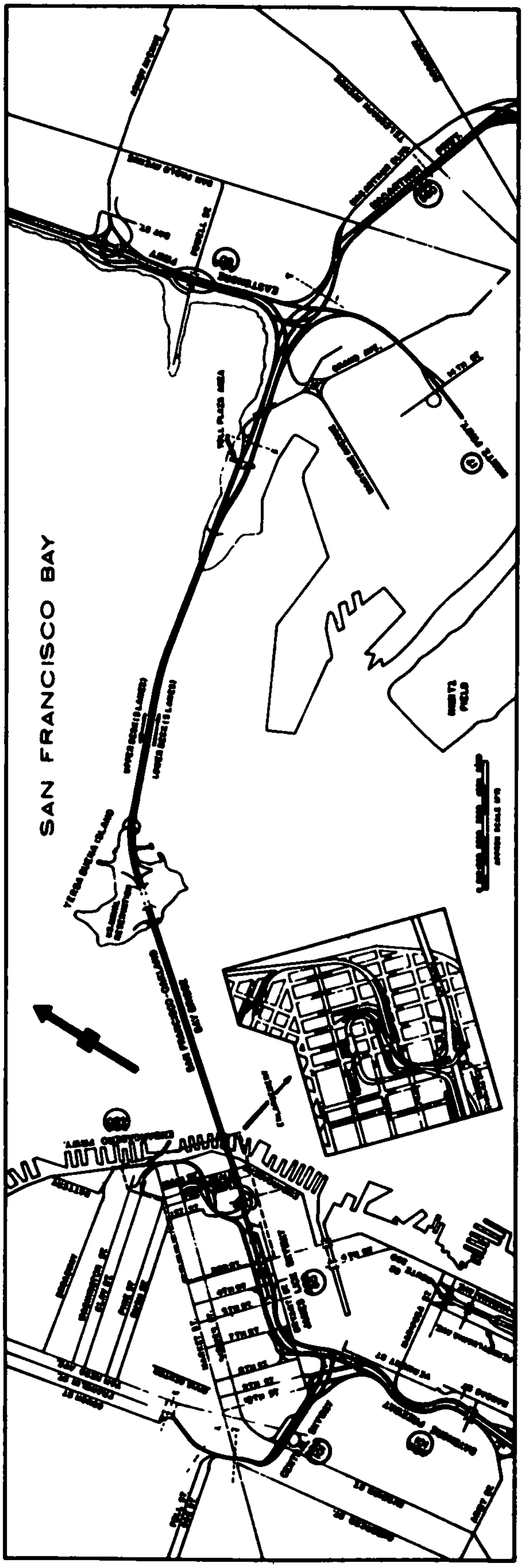


Figure B-43. Location map, San Francisco-Oakland Bay Bridge.

and, after passing through 17 toll collection lanes, merge further into 5 westbound bridge lanes. (Since 1969, tolls have been collected in the westbound direction only.) The bridge provides approximately 5 miles of freeway operation with a speed of 50 mph. Merging traffic is encountered approximately mid-bridge at Yerba Buena Island, but these volumes are insignificant during morning peak hours.

The five westbound lanes on the bridge are the restricting bottleneck. However, once on the bridge traffic moves steadily at the bridge capacity of about 9,000 vph, or 1,800 vehicles per lane. This traffic level, however, produced queuing delays of increasing frequency and duration on the bridge approach (toll plaza) area.

Traffic Volumes

Trends in transbay bus traffic are given in Table B-42 and shown in Figure B-44. Since 1960, daily bus patronage increased about 30 percent, and AM peak-hour bus patronage about 100 percent. Peak-period automobile passengers increased less than 5 percent. Peak-hour person-travel on the Bay Bridge in April 1970, immediately prior to the installation of the bus priority lanes, is given in Tables B-43 and B-44

- During the peak 2.5-hr period, 37,200 people crossed the bridge westbound, 48 percent in buses.
- During the peak hour, 23,400 people crossed the bridge, 55 percent in buses Thirteen thousand people used buses in the peak hour, yet, buses accounted for only 4 6 percent of the total peak-hour traffic.

Travel Times

Results of travel time studies made by the Division of Highways in 1968 and 1969 are summarized in Table B-45

1. The average off-peak bus travel time in the westbound direction between the toll plaza and the San Francisco Terminal Building was 8 75 min. Eastbound off-peak travel took 30 sec longer because buses started from an almost complete stop on a grade of over 3 percent

2. During the peak periods under conditions of good weather, daylight, and no lane blockage, the average travel time for buses approximated 11 min westbound and 11.3 min eastbound.

3. In the westbound direction, the maximum bus delay occurred when leaving the toll plaza between 7:35 and 7·45 AM, the period when queuing from the merge section was at a maximum. The maximum delay obtained from bus travel times on nine different weekdays amounted to 4.75 min. Most of this delay was incurred in the merge section between the bridge and the toll plaza.

4 The delay for eastbound buses was fairly constant throughout the latter part of the peak period (5:00 to 6.00 PM); this was mainly running delay on the bridge. (Running delay is caused by the natural reduction in speed as flow rates increase; queuing delay is caused by excess of demand over capacity.) There was variability whenever accidents or stalls occurred. (On one of the data collection days, two separate lane blocks occurred in the eastbound direction for a total of 27 min This caused maximum delays of 8.5 min per bus. Nonrecurrent congestion occurs frequently, with a high day-to-day variability.) There was variability whenever accidents or stalls occurred.

5. In the eastbound direction, where buses have an exclusive entrance, delay incurred by buses entering onto the bridge was negligible. Autos, in contrast, queued on ramps leading to the bridge.

6. In the westbound direction, there was generally continuous flow except at the merging section near the beginning of the bridge. Six lanes fed into the toll plaza area, but there were only five lanes on the bridge. Because the capacity of the bridge was (and is) less than the capacity of the toll booths, queuing occurs between the bridge and the toll booths.

7. The queuing delay experienced between the toll booths and the bridge (a distance of 3,750 ft) was reported less for the buses than for autos The average queuing delay per auto during the AM peak on October 9, 1968, was 2.30 min, whereas the average queuing delay per bus was 1.50 min The maximum queuing delay was 4 3 min for autos and 2 75 min for buses.

TABLE B-42

BAY PASSENGERS CARRIED BY AC TRANSIT,[a] SAN FRANCISCO-OAKLAND BAY BRIDGE

TIME (AM)	APRIL 13, 1960	APRIL 12, 1961	APRIL 11, 1962	APRIL 17, 1963	APRIL 15, 1964	APRIL 7, 1965	APRIL 13, 1966	APRIL 12, 1967	APRIL 17, 1968	APRIL 16, 1969	APRIL 9, 1970
6:00–6.30	205	172	260	246	215	227	262	251	351	338	384
6 30–7 00	740	732	785	778	779	1,090	967	1,009	1,160	1,255	1,552
7 00–7 30	2,290	2,290	2,783	2,879	3,013	3,218	3,675	3,958	4,386	4,582	4,651
7:30–8.00	2,778	2,895	3,367	3,453	3,971	4,145	3,954	4,381	4,565	4,768	5,064
8 00–8·30	1,618	1,909	1,859	1,860	1,805	1,848	1,959	1,985	1,995	2,168	2,217
8 30–9:00	585	663	579	671	695	686	588	591	680	702	770
Total	8,216	8,723	9,633	9,887	10,478	11,214	11,405	12,175	13,137	13,813	14,638
April, 1960	100%	106 2%	117 2%	120.3%	127 5%	136 5%	138 9%	148 2%	159 7%	168 1%	178 2%

Source Ref (*B-28*)

[a] Westbound toll plaza

8. The average delay on the bridge (running delay) for automobiles was approximately the same as for buses during the peak periods.

The Alameda-Contra Costa County Transit Company reports that it took buses in the peak hour as much time to traverse the 1.6 miles through the toll plaza area as the entire 5-mile trip across the bridge (Table B-46). Buses averaged 5 min behind schedule, with many buses arriving in San Francisco 14 min or more late. Bus frequency averaged 21.3 sec during the 6:00 AM to 9.00 AM period, with a frequency of 10.5 sec during the critical 7:30 AM to 8.00 AM period. Table B-46 also summarizes bus travel times after installation of the bus bypass lane.

Nonrecurrent Congestion

The University of California, in its Traffic Survey Series A-29 and A-30, tabulated the vehicle stalls and accidents that occurred during peak periods on the bridge October 18 and 19, 1967, and April 16 and 19, 1968. An average of 1⅓ incidents occurred daily in the westbound direction, and lasted an average of 19 min each. In the eastbound direction, approximately five incidents occurred daily and lasted an average of 12 min each.

Queuing Model

A queuing model developed by the Division of Highways evaluated the consequences of bus priority lanes across the bridge. Results of this analysis are given in Table B-47 and shown in Figures B-45 and B-46. The model indicated that an exclusive bus lane across the Bay Bridge would substantially increase delays to automobile passengers. The bus bypass lane of the toll station—in essence a queue bypass—was developed as an alternative treatment.

Bus Bypass of Toll Station

Plans to provide a "special permit" or bus bypass lane in the toll plaza area, utilizing excess lane capacity in this "storage" area, were developed cooperatively by the California Division of Bay Toll Crossings, the Division of Highways, the Alameda-Contra Costa Transit District, and the Western Greyhound Company. The bus bypass lane was established April 20, 1970, for exclusive use of commuter buses in the toll plaza area. Charter buses use regular toll lanes. This "special permit" lane in the westbound direction is restricted to commuter buses from 6:00 AM to 9.00 AM each weekday.

Buses initially used toll lane No. 11 (total of 17), with ten car lanes to the left and six lanes to the right. The bus lane started 1,200 ft east of the toll plaza and extended 1,600 ft to the west. It was zoned off with traffic markers (cones) and clearly identified for the exclusive use of commuter buses. Buses proceeded without stopping through the toll booth area. Figure B-47 shows how buses bypass automobile queues.

Bus tolls were reduced from $1.00 to $0.65, with the buses not stopping to pay the toll; monthly bills were sent to the bus companies. This procedure saved the Alameda-Contra Costa Transit District $91,000 annually, and other

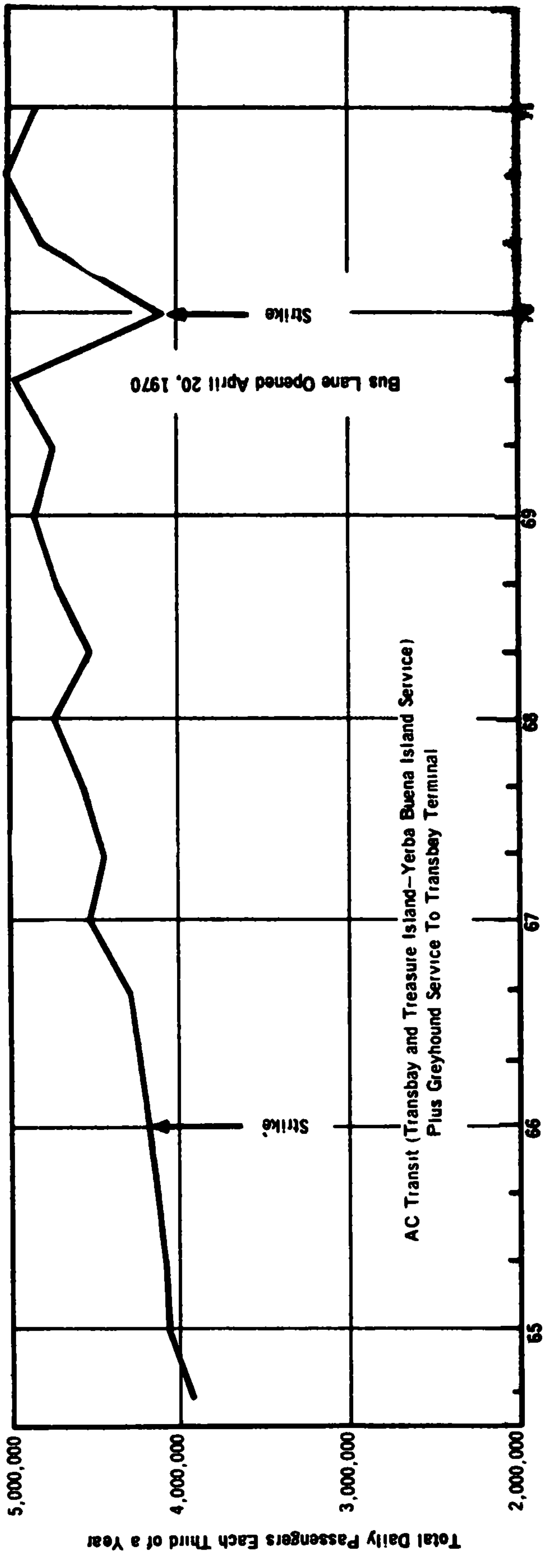


Figure B-44. Bus passengers crossing San Francisco-Oakland Bay Bridge.

TABLE B-43

PEAK-PERIOD BUS AND AUTO PASSENGER VOLUMES, SAN FRANCISCO-OAKLAND BAY BRIDGE [a]

TIME (AM)	AUTOS	LOAD FACTOR	AUTO PASSENGERS	BUSES	BUS PASSENGERS			TOTAL PASSENGERS	PERCENT BUS
					ACT	GREYHOUND	TOTAL		
6·30–7 00	4,108	1 29	5,299	50	1,552	614	2,166	7,465	29
7:00–7·30	3,954	1 23	4,863	134	4,651	1,653	6,304	11,167	56
7 30–8:00	4,162	1 32	5,494	193	5,064	1,660	6,724	12,218	55
8·00–8 30	3,019	1 21	3,653	99	2,217	486	2,703	6,356	43
Total	15,243	1 27	19,309	476	13,484	4,413	17,897	37,206	48

Source Ref (*B-28*)

[a] Data collected on Wednesday, April 8, 1970, in westbound direction

Notes
1 Buses run every 9 3 sec between 7 30 and 8 00 AM, every 15 1 sec from 6 30 to 8 30 AM
2 Buses carry 48 1% of people between 6 30 and 8 30 AM (45 3% in April 1969)
3 Buses carry 55 0% of people between 7 30 and 8 00 AM (54 6% in April 1969)
4 ACT passengers compared to April 1969 6 30 to 8 30 AM, 5 6% increase
5 Total bus passengers compared to April 1969 6 30 to 8 30 AM, 5 6% increase
6 Auto passengers compared to April 1969 6 30 to 8 30 AM, 5 3% decrease
7 AC passengers compared to April 1969 6 30 to 8 30 AM, 81 6% increase
8 Total bus passengers compared to April 1960 6 30 to 8 30 AM, 100 4% increase
9 Auto passengers compared to April 1960 6 30 to 8 30 AM, 3 5% increase (auto vehicles, + 44 8%)

commuter buses $19,000 annually. Tolls are paid on an honor system at the end of each month, and are computed by adjusting the daily scheduled trips for any deviation from normal.

Costs

Costs for signing, lane striping, and plastic traffic posts were minimal. They were estimated to approximate $10,000 for the initial bus bypass installation.

Benefits

Before installation of the "special permit" lane delays of up to 20 min were frequent, with a repeated normal peak average delay of more than 5 min

TABLE B-44

PEAK-PERIOD VEHICLE AND PERSON TRAVEL, SAN FRANCISCO-OAKLAND BAY BRIDGE [a]

ITEM	7.00–8:00 AM		6·30–8:30 AM	
	NO	(%)	NO.	(%)
Vehicles:				
Buses	327	4 0	476	3.0
Cars	8,116	96.0	15,243	97.0
Total	8,443	100 0	15,719	100 0
Persons				
Buses	13,000	55.5	17,900	48 1
Cars	10,400	44.5	19,300	51.9
Total	23,400	100 0	37,200	100.0

Source Division of Bay Toll Crossings, California Department of Public Works, April 1, 1970

[a] Data collected just before installation of exclusive bus lane

The following benefits were reported after inauguration of the exclusive westbound bus bypass lane:

1. *Improved Travel Times.*—Over-all bus travel times were reduced. Traffic surveys made prior to and immediately after inauguration of the "special permit" lane show that previously 84 percent of the scheduled AC Transit trips arrived in San Francisco late during the 7:00 AM to 8·00 AM period. This was reduced to 45 percent with the special lane. From 6.30 to 9:00 AM, late operation reduced from 74 percent to 39 percent, with an average reduction of 2½ min. These time checks did not reflect frequent delays of up to 20 min before the inauguration of the special lane.

2 *Increased Passenger Traffic.*—Operator's toll counts for May 5, 1970, indicate a continuing 1.1 percent increase in Transbay bus passengers when compared with the previous month (before the special lane), and an 8 to 10 percent increase over the previous year. The extent to which this increase is due to the special lane as compared with normal growth was not identified.

3 *Safety.*—Bus safety was improved by eliminating (1) bus-auto conflicts resulting from use of a central lane that opposed freeway traffic; (2) bus stops at toll booths; and (3) bus merging maneuvers. During 1969, AC Transit was involved in 13 accidents within the area of the exclusive bus lane. (Within the same area, during the hours of 6:00 AM to 9:00 AM for the first full month's operation, no accident occurred; during the corresponding period a year ago, AC Transit was involved in one accident.)

Most accidents involved sideswipes between buses and autos when changing lanes. This was believed to result in part from uncertainty as to merging intentions.

4. *Queuing.*—Automobile queues through the toll station, and resulting car travel times in the morning peak hour, are shown in Figures B-48 and B-49. Table B-48 gives the utilization of the toll lanes and Table B-49 indi-

TABLE B-45

DELAY INCURRED BY BUSES, SAN FRANCISCO-OAKLAND BAY BRIDGE[a]

	BUSES		QUEUING DELAY, TOLL PLAZA TO BRIDGE		RUNNING DELAY, EAST END OF BRIDGE TO S F TERMINAL	
TIME (AM)	(NO)	OCCU-PANCY	AVG PER BUS (MIN)	TOTAL PERSON (MIN)	AVG. PER BUS (MIN)	TOTAL PERSON (MIN)
6 55						
7 00	14	32 2	0 25	117	0	0
7 05	11		0 25	117	0.50	234
7 10	18		0 25	191	0 50	382
7 15	25	42 4	0 50	531	1 25	1,330
7 20	21		0 75	667	1 25	1,110
7 25	30		1 25	1,590	1 25	1,590
7.30	23		1 75	1,705	1 25	1,219
7.35	28		2 00	1,975	1.25	1,235
7 40	38		2.75	3,680	1.25	1,675
7 45	39	35 3	2 75	3,780	1 00	1,375
7 50	26		2 25	2,065	0 75	687
7.55	29		2.00	2,050	1.00	1,025
8 00	26		1 75	1,610	1 25	1,150
8 05	34		1.25	760	1.25	760
8.10	21		1 25	588	1 50	705
8.15	25	22 3	0 75	420	1 50	804
8·20	13		0 25	73	1.25	364
8.25	12		–0–	–0–	1.00	269
Total	433			21,919		15,950
Average			1.51		1 10	

Source Ref (*B-29*)

[a] Data collected October 9, 1968, in westbound peak period

TABLE B-46

COMPARATIVE BUS TRAVEL TIMES WESTBOUND, SAN FRANCISCO-OAKLAND BAY BRIDGE[a]

	BEFORE LANE IMPLEMENTED, FEBRUARY 4, 1970				SPECIAL PERMIT LANE,[b] APRIL 22, 1970			
ITEM	TOTAL, 6 33–8 47 AM		PEAK HOUR 7·00–8·00 AM		TOTAL, 6 30–9.00 AM		PEAK HOUR 7·00–8:00 AM	
Distribution ramps to bridge incline·[c]								
Elapsed time, avg	6 20 min		7.26 min		4 03 min		4 42 min	
(Approx 1 6 mi)	15 mph		13 mph		24 mph		22 mph	
Bay Bridge into elevated terminal·								
Elapsed time, avg	8 33 min		8 54 min		8 00 min		8 13 min	
(Approx. 5.0 mi)	36 mph		35 mph		37.5 mph		37 mph	
Scheduled trips								
Ahead of time	60	18 3%	22	9 6%	180	54 2%	107	47.1%
On time	25	7 6%	14	6 2%	23	6 9%	17	7.5%
Late	243	74.1%	192	84.2%	129	38.9%	103	45.4%
Total	328	100 0%	228	100 0%	332	100 0%	227	100.0%
Schedule performance·								
Ahead of time·								
Total hr min (trips)	2 44 (60)		·51 (22)		8 46 (180)		5.25 (107)	
Average (min)	2 73		2 31		2.92		3.04	
Late·								
Total, hr.min (trips)	20 00 (243)		17·32 (192)		5.34 (129)		4·18 (103)	
Average (min)	4.94		5.48		2.59		2 51	

Source Alameda-Contra Costa County Transit District

[a] Time leaving distribution ramps

[b] Routes A and B (local) excluded

[c] Toll plaza area

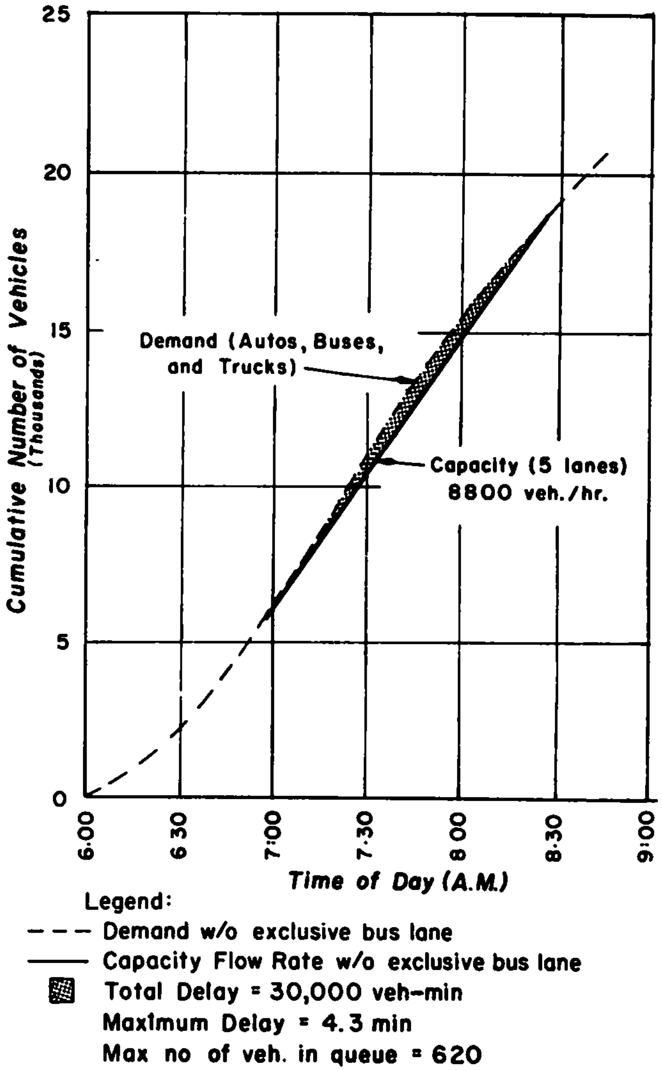


Figure B-45. Peak-hour (AM) *demand and capacity, San Francisco-Oakland Bay Bridge, without exclusive bus lane (Oct 9, 1968).*

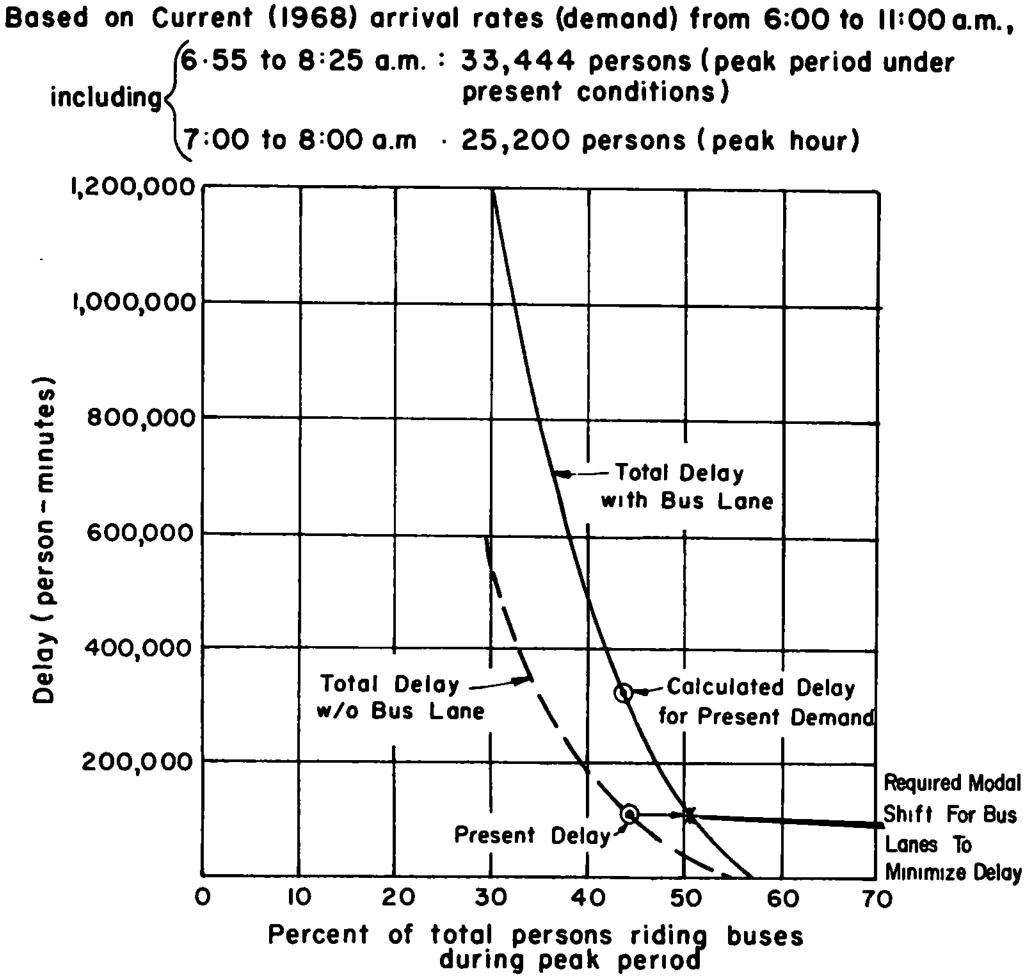


Figure B-46. Person delay with and without exclusive bus lane, San Francisco-Oakland Bay Bridge

Figure B-47A. Bus bypass of car queues at toll plaza, San Francicso-Oakland Bay Bridge.

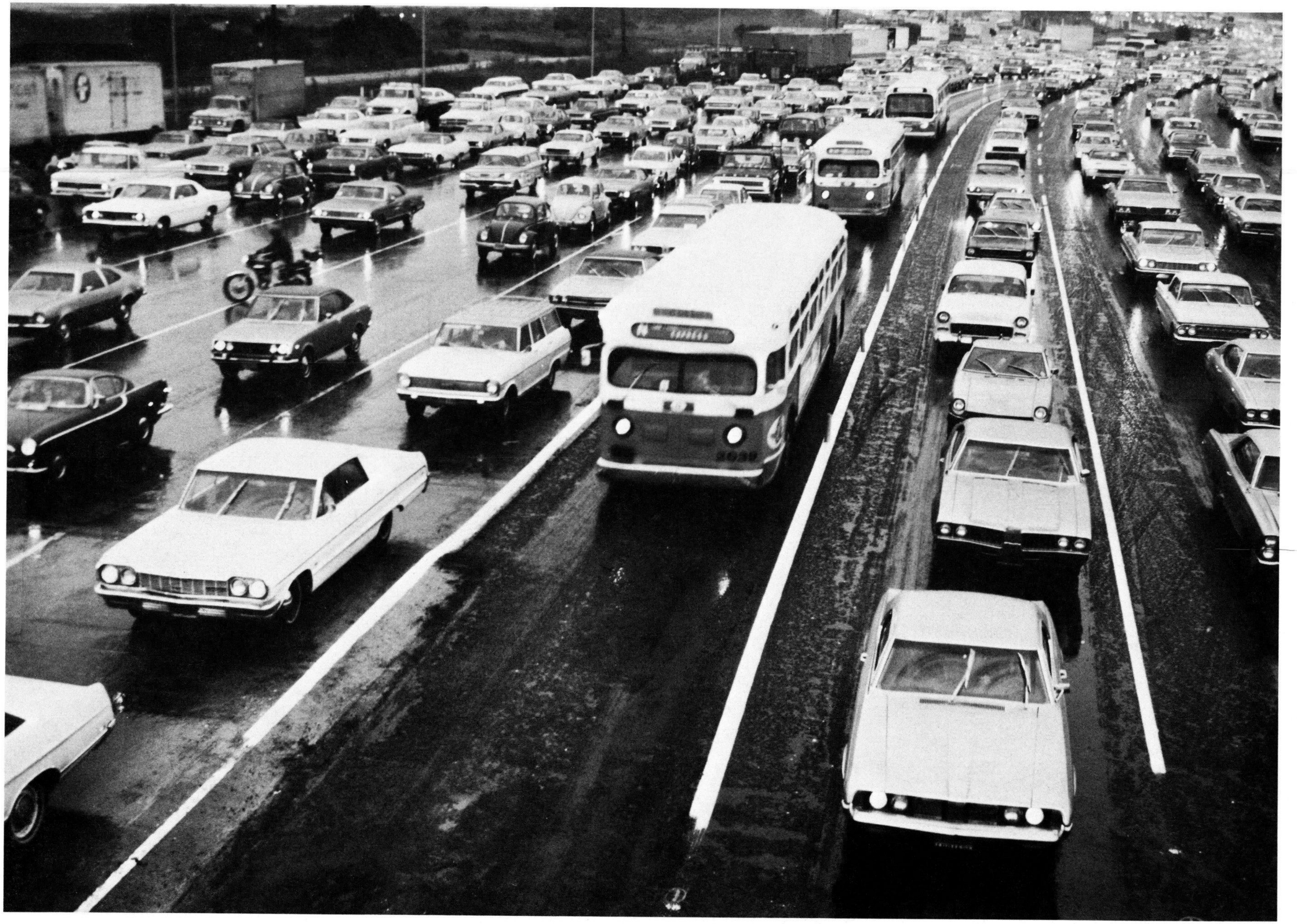


Figure B-47B. Bus bypass of car queues at toll plaza, San Francisco-Oakland Bay Bridge.

Figure B-47C. Bus bypass of car queues at toll plaza, San Francisco-Oakland Bay Bridge.

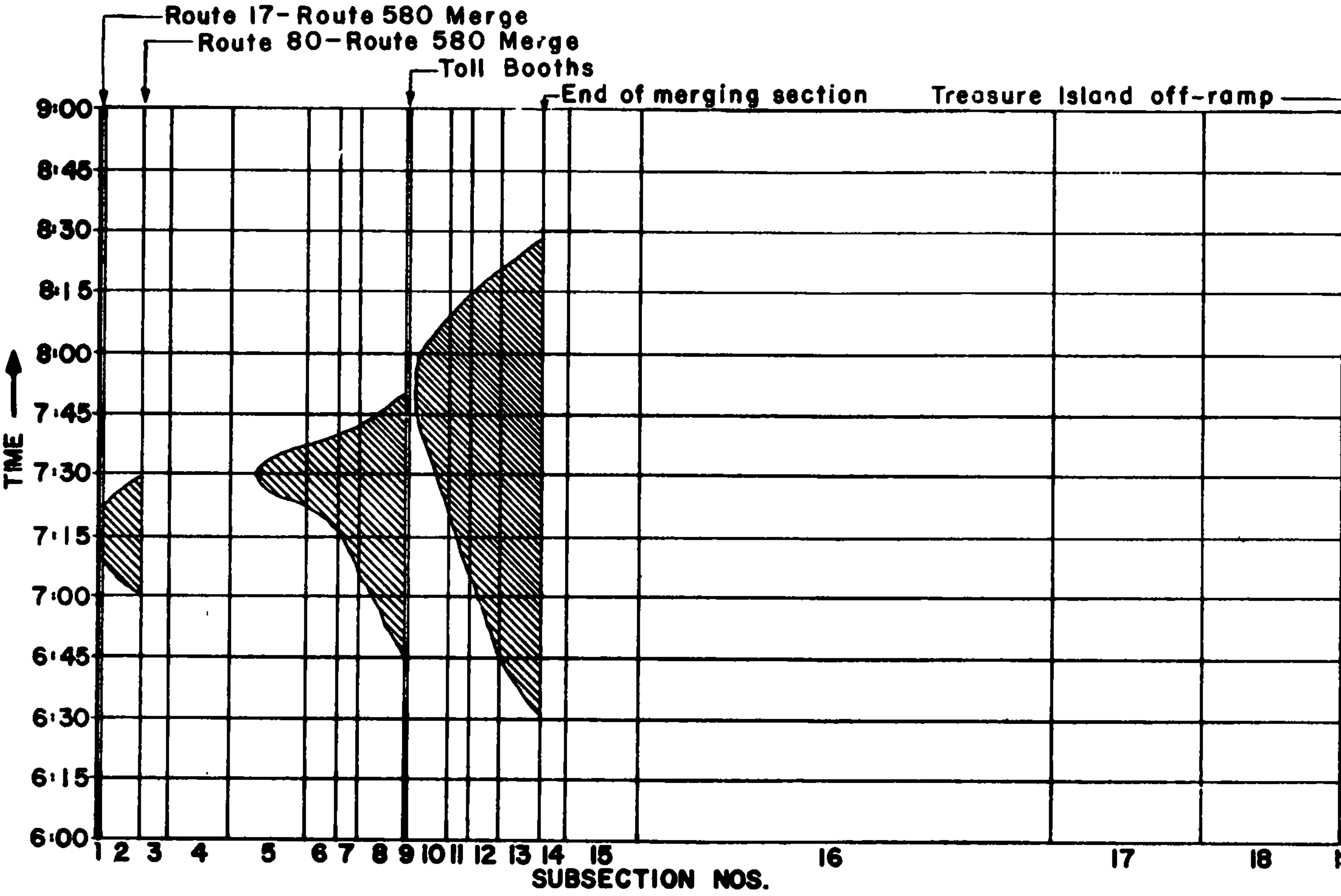


Figure B-48. Queuing diagram, automobile traffic, San Francisco-Oakland Bay Bridge.

cates average toll service times The No. 11 lane location of the "special permit" lane (starting and ending in a central location) produced an uneven division of toll booths (ten lanes left, six lanes right). This produced a minor imbalance in vehicular traffic, with somewhat greater queuing of traffic at the right six toll booths and increased queuing downstream on the left at the bridgehead, where ten toll lanes merge into three bridge lanes.

During the AM peak period, since the bypass lane was placed in operation, there have been approximately 1,700 vehicles in queue, with 1,200 stored upstream of the toll plaza and 500 in storage downstream at the entrance to the bridge.

This suggests a shift of approximately 100 stored vehicles upstream of the toll plaza, as a result of the uneven No. 11 toll lane position. Preliminary figures also indicate that use of toll lane No. 11 as a special lane reduced the toll plaza capacity from 9,700 to 9,400 vph, and it also may have slightly reduced bridge capacity (from 9,100 to approximately 8,800 to 9,000 vph) due to the uneven merging of traffic downstream from the toll plaza.

5. *Overview.*—The California Division of Highways indicates that the bus bypass lane saved 34,300 person-minutes each day, while passengers in other lanes lost 38,400 person-minutes due to increased congestion caused by the priority lane. There is no evidence that bus patronage significantly increased as a result of the bus bypass lane alone.

Bus and Car Pool Lanes

The bus and car pool toll station bypass lanes were installed on December 8, 1971 Lane 10 was designated as the bus priority lane; lanes 8 and 9 were designated as car pool lanes. This represents a shift from the position of the

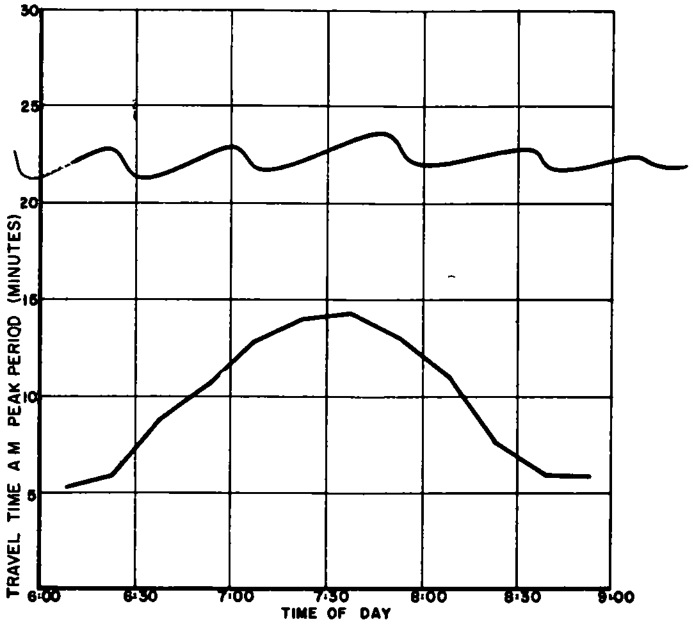


Figure B-49 Westbound automobile travel times, San Francisco-Oakland Bay Bridge

TABLE B-47

TRAFFIC COUNT, SAN FRANCISCO-OAKLAND BAY BRIDGE[a]

TIME (AM)	VEHICLES	CUMULATIVE VEHICLES	15-MIN FLOW RATE
6.00	837	0	3,348
6·15	1,308	837	5,232
6·30	1,871	2,145	7,484
6.45	1,993	4,016	7,972
7:00	2,435	6,009	9,740
7:15	2,455	8,444	9,820
7 30	2,350	10,899	9,400
7·45	1,943	13,249	7,772
8:00	2,048	15,192	8,192
8:15	1,748	17,240	6,992
8:30	1,599	18,988	6,396
8.45	1,466	20,587	5,864
9:00	1,350	22,053	5,400
9:15	1,250	23,403	5,000
9 30		24,653	

Source Ref (*B-29*)

[a] Data taken on October 9, 1968, in mixed traffic in westbound direction

original bus bypass lane to reduce the imbalance in lane use. The approach treatment was lengthened to begin 1,250 ft east of the toll gate and to extend 4,500 ft up to the bridge. The car pool lanes are used by cars with three or more occupants.

The priority lanes are marked with bright-yellow rubber traffic posts. Advance overhead signing is also provided (Fig. B-50). Car pool drivers do not stop at the toll booths, but are required to slow to 15 mph. Costs for these changes were estimated at about $50,000.

Use

During the first two weeks of operation, the number of car pools using the exclusive lanes increased from 1,260 to 2,000. No apparent decrease in auto congestion occurred, and no basic change in bus patronage was reported. Since the current plan went into effect, (1) automobile occupancy increased from 1.33 to 1.45 persons per automobile; (2) bus ridership was virtually unaffected; and (3) about 2,400 additional car passengers were carried although the number of vehicles did not significantly change.

Procedure Modifications

The California Division of Bay Toll Crossings established the car pool lanes on a permanent basis May 1, 1972.

Eligible car pool vehicles receive distinctive identification cards from the State at a cost of $1.00 per month. These cards are displayed in the vehicles

Enforcement

Enforcement of the priority-lane regulations was recognized as potentially difficult. In conducting the experiment, it was decided to determine first the extent of the problem and then to respond with measures that seemed most appropriate. Two general types of violators were found. The

TABLE B-48

TRAFFIC VOLUME THROUGH TOLL PLAZA WITH BUS PRIORITY LANES, SAN FRANCISCO-OAKLAND BAY BRIDGE

HOUR (AM)	LANE 1	LANE 2	LANE 3	LANE 4	LANE 5	LANE 6	LANE 7	LANE 8	LANE 9	LANE 10	LANE 11	LANE 12	LANE 13	LANE 14	LANE 15	LANE 16	LANE 17	ALL LANES
6–7	494	623	544	505	501	494	490	490	427	509		492	450	456	332	344	349	7,400
7–8	525	619	632[a]	541	515	507	546	572	487	592		548	565	529	394	481	542	8,592
8–9	506	579	579	469	470	458	508	543	499	586		490	563	380	293	361	355	7,662
	← AUTO LANES →										← BUS LANE →	← AUTO LANES →		← TRUCK AND AUTO LANES →				

Source Ref (*B-30*).

[a] Highest hourly volume count in the peak hour, October 26, 1970

TABLE B-49

AVERAGE SERVICE TIMES FOR TOLL TRANSACTIONS, SAN FRANCISCO-OAKLAND BAY BRIDGE[a]

	AUTO LANES[b]			TRUCK AND AUTO LANES[c]			ALL LANES[d]		
HOUR (AM)	TOTAL VEH /HR	VEH / LANE	AVERAGE TIME PER VEH (SEC)	TOTAL VEH /HR	VEH / LANE	AVERAGE SERVICE TIME PER VEH (SEC)	TOTAL VEH /HR	VEH./ LANE	AVERAGE TIME PER VEH (SEC)
6 00 7·00	6,019	502	7 2	1,381	345	10.4	7,400	463	7 8
8 00	6,649	554	6 5	1,946	486	7 4	8,595	537	6 7
9 00	6,273	523	6 9	1,389	347	10 4	7,662	479	7.5
6 00– 9·00	18,941	1,578	6 8	4,716	1,179	9 2	23,657	1,479	7 3

Source Ref (*B-30*)

[a] Data collected on October 26, 1970, during the morning period

[b] Lanes 1-10, 12, 13

[c] Lanes 14-17

[d] Excluding bus lane 11

1 Highest hourly volume per lane, 632 vehicles

2 Service time, 5 7 sec per vehicle

3 Highest volume observed, lane 3 between 7 00 and 8 00 AM

first type entered the priority lane at the beginning and continued through the toll lanes and onto the bridge. The second type passed through the nonpriority toll lanes and entered the priority lane through the plastic stanchions delineating it.

The first response was to double up on the stanchions (from 25 to 12.5 ft), thereby reducing the possibility for nonpriority vehicles to make lane change maneuvers. The second step was to monitor the priority lanes for violators, obtain the license numbers of those observed three or more times, secure the names and addresses of the registered owners through the assistance of the Department of Motor Vehicles, and send out warning leters that the operators are subject to being cited.

These two methods were reported to be only partly effective The letters appeared to discourage those contacted from further violations; however, new violators continually took the place of those previously warned Also, as time went on the number of violators who changed lanes increased substantially. Therefore, starting February 22, 1972, the California Highway Patrol cooperated by providing a motorcycle squad at the toll plaza for spot enforcement. As a result, warnings were issued to approximately 150 violators who passed through the toll booths, and the number of violators entering the priority lanes after the toll booths was reduced from about 1,000 to 300.

Significance

The bus lane bypass of the toll station and the Transbay Transit Terminal connections have substantially improved bus travel at minimum cost without adverse effects to motorists A few operational-type treatments (installation costs under $100,000; operating costs $1,000 monthly) substantially benefit the second-highest bus concentration in the United States. Some 350 buses in the peak hour carry 13,000 people and save 5 to 10 min per trip.

The car pool priority lane experiment suggests that car pool formation is possible and some additional reductions in total delay time are reported Enforcement, however, is reported to be a problem.

MARIN COUNTY CONTRA-FLOW BUS LANE

A contra-flow bus lane was installed along 5 miles of US 101 in Marin County in September 1972. The bus lane operates northbound from 4.00 to 6:00 PM between the Golden Gate Bridge and Richardson Bay. Highway 101 is an eight-lane divided freeway in this area, and a raised median separates northbound and southbound travel lanes.

Description

The existing contra-flow bus lane is shown in Figure B-51. During the PM peak, the six traffic lanes of the Golden Gate Bridge operate as two lanes inbound (southbound) and four lanes outbound (northbound). Directly north of the Golden Gate Bridge, nonstop buses are routed west of the median strip into the median southbound lane. Separation of the northbound bus lane from southbound traffic is done by placing plastic cones down the center of southbound lane 3. This placement reduces the southbound traffic to two lanes and leaves a width of approximately 1½ traffic lanes for northbound bus movements (next to the median). Just south of the Richardson Bay Bridge, the median is painted and the buses are routed back across (and through) the painted median and merge into lane 4 of the northbound traffic. The median section used by the buses for merging into the northbound lane is 150 to 225 ft long and is slightly wider than the bus width. Bus speeds have been limited to 40 mph.

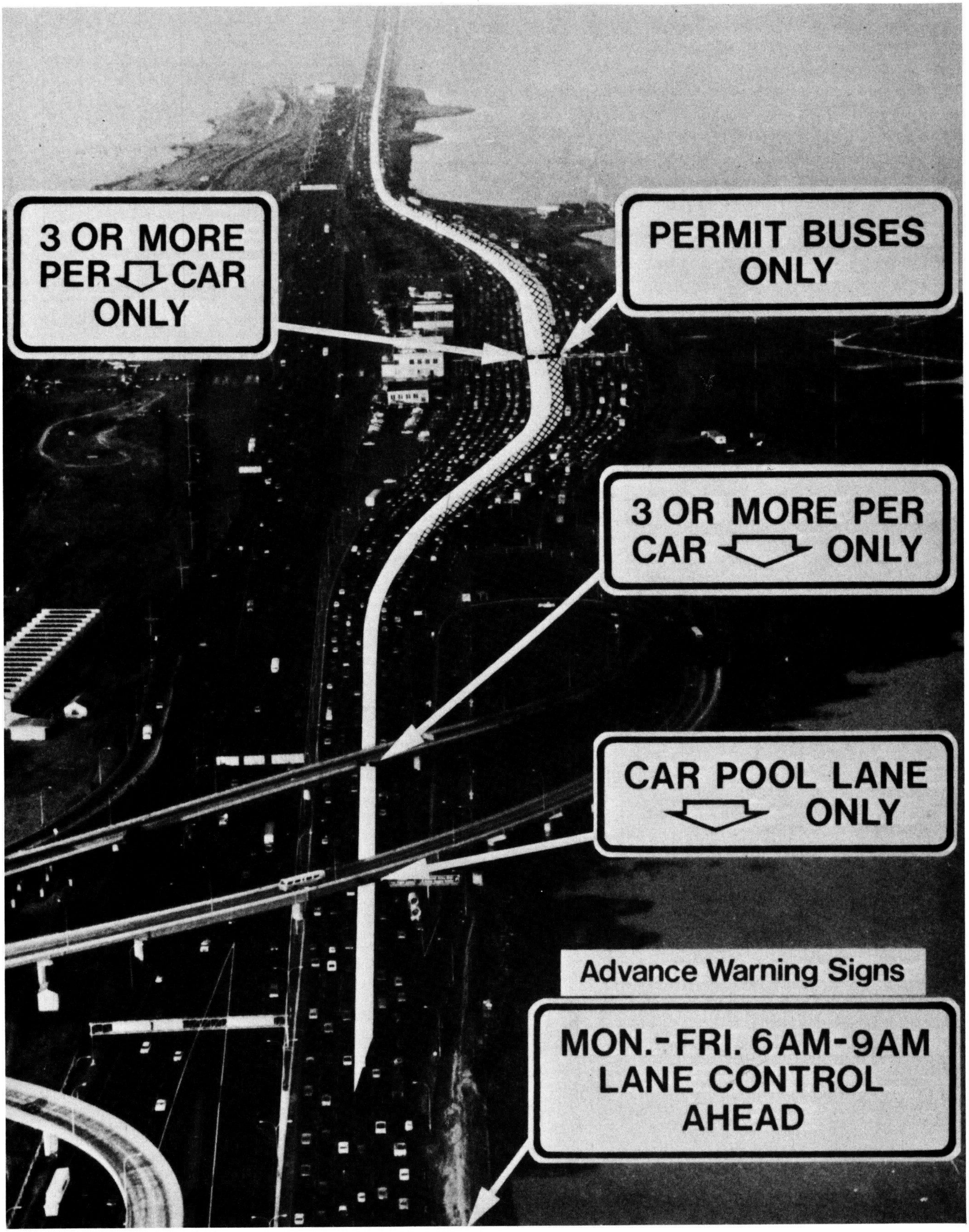


Figure B-50. Typical bus and car pool signing, San Francisco-Oakland Bay Bridge approach.

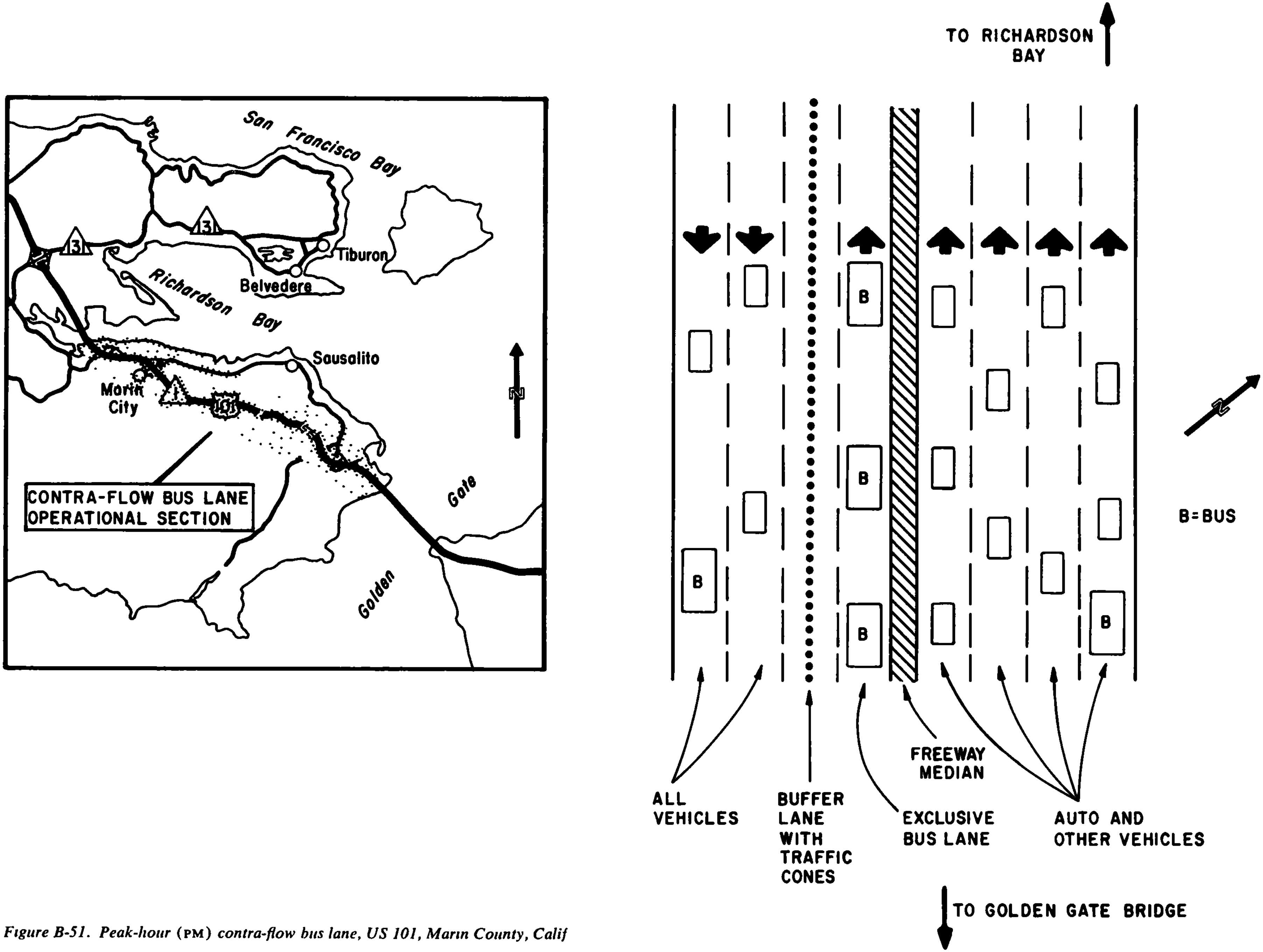


Figure B-51. Peak-hour (PM) contra-flow bus lane, US 101, Marin County, Calif

Use

From 70 to 90 buses currently travel northbound across the Golden Gate Bridge and along US 101 during the PM peak hour. All of these buses use the express lane except for Golden Gate Transit buses destined to Sausalito, Marin City, and Mill Valley. The latter lines use the northbound traffic lanes because they either have interim stops or must leave US 101 before reaching the Richardson Bay Bridge.

Southbound traffic volumes in the PM peak hour average 2,400 vehicles (1,200 vehicles per lane per hour) under the current operations plan Thus, two lanes have sufficient capacity to handle southbound traffic. Northbound traffic approximates 6,600 vph (1,700 vehicles per lane per hour)

Costs and Benefits

Costs for establishing the bus lane were estimated at nearly $200,000. Express lane operation produces an estimated saving of 5 min travel time for buses, as compared with the standard travel time of 13 min for other traffic to negotiate the 5-mile section. Initial reports indicate that the operation is running smoothly, including the merge section at the south end of the Richardson Bay Bridge

Significance

The Marin County bus lane is significant in that it may defer the need for expensive and costly rapid transit construction to provide additional peak-hour person capacity. It is a logical first-stage development of a proposed Marin busway.

FREEWAY BUS STOPS

Freeway bus stops have been provided in California for more than two decades Table B-50 summarizes the use of freeway bus stops both in Marin County and in other parts of the state (*B-14*).

Good use is made of freeway bus stops in the San Francisco Bay area, particularly on US 101 in Marin County and Cal 24 in Contra Costa County. On both routes, bus stops are located in suburban areas 10 to 25 miles from downtown San Francisco and involve relatively long-haul commuter buses.

Most freeway bus stops have these features:

1. They usually are located at a freeway interchange. (If not, they are located close to a pedestrian bridge over the freeway.)
2. Different pavement material (concrete) is used for bus loading and unloading zones.
3. The bus stop is off the main roadway, usually to the right of the through travel lanes.
4. Bus signs are located only at the entrance to the bus right-of-way. The sign BUSES is usually integrated with other highway signs.
5 A bus stop could include some of the following· a wooden shed; a steel post with a small bus sign (a 6-in. by 12-in. plate); a bench for three persons; and a highway-bus sign at the bus right-of-way entrance.
6. People using the bus stops generally must cross at least one freeway on-ramp or off-ramp. There are no signs to alert the motorists of pedestrian crossings.

Construction costs vary, because most bus stops were built as part of the freeway construction.

14. SEATTLE BLUE STREAK EXPRESS BUS SERVICE

Downtown Seattle, Wash., is the focal point for the Seattle-Everett Metropolitan Area, which encompasses 1,400,000 persons Current employment in the downtown area and its environs exceeds 100,000. Each weekday more than 250,000 trips are made to and from this area; about one-half represent work trips, about one-third are made by bus.

The 200-acre CBD contains 27 million square feet of floor space and employs about 60,000 persons. I-5 and the Alaskan Way Viaduct, which flank the CBD on the east and west, respectively, provide major north-south access in the "hour-glass" shaped city. These roadways carry more than 200,000 vpd through the downtown area (Fig. B-52). Many of the city's 500 diesel and trolley buses converge in downtown Seattle.

I-5 was originally designed and located for toll road construction. To accommodate heavy industrial traffic volumes, the freeway was designed with a reversible center roadway between downtown and Northgate Way. This reversible roadway, which varies from one to four lanes in width, operates southbound from 5:00 AM until noon and is then closed for an hour to clear cars. At 1:00 PM the lanes are opened for northbound traffic until 4:00 PM. Ramps in the downtown area operate in conjunction with the reversible lanes. Intersection gates, message signals, and signs are used on the ramps to aid motorists in determining the directional flow of the express lanes. The Blue Streak Express Bus Service uses these reversible lanes (*B-31*).

Description

The Blue Streak Demonstration Project was conceived by the Seattle Transit System in June 1966 as an improved express bus service that would provide service competitive with automobile travel. It was initiated in September 1970 as a demonstration project funded by the Urban Mass Transportation Administration, U.S. Department of Transportation. It serves 150,000 people in North Central and Northwest Seattle.

The Blue Streak Service includes the following:

1. A new express bus service uses the I-5 reversible lanes between downtown and a 500-space parking lot near Northgate Center, a distance of about 8 miles.
2. Seven restructured bus routes operate along portions of the I-5 reversible lanes and complement regular local bus service.
3. Buses have exclusive use of the Cherry-Columbia "reversible" ramp in downtown Seattle.
4. Free parking is provided at a new 500-car lot at the northern terminal. This facility is leased with an option to purchase at the end of the demonstration period.

TABLE B-50

SUMMARY OF EXISTING FREEWAY BUS STOPS, CALIFORNIA

LOCATION	ESTIMATED COST ($)	PASSENGERS PER DAY
I-80, Sacramento to Nevada State Line		
Lee Mine Rd.	4,000	1
Newcastle Rd	4,000	1
Weimar	14,150	2
Colfax	14,150	1
Monte Vista	3,650	0
Baxter	3,650	0
Putts Lake	2,700	0
Donner Park	4,600	0
Floriston	6,300	0
US 99, South Sacramento Freeway		
47th Avenue	13,500	200[a]
Fruitridge	7,300	200
12th Avenue	2,000	200
Broadway	2,500	200
SSR 24, Contra Costa County.		
Orinda	70,000	1,000
Charles Hill Rd	2,600	70
Acalanes Road	30,000	35
Pleasant Hill Rd (EB)	1,000	—
El Curtola Boulevard	1	30
US 101, Redwood Highway		
Marin County		
Sausalito	2,000	10
Spencer Ave.	4,000	70
Richardson Bay	83,000	25
Alto	17,000	200
Corte Madera	15,000	20
Lucky Drive	80,000	15
San Pedro Road	2,500	20
Freitas Parkway	20,000	250
Miller Creek Rd	16,000	200
Sonoma County		
Windsor	4,500	7
East Fulton Rd	26,500	2
Humboldt County		
Weott	11,300	7
US 101, Bayshore Freeway		
Moffett Boulevard	33,500	35
3rd Ave.-San Mateo	41,200	95
US 101, Hollywood Freeway		
Alvarado Street	294,000[b]	116[c]
Vermont Avenue	212,000[b]	278[c]
Western Avenue	392,000[b]	140[c]
I-10, San Bernardino Freeway		
Eastern Avenue	75,000	31[c]
Puente Avenue	—[d]	24[c]
Pacific Avenue	—[d]	28[c]
Vincent Avenue	—[d]	49[c]
Azusa Avenue	—[d]	35[c]
Citrus Avenue	—[d]	47[c]
SSR 11, Harbor Freeway		
7th Street	299,000[b]	—[e]
Pico Boulevard	—[f]	—[e]
Jefferson Blvd. and Santa		76[c]
Barbara Blvd	—128,000[b]	32[c]
Vernon Avenue		258[c]
Slauson Avenue	56,000[b]	4[c]
Florence Avenue		—[e]
76th St and Manchester Ave	32,000	13[c]
I-5, San Diego		
Washington Street	700	197
I-8, San Diego.		
Grossmont	24,000	60

Source Ref (*B-14*)

[a] Bus service since 1970

[b] Financed by City of Los Angeles

[c] Based on counts of peak hour and some midday observations, total daily count could be slightly higher

[d] Bus stops not constructed, buses stop on ramp shoulders

[e] Not used

[f] The original bus stops cost $223,000 and were financed by the City of Los Angeles Subsequently, during construction of the Santa Monica Freeway Interchange, the bus stops were relocated at state expense (cost unavailable)

Installation

The City of Seattle Transit Department (previously Seattle Transit) developed the parking lot and the revised bus routing plan The City Traffic Engineering Department made the necessary street revisions, including traffic signal modifications, channelizations, minor widenings, parking restrictions, and signing.

For two to three weeks prior to initiating Blue Streak, an extensive advertising campaign "advocated" the advantages of Blue Streak travel. These advertisements indicated that the Columbia-Cherry ramp would be closed to all vehicular traffic except buses.

Some complaints from motorists were received by agencies prior to the start of Blue Streak. For the three weekdays preceding the ramp closure, handbill-type notices were given to ramp users, further warning them of the forthcoming closure date. During the first morning's operation, approximately 15 motorists failed to heed the signs and used the ramp during the two-hour peak period; they were also handed warnings. During the afternoon period for the first few days a patrolman diverted would-be users. Congestion and delay increased on both the reversible and outer roadways as motorists sought other routes. This congestion was no more severe than that occurring at other times (sometimes only because of changes in climate), and it has subsequently declined.

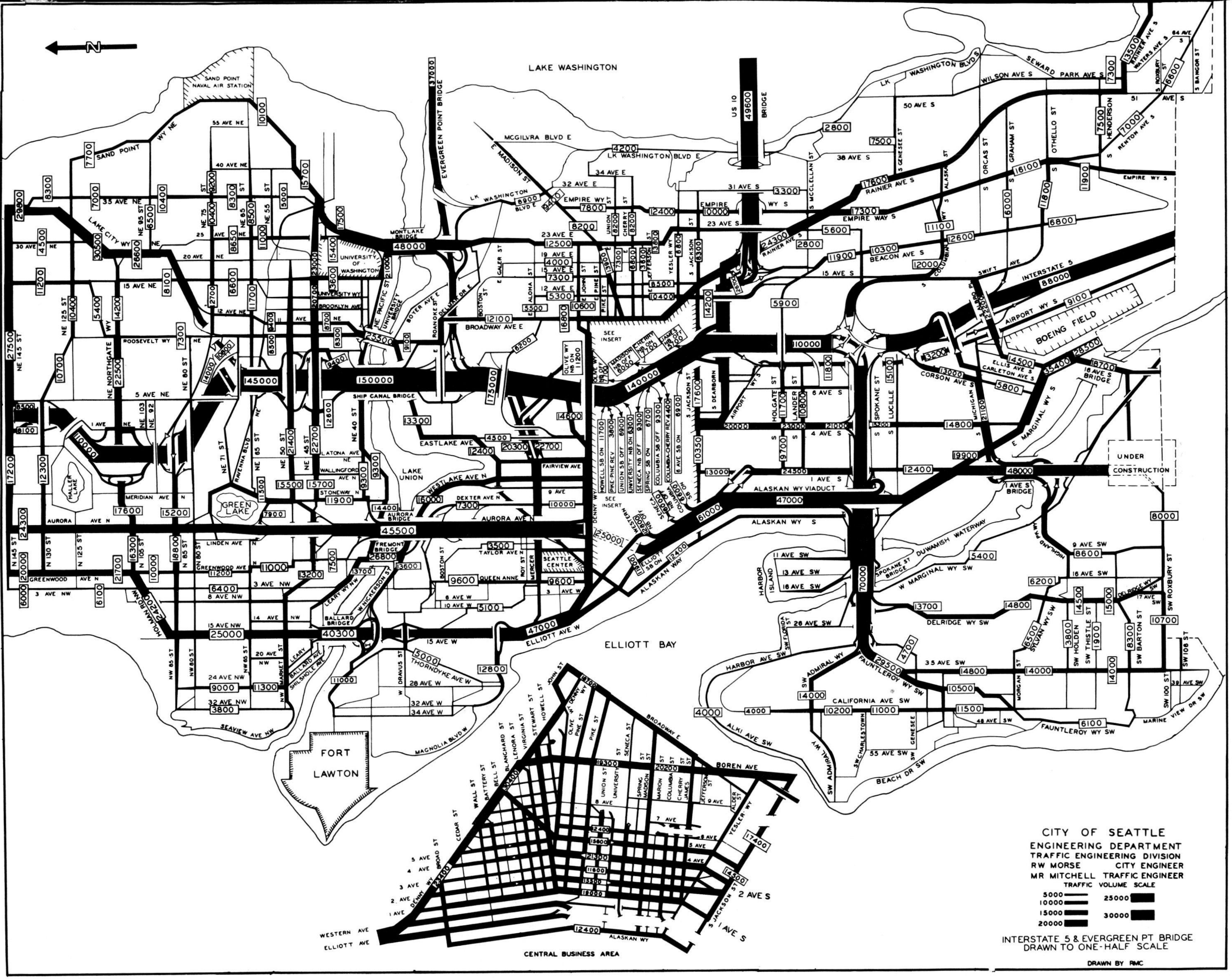


Figure B-52. 1968 daily traffic volumes, Seattle, Wash.

Bus Routes

Blue Streak express buses use the reversible I-5 roadway to and from the Columbia-Cherry ramps, Monday through Friday from 7:00 AM to 7:00 PM They use the reversible roadway inbound in the morning and return via the outer roadway; this pattern is reversed at noon each weekday. The headway between buses at the fringe parking lot is about 5 min; the fare is $0.35.

The eight Blue Streak bus routes are shown in Figure B-53, and are briefly described as follows.

41 Blue Streak.—This new route serves the park-ride lot, as well as surface streets. It uses the N.E. 103rd Street ramp for the express lanes and the N.E. Northgate Way ramps for travel in the direction opposite to the express lane flow, except for Lake City runs using the Lake City ramps southbound after 11 30 AM.

5 Phinney.—Southbound morning buses enter the outer roadway at north 85th Street and exit at the N E. 45th Street ramp. They then follow local streets and enter the express lanes at the N.E. 42nd Street reversible ramp to the CBD. Northbound, buses use the regular freeway ramp at N. 85th, but leave the freeway briefly for a stop at N.E. 45th Street. This pattern is reversed in the afternoon.

16 Meridan.—This service operates southbound from 7:00 to 9:00 AM and northbound from 4:00 to 6:30 PM. The route crosses under the freeway at Ravenna Boulevard and gets on and off the express lanes at the N.E. 42nd Street reversible ramp. Northbound, the route leaves the reversible lane at 42nd Street and uses the freeway outer roadway from 45th to 65th Streets.

7-15 Avenue N.E.—Buses in peak hours enter and leave express lanes at Lake City Way, and use the N. 85th Street ramp on the regular freeway when traveling in a direction opposite to express-lane flow. During off-peak, buses travel on arterials to the N E. 42nd Street reversible ramp, and use the N.E. 45th ramps for travel in the direction opposite to the express-lane flow.

7-Lake City, 7-View Ridge, 8-Ravenna, and 22-Roosevelt.—These routes enter and leave the express lanes at the N E. 42nd Street reversible ramp. Buses use the N.E. 45th ramp when traveling in a direction opposite to the express-lane flow After 4·00 PM, southbound Routes 7 and 8 bypass the freeway entirely and follow arterial streets to downtown. (The time saved using the regular freeway lanes would be lost by traveling on arterials to reach the southbound on-ramp at N.E. 45th Street.)

Local bus service is maintained on arterials previously served. During the periods that Blue Streak does not operate, all service is provided by these local routes. After the Demonstration Project is completed, the duplication of local and express service in off-peak periods will be eliminated.

The number of buses crossing the Ship Canal on arterials has remained almost the same as before Blue Streak. Although some buses were added in the peak period, the peak-to-base ratio is reported to have actually decreased.

Downtown Distribution

Downtown bus routings are shown in Figures B-54 and B-55. In the morning, Blue Streak buses follow their local routes on surface streets in their respective service areas They enter the reversible lanes southbound at one of three ramps north of the Ship Canal. They then proceed on the express lanes into the CBD, exiting from the express lanes at an exclusive bus-only ramp at Cherry Street. In essence, buses use 1½ mile of an inbound bus-only freeway lane on approach to this ramp.

From Cherry Street, the buses enter the CBD southbound via Fifth Avenue, westbound via Terrace and Yesler Streets, then northward via two-way Third Avenue. After stopping in the CBD, buses return to the freeway at Olive Street to make their outbound trips by means of the outer I-5 roadway, exiting at appropriate ramps in North Seattle

During the periods when the express lanes are closed for changeover (12 N to 1.00 PM), Blue Streak buses operate over the regular north- and southbound outer roadway lanes of the freeway. They enter the CBD on the Stewart Street ramp and leave the CBD on the Cherry Street ramp of the regular outer roadway.

After 1:00 PM, inbound Blue Streak buses operate on the outer freeway roadway. Buses leave the freeway at Stewart Street and proceed south through the CBD on Third Avenue. During this period, northbound passengers board Blue Streak buses southbound on two-way Third Avenue. The bus stops are moved from the east side to the west side of the street by use of signs with sliding changeable message faces that are controlled by a bus inspector.

From the south end of downtown, buses reach 5th Avenue via Yesler and Terrace Streets. Blue Streak buses proceed up 5th Avenue to the Cherry Street ramp, using a reserved contra-flow northbound bus lane. The buses then use the reversible ramp to return to their outbound destinations by means of the express freeway lanes.

The Columbia-Cherry reversible ramp to and from I-5 is shown in Figure B-56. Buses were granted exclusive use of this ramp by the Washington State Highway Commission with approval of the Federal Highway Administration.

Use

Use of I-5, downtown ramps, and Blue Streak bus service has been continually monitored by the City.

I-5 Freeway Volumes

A permanent counting station is maintained south of the Ship Canal by the State Average weekday traffic volumes increased from about 110,000 in 1967 to 150,000 in 1969 Daily 1970 traffic volumes ranged from 130,000 to 140,000 This lack of growth may have resulted from the cutback in Boeing employment in South Seattle.

Peak-hour volumes remained relatively constant During a typical 1970 morning and evening peak hour, the following flows were observed·

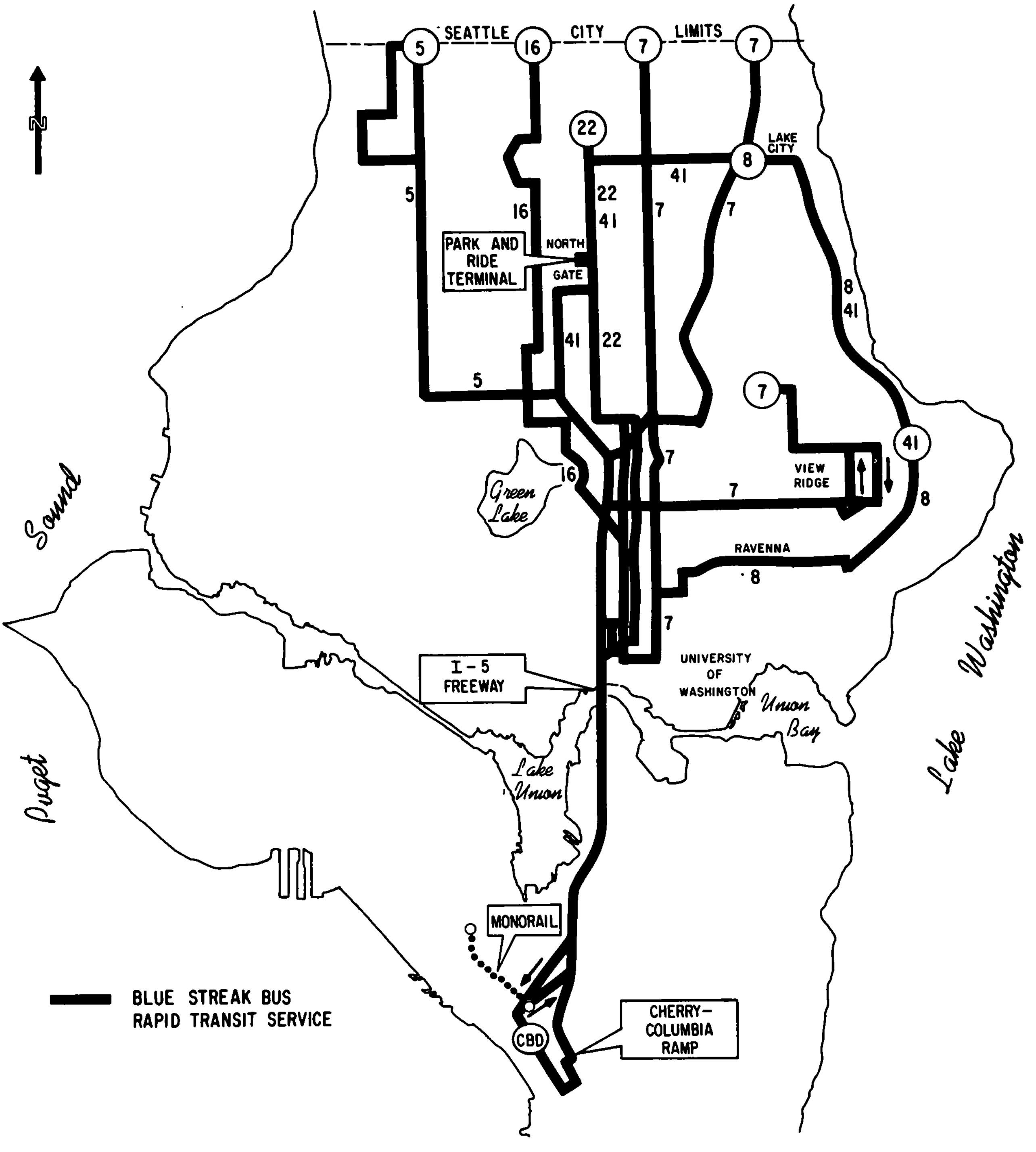


Figure B-53 Blue Streak bus routes, Seattle, Wash

	TRAFFIC FLOW (MPH)	
ROADWAY	AM	PM
Southbound outer road	4,200-4,500	4,000
Reversible road (SB AM, NB PM)	5,100-5,300	4,600-5,000
Northbound outer road	2,700-3,000	4,600

Transit Riding

Transit riding on the entire system declined about 6 percent from 1970 to 1971. Monday-Friday riding averaged about 450,000, or 90,000 passengers per day.

At the same time, the Blue Streak service reported a 33 percent gain in patronage. The buses served 12,000 passengers per day in 1971, as compared with 9,000 before

Figure B-54 AM *downtown routing pattern, Blue Streak bus service, Seattle, Wash*

the service. Prior to Blue Streak, the routes represented by the service accounted for 9.5 percent of the total system patronage; in 1971, they accounted for about 13.5 percent. Approximately 18 to 25 percent of the riders were former motorists.

Much of the diversion from autos to buses resulted from parking cost factors. The maximum round-trip fare on Blue Streak is $0.70, and compares favorably with downtown parking rates, which vary from $0.75 to $2.50 per day, depending on location.

During the peak hour, buses operate on a 75-sec headway. Some 50 buses carry about 2,500 people into down-

Figure B-55. PM *downtown routing pattern, Blue Streak bus service, Seattle, Wash*

town—approximately one-fourth of the peak-hour person flow carried in the reversible lanes.

Ramp Volumes

Changes in CBD ramp volumes based on surveys taken November 2 and 3 are summarized in Tables B-51 and B-52. The Stewart and Pine reversible ramps accommodate most of the traffic formerly leaving the freeway in the morning rush hours. Similarly, the Pike reversible ramp and the Seventh Street on-ramp accommodate most of the outbound traffic previously using the Columbia-Cherry ramp. Prior to its closing, the Columbia-Cherry ramp was the heaviest used CBD reversible ramp.

Counts of Blue Streak buses using the Columbia-Cherry reversible bus ramp are summarized in Table B-53. During the peak hour, bus volumes approximated 50. Nineteen motorist violations were reported in the morning peak period and 12 in the evening.

Bus passenger volumes on the Columbia-Cherry ramp

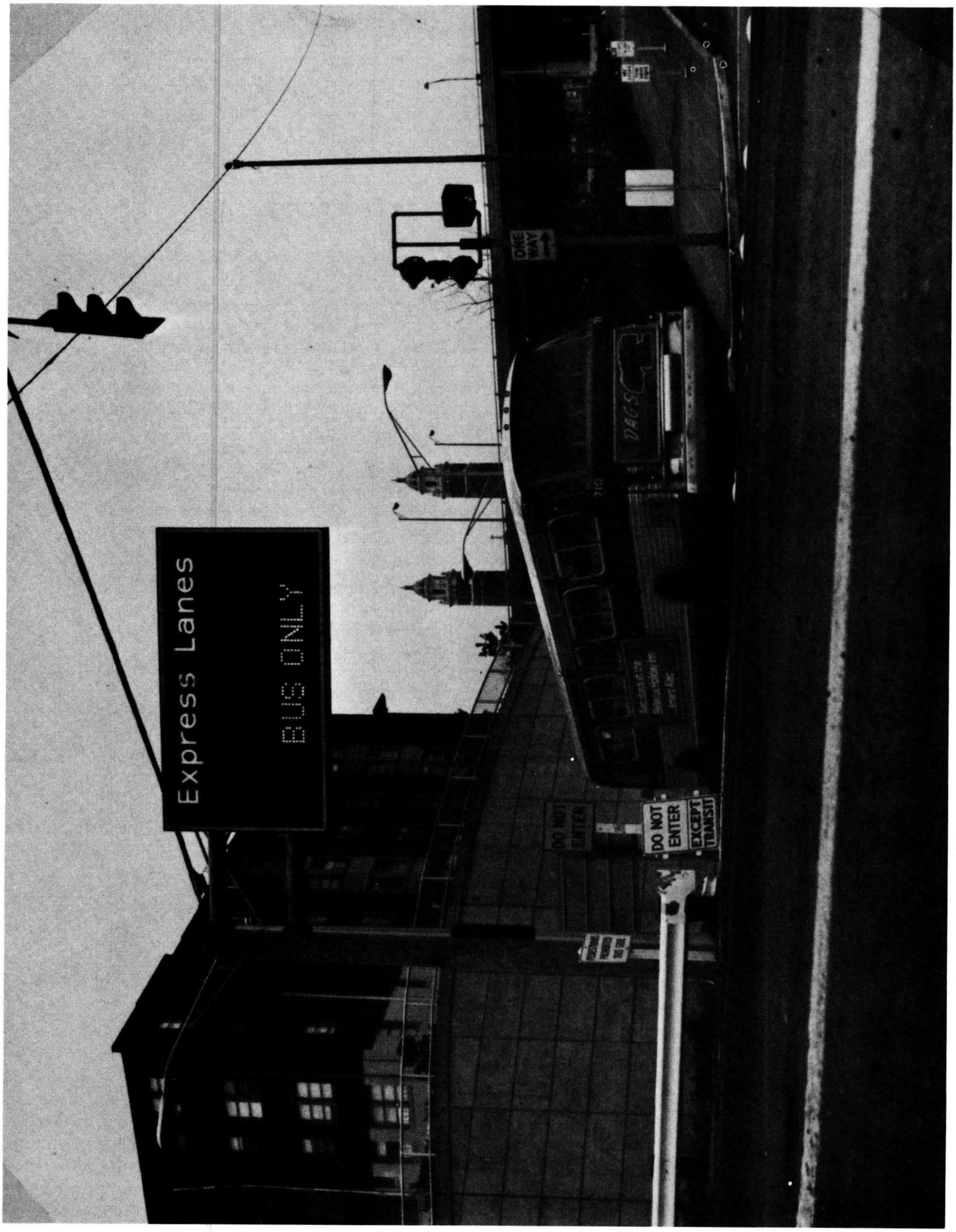


Figure B-56. Blue Streak exclusive northbound bus ramp onto I-5, Seattle, Wash.

TABLE B-51

DAILY RAMP VOLUMES, I-5, SEATTLE

		VOLUME		
RAMP LOCATION	DIRECTION	BEFORE BLUE STREAK (8/25/70)	AFTER BLUE STREAK (9/16/71)	DIFF.
Mercer	SB Off	10,510	10,410	−100
	Rev. Off	2,620	2,730	+110
Stewart	SB Off	12,841	12,360	−481
	Rev. Off	2,260	2,800	+540
Union	SB Off	1,570	1,770	+200
Pine	Rev. Off	1,940	3,040	+1,100
Col-Cherry	Rev Off	2,610	160	−2,450
6th	SB Off	9,220	10,310	+1,090
Mercer	NB On	12,090	12,360	+270
	Rev On	6,060	6,130	+70
Howell	Rev. On	1,670	1,710	+40
Olive	NB On	10,320	10,640	+320
University	NB On	6,280	6,430	+150
Pike	Rev. On	2,380	2,790	+410
Col-Cherry	Rev On	2,530	210	−2,320
7th	NB On	7,650	9,300	+1,650

Source Ref (*B-32*)

with Blue Streak were reported at 10,700 to 12,100. This represents a gain of 4,000 passengers over the 7,000 to 8,000 passengers previously accommodated by all modes. Although some of this increase resulted from rerouting of bus lines, it clearly suggests that bus priority treatments can increase the person capacity of a downtown ramp.

TABLE B-52

BLUE STREAK BUS VOLUME AND HEADWAY COUNTS, CHERRY STREET REVERSIBLE RAMP, I-5, SEATTLE[a]

		HEADWAY (MIN)			
TIME PERIOD	BUSES	AVERAGE	SHORTEST	LONGEST	PASS CAR VIOLATORS
Southbound:					
7–8 AM	39	1.53	0.33	5	3
8–9 AM	42	1 43	0.33	4	5
9–10 AM	17	3.53	0.50	13	6
10–11 AM	18	3 33	1.00	9	2
11 AM–12 PM	14	4 37	1 00	13	3
Total	130	2.62			19
Northbound.					
1–2 PM	16	3.75	0 50	10	0
2–3 PM	16	3.75	0 50	10	7
3–4 PM	18	3.33	0.50	8	1
4–5 PM	41	1 47	0.50	6	1
5–6 PM	47	1.27	0.33	5	3
6–7 PM	23	2 50	0.33	10	0
Total	161	2 30			12
AM peak (2 hr)	81	1.50			
PM peak (2 hr)	88	1 37			
Off-peak	122	3 45			

Source Ref (*B-31*)

[a] Data collected November 2 and 3, 1970

TABLE B-53

CBD PEAK-HOUR RAMP VOLUMES, BEFORE AND AFTER BLUE STREAK BUS SERVICE, I-5, SEATTLE

		AM PEAK			PM PEAK		
RAMP	DIRECTION	BEFORE	AFTER	DIFF	BEFORE	AFTER	DIFF.
Mercer	SB Off	993	943	−50			
	SB Rev.	913	1,010	+97			
Stewart	SB Off	1,424	1,353	−71			
	SB Rev.	922	1,208	+286			
Pine	SB Rev.	866	1,366	+500			
Union	SB Off	864	866	+2			
Col-Cherry	SB Rev	1,105	65[a]	−1,040			
6th	SB Off	1,320	1,571	+251			
Rev. Term.	SB Rev	1,879	1,971	+38			
All	SB	10,286	10,299	+13			
Mercer	NB On				1,215	1,284	+69
	NB Rev				1,185	1,168	−17
Olive	NB On				1,103	1,033	−70
Howell	NB Rev.				557	617	+60
Pike	NB Rev				618	966	+348
University	NB On				879	840	−39
Col-Cherry	NB Rev.				911	56	−855
7th	NB On				1,248	1,522	+274
Rev. Term	NB Rev.				1,724	1,832	+108
All	NB				9,440	9,348	−92

Source Ref (*B-31*)

[a] Blue Streak buses

Travel Patterns

Origin-destination surveys were made during August 1970 of transit passengers and motorists that crossed the Ship Canal. Mailback questionnaires were given to drivers using the northerly-serving ramps between 6:00 AM and 8:00 PM. In this period, 83,100 vehicles and 121,300 persons used these ramps; 52,700 questionnaires were distributed, and 20,400 (40.6 percent) were returned. Nearly 13,000 transit passengers (one-half of the 25,500 interviewed) responded. Results of these surveys are summarized in Table B-54.

- Approximately 60 percent of all travelers (both bus and car) made work trips.
- Approximately 14 percent of the auto travelers reported that they did not park, hence were traveling through the CBD.

TABLE B-54

CHARACTERISTICS OF I-5 TRAVELERS, BLUE STREAK BUS SERVICE CORRIDOR, SEATTLE, 1970

ITEM	NORTH-BOUND VEHICLES	SOUTH-BOUND VEHICLES	BUS PASSENGERS NORTH-BOUND	BUS PASSENGERS SOUTH-BOUND
Trip purpose				
Work	58	63	58	62
Shop	4	4	4	4
Personal business	15	13	15	13
Serve passengers	7	7	—	—
Medical-dental	5	4	5	4
Social	5	6	5	6
Education	2	1	2	1
Other	4	2	11	10
	100	100	100	100
Type of parking				
Lot	38	39	—	—
Garage	19	18	—	—
Curb	16	18	—	—
Other	12	12	—	—
Did not park	15	13	—	—
	100	100	—	—
Family income				
<3,000	—	—	18	17
3–4,000	—	—	10	11
4–6,000	—	—	18	18
6–8,000	—	—	16	16
8–10,000	—	—	13	14
>10,000			25	24
	—	—	100	100
Car ownership				
None	—	—	36	37
1	—	—	44	44
2 or more	—	—	20	19
	—	—	100	100
Car availability				
Yes	100	100	27	30
No	0	0	73	70

Source Ref (*B-31*)

- One-quarter of all bus riders had income of more than $10,000; 20 percent came from multicar households.

Approximately 30 percent of all bus riders had cars available. This suggests that the Blue Streak bus service attracted "choice" riders, who, without the service might have driven their cars downtown.

Origin patterns of people interviewed are shown in Figure B-57. More than one-third of travelers from northern parts of the city used bus service, as compared with about 10 percent from suburban areas. The highest transit use (more than 50 percent) was found in the Green Lake-North Park corridor.

Parking Lot Utilization

The 500-space park-and-ride lot (Figure B-58) was filled to about three-fourths of its capacity on the first day of operation. Within a week's time it was operating full, within a month's time it was filled before 8:30 AM, with another 50 vehicles parking illegally. Its use verified acceptance of Blue Streak by the public The early filling of the lot left no space for midday users. This condition limits the number of auto drivers that can change modes during the remainder of the day.

Costs

The estimated implementation costs of the Blue Streak service are shown in Figure B-59. Total project costs were estimated at $1.9 million, of which $1 million represents the costs of added hours of bus service after deducting increases in revenue. Costs for traffic controls were estimated at $114,000, and costs for the fringe parking lot at $405,000 The remaining costs represent promotion, publicity, and monitoring.

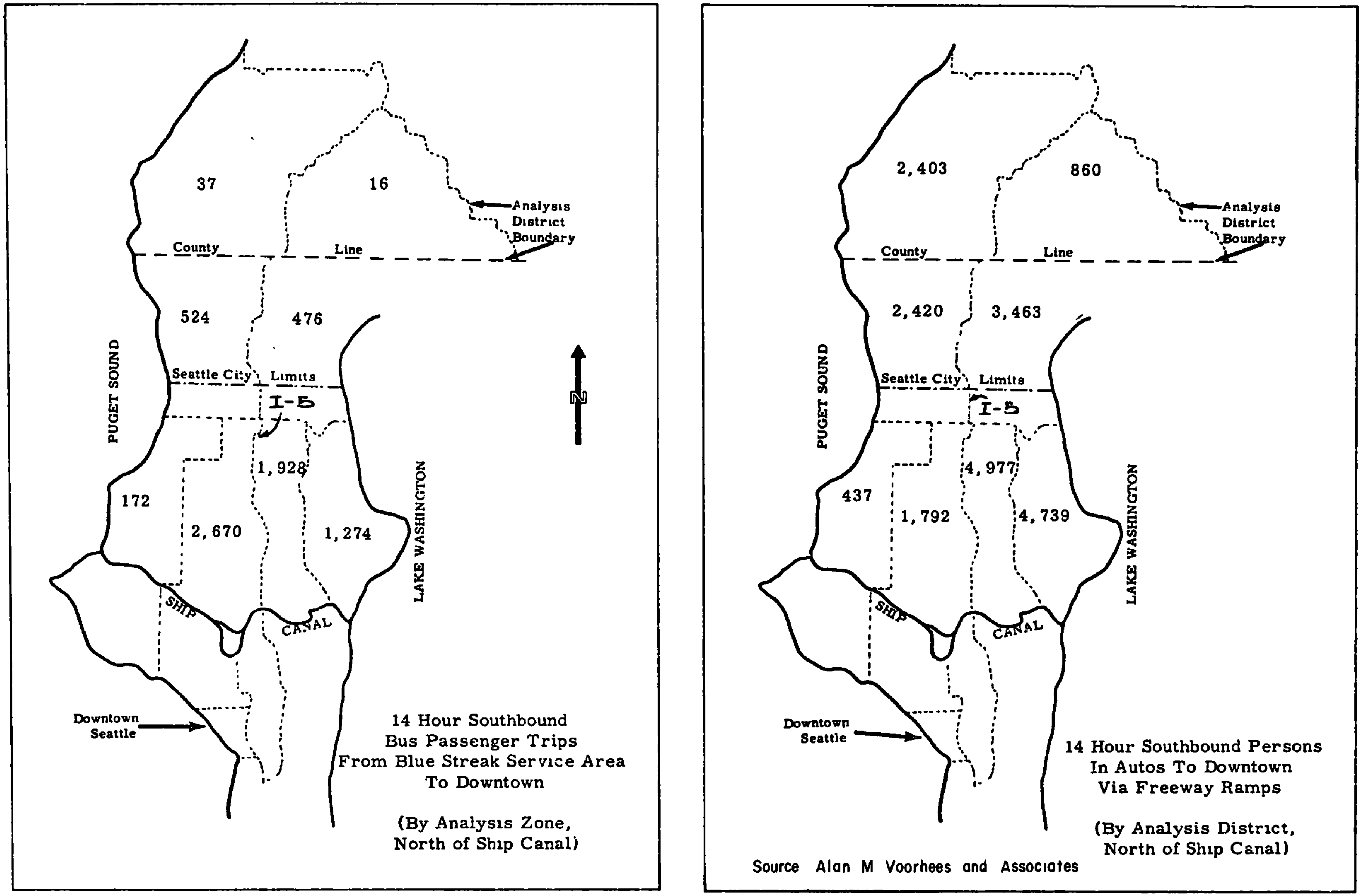
Reported Benefits

The Blue Streak service has increased bus patronage from its tributary area. This has been accomplished through substantial reductions in bus travel times. High speeds, for example, have contributed to the success of the park-and-ride concept. The 8-mile trip from the parking lot to the center of the CBD, including travel on CBD streets, takes about 15 min. Previously the trip took 30 to 40 min. This time saving allows one bus to make several trips in the peak period (The running time from the lot to the Seattle Municipal Building is 12 min; it is 16 min to 3rd Avenue and Union Street. The running time to the centroid of the CBD is 18 min, representing an average speed of about 30 mph.) These Blue Streak speeds compare favorably with speeds attained by North American rail rapid transit systems.

On other routes making up the Blue Streak System, time savings are less because of the surface time necessary to pick up loads before entering the Blue Streak freeway lanes However, for many areas there are substantial time savings over the previous local transit service.

Significance

The Blue Streak project, through use of a reversible bus-only ramp, has provided express transit service competitive



Source Alan M Voorhees and Associates

Figure B-57. Origin patterns of I-5 travelers, Blue Streak bus service, Seattle, Wash

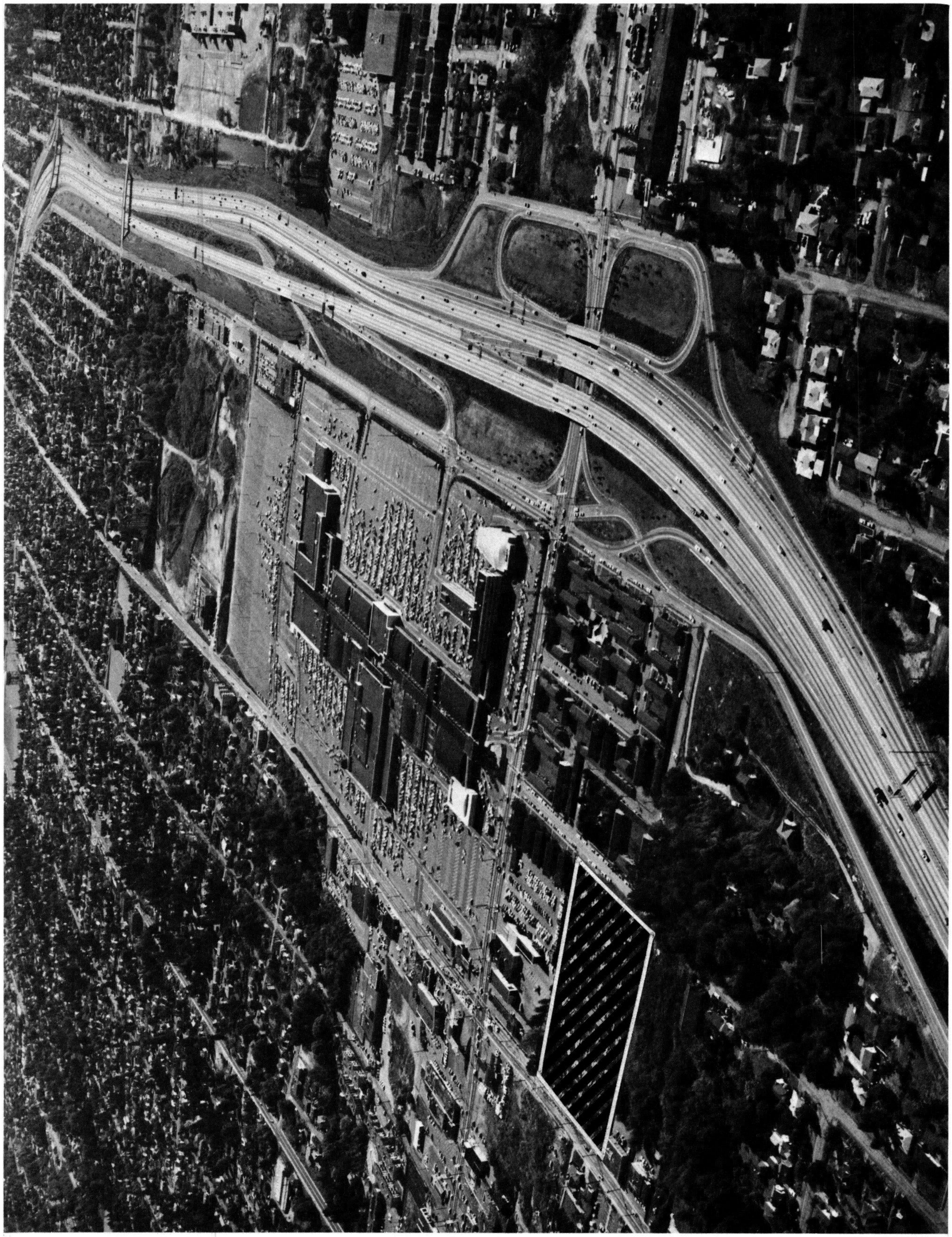


Figure B-58. Park-and-ride lot, I-5, Blue Streak bus service, Seattle, Wash.

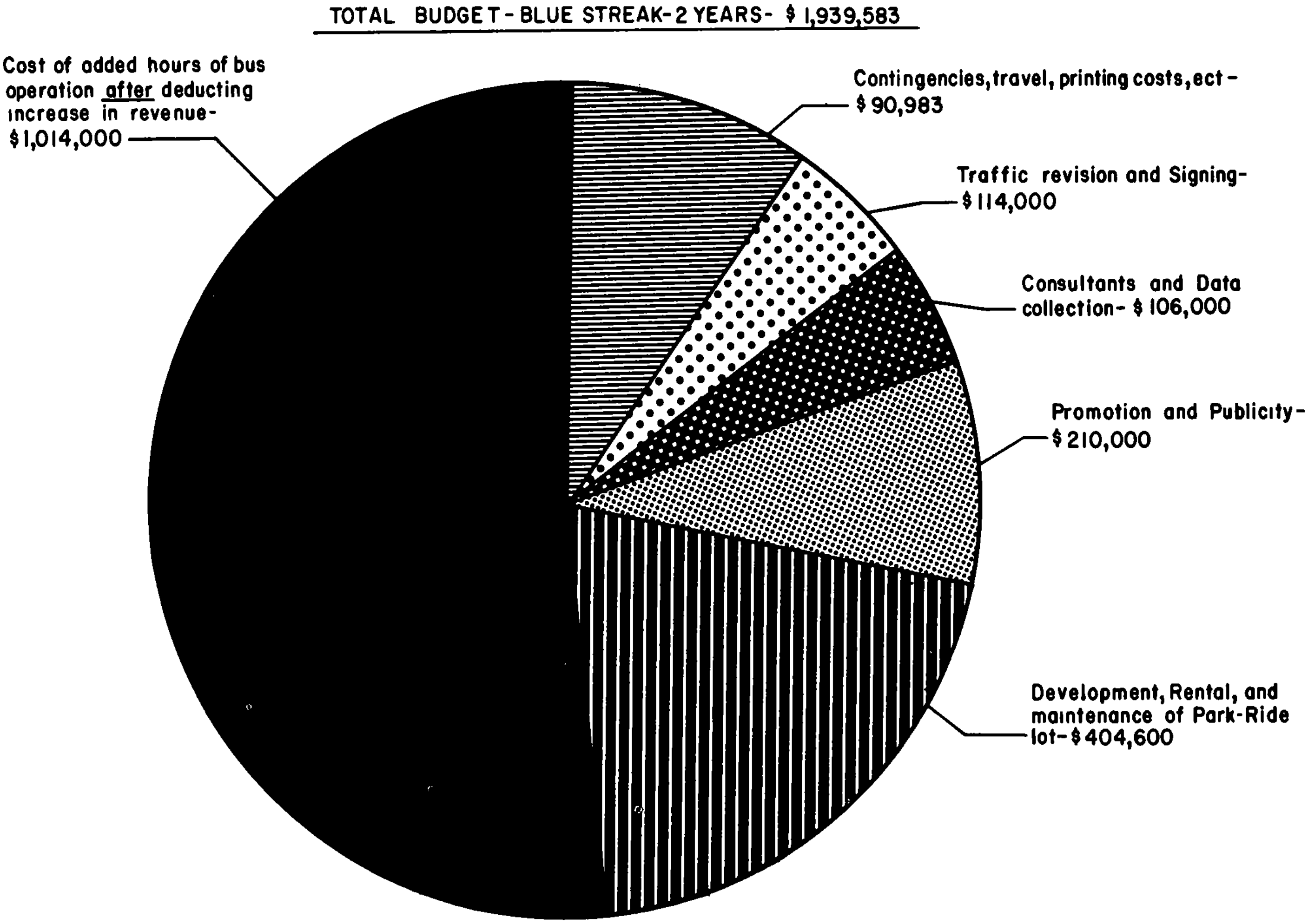


Figure B-59. Estimated costs, Blue Streak bus service, Seattle, Wash.

with the automobile. It provides substantial time reductions for bus riders. Buses average about 55 mph on the freeway, and about one in four riders represent former motorists. Some 25 percent of the I-5 reversible lane peak-hour person flow is carried by bus.

All of the 8 5 miles of reversible roadway is shared with cars and trucks without hindrance to either buses or other traffic. Automobile travel times on I-5 during the peak hour have remained essentially unchanged since inauguration of the service (Table B-55).

Delays are reported in the evening peak hour on the northbound reversible lane terminus between 112th and 103rd Streets A single-lane freeway exit creates queues that interfere with buses trying to leave the roadway. To alleviate this condition and to improve the parking supply, a proposal was submitted in January 1972 to the State Highway Commission. This proposal, jointly prepared by the State and the City Departments of Transportation and Development, calls for a $3½ million expenditure for (1) 1,000 additional parking spaces, (2) a new exclusive bus ramp from the parking lot to the freeway, and (3) revision of the northbound ramps from the express lane into the northbound local freeway lanes.

TABLE B-55

AUTO TRAVEL TIMES, I-5, SEATTLE

LOCATION	BEFORE BLUE STREAK, AUG 1970 (SEC)	AFTER BLUE STREAK, OCT. 1970 (SEC)	DIFF. (SEC)	CHANGE (%)
NB outer roadway, Yesler to 205th				
AM	710	750	+40	+5
PM	963	972	+9	+2
Reversible roadway, Yesler to Northgate				
AM	478	544	+66	+13
PM	625	588	−37	−6
SB outer roadway, 205th to Yesler				
AM	904	1,118	+214	+23
PM	842	822	−20	−3

Source Ref (*B-31*)

This proposal is well conceived. It simultaneously alleviates a traffic bottleneck, improves the quality of transit service, and provides needed fringe parking It is the type of innovative treatment that has broad potential applicability.

The public reaction to Blue Streak has been good. It is reported to have prompted a reappraisal of transit planning for I-90 across Lake Washington Consideration is being given to provision of two exclusive transit lanes which would initially operate as bus lanes, in conjunction with a new Lake Washington Bridge

15. WASHINGTON METROPOLITAN AREA BUSWAYS AND BUS PRIORITY LANE

The Washington Metropolitan Area (population 2,752,000 in 1970) has taken several major steps to improve public transport services Construction is proceeding on the Metro rail rapid transit system, and the potentials for more immediate benefits from bus rapid transit are being extensively explored Bus rapid transit is seen as a valuable complement to the rail network, particularly in serving low-density areas.

The first busway in the U S. was initiated along Shirley Highway in 1969, and subsequently expanded Proposals were set forth for improved bus services along the Georgetown Branch Railroad and across the South Capital Street Bridge

SHIRLEY BUSWAY

The Shirley Highway Express Bus Demonstration Project is sponsored jointly by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) It involves operation of express buses on an exclusive right-of-way for approximately 9 miles along the Shirley Highway (I-95) from Northern Virginia suburbs into Washington, D C (*B-33*)

Other agencies involved in the project include: AB&W Transit Company (privately owned), WV&M Coach Company (privately owned), Virginia Department of Highways, D C Department of Highways and Traffic, Washington Metropolitan Area Transit Commission, Metropolitan Washington Council of Governments, Washington Metropolitan Area Transit Authority, and Northern Virginia Transportation Commission

Corridor Description

The Shirley Highway Corridor in Northern Virginia is bordered by US 50 (Arlington Boulevard) and the Potomac River. Its southern limits include the rapidly developing suburban areas of Fairfax County (Fig B-60) Access from the Corridor to the District of Columbia is provided by the Memorial and 14th Street Bridges across the Potomac River.

The Shirley Highway varies from a four-lane divided freeway on its older portions to an eight-lane freeway with two center reversible lanes on recently reconstructed segments Reconstruction of all of the old four-lane sections is either under way or is programmed for the next few years

Average daily traffic volumes range between 70,000 and 110,000. Adjacent radial routes in the corridor vary from four-lane undivided arterials to six-lane parkways and carry from 15,000 to 50,000 vehicles each day

A 1968 origin-destination survey of Shirley Highway users indicated that about 23,400 Northern Virginia auto commuters entered the highway between the Springfield interchange and Columbia Pike. Of these, approximately 12,700 were from areas that would benefit directly from improved bus service over the Shirley Highway Peak-hour radial transit modal split was estimated as 23 percent

Traffic congestion on Shirley Highway and other Corridor arterial roads is common, because most radial routes operate at service levels E and F. Recent growth trends on these roads vary from 4 to 33 percent per year. They reflect the rapid development of Northern Virginia suburbs and pinpoint the need for additional peak-period transport capacity.

Background

Reconstruction of Shirley Highway has been under way about eight years. Initial plans called for an eight-lane freeway with three lanes each way and two reversible lanes in the median. As early as 1964, express bus service was planned for the reversible lanes. This led to the redesign of three interchanges to allow exclusive bus access to the reversible lanes. In 1968, an FHWA-funded feasibility study was started.

On September 22, 1969, as a result of an interim recommendation of the feasibility study, the portion of I-95 where construction of the reversible lanes was completed began operation as exclusive bus lanes during the morning peak period This section covered a distance of 4 8 miles from the vicinity of Springfield, Va , to within about 4 miles of the Potomac River. The time savings were about 12 to 18 min per bus, and the ridership increased some 15 to 20 percent.

In March 1970 the feasibility study was completed (*B-34*). It recommended construction of a temporary busway for the remaining 4 miles from the completed reversible-lane section to a new bridge that was being built across the Potomac River. The recommendation was incorporated into two ongoing construction projects, and the first portion of temporary bus lane (1.5 miles) was opened in September 1970 At the point where the temporary bus lane begins, a slip ramp was constructed to permit an additional 50 buses to gain access to the reserved lanes from Shirlington Circle.

The remaining portion of the temporary lane was opened to the new Potomac River Bridge on April 5, 1971, and provided a total savings of 30 min over automobile travel time. Simultaneously, the D.C. Department of Highways and Traffic allowed buses to use the new center bridge, which was substantially completed but which could not be opened to general traffic until the approaches are built These three links—the reversible roadway, temporary bus roadway, and new bridge—total about 9 miles of roadway exclusively for bus use in the peak direction of travel. The D.C Department of Highways and Traffic also instituted

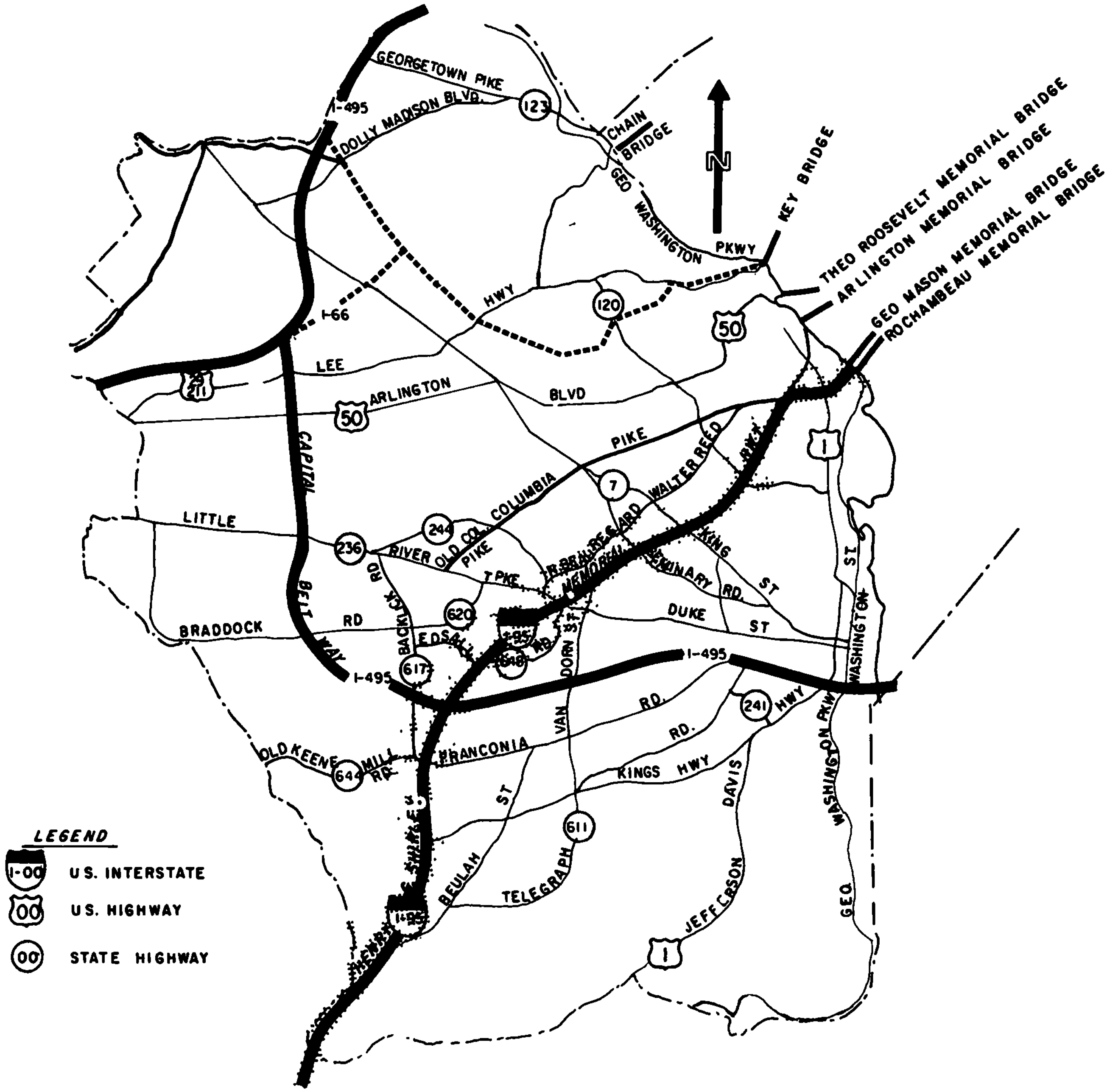


Figure B-60 Location map, Shirley Highway corridor, Virginia

a system of priority bus lanes on downtown Washington streets to expedite bus movements.

On June 14, 1971, the Shirley Highway Express Bus Experiment entered a new phase as 30 additional buses were placed in operation on eight routes (some were variations of existing routes and others were completely new routes). The 30 buses were purchased by the Northern Virginia Transportation Commission (NVTC) under an UMTA demonstration grant. They are operated by the AB&W Transit Company for NVTC. By January 1972 patronage south of Shirlington exceeded 6,200 riders per day.

Description

General characteristics of the 9-mile Shirley Highway reversible bus lanes are summarized in Table B-56. The lanes operate only during peak hours: inbound from 6:30 AM to 9 30 AM and outbound from 4·00 PM to 6·30 PM They are used by all types of buses.

The permanent busway lanes are 24 ft wide, with 10-ft shoulders. The temporary busway lanes are 18 ft wide, but narrow in some locations to 11 ft Typical busway views are shown in Figures B-61 and B-62.

TABLE B-56

GENERAL CHARACTERISTICS OF SHIRLEY HIGHWAY BUS LANES, VIRGINIA

Location	9 miles in median of Shirley Highway southwest of Washington, D C.	
Length·	Sept 1969	4 5 mi opened
	Sept 1970	1 5 mi (temporary construction)
	April 5, 1971	3 0 mi (final) across Potomac River into D.C.
		9 0 mi
Types of vehicles	Open to all buses (private, public, military, local, and long-distance) and emergency vehicles	
Hours of operation	6·30–9 00 AM inbound, 4 00–6.30 PM outbound	
Design	11′ to 18′ temporary bus lane, 24′ permanent lanes	
Use	June 1971; AM peak period, 275 buses, 11,300 people; PM peak period, 310 buses, 12,000 people	
Costs:	Construction of bus lanes and temporary construction, $2 8 million.	
Reported benefits	Time savings up to 30 min for full-length trip	

Source Metropolitan Washington Council of Governments, 1971

Access Ramps

Locations of permanent and temporary access ramps are shown in Figure B-63 Permanent ramps exist at Turkeycock and Seminary Roads, and a ramp is being developed at Springfield. The Turkeycock ramp is entered on the right and curves under the main three-lane roadway onto the two reversible lanes; signing indicates use by buses only. The Seminary "bus only" ramps slope down to the reversible lanes.

A temporary busway entrance is provided at Shirlington Circle (Fig. B-64). Buses enter the Shirley Highway at Shirlington Circle, where the left lane of the two-lane ramp is reserved for buses. At this location entering buses weave across two general traffic lanes, with priority assigned to the buses by YIELD signs. As this area is under construction, and peak-period highway congestion is normal, this bus priority does not significantly delay car and truck traffic (Under free-flowing conditions, however, such an arrangement would present a serious safety hazard and would impose costly delays on other road users)

In Washington, buses also weave across highway lanes in transitioning between the median busway and reserved 14th Street curb bus lanes. Flashing neon signs read YIELD TO BUSES.

Speeds

Buses operate nonstop on the bus roadway at speeds up to 60 mph; speeds at Seminary Road average 40 mph. Morning automobile traffic speeds vary from 60 mph south of Seminary Road to stop-and-go conditions between Seminary Road and Shirlington, where the three travel lanes reduce to two.

In the PM peak period, congestion extends across the 14th Street Bridge and past the Pentagon area. In the "Mixing Bowl" area, where Washington Boulevard merges with Shirley Highway, severe congestion reduces traffic flow. Southward, from this merge to Glebe Road, traffic moves steadily through the construction detours; beyond Glebe Road speeds are improved as the roadway widens.

Comparative bus and auto times between downtown Washington and three points along the Shirley Highway are given in Table B-57. Bus travel time to Turkeycock ramp averages 14 to 15 min, a 20-min time saving over car travel.

Downtown Distribution

Inbound buses cross the Potomac River on a reserved lane of the new 14th Street Center Bridge, weave across traffic, and are then given priority use of 14th Street curb lanes from D Street S.W. to New York Avenue. These priority lanes, combined with turn prohibitions at intersections and retimed signals along the bus routes, give additional advantage to buses. To facilitate bus movements and passenger transfers, stops were relocated at 14th Street and Constitution Avenue, I Street between 16th Street and Vermont Avenue, I Street between 14th and 15th Streets, and on Pennsylvania Avenue between 14th and 15th Streets.

Travel times from the 14th Street Bridge to and from Farragut Square average 15 min in the morning peak period, and 15 to 20 min in the evening. No decreases in travel times were reported as a result of the curb bus lanes

A special study conducted in December 1971 of PM peak-hour travel on bus route 7G (11.5 miles in length) confirms these findings. The bus took 19 min to travel the 3 miles from 20th Street between I and K Streets to the Virginia line; 9 min to go the 5 3 miles along the busway nonstop from the Virginia line to Seminary Road; 11 min to go the final 3 miles, which included about eight stops in Virginia (including several where the bus circled in and out of large apartment complex driveways and operated on surface arterials and neighborhood streets). The bus averaged 9.4 mph in D.C, 35 mph on the busway, and 16.4 mph on surface streets in Virginia, for an over-all speed of 17.5 mph.

Bus travel times for the few miles from the 14th Street Bridge to Farragut Square exceed those along the 9 2-mile busway to Turkeycock Road. The time losses in the downtown area limit portal-to-portal speeds and seriously decrease the possibility of additional peak-hour runs by bus drivers This condition should be given increased consideration in upgrading express bus service.

Use

Approximately a dozen AB&W bus routes use the Shirley Highway. Routes 2G, 4G, 6G, 7W, 8G, 17G, 18G, and 19G, use the busway during peak periods Routes 1A, 1B, 17G and 18G use the highway during the midday periods. The shortest route on the busway (route 6G) is 10.4 miles, terminal to terminal; the longest route (17G) is 20.8 miles, terminal to terminal.

Peak-hour AB&W busway trips from 7:15 to 8:15 AM, in November 1971, totaled 110 trips at the maximum load point. At 14th and C Streets there were 116 peak-hour trips, suggesting that the available curb loading capacity is fully utilized.

Peak-period total busway passenger volumes are summarized in Table B-58. One-way volumes exceed 12,000 persons and 300 buses during peak 2½-hour periods at the maximum load point.

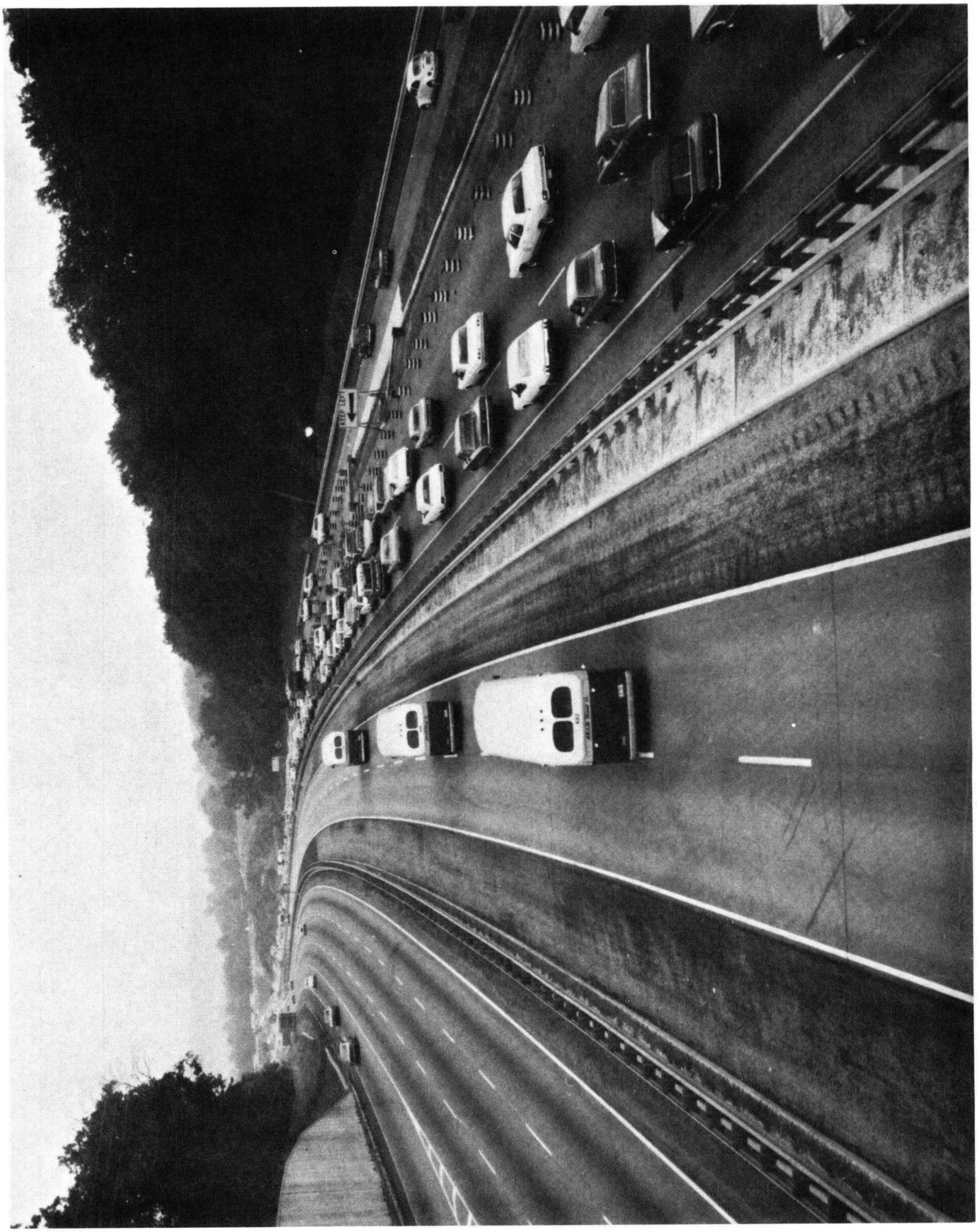


Figure B-61. Completed section with reversible bus lanes, Shirley Highway, Virginia.

User Characteristics

In April 1971, an AM peak-period (6:30 to 9:00 AM) survey was made of commuters traveling through the Shirley Highway Corridor. Approximately 900 auto users and 2,300 bus users were surveyed through a mail-back questionnaire. The response rate was 31 percent for auto drivers, 19 percent for auto passengers and 55 percent for bus passengers. This survey, summarized in Tables B-59, B-60, B-61, and B-62 (*B-35*), indicates the following:

1. Almost three out of five of the bus users have a choice

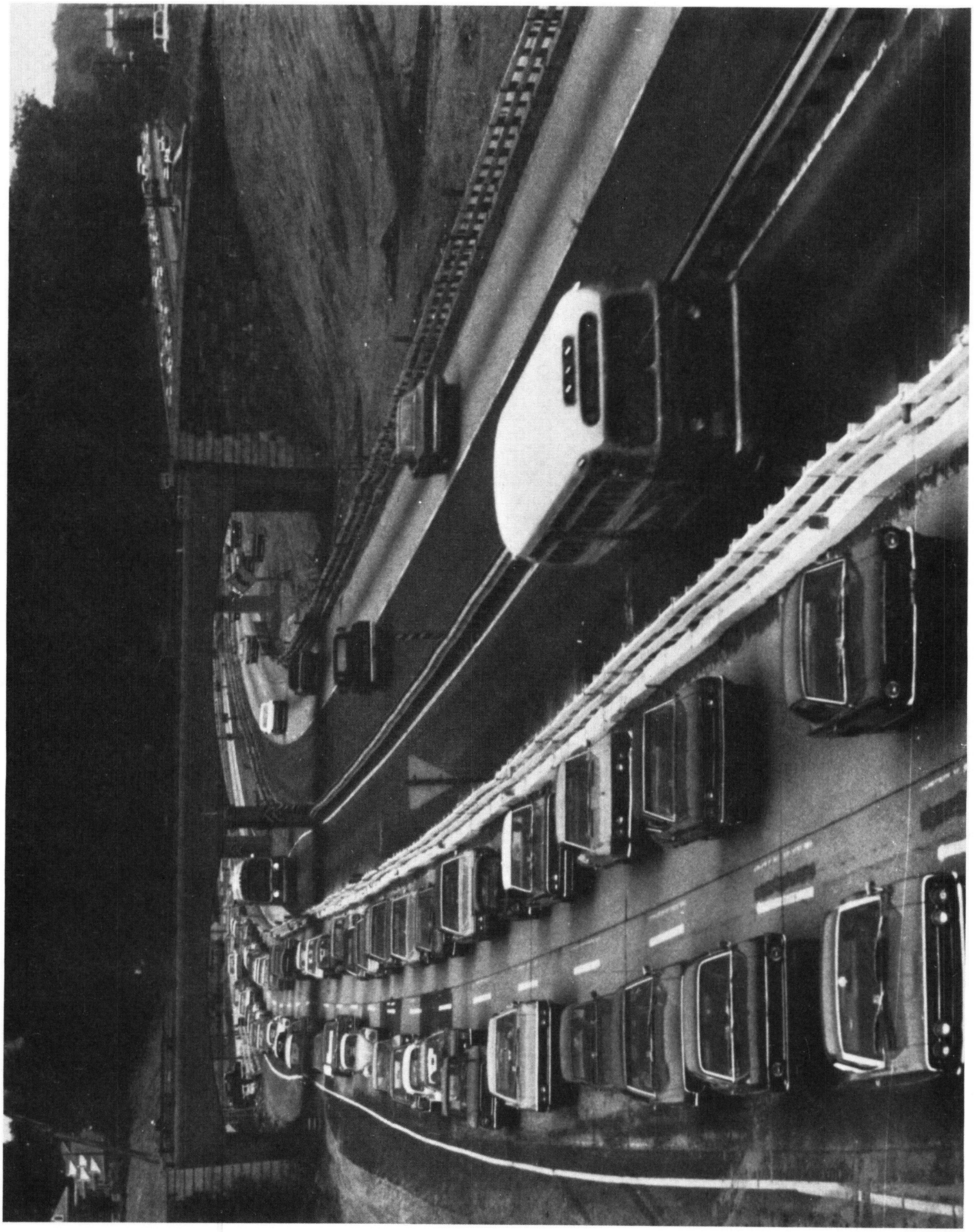


Figure B-62. Temporary bus lane, Shirley Highway, Virginia.

between the bus system and their own automobile (59 percent of Shirley users as compared to 44 percent of other bus riders in area)

2 Out of every four new Shirley express bus riders, approximately one automobile is diverted from the roads (23 percent formerly drove alone).

3 The principal reasons for using the bus, as stated by the present bus users, are to avoid driving under congested conditions and the inconvenience and high costs of parking

4 More than one-half of the car drivers park free. Parking costs for those that pay average $1.15 per day.

5 Of the Shirley bus riders, 17 percent diverted from another bus line.

Trends

The growth in transit ridership south of Shirlington is shown in Figure B-65 Ridership has climbed steadily since 1969, reflecting extensions of the busway and availability of equipment The response of ridership to the increase in peak-period capacity illustrates the fact that higher bus capacity (and consequently shorter waiting time intervals) is as important as higher running speeds in achieving potential demands for public transport service.

Table B-63 indicates how ridership south of Shirlington has grown. Ridership on this portion of the system is mainly from route 18 (West Springfield-Springfield), route 17 (Kings Park), route 4 (Annandale), and route 7 (Lincolnia, Southern Towers).

The number of bus passengers increased from less than 2,000 in 1969 to more than 6,200 in 1972, a growth of 225 percent. The high occupancy factors (up to 54 6 passengers per 55-seat bus) confirm that the capacity of the service is being fully utilized and suggest that providing additional bus capacity would further increase peak-hour riding on these services.

Costs and Revenues

Financial information on the portion of the Shirley Highway Express Bus Project related to the Transit Service Agreement between Northern Virginia Transportation Commission (NVTC) and the AB&W Transit Company, were set forth for the period from April 22, 1971, the date the agreement was executed, through September 30, 1971.

Operating Costs

The Transit Service Agreement provides for AB&W to operate and maintain all NVTC buses used in the Shirley Highway service. Thirty-four buses fall into this category, and 30 additional buses were placed in operation by June 1972. AB&W is reimbursed for all costs incurred in operating these buses. Some of these costs, such as the operators' wages and benefits, repairs to the buses, and fuel, are charged directly to the project. Other costs are incurred on an indirect basis and are based on the percentage that NVTC buses bear to the total of NVTC and AB&W buses Indirect costs include general and administrative office expenses, servicing of buses, and operating rent of the 4-mile-long facility. Such percentages can be expected to change

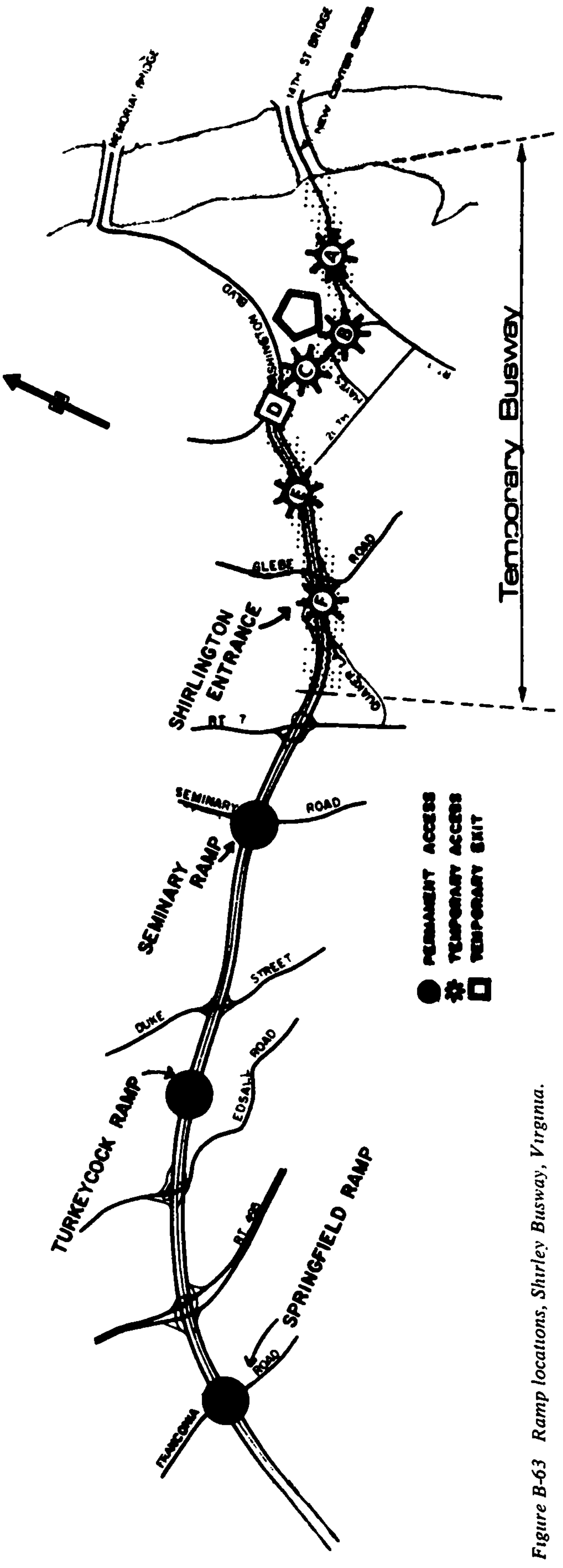


Figure B-63 Ramp locations, Shirley Busway, Virginia.

Figure B-64. Bus access to temporary bus lane (looking north from Shirlington Circle), Shirley Highway, Virginia.

periodically to reflect actual buses and operating miles and changes in these relationships.

Monthly and daily operating and maintenance costs, fixed fee, and diversion payments from the start of NVTC's transit service on June 14, 1971, through September 1971, are given in Table B-64. The fixed fee reflects an average for all days, including Saturdays and Sundays.

1. Operating Cost Details.—Operating costs decreased by $125 per day between June and August, even though five additional daily peak-period trips were added. (The August 1971 figure is more representative of normal costs, because in June and July there were several unusually large expense items associated with the start-up of service with 30 new buses. Four additional peak-period trips were added on September 27, 1971, which caused the daily operating costs to rise slightly in September.) Operating costs are further detailed in Table B-65. Transportation expense (primarily wages of bus operators) accounted for one-half of all operating expenses. Sixty-nine percent of the $220,195 total operating costs from June 14 through September 30, 1971, was for labor (bus operators and executive, supervisory, maintenance, and administrative personnel).

2. Nonrecurring Initial Expenses.—The large initial expense in June for traffic, solicitation, and advertising reflects the costs of (1) printing new schedules and tickets, and (2) additional advertising of the new service. In August, there was a large one-time expense item for an insurance premium that is not included in the other months.

Start-up costs for the first 30 NVTC Shirley Highway buses are summarized in Table B-66. Each time additional buses were put in service at one time, start-up costs were incurred similar to those experienced with the first increment of buses. Estimates of these costs were made for the next 20 buses, which were placed into service in February

TABLE B-57

AUTO AND BUS TRAVEL TIMES, SHIRLEY HIGHWAY, VIRGINIA[a]

BUSWAY ENTRANCE	AUTO (REGULAR LANES) (MIN)	BUS (BUSWAY) (MIN)	TIME SAVINGS BY BUS (MIN)
AM peak (inbound)·			
Turkeycock	37	14	23
Seminary Road	30	9	21
Shirlington Circle	16	6	10
PM peak (outbound)			
Shirlington Circle	26	7	19
Seminary Road	29	10	19
Turkeycock	34	15	19

Source Ref (*B-33*)

[a] Based on auto speed and delay studies conducted in March-April 1971, and scheduled bus running times as of June 1971 Data represent typical times between busway entrances and south end of 14th Street Bridge

TABLE B-59

BUS AND AUTO COMMUTER PROFILE, SHIRLEY BUSWAY, VIRGINIA[a]

ITEM	BUS	AUTO
Percent male	49	73
Average age	37	40
Percent married	68	83
Median household income	$15,500	$19,500
Attitude score[b]	1 9	2 7
Cars per household	1.1	1 7
Cars per licensed driver	0.6	0 9
Captive, no auto	33%	—
Choice, auto available	52%	—
Auto avail., but hardship	14%	—

Source Ref (*B-35*)

[a] Data collected April 1971

[b] 1 0 = very positive, 4 0 = very negative

1972; major anticipated costs were $25,000 for training of new drivers, $4,000 for preparation of new routes and schedules, $5,900 for preparation of the buses for service, and $7,000 for miscellaneous direct charges.

3. *Fixed Fee.*—In addition to reimbursement of operating costs incurred by AB&W in operation of NVTC buses, NVTC also pays AB&W a fixed fee of $1,041 per week. This fee is about 7 percent of estimated project costs and can be adjusted with the addition or deletion of NVTC buses, to insure that the carrier will receive a fee commensurate with all costs incurred by it.

4 *Diversion from Existing Lines.*—The agreement also requires that AB&W be reimbursed for the daily diversion of revenue from its existing scheduled lines because of the project. Diversion is computed each month by taking the difference between the total weekday revenue on all AB&W scheduled lines for that month and the revenue that would result from multiplying the average AB&W weekday revenue during the base period of March 5 through April 4, 1971, as adjusted for the current month, by the number of normal weekdays in the month.

Diversion payments decreased sharply from August to September 1971; in September, diversion was about $500 per day less than in June. The high diversion in August was attributed to the vacation period, which affected overall transit ridership. The diversion is expected to reduce

TABLE B-58

PEAK-PERIOD PASSENGERS AND BUS TRIPS, SHIRLEY HIGHWAY, VIRGINIA

	WEEK OF COUNT					
ITEM	APR. 17	APR 28	MAY 10	MAY 17	JUNE 1	JUNE 22
Passengers·						
AB & W buses, AM peak period[a]	9,352	9,320	9,737	9,706	9,666	10,304
Other buses[b]	—	—	—	1,027	1,027	1,027
AB & W buses, PM peak period[c]	10,193	9,467	9,792	9,639	9,554	11,323
Other buses[b]	—	—	—	745	745	745
All buses, both peak periods	19,545	18,787	19,529	21,117	20,992	22,934
Bus trips						
AB & W buses, AM peak period[a]	202	200	208	216	211	252
Other buses[b]	—	—	—	35	35	35
AB & W buses, PM peak period[c]	217	214	220	226	216	276
Other buses[b]	—	—	—	34	34	34
All buses, both peak periods	419	414	428	511	496	597

Source Ref (*B-33*)

[a] 6 30-9 00 AM [b] W V & M Transit Company, Trailways, Greyhound, charter, and military buses These buses were only counted once, in May, June totals assume the same count [c] 4 00-6 30 PM

TABLE B-60

BUS COMMUTER PROFILE, SHIRLEY BUSWAY, VIRGINIA [a]

ITEM	%
Work trip	92
Access mode	
Walk	83
Driven	8
Drive/Park	8
Bus	1
Egress mode	
Walk	87
Transfer	12
Taxi, other	1
Five days per week	88
Date began busing	
After 1/1/71	18
After 5/1/70	45
After 5/1/69	65
Seat availability	
Always	55
Usually	34
Seldom	9
Never	3

Source Ref (*B-35*)

[a] Data collected April 1971

TABLE B-61

AUTO COMMUTER PROFILE, SHIRLEY BUSWAY, VIRGINIA [a]

ITEM	%
Submode	
Drive alone	50
Alternate driver	14
Paying passenger	13
Nonpaying passenger	23
Carpool access mode	
Picked up at home	35
Drive own car	30
Other (e g , walk)	36
Egress mode	
Walk	49
Park in/by building	43
Carpool cost paying passengers pay $0.68 per day	
Could use bus	
Yes	17
Don't know	11
Parking cost	
Drivers paying zero	55
Drivers paying $1 15 per day	45
Have made trip by bus	19
Began auto trip	
Within 4 months	8
Within 1 year	30
Within 2 years	50
Flexibility requirements	22
Report time varies	2
Use car during day	19
Work location varies	1

Source Ref (*B-35*)

[a] Data collected April 1971

because of the over-all growth in patronage on Shirley Highway, as reflected in passenger counts taken during October.

Revenues

Revenues to support the project came from two sources· (1) fare box revenue, deposited in an NVTC account and used to pay operating expenses, and (2) funds from the U.S. Department of Transportation in the form of a demonstration grant, a portion of which is used to cover those costs that exceed the fare box revenue.

TABLE B-62

BUS USER CHARACTERISTICS, SHIRLEY HIGHWAY VS NON-SHIRLEY HIGHWAY PASSENGERS, VIRGINIA [a]

PASSENGER CHARACTERISTICS	SHIRLEY	NON-SHIRLEY
More often male	57%	45%
More often married	71%	61%
Richer	$16,500	$14,500
More favorable to bus	1 74	1 90
More cars/household	1 21	1 10
More choice (auto available)	59%	44%
Less captive (no auto)	24%	37%
Previous mode		
Did not make trip	48%	60%
Drove alone	23%	16%
Used another bus	17%	13%
Carpooled	12%	11%
Better access (walk)	87%	81%
Better egress (walk)	91%	84%

Source Ref (*B-35*)

[a] Data collected April 1971

Monthly and daily revenues since the start of the project are given in Table B-67. Daily revenues increased steadily from June through September 1971. October 1971 showed a continuing increase, with a daily average of $3,090 (almost triple the revenues on the first day of service). Five months after inception, revenues were at a point where the existing scheduled bus trips were carrying capacity loads in peak periods and were not able to accommodate additional passengers.

Cost-Revenue Comparisons

Costs and revenues are summarized in Table B-68 for the four-month period June 14 to September 30, 1971 Total costs exceeded fare box revenues by almost $160,000 in this period $250,000 of demonstration grant funds were expended by September 30, 1971, including start-up costs.

Project revenues have progressively developed to the point where they equal operating costs These comparisons are shown in Figure B-66 for June through September

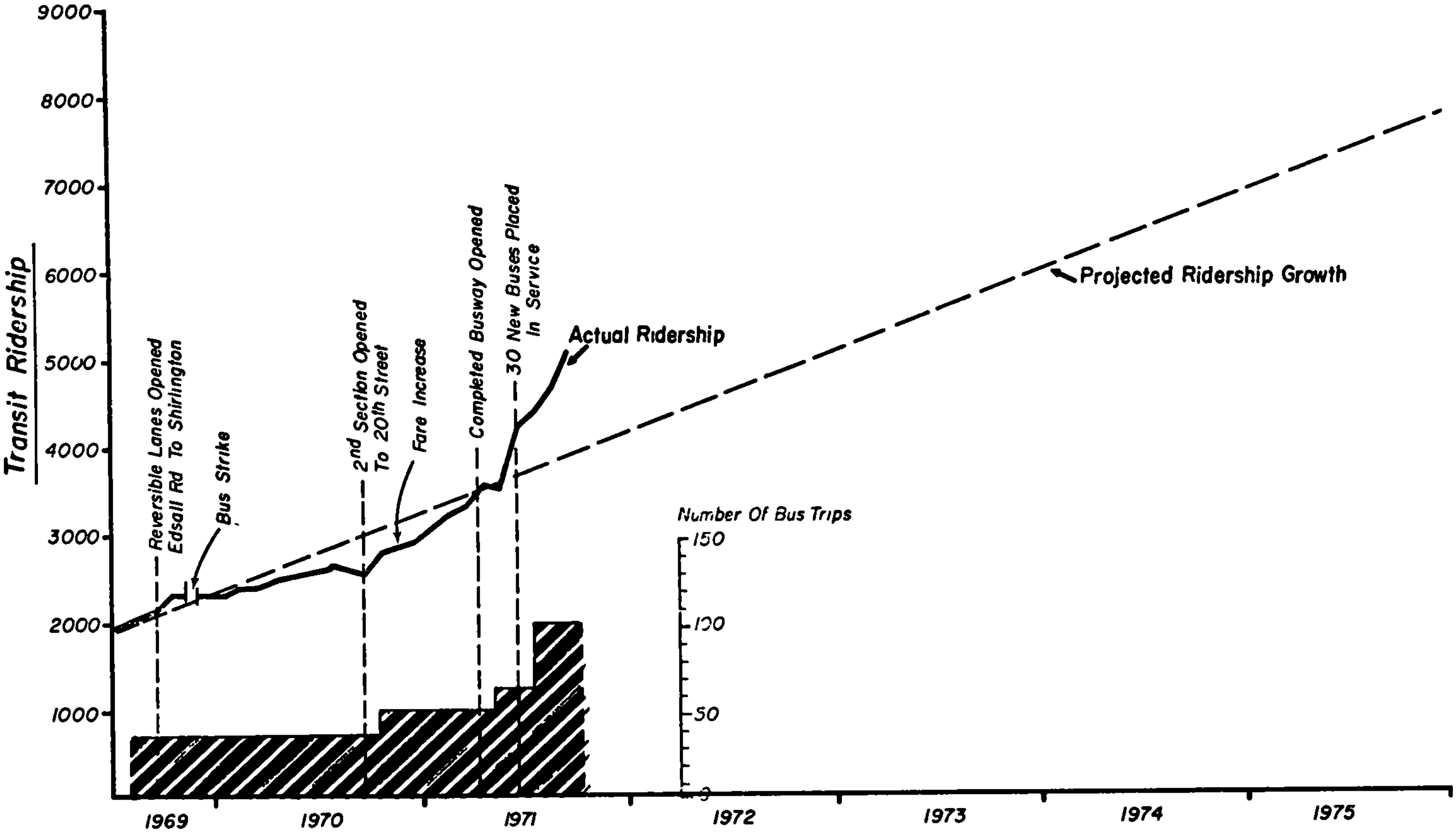


Figure B-65 Peak-period (AM) *transit ridership growth south of Shirlington, Shirley Busway, Virginia*

1971, with projections through January 1972. The cost-revenue picture was further influenced in February 1972, when 20 additional NVTC buses were placed in service Start-up costs for these buses were estimated at about $47,000, buses are 102 in wide, and provide V-8 engines and improved interior lighting.

Analyses were made on each NVTC bus route using a "five-factor cost formula " Because revenues were not separated by route, estimates were derived from passenger counts taken on each route at the fare zone boundaries. The results of the analyses for August 1971 are given in Table B-69.

Even though operating costs for August exceeded revenues by more than $5,000, four peak-period routes reported substantial profits, and revenues from the entire peak-period service exceeded costs by about $1,675. The analyses indicated that even though the cost per mile for operating midday service was less than one-half of the peak-period costs it still produced a large deficit

Benefits

Substantial time savings accrue to bus riders each day As shown by Table B-70, busway riders save up to 26 min over previous routings. These time savings, when related to daily peak-period users, total $3,400,000 annually (15 to 20 min time savings per user, $3.00 per hour, and 22,000 daily riders).

Some 5,000 to 6,000 peak-hour bus riders, if traveling by automobile, would require about three additional highway lanes At an assumed cost of $2 million per lane-mile, the bus operation would obviate approximately $54 million in "equivalent freeway construction " (This cost would offset the over-all costs of the two-lane busway construction.)

Significance

The Shirley Busway has evolved into the first successful bus rapid transit operation in the U.S Patronage has grown subject to the availability of buses. Bus use is reinforced by extreme traffic congestion on the gateways to downtown Washington and by high parking charges in the downtown area. Some of the gains in peak-period use may reflect rerouting of buses from the Memorial Bridge to the 14th Street Bridge.

Service efficiency is seriously hampered by slow, congested on-street operations in downtown Washington These low speeds limit peak-hour driver productivity. Although the service is reported to be breaking even financially, more information is needed as to its economic impact on parallel bus routes.

Better use of the 9th-11th Street Expressway spurs, creation of contra-flow bus lanes or all-bus streets, and possibly short sections of below-grade busways, could substantially reduce travel times. Ultimately rail rapid transit service will intercept buses in Virginia, thereby alleviating operating problems in downtown Washington

TABLE B-63

COMPARISON OF PASSENGERS USING EXCLUSIVE BUS LANES, SHIRLEY BUSWAY, VIRGINIA [a]

DATE	NUMBER OF		AVERAGE PASSENGERS PER TRIP	INCREASE [b] FROM SEPT 1969 (%)
	PASSENGERS	BUS TRIPS		
Sept 1969	1,914	38	50 4	—
Oct. 1970	2,622	53	49 5	37
Mar 1971	3,313	62	53 5	73
June 1971	3,641	68	53 5	90
Aug. 1971	4,697	107	43 9	145
Sept 1971	5,107	108	47 3	167
Oct 1971	5,551	109	51 0	190
Nov 1971	5,967	112	53.2	211
Jan 1972	6,223	114	54 6	225

Source Ref *(B-36)*

[a] Data for buses entering south of Shirlington Circle in the morning rush hour (6 30-9 30 AM)

[b] In passengers

TABLE B-64

OPERATING, FIXED FEE, AND DIVERSION COSTS, SHIRLEY BUSWAY SERVICE, VIRGINIA

ITEM	JUNE 1971	JULY 1971	AUG 1971	SEPT 1971
Operating cost ($)	38,139 63	61,002.45	61,788 77	59,264 59
Fixed fee ($)	2,528 15	4,610 14	4,610 14	4,536 85
Diversion ($)	19,449 96	30,443 05	38,001 20	20,769.30
Total costs ($)	60,117 74	96,055 64	104,400.11	84,570 74
Operating days	13	21	22	21
Operating cost/ day	2,933 82	2,904 88	2,808 58	2,822.12
Fixed fee/day	148 71	148.71	148 71	151 23
Diversion cost/ day	1,496 15	1,449 64	1,727 33	990 99

Source Ref *(B-37)*

PROPOSED GEORGETOWN BUSWAY

The possible conversion of the Georgetown Branch railroad right-of-way into a busway was one of the bus service recommendations given consideration by the Metropolitan Washington (D.C.) Council of Governments *(B-38, B-39)*. Studies focused on service and feasibility factors and did not develop patronage forecasts.

Corridor Description

The Georgetown Branch of the Baltimore and Ohio (B&O) Railroad is a lightly used single-track freight line forming an arc between Silver Spring and the Potomac River near the Maryland-District of Columbia line, and then following the Potomac to the 30th Street freight terminal in Georgetown (Fig B-67) This terminal is about 1.5 miles west of Farragut Square, a major employment center in the expanding CBD.

The B&O Railroad reportedly had no plans for major service changes on the Georgetown Branch, and abandonment of the line was unlikely. Under these conditions, any transit service in the corridor would have to share the same right-of-way with the freight service. However, the industries along K Street, currently served by the railroad, would be forced to relocate, probably out of the area, if the Three Sisters Bridge is built and if the Georgetown waterfront is

TABLE B-65

OPERATING COSTS, SHIRLEY BUSWAY, VIRGINIA

EXPENSE ITEM	JUNE 1971	JULY 1971	AUGUST 1971	SEPTEMBER 1971
Equipment maintenance and garage	$ 6,613 48	$10,729 58	$ 9,000 89	$ 9,039 23
Transportation	19,028.23	33,156 57	32,286 16	33,385.81
Station	281 20	494 90	480 27	496.49
Traffic, solicitation, and advertising	3,789 80	1,226 14	1,449 44	2,206.72
Insurance and safety	846 21	1,617.88	5,799 64	1,963 56
Administrative and general	3,296 24	6,966 02	6,340 84	5,868 39
Depreciation	147 77	234.66	237 39	262.52
Operating taxes and licenses	2,629 20	4,275 52	4,153 97	3,844 97
Operating rents	1,507 50	2,301 18	2,040.17	2,196 90
Total	$38,139.63	$61,002 45	$61,788 77	$59,264.59

Source Ref *(B-37)*

TABLE B-66

INITIATION COSTS FOR FIRST 30 BUSES, SHIRLEY HIGHWAY, VIRGINIA

CATEGORY	COST ($)
Legal services	8,766 36
Accountant services	4,875 00
Executive department	5,046 42
Operation and scheduling dept	11,997 68
Accounting and general office	1,539 78
Maintenance department	8,862 43
Miscellaneous direct charges	8,716 13
Training of drivers and supplies	40,330 96
Total	90,134 76

Source Ref (*B-37*)

redeveloped This would leave the B&O without customers south of MacArthur Boulevard, making a portion of the right-of-way available for other uses, including transit.

Inspection of the existing railroad track revealed that it was in fair-to-poor condition, with loose spikes, deteriorated ties, eroded ballast, and poorly aligned and butted joints at various locations. Although that track would not be suitable for passenger service, it was adequate for the nature and frequency of the present freight service over the Georgetown Branch.

Between Silver Spring and River Road (Westwood), the rail right-of-way crosses at least four streets at grade, including Jones Bridge Road, which is severely congested in the morning and evening peak periods. Highway access to the railroad tracks varies from good to poor, restricting potential feeder bus access to any improved facility. Combined with the speed restrictions imposed by the grade crossings, the access constraints serve to make this position of the Georgetown Branch unsuitable for transit operations, especially rail.

From River Road to Georgetown, the right-of-way is entirely grade separated. The alignment is conducive to high bus speeds with an improved surface or trackage. The route is also scenic, as it passes through wooded areas and a river-oriented park.

Comparison of Technologies

Comparative analyses were made of rail-bus and a busway for service potentials and economic feasibility in the corridor between River Road and Georgetown. The investigations analyzed capital costs, operational procedures and problems, and the possible regulatory and legal obstacles facing an interstate operation.

Total costs of a busway over the existing railroad tracks were estimated at $1,010,000, as compared with $1,075,000 for a rail-bus operation and $1,700,000 for a wholly new busway (Table B-71). The legal and regulatory obstacles associated with rail-bus operations were found to be severe; legal considerations could possibly preclude an interstate rail-bus operation unless special legislation is obtained or, at the minimum, a favorable ruling is obtained from the Interstate Commerce Commission (*B-39*).

TABLE B-67

FARE BOX REVENUES, SHIRLEY HIGHWAY BUS SERVICE, VIRGINIA

ITEM	JUNE, 1971	JULY, 1971	AUGUST, 1971	SEPTEMBER, 1971
Total revenue	$22,272 37	$47,429 80	$56,684 33	$58,957.88
Operating days	13	21	22	21
Revenue per day	$ 1,713 26	$ 2,259 04	$ 2,576 56	$ 2,807 52

Source Ref (*B-37*)

TABLE B-68

COST AND REVENUE SUMMARY, SHIRLEY HIGHWAY BUS SERVICE, VIRGINIA [a]

ITEM	AMOUNT ($)
Operating cost, fixed fee, and diversion	345,144 23
Less farebox revenue	—185,354 38
Operating deficit	159,789.85
Start up costs (prior to June 14, 1971)	90,134 76
Total paid from demonstration grant	249,924.61

Source Ref (*B-37*)
[a] Data for June 14 through September 30, 1971

TABLE B-69

COSTS AND REVENUES BY BUS ROUTE, SHIRLEY HIGHWAY, VIRGINIA [a]

ROUTE	DESCRIPTION	OPERATING COST ($)	REVENUE ($)	NET REVENUE ($) (LOSS)
	(*a*) Peak-Period Service			
2G	Hayfield Farms	7,009	4,822	(2,187)
4G	Heritage Mall	5,715	6,903	1,188
6G	Parkfairfax	4,552	4,486	(66)
7G	Lincolnia	8,274	10,474	2,200
8G	Shirley Duke	5,445	4,356	(1,089)
17G	Kings Park	6,628	7,121	493
18G	Springfield	8,411	10,471	2,060
19G	Huntington	4,309	3,384	(925)
Peak-period total		50,343	52,071	1,674
	(*b*) Midday Service			
1A	Clockwise loop	2,297	584	(1,713)
1B	Counterclockwise loop	2,324	631	(1,693)
17G	Kings Park	3,362	1,239	(2,123)
18G	Springfield	3,452	2,025	(1,427)
Midday total		11,435	4,479	(6,956)
Totals		61,778	56,496	(5,282)

Source Ref (*B-37*)
[a] Data collected during August 1971

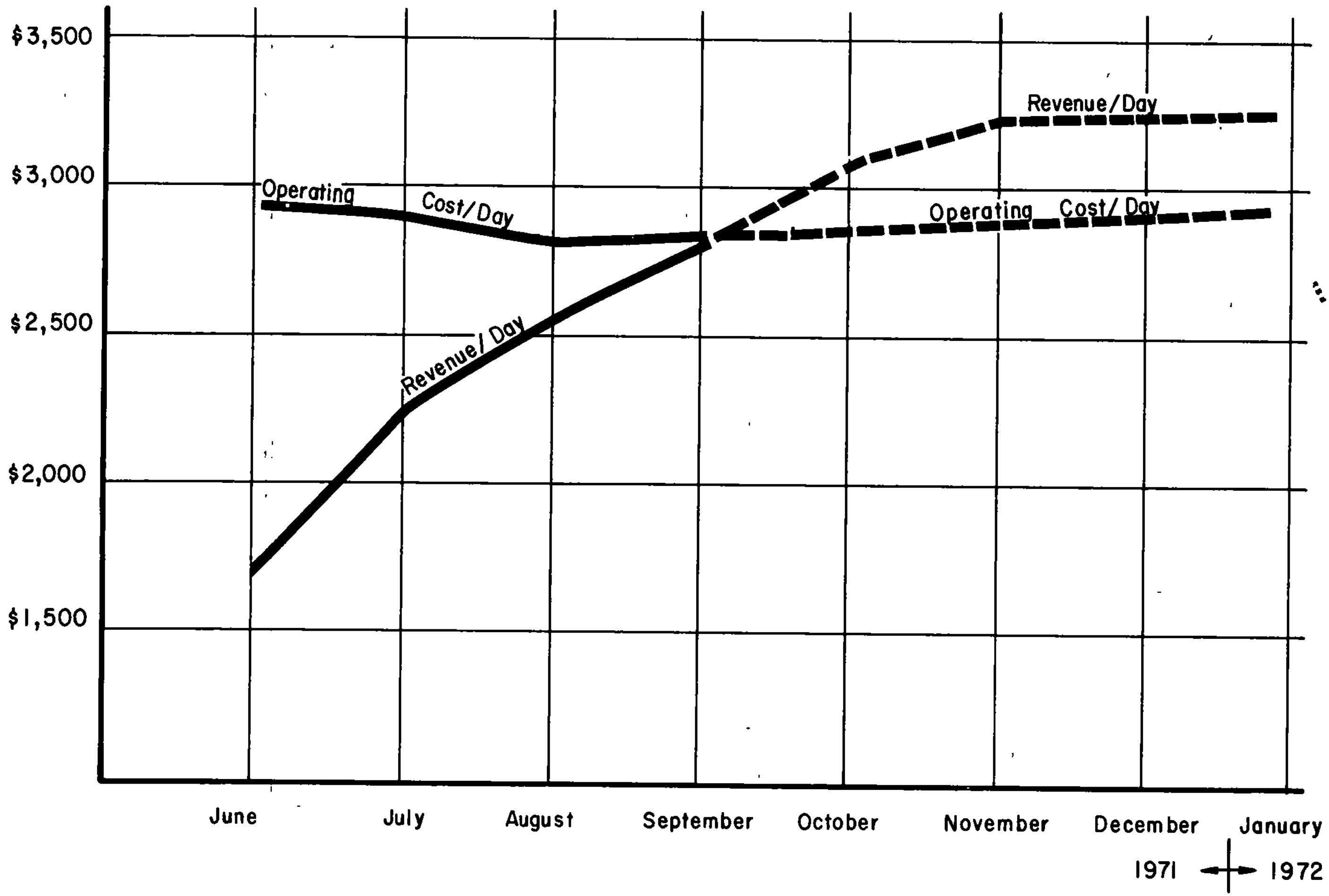


Figure B-66 Daily revenues and operating costs, NVTC Shirley Busway service, Virginia

Accordingly, it was concluded that a paved busway was more suitable than rail-bus in this corridor for four principal reasons:

1. The speed, comfort, safety, and capacity of the busway would be superior to those of rail-bus.

2 Busway operations would permit limited two-way operation by providing easily constructed "pull-outs" along the route, whereas the railbus would require the laying of new tracks and switches. (The physical characteristics of the route make the cost of widening for conventional two-way operations prohibitive, especially when relatively uncongested surface streets are available for operation in the reverse direction from normal commuter traffic.)

3. The capital costs for a paved busway were estimated to be slightly lower than those of the track improvements necessary for a rail-bus operation.

4 The operational, institutional, and legal problems related to a busway would be much less complex than those associated with a rail-bus service.

TABLE B-70

CHANGE IN BUS TRAVEL TIMES, SHIRLEY HIGHWAY, VIRGINIA

			PEAK-PERIOD RUNNING TIME TO FARRAGUT SQUARE (MIN.)		
NEW ROUTE	EXISTING ROUTE	FROM	NEW ROUTE [a]	EXISTING ROUTE [b]	TIME SAVING
2G	11	Rose Hill	42	68	26
4G	16	Annandale	35	53	18
6G	6	Brad Lee	32	42	10
7G	7	Beauregard	37	56	19
8G	8	Shirley Duke	38	46	8
17G	17	King's Park	47	71	24
18G	18	West Springfield	55	76	21
19G	11	Huntington	46	56	10

Source Ref (*B-33*)

[a] Based on June 1971 scheduled times

[b] Based on January 1971 scheduled times

Design Alternatives

Two alternative designs of the potential busway were identified. one with rail service retained, and one assuming abandonment of rail service (Fig B-68). Each assumed a basic 12-ft traffic lane with 3-ft paved shoulders on each side, making a paved surface 18 ft in width. The presence

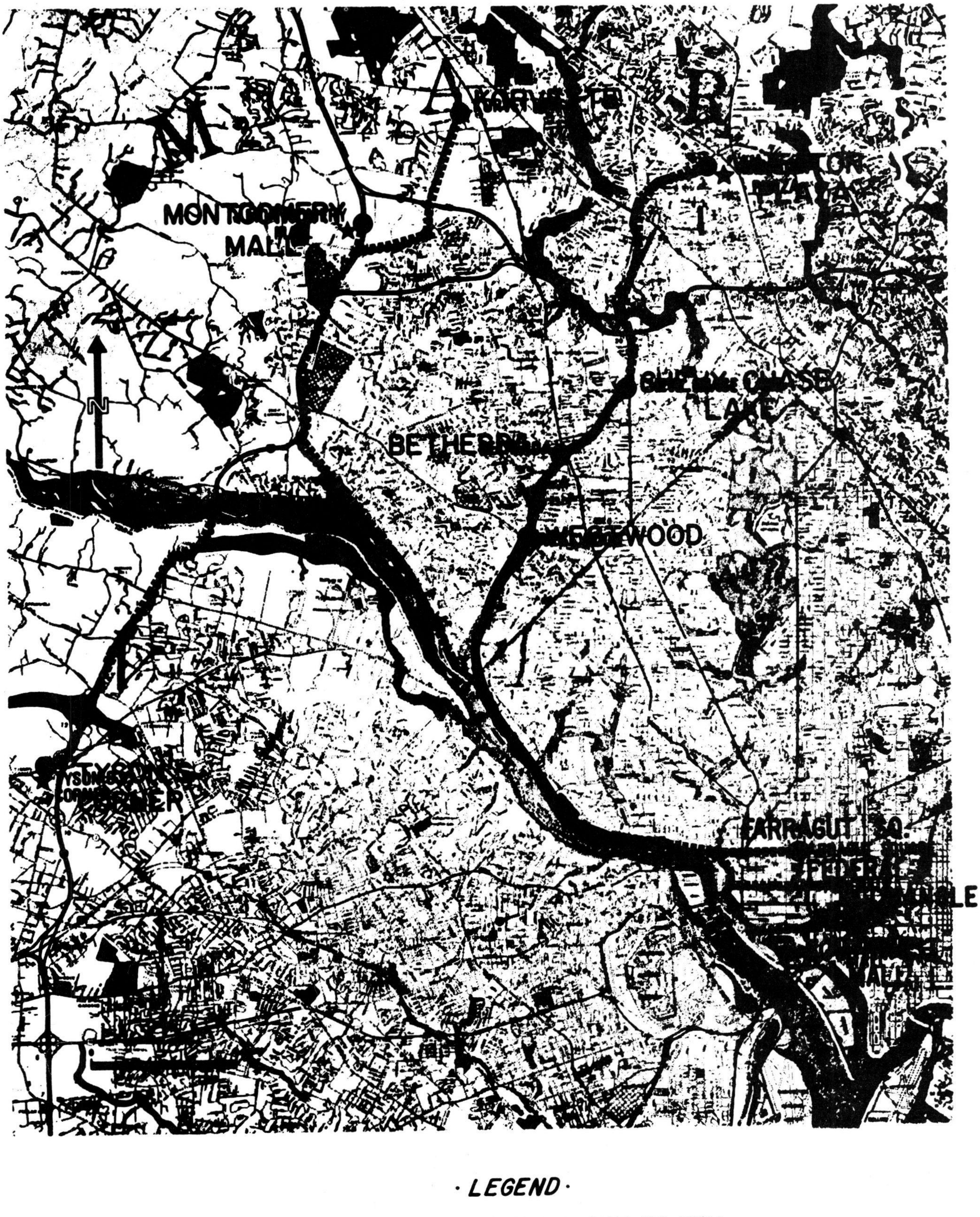


Figure B-67. Proposed Georgetown Branch Busway, Washington, D.C.

TABLE B-71

CAPITAL COSTS FOR ALTERNATIVE TRANSIT ALIGNMENTS, GEORGETOWN BRANCH BUSWAY, WASHINGTON, D.C [a]

	AREA		
OPTION	GEORGETOWN TO WESTWOOD	WESTWOOD TO CHEVY CHASE LAKE	TOTAL, GEORGETOWN TO CHEVY CHASE LAKE
Improved rail for rail-bus operations, 20-year life	$ 720,000[b]	$355,000[b]	$1,075,000[b]
Busway over existing railroad, 10- to 15-year life	$ 660,000	$350,000	$1,010,000
Busway in place of railroad, 20-year life	$1,135,000	$565,000	$1,700,000

Source Ref (*B-38*)

[a] Exclusive of right-of-way costs

[b] Exclusive of cost of vehicle conversion for rail use ($15,000 per unit)

of the rail tracks has no significant design influence except to reduce the roadway crown.

Operational and Control Considerations

If the railroad were replaced by a busway, the bus operations could be scheduled throughout the day as warranted by demand. It is likely that emergency vehicles (police, fire, and ambulances) would also be permitted to use the busway, as proposed in other cities. Potential use by fire engines, however, could impose some design constraints, particularly as regards curve radii on access ramps.

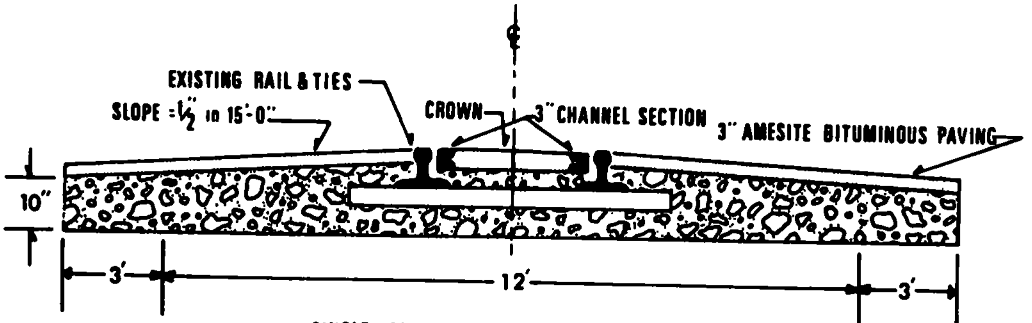
If the railroad tracks were retained, the bus and freight-train schedules would have to be closely coordinated to assure the safety of the transit operations. The present railroad operation is counter to normal peak-hour commuter travel, making this scheduling especially critical. The following time allocations were suggested:

7:00 to 9.00 AM—Commuter buses inbound
9.00 AM to 4:30 PM—Railroad operations
4:30 to 6·30 PM—Commuter buses outbound
6 30 PM to 7.00 AM—Railroad operations

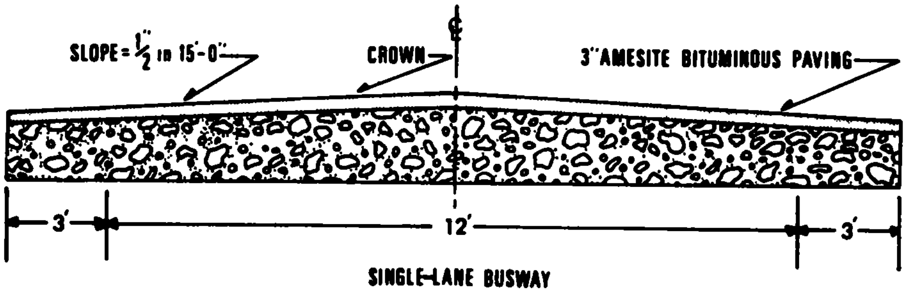
This schedule would create no apparent undue hardships for the railroad, but it would require that railroad crews not be delayed in returning to Georgetown in the afternoon. Rail siding activities (loading and unloading) would probably have to be more carefully scheduled than at present.

Radio-operated access barrier gates would be required at each end of the busway and at intermediate access points. Authorized vehicles could be equipped with limited-range transmitters to actuate the gates. Control units would be required on the gates to prevent bus access while a train was in the busway section, or conversely. This type of safeguard would not require any special technological development.

Special controls (e g , barrier gates) would be required wherever a grade crossing existed along the busway. Crossing protection signals could be coordinated with gate operations to help assure the safety of transit patrons as well as motorists on the street.



SINGLE-LANE BUSWAY ON SINGLE-TRACK RAILROAD



SINGLE-LANE BUSWAY

Figure B-68 Alternative cross-section designs, Georgetown Busway, Washington, D C

Proposed Concept: Costs and Benefits

The 9-mile busway would be implemented in three phases. The first phase, involving a temporary bus roadway, bus-actuated barrier gate, and traffic control signal, would cost about $40,000. Phase 2 would involve construction of a busway on slightly more than 3 miles of railroad trackage (retaining the rails) at a cost of approximately $500,000 The phase 3 extension to River Road (Westwood) would cost approximately $325,000, and a continuation to Connecticut Avenue would add about $425,000. Thus, the total cost would approximate $1,290,000.

Anticipated time savings are summarized in Table B-72 The first phase would produce time savings from 5 to 11 min The subsequent phases would save up to 14 min

Significance

Although it is technically feasible, this project must be evaluated in the context of other rapid transit proposals in the Washington area. However, the concept is innovative (like the New Haven Canal Line proposal) and may have application in other areas.

TABLE B-72

BUS TRAVEL TIME COMPARISONS, GEORGETOWN BRANCH BUSWAY, WASHINGTON, D.C.[a]

LOCATION	ARTERIAL STREETS (SEPT. 1968) (MIN)	PHASE 1 GEORGE WASHINGTON PARKWAY (MIN)	PHASE 2 GEORGE WASHINGTON PARKWAY AND B&O RR (MIN)	PHASE 3 B&O RR (MIN)
Tyson's Corner	37·00	32·00	29:00	—
Montgomery Mall	39:00	28:00	25 00	—
Korvette's, Rockville	43 00	32.00	29.00	—
Wheaton Plaza	45.30	—	—	41·10 (34 10)[b]
Westwood (Kenwood)	26·00	—	—	17:15
Chevy Chase Lake	27:00	—	—	22·40
Kensington	41.00	—	—	36:40 (29.40)[b]

Source Ref (*B-38*)

[a] Travel time computed on the inbound morning peak-hour run to Farragut Square

[b] With Jones Bridge Road bypass

SOUTH CAPITOL STREET CORRIDOR IMPROVEMENTS

The South Capitol Street Corridor, serving the western part of the Anacostia area in the District of Columbia and southwestern Prince Georges County, Md, was one of the study areas selected under the U.S. Department of Transportation's Urban Corridor Demonstration Program. The over-all goal was the improvement of peak-period travel conditions in the corridor by increasing bus use, improving existing vehicular flow, and encouraging car-pooling. The primary focus was to reduce congestion by improving the quality of transit service Traffic operations and control changes were recommended to help upgrade the quality of bus service in the corridor.

Corridor Characteristics

The study corridor extends from the CBD in Washington southerly to encompass the portion of Prince Georges County beyond the Capitol Beltway (I-495). The major streets and highways in the corridor include the following·

- South Capitol Street (known as Indian Head Highway, or Route 210, in Maryland).
- Southwest Freeway (I-695).
- Anacostia Freeway (I-295).
- Suitland Parkway.
- Capitol Beltway (I-495).
- South Capitol Street Bridge (also known as the Frederick Douglass Bridge).
- 11th Street Bridge (also known as the Anacostia Bridge), actually two four-lane bridges, each one-way.
- M Street, S.W.
- Martin Luther King, Jr, Avenue, Southern Avenue, and Livingston Road.

North of the Anacostia River, the South Capitol Street Bridge is served directly by I-95 and by M Street indirectly via Eleventh Street South Capitol Street and I-295 are roughly parallel north of the bridge. Suitland Parkway merges with South Capitol Street and I-295 just south of the South Capitol Street Bridge. Suitland Parkway is the main feeder to the bridge from a major employment center east of the study area that contains such government installations as the U.S. Bureau of the Census, the Federal Records Center, the Navy Oceanographic Office, and Andrews Air Force Base The parkway bypasses the Eleventh Street Bridge and has no direct connection with it. In effect, the parkway intercepts a large volume of traffic whose origin or destination might relate more directly to the Eleventh Street Bridge, and feeds this traffic to the South Capitol Street Bridge.

Only two bridges—South Capitol Street and Eleventh Street—cross the Anacostia line in the study corridor. These bridges are heavily congested during morning and evening peak periods There are no bus priority lanes on either bridge, and buses experience the same delays as other vehicles during peak periods

The major traffic problems occur on the South Capitol Street Bridge, and along South Capitol Street from Halley Place to Livingston Road. Approaches to the Eleventh Street Bridge do not carry as heavy peak-hour peak-direction volumes.

Characteristics of peak-hour dominant traffic and person flows on the two bridges are given in Tables B-73 and B-74. Although buses represent only about 1 percent of the vehicles in the morning peak hour, they carry 23 to 27 percent of the inbound passengers across the two bridges. This represents the type of operation that should be expedited, through preferential lanes and similar traffic engineering techniques, together with related physical changes.

TABLE B-73

AM TRAFFIC CHARACTERISTICS, SOUTH CAPITOL AND 11TH STREET BRIDGES, WASHINGTON, D C[a]

ITEM	S CAPITAL ST BRIDGE (NO)	S CAPITAL ST BRIDGE (%)	11TH ST BRIDGE (NO)	11TH ST BRIDGE (%)
Auto occupants	5,553	76 4	7,733	72 9
Automobiles	3,431	99 1[b]	4,121	98 7[b]
Avg occupancy	1 62	—	1 88	—
Bus occupancy	1,715	23 6	2,872	27 1
Transit buses	32	0 9[b]	54	1 3[b]
Avg occupancy	53 6	—	53 2	—
Total occupants	7,268	100 0	10,605	100 0
Total vehicles[c]	3,463		4,175	
Trucks and other buses	77		155	
Total vehicles	3,540		4,330	
ADT[d]	81,300		47,100	

Source Ref (*B-40*)
[a] Selected AM peak-hour inbound traffic collected in May 1970
[b] Percentage of auto plus transit bus only
[c] Autos and transit buses only
[d] Estimated from corridor count

TABLE B-74

PM TRAFFIC CHARACTERISTICS, SOUTH CAPITOL AND 11TH STREET BRIDGES, WASHINGTON, D C[a]

ITEM	S CAPITOL ST BRIDGE (NO)	11TH ST BRIDGE (NO)
Auto occupants	6,026	6,850
Automobiles	3,585	3,850
Average occupancy	1 68	1 79
Bus occupants[a]	N/A	N/A
Transit buses[a]	N/A	N/A
Average occupancy	N/A	N/A
Total occupants[c]	6,026	6,850
Total vehicles[c]	3,585	3,832
Trucks	112	44
Buses[d]	33	54
Total vehicles	3,730	3,930
ADT[e]	81,300	47,100

Source Ref (*B-40*)
[a] Selected PM peak-hour outbound traffic collected in May 1970
[b] Transit buses outbound not separately identified for PM peak hour
[c] Automobiles only
[d] Including transit buses
[e] Estimated from corridor counts

The 1966-1970 morning peak-period trends in passenger vehicles and passenger flow on the two bridges further indicate the importance of transit (Table B-75). Although the primary growth in passenger volumes resulted from increased auto use, it is significant that buses, although involving only 1 0 to 1 3 percent of the passenger vehicles over the 2-hr period, transported 27 to 34 percent of the peak-period passengers across the Anacostia River

The buses added to the South Capitol Street Bridge traffic between 1966 and 1970 averaged 50 passengers each, at a patronage level representative of buses in this corridor The added buses on the 11th Street Bridge averaged 33 passengers each.

TABLE B-75

SELECTED PEAK-HOUR TRENDS, ANACOSTA RIVER BRIDGES, WASHINGTON, D C.[a]

ITEM	VEHICLES 1966	VEHICLES 1970	VEHICLES INCREASE (%)	PASSENGERS 1966	PASSENGERS 1970	PASSENGERS INCREASE (%)
South Capitol St Bridge						
Auto	6,098	6,664	9 6	11,475	10,930	4 5
Bus[b]	51	66	13 0	2,696	3,445	12 8
Total	6,149	6,730	9 4	14,171	14,381	1 5
11th Street Bridge						
Auto	5,222	6,842	31 0	8,350	12,389	48 2
Bus[b]	86	91	10 6	4,526	4,689	3 2
Total	5,308	6,933	30 6	12,876	17,078	32 6

Source Refs (*B-41* and *B-40*) ,
[a] Data collected between 7 00 and 9 00 AM
[b] Transit bus only

Transit service in the corridor is provided by the D.C. Transit System (DCT), and the WMA Transit Company In general, DCT serves only passengers who board or alight in the District of Columbia, and WMA serves passengers who board or alight in Maryland. However, WMA buses are permitted to pick up in the District while inbound and discharge while outbound at the South Capitol Street fringe parking lot when DCT is not serving that facility. Because of the operating rights granted to DCT and WMA, they are not permitted to furnish regular route service (both boarding and alighting) in both the District of Columbia and the Maryland areas of this corridor, but are restricted to their own exclusive areas

Both companies operate along South Capitol Street, once in the corridor In downtown Washington, however, the companies serve the same general areas (Southwest and the Mall, Federal Triangle, and Farragut Square) but operate on different streets.

Although the two companies operate over similar routes, their service patterns vary considerably DCT buses operate principally during the morning and evening peak hours in the direction of predominant travel, whereas WMA buses operate from 6 00 AM to 9:40 PM in both directions to and from downtown. The characteristics of these services are summarized in Table B-76.

In the morning peak period, WMA serves only Maryland, boarding passengers, in the evening, Maryland, alighting only DCT's operations are restricted to D C -oriented patrons About 70 percent of the patrons are destined for the Federal Triangle area and another 22 percent for the Farragut Square area

Improvement Concept

Coordinated traffic operations, traffic control, transit, parking, and construction projects were developed to improve mobility and encourage transit use. (Those directly concerned with bus transit operations are discussed here)

The South Capitol Street Bridge and environs, a four-lane facility with sidewalks on either side, represents the major traffic bottleneck in the corridor Various operational plans were considered for obtaining maximum use of the bridge during the morning peak period, including

- Two lanes mixed traffic each way (as at present)
- Two lanes mixed, one bus in; one mixed out
- Three lanes mixed in; one out
- Three lanes mixed, one bus in, none out
- Four lanes mixed in; none out.

Another set of alternatives was developed for a five-lane bridge when it became clear that such a plan would be considered by the D.C. Department of Highways and Traffic. These treatments were predicated on (1) widening of the pavement surface by eliminating the seldom-used wide sidewalks and (2) strengthening the cantilevered portions of the walks to carry dynamic vehicle loads It was also recognized that any unbalanced lane operation must consider the ability of approach roadways to accommodate the traffic that would be delivered or received. These options were.

- Four lanes mixed in, one mixed out
- Three lanes mixed, one bus in, one mixed out.
- Three lanes mixed in; two mixed out
- Two lanes mixed, one bus in, two mixed out

Criteria

The D.C Department of Highways and Traffic established the following design standards for bridge operations·

- Maximum curb-to-curb width, 66 ft.
- Minimum lane width, 12 ft.
- Physical barrier required between opposing directions of traffic on the bridge. (This served as a major constraint in developing acceptable concepts.)
- Two barriers to be constructed for a median bus lane (a very stringent condition).
- Minimum width between barriers, 16 ft.

Recommendations

These criteria eliminated a reversible car or bus median lane as a viable design alternative Accordingly, the study recommended a permanent arrangement of three southbound and two northbound lanes on the South Capitol Street Bridge. This concept is shown in Figure B-69. Northbound traffic would use two lanes. Morning peak-period traffic would have a special phase at the South Capitol-Suitland Parkway signal to meter buses to the head of the queue The southbound direction would use three lanes on a permanent basis, with either the curb or the median lane designated as a bus priority lane during the evening peak period, depending on bus routings on the approaches to the bridge Four lanes lead away from the bridge southbound, two to Suitland Parkway and two to South Capitol Street, thus, it was considered desirable to favor southbound traffic

A *priority bus lane* was recommended for South Capitol Street, commencing approximately 2,000 ft south of the intersection with Sterling Avenue. The lane would continue to a signalized merge with the Suitland Parkway, bus-actuated signals would guarantee sufficient merge and clearance times Passenger cars headed for the fringe parking lots could share the bus lane from its beginning to Anacostia Drive This would help to simplify traffic operations and provide an incentive to bus use.

Bus priority lanes were also proposed in the eastbound curb lane on M Street from 6th Street, S W , continuing to South Capitol Street, S.W., and then in the curb lane, connecting with the curb lane of the bridge

An elaborate signing system (Fig. B-70) was identified as an integral part of the over-all plan The sign legends, placements, and sequence were developed from extensive investigations of driver behavior and response to various types of words and messages. The signs would be blanked out during off-peak periods

TABLE B-76

SELECTED PEAK-PERIOD BUS OPERATIONS, SOUTH CAPITOL STREET CORRIDOR, WASHINGTON, D C

	INBOUND, 6 30–9 00 AM		OUTBOUND, 4 00–6 30 PM	
BUS OPERATOR	TRIPS (NO)	AVG HEADWAY (MIN)	TRIPS (NO)	AVG HEADWAY (MIN)
DCT	46	3 3	41	3 7
WMA	23	6 5	18	8 3
Total	69		59	
Average		2 2		2 5

Source Ref (*B-42*)

Benefits

The potential benefits from the changed use of the bridge were based on the following assumptions.

- Bus passengers would save 2 min each, as the result of a speed increase from 8 to 15 mph in the vicinity of the bridge.
- Automobile occupants would save 1 min each, as the result of an increase in the average speed from 11 to 15 mph on the bridge.
- Nearly all seats on the buses would be occupied if the demonstration was successful, i.e , 50 riders per bus.

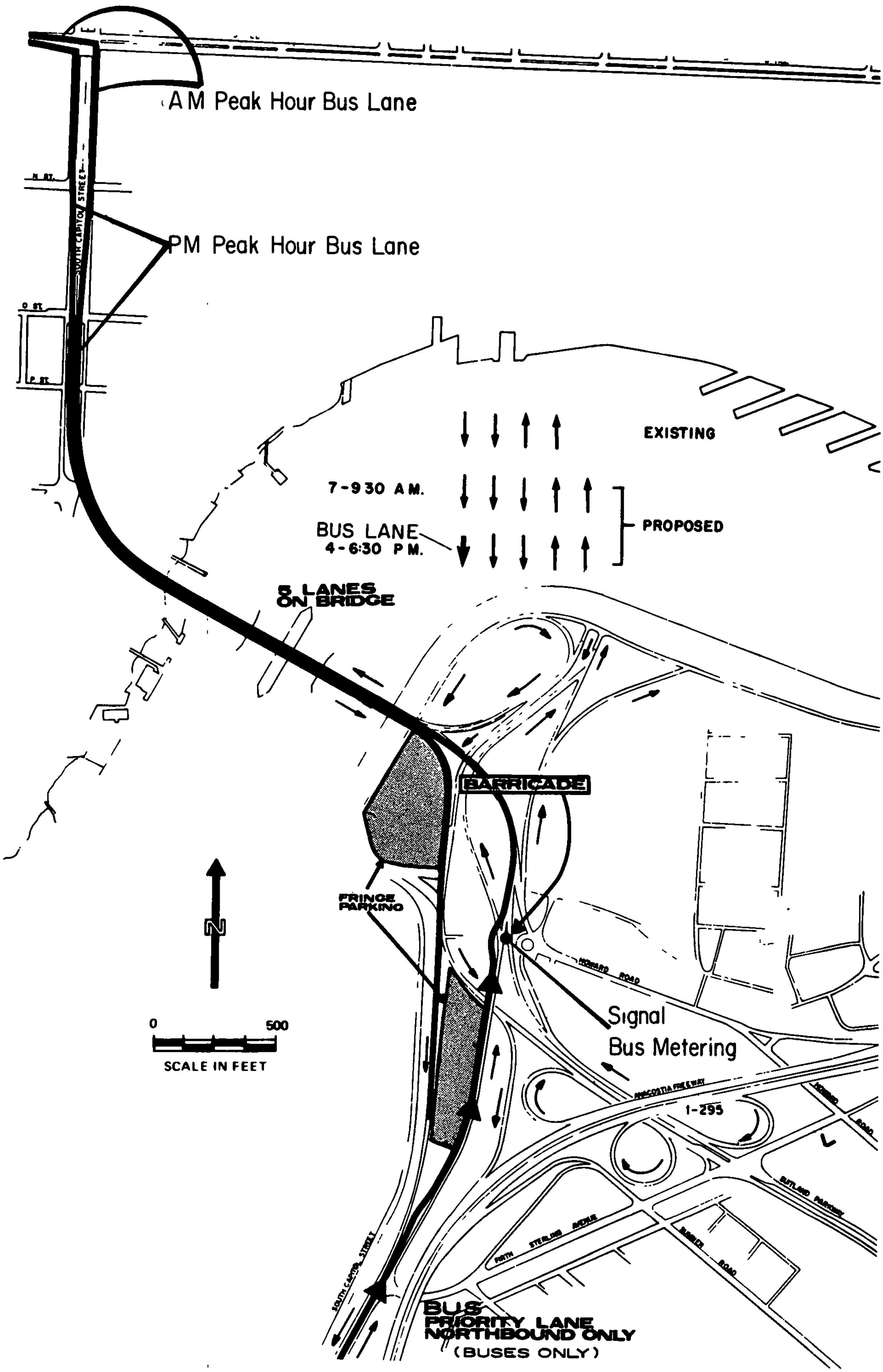
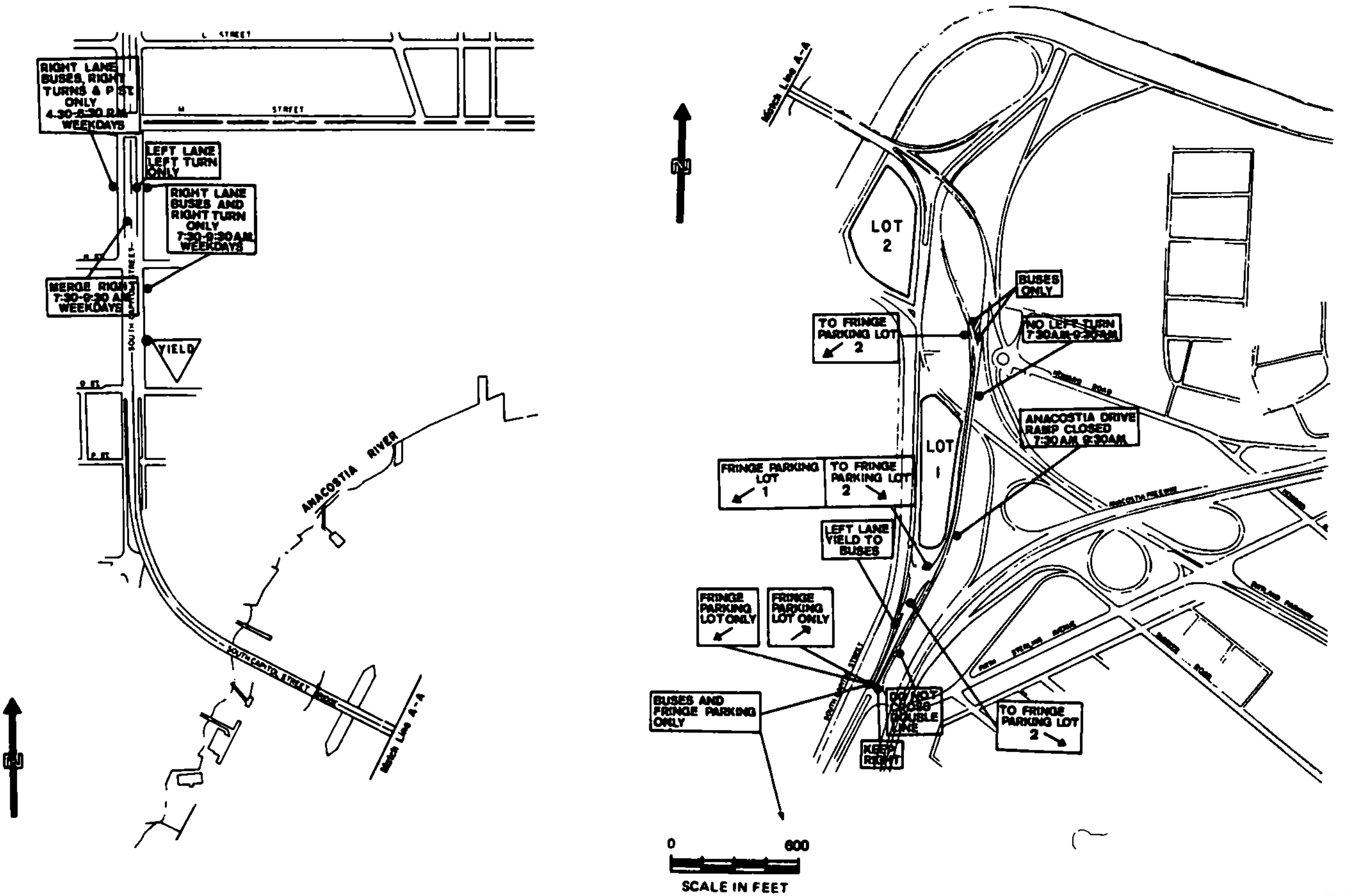


Figure B-69. Proposed bus priority treatments, South Capitol Street Bridge and approaches, Washington, D.C.



NORTH OF ANACOSTIA RIVER

SOUTH OF ANACOSTIA RIVER

Figure B-70 Peak directional signing plans, South Capitol Street Bridge and approaches, Washington, D C

This is consistent with the observed pattern over the 1966-1970 period.

Time was assumed to be worth $3.00 per hour per person, on the average. Approximately 3,000 automobiles per hour would cross the South Capitol Street Bridge, and there would be about 60 buses in the peak direction per hour, or an average of one bus a minute. Accordingly, annual time savings to bus patrons were estimated at $156,000, assuming 260 work days per year, auto riders would save an additional $117,000 yearly. The combined total of $273,000 represents a significant potential savings for peak-period travelers, primarily transit patrons.

Corollary Improvements

Fringe parking lots were proposed at two locations in the corridor. These free parking areas would be serviced by peak-period D C. Transit Company buses operating to and from downtown Washington

A *bus transfer terminal* was proposed for the intersection of South Capitol Street and Martin Luther King, Jr , Avenue, at an estimated construction cost of $713,000, excluding land It would serve as a major transfer point and as the focus for a proposed community-based jitney service for people without (or not desiring to use) other transportation.

A series of traffic engineering improvements and related changes was also proposed, including Enforcement of parking restrictions in the downtown area, especially along D Street near the Southwest Bus Terminal; increasing corner radii to 30 ft or greater for easier bus turning, installation of pedestrian barriers along all four legs of the intersection of 7th and D Streets, S.W.; peak-period signalization of the intersection of 6th and D Street, S.W., widening of other corner radii to facilitate turning and reduce or eliminate the use of two lanes for the turn maneuver; modification of lane use and/or signalization of several intersections to provide better service to peak-period bus movements, modification of lane operations along some nonsignalized sections of roadway; establishment of new peak-period parking restrictions along certain streets near the proposed bus transfer terminal, prohibition of left turns during peak periods on selected intersections; and addition of a left-turn lane for buses entering the transfer terminal

Revised transit routings for express buses in the downtown area were also suggested The changes were designed to minimize delays, maximize service rendered to patrons, and better utilize available bus priority lanes. Some of these changes will become increasingly important as the District of Columbia selectively expands its bus priority lane program.

Several new and expanded bus services in the corridor have been implemented on both WMA and D.C Transit lines Patronage reportedly has increased, even with the limited traffic engineering and other changes that have been made. This experience suggests that there is good potential for high-quality express bus service in the corridor

Significance

The South Capitol Street Urban Corridor recommendations combine several key concepts

1 The additional lane provided for buses in the flow direction by reallocating lanes is similar, in part, to the contra-flow expressway bus lanes in Boston, New York, and San Francisco

2 Bus priority through a bottleneck point by means of signalization is similar, conceptually, to the bus bypass of the San Francisco-Oakland Bay Bridge toll station, and the Blue Streak exclusive bus ramp in Seattle

There is a heavy peak-hour person-flow across the South Capitol Street Bridge inbound in the morning and outbound in the evening This person-flow could be better accommodated by a reversible lane arrangement that provides three lanes across the bridge inbound during the morning peak hours and outbound during the evening However, the design standards established for reversible-lane operations precluded such a treatment and appear out of scale for urban conditions The proposed widening of the bridge would produce a 60-ft roadway width, more than ample for reversible-lane operations in an urban area

16. PERTH, AUSTRALIA, BUSWAY

A 65-mile exclusive busway, following and replacing routes of existing suburban rail lines, was recommended in the 1971 Perth Regional Transportation Study (*B-43*) Five radial busways would be linked by an underground busway and bus station in the central area Other recommendations include expanding the bus fleet from 700 to 1,200 vehicles, and initiating an extensive minibus service in the downtown. The busways would be designed to allow for conversion to fixed guideway transit when justified by population density (Perth currently has a population of 500,000)

Costs for the proposed transportation plan would approximate $415,000,000 Of this total, busways on railway reserves would cost $15,800,000, busways on freeways, $11,200,000, passenger terminals, $7,000,000, car parks along busways, $2,000,000, and new highways, $346,000,000 Financing of transit improvements would be through four new taxes

17. REDDITCH, ENGLAND, BUSWAY

Redditch New Town is located in the West Midlands region of England about 100 miles northwest of London and about 72 miles south of Birmingham (corporate population, approximately 1,000,000) The new town is designed to accept overspill population from the West Midlands conurbation (urbanized area), as part of a continuing plan by the British Government to control the size of large urban agglomerations and to channel new development into smaller satellite communities These communities, known as "new towns," balance job opportunities and resident workers, contain a strong regional shopping center, and provide a high level of community services The planned "target" population for Redditch is 90,000, and by 1980 it is expected to have about 70,000 inhabitants.

The basic land use and transportation plan for the new town is shown in Figure B-71 The site, when fully developed, will occupy 7,200 acres, including parks, greenbelts, and extensive areas reserved for industrial development The present population of the site is about 45,000, of whom 15,000 now live in the developed area of the new town An additional 30,000 live in an existing town in the northwest section of the designated site. This area will be integrated into the new town with the minimum redevelopment necessary to provide a town center for the ultimate population and to assure satisfactory access and circulation A busway concept is a key element in minimizing the need for road space and parking area for private cars as the new town develops

Busway Concept

The new town has been planned around a $9 million, 15-mile busway system consisting of a series of bus priority roads connecting residential and industrial areas with each other and with the town's administrative and business center This busway will be completed by 1981. Nearly $7 million will be spent on construction and design for the new route The remaining cost will be used for adapting an additional 8 miles of existing roadways to busway operations.

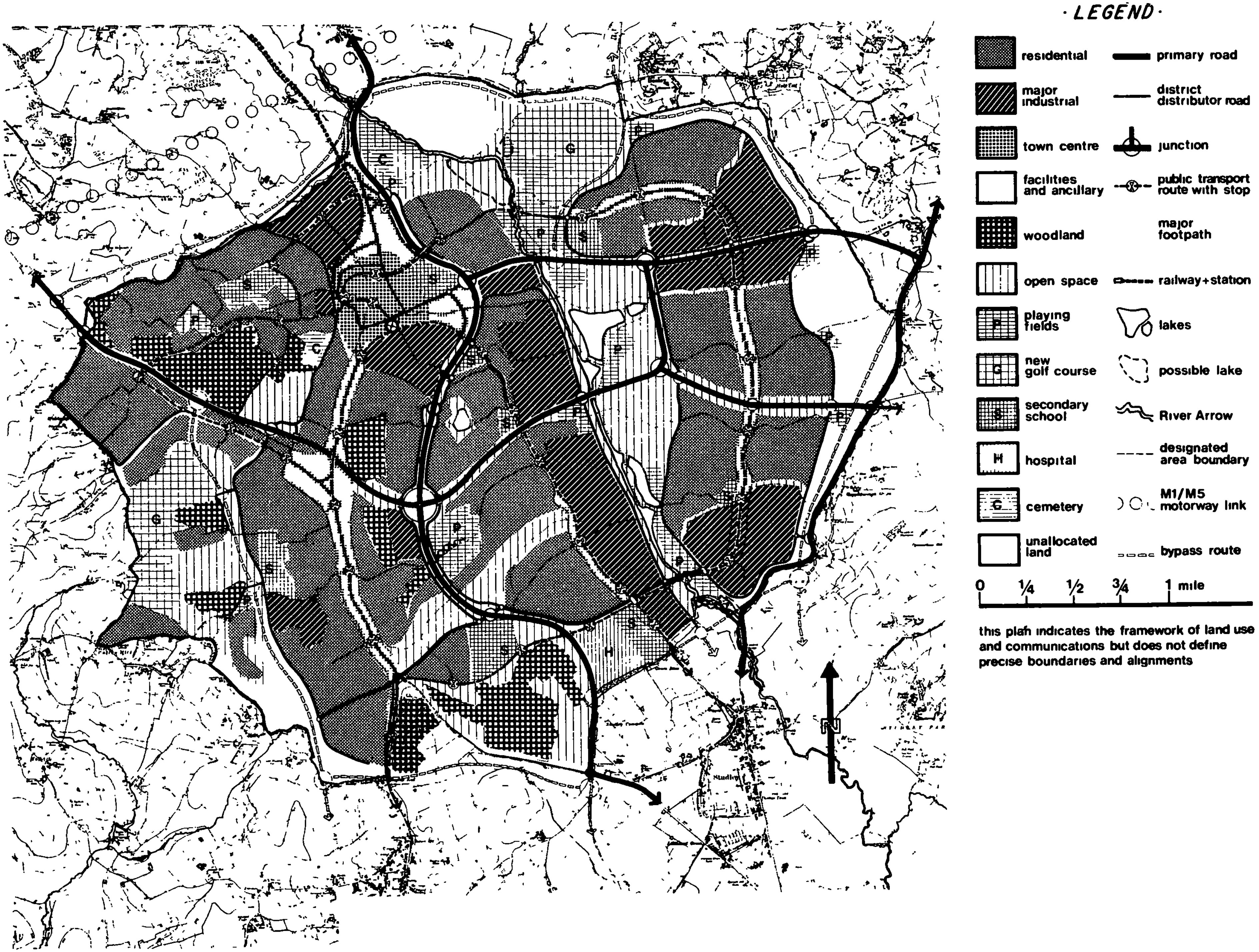
The national treasury, through the Ministry of the Environment, is paying 75 percent of the $3 million construction cost for the first 3 miles of the bus-only roadway. One mile of this initial construction was opened for bus operations in June 1972. The remaining 2 miles will be placed in service by 1974.

Design Features

Grade separations will be provided wherever the busway crosses the primary (i e , arterial or expressway) road network. Bridges over the busway will allow operation of standard British double-deck buses

The bus roadways are 24 ft (7 3 m) wide and follow the natural terrain of the area Shoulders vary in width depending on the adjacent land uses, but a minimum of 6 5 ft (2 5 m) is established Where the public transport route crosses distributor roads, land is reserved for future grade separations

In studying the busway, the Redditch Development Corporation determined that ". the public transport route should be used as an all-purpose road, particularly for traffic to the centers of environmental areas, with short sections of road between the areas reserved exclusively for public transport vehicles Roads built specifically for public transport vehicles and reserved for their use alone would thus be limited" (*B-44*) The busways, therefore, will also function as collector streets that carry local traffic to neighborhood centers, with inter-neighborhood route continuity limited to buses



this plan indicates the framework of land use and communications but does not define precise boundaries and alignments

Figure B-71. Proposed land-use and busway plan, Redditch New Town, England

The report sets forth the following operational concept for the busway: "(1) It should enable a continuous public transport route to be provided which is more direct than the equivalent all-purpose route; (2) The adjoining all-purpose roads will be cut so that private vehicles cannot use the public transport route for the longer cross-town journeys Besides allowing public transport to have the advantage of a more direct route, this will reduce the amount of vehicular traffic using the public transport route and thereby allow a reliable bus service to be operated without delays arising from congestion."

The number of buses anticipated on each link of busway in 1980 is shown in Figure B-72 These estimates are based on projected travel demands and a predetermined modal split, the number of buses required to accommodate passenger loadings is based on an occupancy of 60 persons per bus Nearly 60 buses per hour are projected for PM peak-hour travel on the northeastern approaches to the town center, with about two-thirds of them outbound from the center Other segments of the busway system would probably generate lower passenger demands.

Eventually, some 30 buses will use the full 15-mile circuit during peak hours, each carrying up to 60 passengers at an average speed of 30 mph, with stops spaced about one-third mile apart. Achieving this average speed at peak periods will require high-performance vehicles, as well as skip-stop operation. (In June 1972 buses were reported operating on a 60-min headway.)

Benefits

The Development Corporation expects several advantages from busway development. The more significant are: "(1) The provision of the reserved route, by increasing the attractiveness of public transport, could correspondingly reduce the use of private motor cars and this should lead to considerable capital savings on car parking facilities in industrial and central areas (2) The provision of a reserved public transport route would allow for unforeseen contingencies by providing a greater reserve capacity more cheaply than could be achieved with an all-purpose highway system This could allow for such unforeseen contingencies as (a) traffic forecasts which prove to err on the low side, (b) delays in constructing the highway network which might arise from financial stringency, and (c) a future population growth greater than is now envisaged."

Significance

The Redditch busway represents a variation of the treatment employed in Runcorn. As in Runcorn, the investment in a busway is being made to assure optimum public transport operations free of congestion and impediments that might occur in mixed traffic. However, general traffic will use the busway for short intra-neighborhood trips Bus priority will be implemented by providing short sections of bus-only roadways near the boundaries of neighborhood areas The discontinuity in general traffic flow will prevent the busway being used as a primary road by cars and trucks.

However, provision has been made in the basic plan for eventual development of an exclusive busway on those portions of route that initially will be open to joint use by other vehicles, in the event that such specialized treatment is needed to preserve free-flowing bus operations. By making bus service efficient, reliable, and attractive, the town's planners intend to minimize the need for land and capital investment in road and parking capacity, particularly in the highly concentrated town center.

18. RUNCORN, ENGLAND, BUSWAY

Runcorn is a planned new town approximately 12 miles southeast of Liverpool on the west coast of England and located along the Mersey River. Runcorn, like Redditch, is part of an extensive plan by the British Government to control the size of larger cities by creating smaller well-balanced communities near them. It is constructed partially on the site of a historic existing town. Although the current population is 36,000, an ultimate population of 100,000 is expected by 1990.

Busway Concept

The entire city, as indicated in the land use and transportation plan, has been planned around a $6 million, 12-mile, figure 8 busway system consisting of several loops (Fig. B-73). The new town is also served by two freeway loops, offering easy access to Liverpool and connections to Manchester and London while separating industrial from residential land uses

The busway concept is further delineated in Figure B-74 Several bus routes follow a figure 8 alignment that crosses in the town center, where nearly 600,000 sq ft of commercial space will be provided (*B-45*). The busway ties together residential areas, work places, shopping centers, and residential facilities. Industrial areas are linked to the busway chain by loops and spurs. The busway routing is direct and was estimated to save up to 50 percent in length when compared with bus routes in towns of similar population.

By the late 1970's the total length of reserved busway track will measure some 12 miles (19 km). It is likely to remain at this extent for a number of years until older residential areas become due for renewal Until that time the service will leave the private right-of-way in these areas and continue along 1.5 miles (2 4 km) of expressway and approximately 3 miles (4 8 km) of existing all-purpose roads.

Development of the busway was based on the following assumptions and policy decisions

1 There will be an ultimate working population of 44,000, of which 32,000 will need transport within Runcorn.

2 Sixteen thousand individual workers will use the bus system daily.

3. Forty buses will be required during the peak hours, 12 will be required off-peak, where they will operate at 5-min headways in most sections.

4 Automobile occupancy will be 1 5 for work trips.

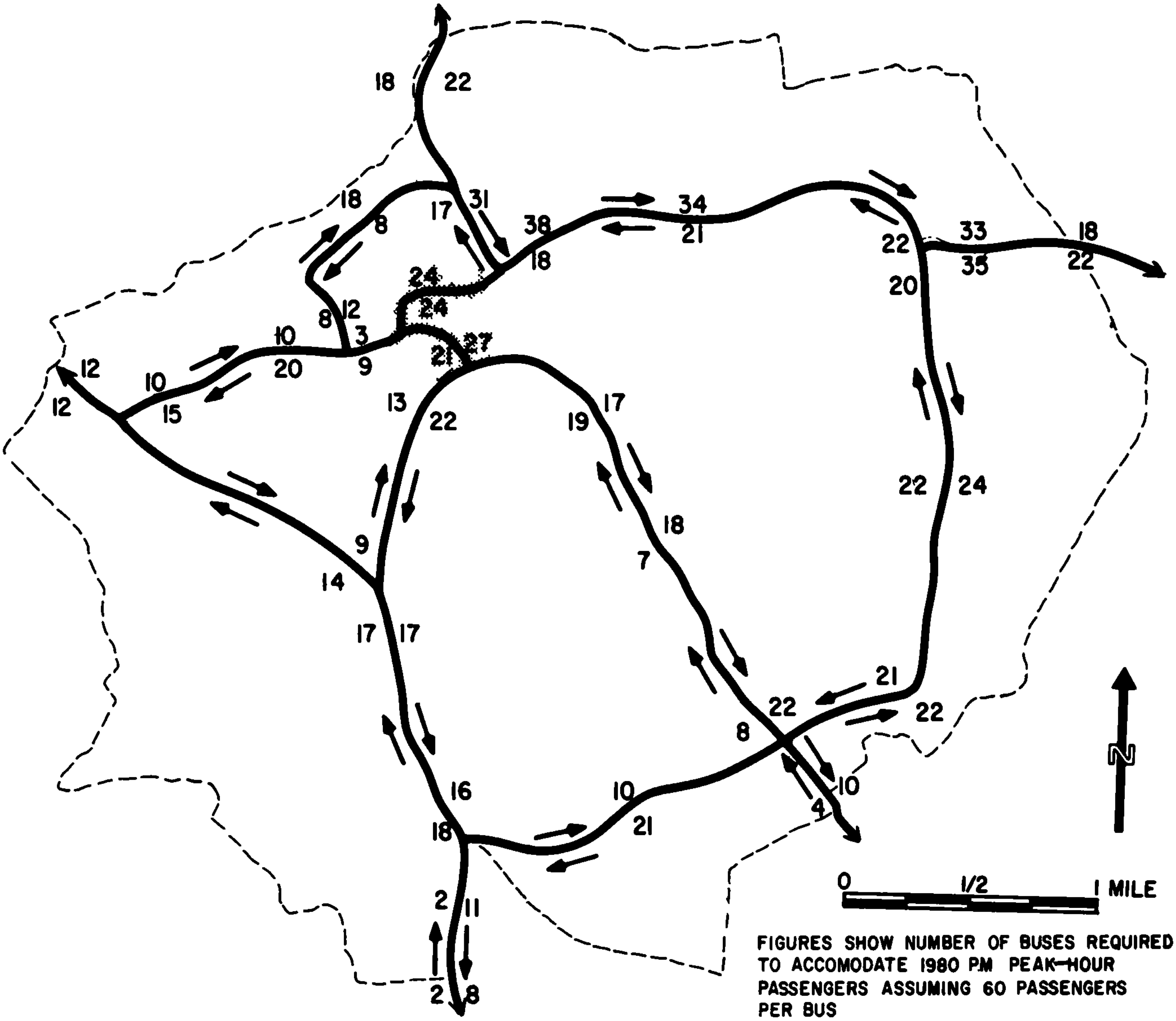


Figure B-72 Anticipated 1980 peak-hour bus volumes, Redditch, England

Design Features

The busway was designed according to standard British and American highway practice. Typical cross-sections are shown in Figure B-75.

Design Speed.—The track was designed for 40 mph (65 kph) wherever possible, although there are some locations where this standard was relaxed and a 30-mph (50-kph) design speed was adopted.

Track Width.—Apart from the town center viaducts, where the track is 20 ft (6.1 m) wide and intended for one-way operation, the basic design provides a two-way carriageway 22 ft (6.7 m) wide.

Camber and Superelevation.—The standard camber was set at 1 in 40 and the preferred maximum superelevation at 1 in 24 This may be increased to 1 in 14.5 in certain circumstances, but it will not be employed at junctions, road crossings, and stopping places

Horizontal Curves—The desirable minimum radius was set at 480 ft (146.3 m) and includes provision for spiral transition curves. Horizontal curvature may be reduced further only in special circumstances.

Gradients.—Gradients are generally not steeper than 1 in 25 (4 percent), although 1 in 16.7 (6 percent) may be used where the length of grade does not exceed 650 ft (198 m)

Lighting.—Suitable lighting is provided for passenger waiting areas at stopping places, but otherwise it is not intended to light the route. Overspill lighting from adjacent development is kept to a minimum

Pedestrian and vehicle overbridges across the track have a headroom of 12 ft (3.7 m), as compared with the national requirement of 16 ft 9 in. (5.11 m) on all-purpose

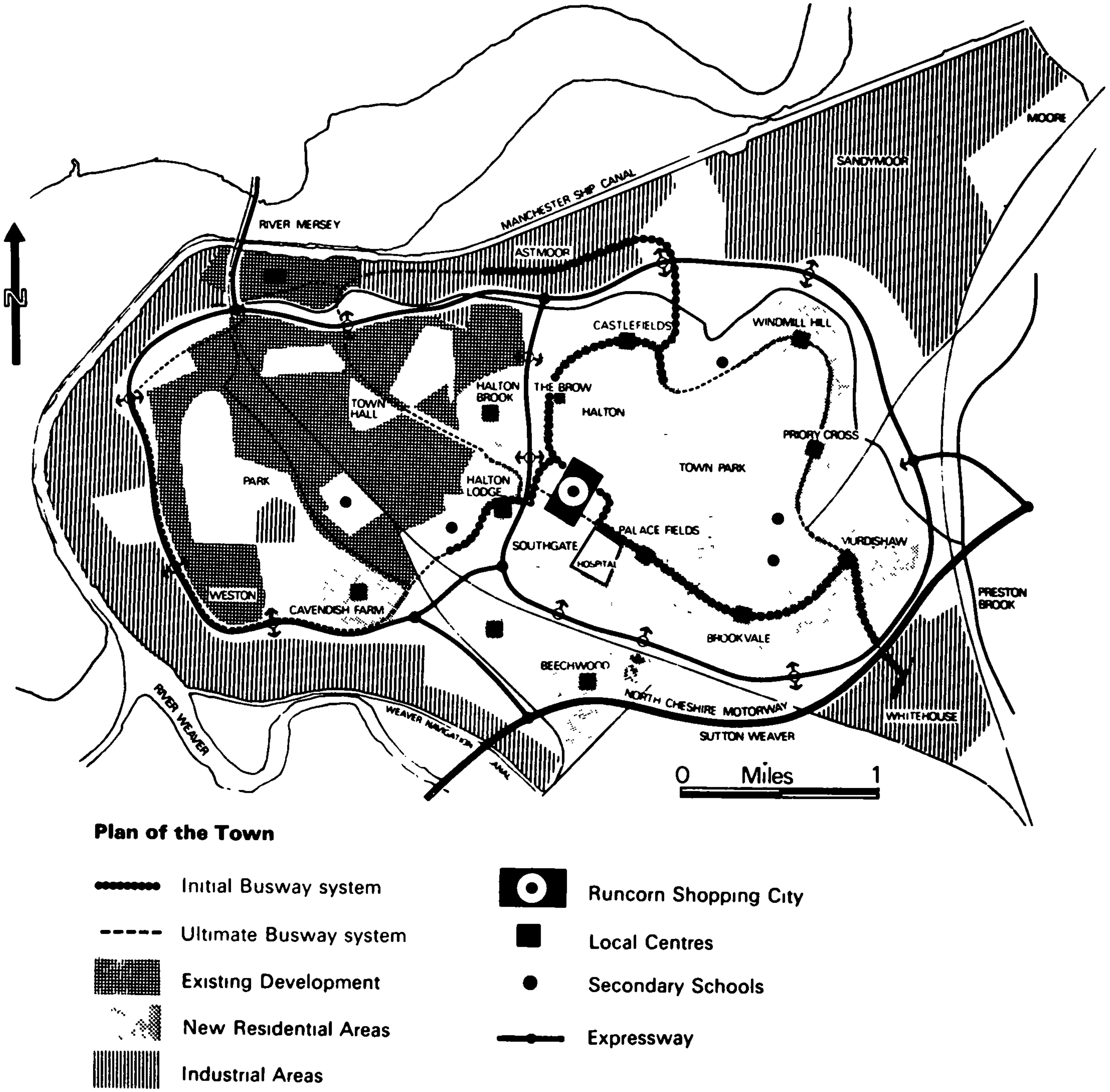


Figure B-73 Land-use and busway plan, Runcorn New Town, England

roads. This will assist in reducing structural costs and will shorten pedestrian ramps and stairs. However, it will preclude the use of double-deck buses, which predominate on British urban routes. At-grade pedestrian crossings are discouraged through fencing both the route and the central reservation at stopping places.

Where topography permits, intersections between the busway and general-purpose roads are grade separated. At other locations, bus-actuated traffic signals give priority to buses.

Buses are intended to average 21 to 22 mph (including stops) on the busway Because the busway is built to operate at grade, speeds in some sections will be lower where buses may conflict with other traffic. Speeds will also be lower where stops are frequent, such as in the town center.

Bus stops are located at approximately ¼-mile intervals. The 22-ft busway increases to 47 ft in width at most stations for an 85-ft distance to allow for acceleration, deceleration, and passing

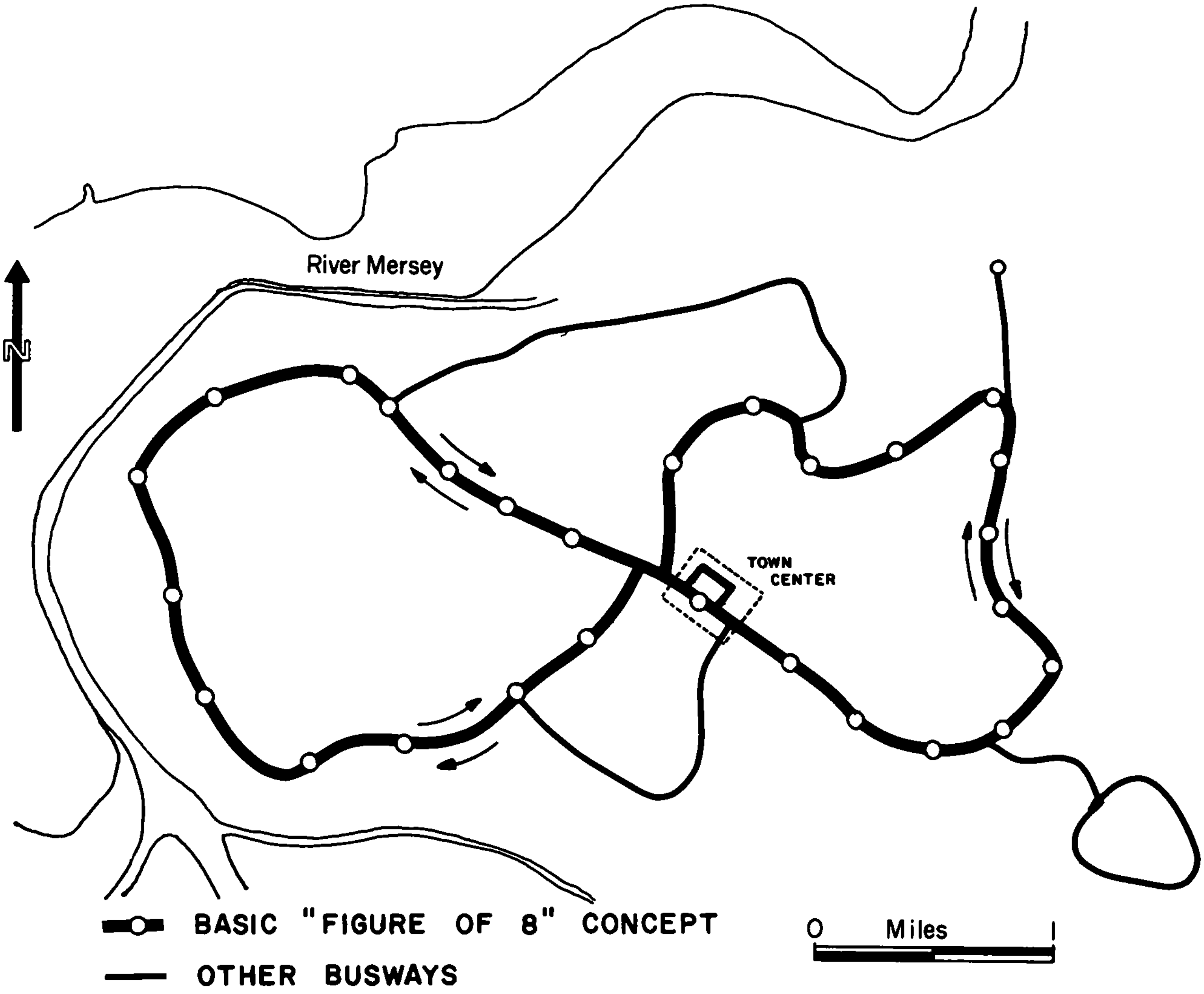


Figure B-74 "Figure-8" busway concept, Runcorn, England

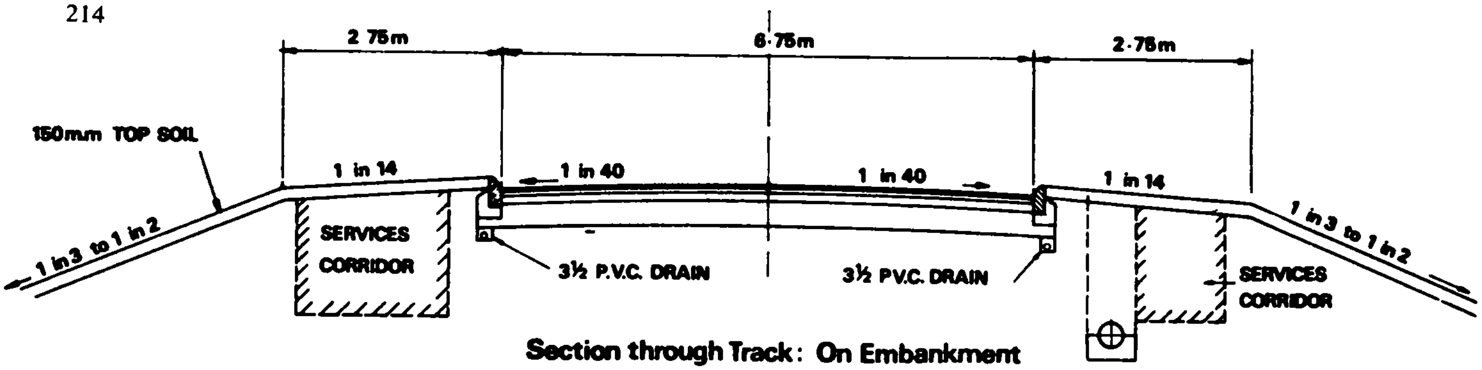
The design of residential areas recognizes that bus service must be made attractive to prospective users in terms of over-all journey times if it is to successfully compete with the private automobile Accordingly, the residential areas are designed to permit all residents to reside within a 5-min walk (500 yards; 460 m) from a busway stop. This requirement coincides with similar desirable maximum walking distances to the local shopping and community facilities. Local centers, each with a busway stop, have been planned along the route at approximately ½-mile (0 8 km) intervals to serve a series of communities, each housing a population of about 8,000. In some cases additional busway stops will be provided at positions other than local centers where the walking distance to the local center exceeds the 500-yard (460-m) limit.

Existing Operations

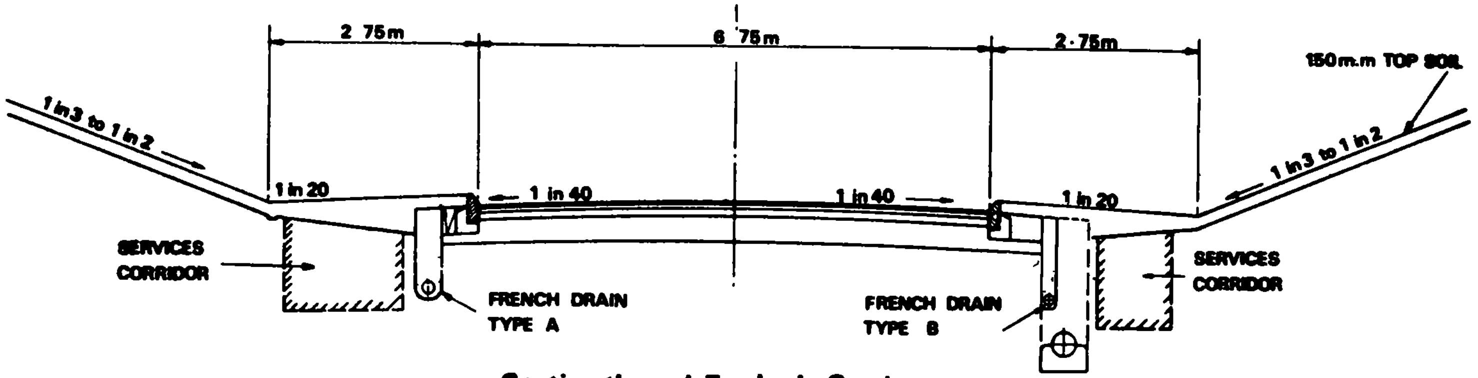
In October 1971, a 7-mile portion of the busway was opened This facility presently is served by five vehicles. Peak-service headways currently approximate 5-min (Fig B-76). Conventional single-deck buses are used, they are 36-ft-long and 8-ft-wide Sedden Pennine vehicles

Figures B-77, B-78, and B-79 are typical views of the completed busways Figure B-77 shows part of the elevated busway. In the background is a downtown bus stop with no turnout provided because of cost constraints. (Vehicles may queue behind each other at such stations) Figure B-78 shows a station on the at-grade part of the busway. Turnouts and acceleration-deceleration lanes are provided at these stations. The bus-priority traffic controls, where the busway intersects surface streets at grade, are shown in Figure B-79. The signals are bus-actuated, and turns from the street into the busway are prohibited.

During busway construction, it will be necessary for buses to use specially constructed turning circles until structures are finished The turning circles will then remain as parts of the final busway and provide necessary random turnouts



Section through Track: On Embankment



Section through Track: In Cutting

Figure B-75. Typical cross sections, "figure-8" busway, Runcorn, England.

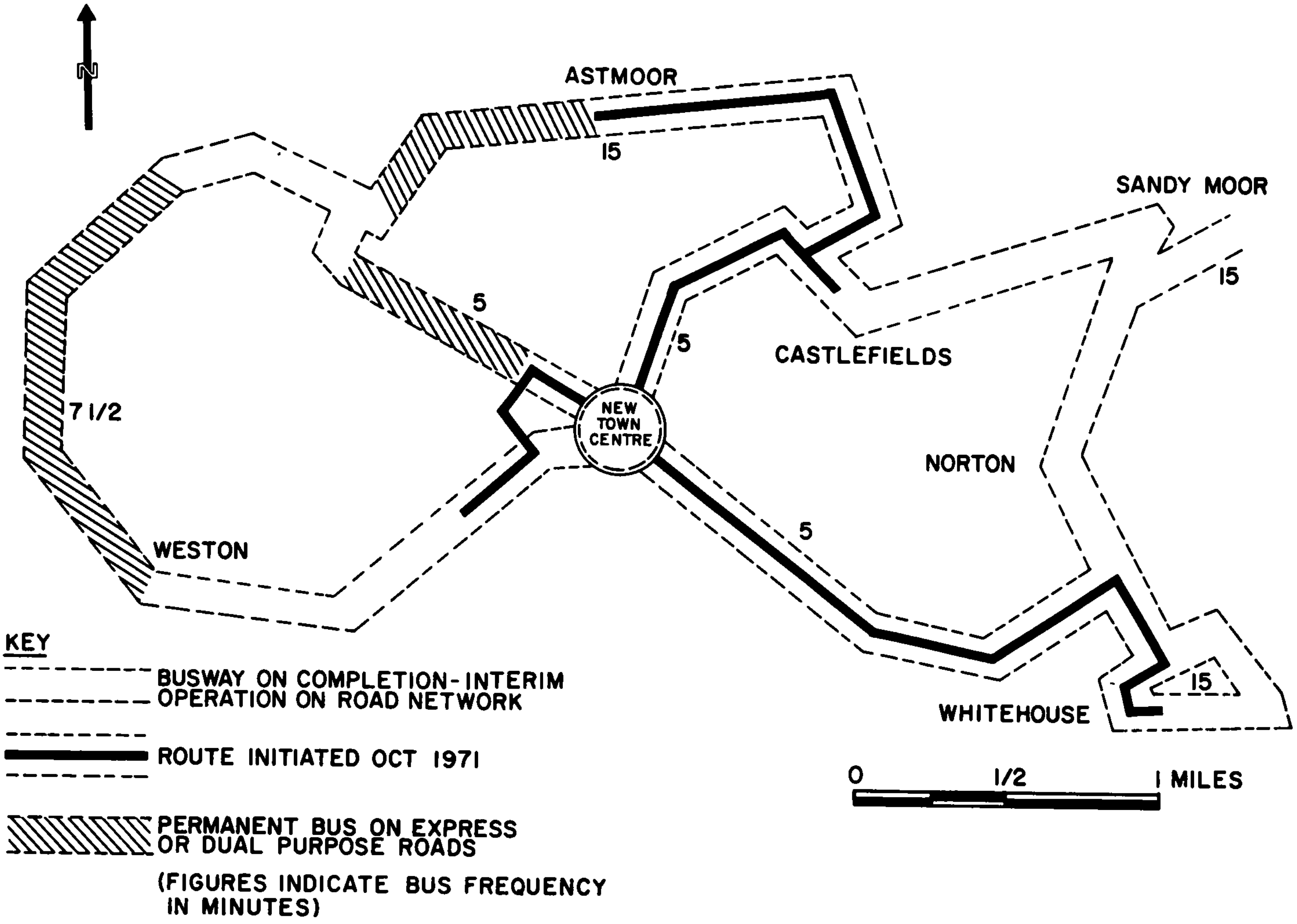


Figure B-76 Stage development, Runcorn Busway, England

Benefits

The economics of the busway at first appear questionable when viewed as an investment in addition to that required for highways and when measured by the frequency of bus service. However, as a result of the busway, Runcorn's planners anticipate that land normally dedicated to transportation will be developed for other purposes. Moreover,

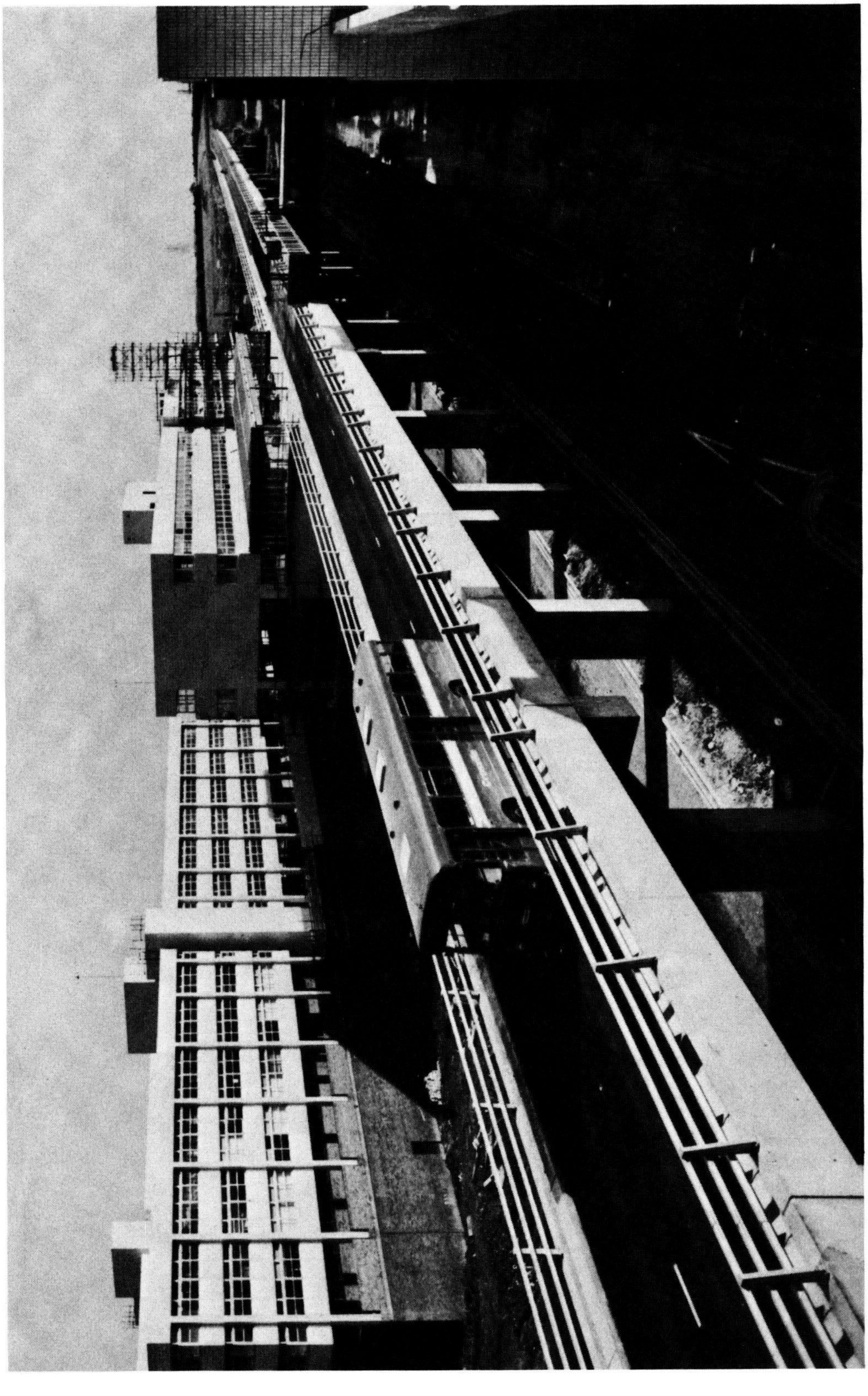


Figure B-77. Elevated busway in town center, Runcorn, England.

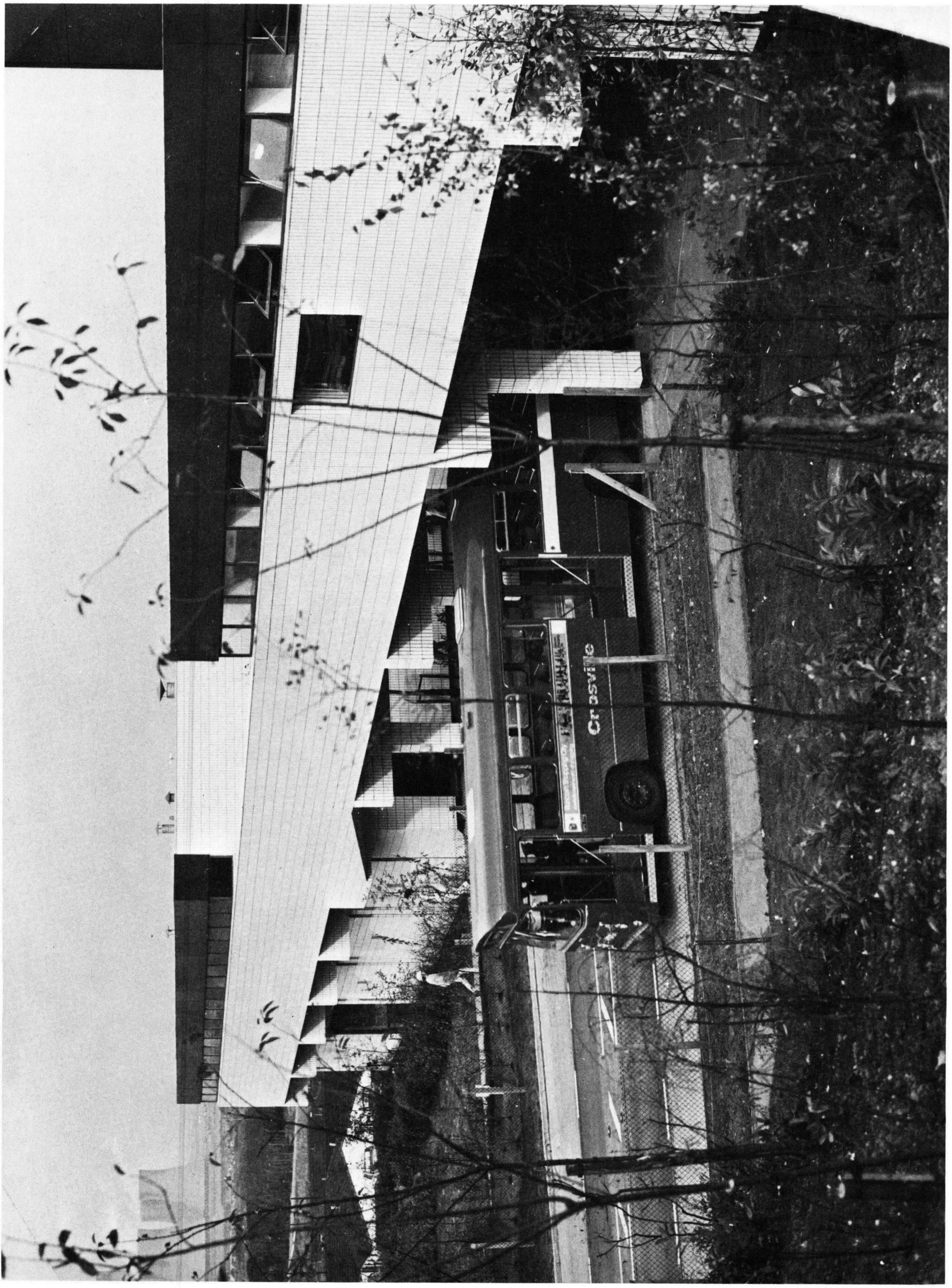


Figure B-78. Busway at station, Runcorn, England.

Figure B-79. Typical traffic controls on busway, Runcorn, England.

families living and working in Runcorn are expected to need only one car, mainly for out-of-area travel

Without the busway, planners estimated that approximately 20 acres of additional land would have to be provided in industrial areas and 60 acres in residential areas to accommodate ground-level parking. This would cause difficulties, because both the industrial areas and the residential areas are being developed at high-density levels as a result of a shortage of suitable land.

The busway also is believed to virtually eliminate the second tier from Runcorn's road hierarchy; namely, the district distributor. The environment of residential areas will benefit considerably from this measure because the busway will be narrower, shorter, quieter, and therefore less obtrusive than a district distributor

Significance

The Runcorn busway is a clear example of how public transport can be integrated with land-use planning. It adopts a "public works" rather than a "management" policy toward bus use. This is an important contrast to most bus priority proposals in the United States and Britain.

The facility is the first busway to be fully integrated into a planned central business district, allowing buses to penetrate the town center on their own right-of-way The advantages of CBD penetration may, however, be partially offset by the restrictive design of stations on the elevated section of the route.

The value of the Runcorn experiment was recognized early in 1970 when the Ministry of Transport awarded a grant of 75 percent towards the construction cost of the busway track under the 1968 Transport Act.

Whether or not the specific economics of the Runcorn experiment are sound, the basic policy-concept approach has important transferability to new town planning elsewhere, as well as the revitalization of existing urban communities. It is a clear statement of a public-transport-oriented policy.

REFERENCES

B-1 *Rapid Transit for Metro Atlanta.* Metropolitan Atlanta Rapid Transit Authority (Sept. 1971).

B-2 *Transportation Facts for the Boston Region.* Transportation Planning Dept., Boston Redevelopment Auth., 2nd Ed. (1968)

B-3. *Report of the Exclusive Bus Lane Demonstration on the Southeast Expressway.* Bur. of Traffic Operations, Massachusetts Dept. of Public Works (1971)

B-4. Harrington, P., Kelker, R. F., and De Leuw, C E., *A Comprehensive Local Transportation Plan for the City of Chicago* (1937).

B-5. *Chicago Crosstown Expressway, Preliminary Design.* Crosstown Public Transportation System, Crosstown Associates (Oct 1971)

B-6 *Dallas Bus Operational Study.* Wilbur Smith and Associates (1971).

B-7. *Urban Corridor Demonstration Program for Dallas, Texas.* City of Dallas and Dallas Transit System (Dec. 1971).

B-8 *Dallas Center City Transportation Project.* Wilbur Smith and Associates (Sept 1970).

B-9 "Shortcut Modal Split Formula, A Method for Estimating the Impact of Travel Time or Cost Changes on Diversion of Car Drivers to Transit Work Travel to Central Business District." Wilbur Smith and Associates (1968).

B-10. *Urban Corridor Demonstration Program System Planning Final Report* Montgomery-Greene County Planning Commission (Oct. 1971)

B-11. *Concept of a Rapid Transit System.* Howard, Needles, Tammen and Burgendoff, Kansas City, Mo. (Mar. 1968).

B-12 *Kansas City Rapid Transitway Engineering Design Report.* Howard, Needles, Tammen, and Bergendoff (1969).

B-13. *Santa Ana Freeway Corridor Study Final Report.* Los Angeles Region Transportation Study and Southern California Association of Governments (Dec. 1971).

B-14. Wilson, J. C., "Usage of Freeway Bus Stops in California." *Traffic Bull. No 12,* California Dept. of Public Works (Aug 1964).

B-15. *Milwaukee Area Transit Plan A Mass Transit Technical Planning Study.* Barton-Aschman Associates (June 1971).

B-16. *Milwaukee Central Area Transit Distribution System.* Barton-Aschman Associates (Jan. 1971).

B-17. *General Criteria for Transitway Design, Milwaukee County Transitway.* Barton-Aschman Associates (Dec. 1968).

B-18. *Design and Performance Criteria for Improved Non-Rail Urban Mass Transit Vehicles and Related Urban Transportation Systems.* Nat. Academy of Engineering (1968).

B-19. *St. Louis Metropolitan Area Transportation Study. 1957, 1970, 1980.* W. C. Gilman and Company (Aug. 1959).

B-20. *I-35W Urban Corridor Demonstration Project Bus-Metered Freeway System: Final Report.* Bather-Ringrose-Wolsfeld, Inc., et al., Minneapolis, Minn. (Sept. 1971).

B-21. *Route 10-Canal Line Urban Corridor Demonstration Program (Summary).* Frederick R. Harris and Associates, Stamford, Conn (1971).

B-22. *Urban Corridor Demonstration Program Interim Report 1.* Tri-State Regional Planning Commission.

B-23. *Urban Corridor Demonstration Program: Interim Report 2* Tri-State Regional Planning Commission.

B-24. *Final Report, Urban Corridor Demonstration Program, Manhattan CBD-North Jersey Corridor,* "Summary of Findings," "Program for Action." Tri-State Regional Planning Commission (1971).

B-25. Goodman, L. P., "Bus Rapid Transit on Existing Highways—The I-495 Exclusive Bus Lane" Presented to ASCE Metropolitan Section Transportation Group, New York City (Feb. 9, 1971).

B-26 *Allegheny County Rapid Transit.* Port Authority of Allegheny County (1969)

B-27. ZELL, C E., "San Francisco-Oakland Bay Bridge Trans-Bay Bus Riders Survey" *Hwy Res Record No 114* (1966) pp. 169-182.

B-28. "Oakland Bay Bridge Traffic Surveys (1960-1970)" Inst of Traffic and Transp Eng, Univ of California, Berkeley

B-29 "Feasibility of an Exclusive Lane for Buses on the San Francisco-Oakland Bay Bridge." Div. of Highways and Bay Toll Crossings, California Dept. of Public Works (June 1969)

B-30. "Feasibility Study of an Exclusive Lane for Buses and Car Pools on the San Francisco-Oakland Bay Bridge." California Dept of Public Works (Apr. 1971).

B-31 *Blue Streak Bus Rapid Transit Demonstration Project Phase I Interim Report* Alan M Voorhees and Associates, Seattle, Wash. (1971).

B-32 *Blue Streak Bus Rapid Transit Demonstration Project Phase I Interim Report* Alan M Voorhees and Associates, Seattle, Wash. (1972)

B-33 *The Shirley Highway Express Bus-on-Freeway Demonstration Project.* Nat. Bur of Standards, U S. Dept of Commerce (Aug 1971).

B-34 *Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor.* Howard, Needles, Tammen, and Bergendoff (Mar. 1970).

B-35. "Shirley Highway Express Bus System Profile. Demonstration Statistics" *News Notice No. 3,* Urban Mass Transportation Admin., U.S. Dept. of Transportation (Oct. 1971)

B-36 *Shirley Highway Express Bus-on-Freeway Project Status Report* Northern Virginia Transportation Commission (Feb. 12, 1972)

B-37 *Shirley Highway Express Bus-on-Freeway Demonstration Project. Financial Summary* Northern Virginia Transportation Commission (Nov 1971).

B-38 *Use of Baltimore & Ohio Georgetown Branch for Public Transportation.* Metropolitan Washington Council of Governments (Oct. 1968).

B-39 *Traffic Improvements to Speed Express Bus Operations.* Metropolitan Washington Council of Governments (Jan 1969).

B-40 *Summary Report of the D.C. Cordon Traffic Survey, 1970* D C Dept. of Highways and Traffic (1970).

B-41. *Summary Report of the D C. Cordon Traffic Survey, 1966.* D.C Dept of Highways and Traffic (1966)

B-42 *South Capitol Street Urban Corridor Study.* Alan M Voorhees and Associates (Sept. 1971).

B-43 "Exclusive Busway System in City Transport Report." *Truck and Bus Transp*, Sydney, Austr. (Mar. 1971).

B-44. *Redditch New Town Report on Planning Proposals* Prepared for Redditch Development Corp by H. Wilson and L. Womersley, Town Planners, in association with M. Brown, Landscape Architect (Dec 1966)

B-45 MERCER, J, "Runcorn Plan for a Rapid Transit Bus Service." Presented at Symposium for Public Transport Policy Makers, Univ. of Newcastle-Upon-Tyne (Mar. 1971)

APPENDIX C

CASE STUDIES OF ARTERIAL BUS PRIORITY TREATMENTS

This appendix describes and interprets examples of bus priority treatment along arterial streets. Included are bus streets, bus lanes, traffic signal priorities, and related treatments along arterial streets. Experiences in the United States and Canada are discussed first, followed by significant experiences in other countries.

1. ATLANTA BUS PRIORITY LANES

Atlanta, Ga., was one of the U S. cities that pioneered in providing bus priority treatments. The nature and extent of these treatments varied depending on street routing and bus operating plans. Previous, existing, and proposed bus priority treatments are shown in Figure C-1.

Downtown Bus Lanes

Peachtree Street

The first of four CBD exclusive bus lanes was placed into effect on January 27, 1958, on three blocks of Peachtree Street between Forsyth and Harris Streets

The plan was recommended to the Police Committee of the Board of Aldermen, and the Committee agreed to try it for a 90-day period to determine public reaction After the lane was installed, police officers directed traffic to achieve proper use of the bus lane. Within a few days, the transit lane received wide acceptance and was operating smoothly.

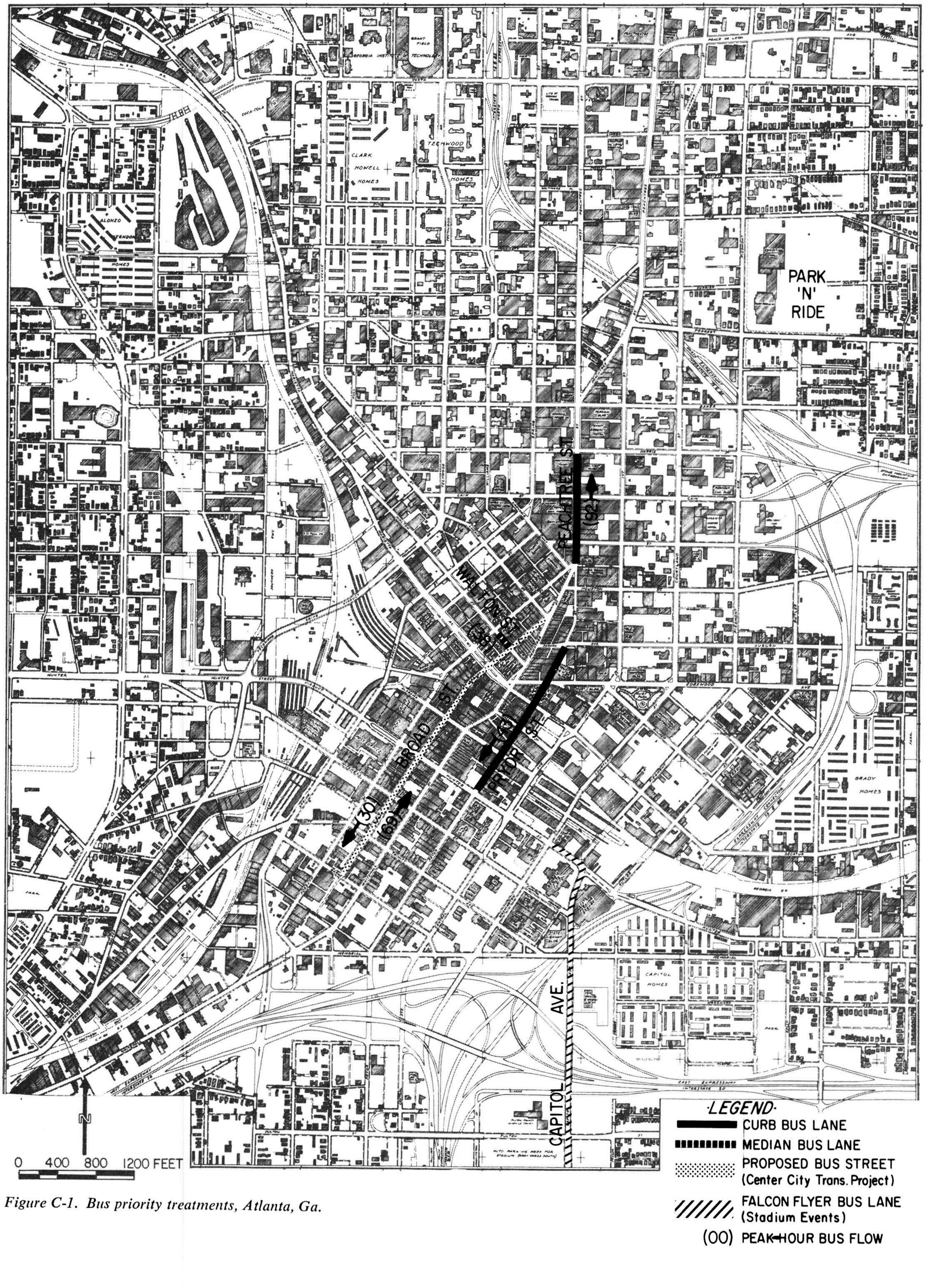


Figure C-1. Bus priority treatments, Atlanta, Ga.

The bus lane, located on the northbound side of Peachtree Street, was in effect from 7 00 to 9 00 AM and from 4.00 to 6 00 PM on weekdays. Two auto travel lanes were provided in each direction on the 5-lane street, thus, there was no reduction in the number of through auto lanes Bus stops remained about 300 ft apart. Approximately 50 to 60 buses used the lane each peak hour

The lane was marked by double yellow lines and crosshatching. Fifteen red and black signs reading "CURB LANE, BUSES ONLY, 7 00 to 9 00 AM and 4 00 to 6.00 PM" were placed on trolley span poles At intersections where right turns were permitted this and other downtown bus lanes terminated 100 ft before the corner to allow the turns by autos The Atlanta Transit System indicated that the right-turn conflicts limited the effectiveness of the lanes

Results of before and after studies on Peachtree Street are summarized in Table C-1 The flow of buses was speeded up 33 percent during the evening rush hour and 4 percent during the morning rush hour. The exclusive bus lane also permitted an increase in automobile speeds of 110 percent in the morning peak and 61 percent in the evening peak.

The lane was removed from service in 1962 At that time, the street was re-marked to provide three southbound and two northbound lanes

Presently (1972) there is little northbound automobile traffic in the curb lane during the peak periods The heavy bus flow preempts the lane, even without special bus lane designation.

Other Streets

Bus lanes were also in effect on Pryor Street and Broad Street The Pryor Street exclusive bus lane was discontinued when the street was made one-way in 1963. The Broad Street exclusive bus lane was discontinued when automobile traffic flow became unduly restricted. Currently, during peak periods Broad Street operates like a bus street (or series of bus lanes) because of the number of buses using it.

The one remaining exclusive bus lane is found on Walton Street between Broad and Forsyth Streets. A pedestrian loading island in the middle of the street served by this lane is one of the main bus transfer points in the CBD.

The report on the Atlanta Center City Transportation Project (*C-1*) suggested that Broad Street become a two-way transit street The objective was to create a sense of transit identity and to remove automobile traffic from key pedestrian streets. Nearly 100 buses per hour currently use this street in the peak hours (Table C-2).

Falcon Flyer Bus Lanes

Substantial "special event" bus service is operated by the Atlanta Transit System An exclusive bus lane along Washington Steet is designated for professional baseball and football activities. This lane extends along Capitol Avenue to the stadium (Fig C-2) In addition to this, the Falcon Flyer (express bus service) operates from 18 outlying shopping centers to the stadium. Buses operate for approximately 1½ hours with the last bus leaving the shopping centers one hour before the scheduled event. The Falcon Flyer mainly operates on freeways and uses preferential streets when approaching the stadium Upon leaving the stadium, the Falcon Flyer and downtown shuttles receive special ramp entry preference, with police officers stopping other traffic. Up to 37 percent of all persons attending stadium football events use Atlanta Transit System buses.

TABLE C-1

SUMMARY OF TRANSIT AND AUTOMOBILE SPEEDS, PEACHTREE STREET, ATLANTA, GA [a]

			ELAPSED TIME		SPEED	
VEHICLE TYPE	SURVEY	TIME	(MIN)	IN-CREASE (%)	(MPH)	IN-CREASE (%)
Transit	Before	AM	2.94		6 19	
		PM	4 73		3 84	
	After	AM	2 83	—	6 42	4
		PM	3 56	—	5 11	33
Auto	Before	AM	2 41		7 51	
		PM	3 33		5 46	
	After	AM	1 15	—	15 81	110
		PM	2 07	—	8 78	61

Source Atlanta Transit System (1958)

[a] Northbound from Paramount Theater to Harris Street, Jan 27, 1958.

Downtown Shoppers' Shuttle

Special Town Flyer bus service was inaugurated in December 1969 as a joint effort of the City of Atlanta, Atlanta Transit System, and the business community. It was designed to intercept shoppers and workers at peripheral CBD parking facilities located adjacent to express highways. The 2-mile route connects the stadium and the Civic Center with the CBD Service is provided by the Atlanta Transit System, federal funds helped with publicity costs Fares were set at $0 50 for the auto driver (including parking fee and round-trip bus ride), and $0 15 per ride for other passengers. One-way travel time averages 10 to 12 min to the CBD The service has reportedly removed about 200 cars from downtown Atlanta streets during each peak hour.

Bus Turn-Arounds

Six exclusive bus turn-arounds are located at the ends of bus routes. These turn-arounds are located either on private property or on property owned by Atlanta Transit Those located on private property are made available through easements

2. BALTIMORE BUS PRIORITY LANES

The designation of "bus only" curb lanes was inaugurated in Baltimore, Md , on May 26, 1958. This initial designation of eight blocks on a single street was gradually increased, there are now (1972) eleven streets with reserved bus lanes aggregating about 60 blocks (approximately 5 miles). The locations of bus priority lanes in central Baltimore are shown in Figure C-3, the general characteristics of these lanes are given in Table C-3

Legal Basis

Bus priority lanes in Baltimore were installed under Administrative Regulation No 14 issued by the Commissioner of Transit and Traffic This regulation, as amended in November 1963, reads as follows:

> *Section 1* Pursuant to the power and authority contained in Article 38, Section 2J and 2X of the Baltimore City Code (1950 Edition) as amended by Ordinance No 1006, approved by the Mayor on June 18, 1957, the Commissioner of Transit and Traffic hereby enacts an Administrative Regulation designating portions of the following streets as transit lanes and prohibiting the use of said lanes by vehicles other than those used for mass transit.
>
> *Section 2.* It is hereby ordered and directed by the Commissioner of Transit and Traffic of the City of Baltimore that the following lanes of the following streets and thoroughfares within the City of Baltimore are hereby designated transit lanes to be used solely by buses during the periods specified, and it is further ordered and directed that when the said lanes have been designated as transit lanes that during the hours that said lanes are so designated for the exclusive use of buses, it shall be illegal for any vehicle other than a bus to use said lanes, except that vehicles other than buses shall be allowed to use said lanes one block prior to executing right-hand turns

Warrants

The selection of reserved lanes is based on the following formula established by the Department of Transit and Traffic:

> When the number of transit riders carried in one lane

TABLE C-2

TRAFFIC CHARACTERISTICS, BROAD STREET, ATLANTA, GA.[a]

	VEHICLE VOLUME		
PERIOD, DIRECTION, AND CLASSIFICATION	NO	PERCENT BY DIRECTION AND CLASS	PERCENT OF 12-HR PERIOD
(*a*) AM PEAK PERIOD			
8 00–9.00 AM			
Northbound traffic			
Automobiles	297	79.2	
Commercial vehicles	25	6 4	
Buses	54	14 4	
Subtotal	376	100 0	(5 7)
Southbound traffic			
Automobiles	246	80 4	
Commercial vehicles	30	9 8	
Buses	30	9.8	
Subtotal	306	100 0	(4 7)
Total	682		(10 4)
(*b*) 12-HOUR COUNT			
Northbound traffic			
Automobiles	2,034	59 6	
Commercial vehicles	906	26 5	
Buses	474	13 9	
Subtotal	3,414	100 0	52 3
Southbound traffic			
Automobiles	1,973	63 3	
Commercial vehicles	852	27 4	
Buses	291	9 3	
Subtotal	3,116	100 0	47 7
Total	6,530		100 0
(*c*) PM PEAK PERIOD			
5 00–6·00 PM			
Northbound traffic			
Automobiles	201	56 3	
Commercial vehicles	87	24 4	
Buses	69	19 3	
Subtotal	357	100 0	(5 4)
Southbound traffic			
Automobiles	228	67 3	
Commercial vehicles	81	23 9	
Buses	30	8 8	
Subtotal	339	100 0	(5 7)
Total	696		(10 6)

Source Atlanta Transit System (1970)

[a] Data collected during 1970

TABLE C-3

SUMMARY OF EXCLUSIVE BUS LANES, BALTIMORE, MD

LOCATION	HOURS OF OPERATION	NO OF BLOCKS
Charles St from Madison to 26th (east side)	4 00–6 30 PM	16
St Paul St from Eager to Preston (west side)	7 30–10 00 AM	3
Calvert St from Lexington to Madison (east side)	3 00–6 30 PM	6
Howard St from Franklin to Fayette (west side)	7 00–10 00 AM 4·00–6 00 PM	6
Paca St from Redwood to Mulberry (east side)	7 00–10 00 AM 4 00–6 00 PM	5
Greene St from Fayette to Franklin (west side)	7 00–10 00 AM 4·00–6 00 PM	4
Saratoga St from Cathedral to St Paul (north side)[a]	24 hr daily	2
Lombard St from Greene to Hanover (south side)	7·00–9 00 AM	4
Pratt St from Paca to Light (north side)	4 00–6 30 PM	6
Baltimore St from Hopkins Place to Gay (south side)	7 00–9 00 AM 4 00–6 00 PM	6
Fayette St from Eutaw to Calvert (north side)	7 00–9 00 AM 4 00–6 00 PM	

Source Baltimore Transit Company and Baltimore Department of Transit and Traffic (1967)

[a] Buses only

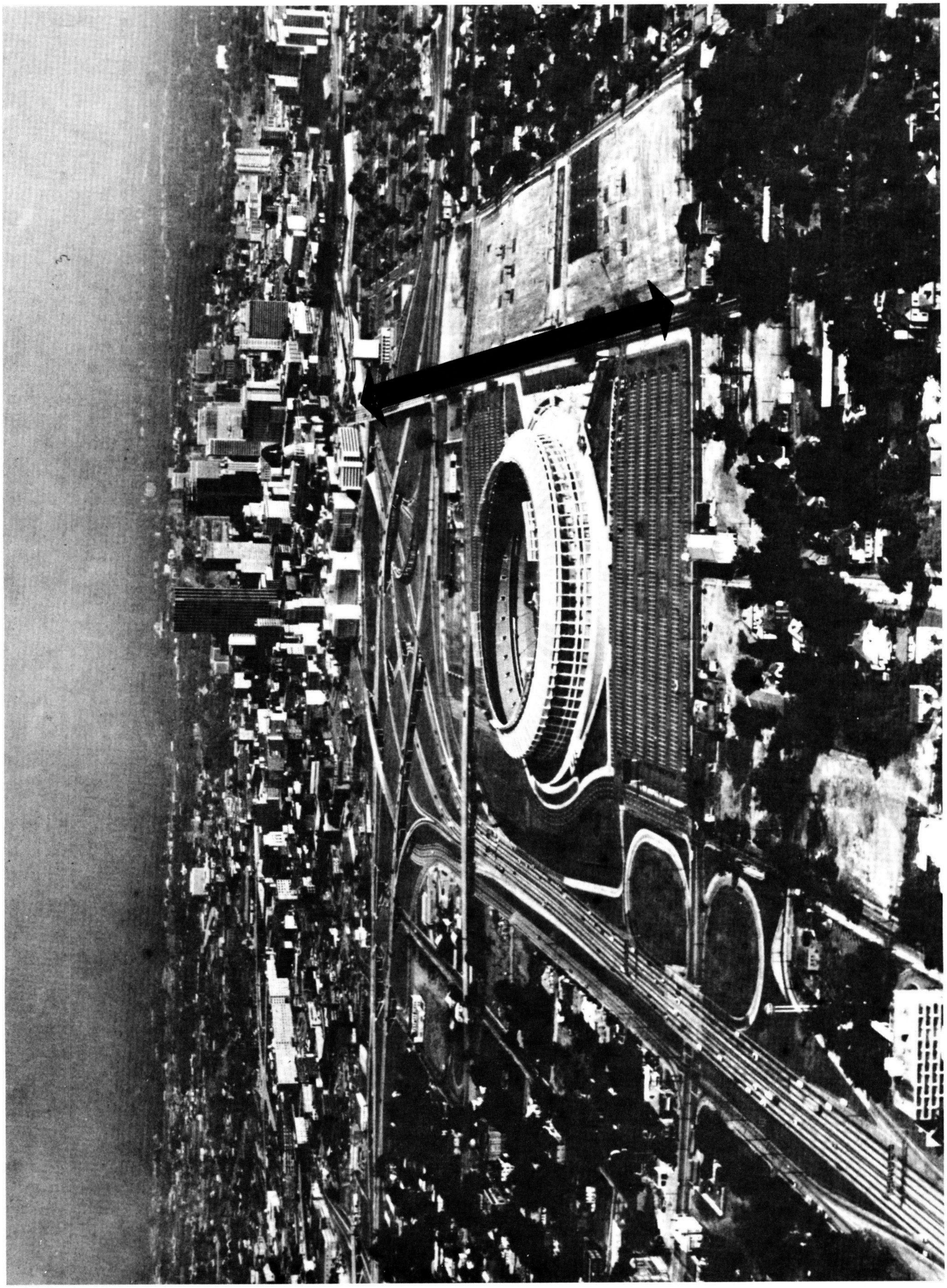


Figure C-2. Falcon Flyer special events bus lane, Atlanta, Ga.

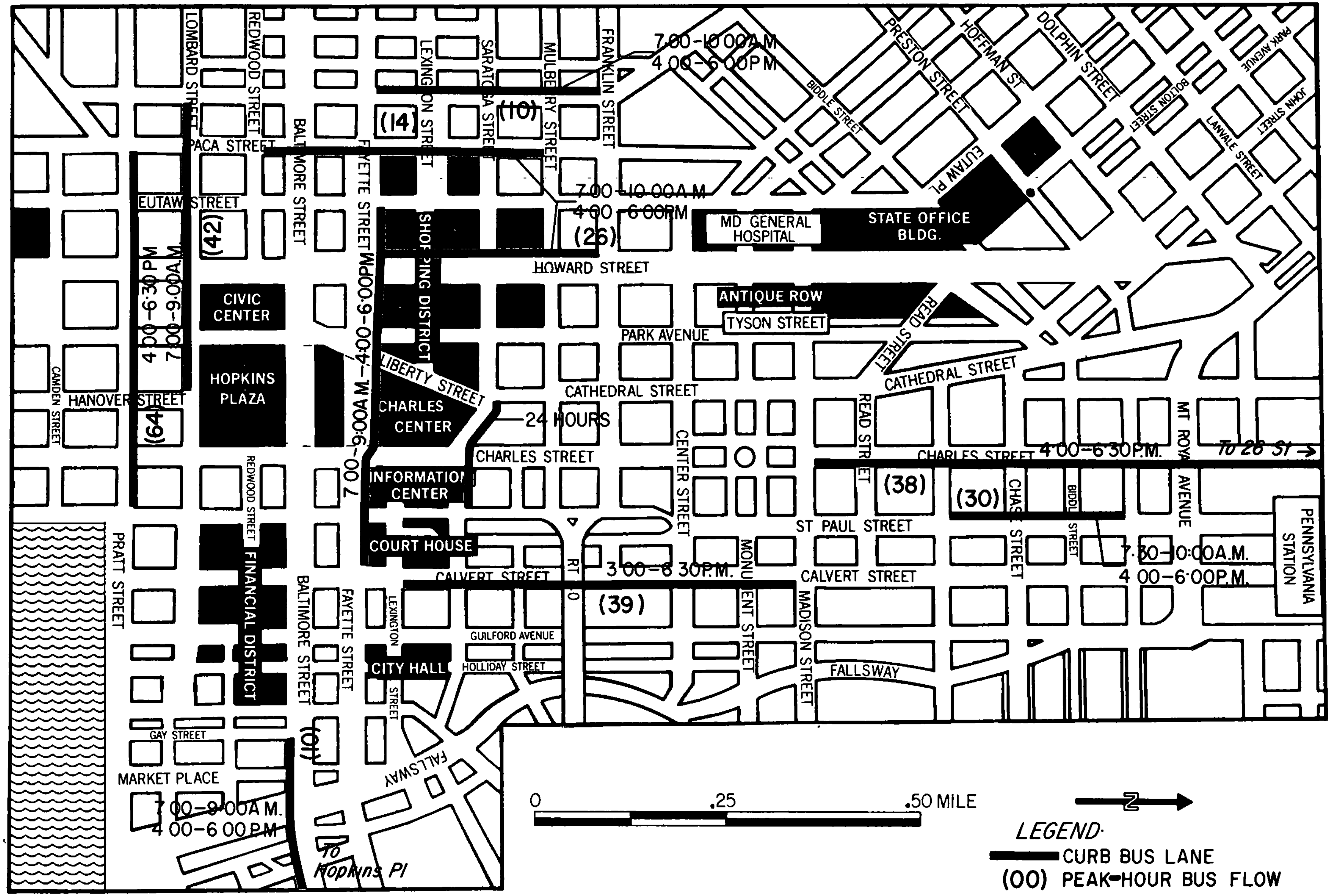


Figure C-3. Location of bus priority treatments, Baltimore, Md

> in a particular artery equals the number of occupants in automobiles in an adjoining traffic lane, then the bus (or transit rider), is entitled to the exclusive use of the first lane

This warrant differs from those established by the Institute of Traffic Engineers, but represents a more realistic approach to bus lane development.

As a result of this warrant, most existing lanes in Baltimore are found on four-lane one-way streets.

Reserved transit lanes generally have not been provided because· (1) vehicular volumes did not warrant the prohibition of parking, a prerequisite for curb bus lanes, (2) there were insufficient transit riders to meet the warrant; and (3) there were insufficient traffic lanes to permit establishing reserved transit lanes.

Controls and Operations

The CBD bus lanes are in effect during the morning and evening peak periods, usually from 7 00 to 9 00 AM and 4 00 to 6.00 PM All bus lanes are along curbs in the flow direction. A curb lane sign in each block with a transit lane states either BEGIN CURB LANE RIGHT TURNS AND BUSES ONLY 4 00 PM to 6 30 PM or CURB LANE BUSES AND RIGHT TURNS ONLY 4 00 PM to 6 30 PM Bus lanes were originally delineated by dashed yellow lanes, a type of marking that no longer conforms to the *Manual on Uniform Traffic Control Devices* (*C-2*).

In areas where express buses do not stop, they can use the second lane from the curb to bypass local vehicles. No enforcement is directed against motorists who drive or stop in the bus lanes, nor have right turns been prohibited. No minor side streets are blocked.

Illustrative results of a comprehensive bus lane survey made in 1963, showing how bus lanes relate to designated warrants, are given in Table C-4 Buses represent 15 to 50 percent of the total peak-period passenger flow on principal downtown streets (The 50 percent rate is achieved on Howard Street.)

Benefits and Significance

Reported time savings have varied greatly. Checks by the Department of Transit and Traffic in May, June, and July 1958 showed time savings ranging from 12 to 58 percent in the transit lane and from 7 to 49 percent in other lanes Figures released by the Department in June 1958 showed an average time savings of 19 percent in the transit lanes and 31 percent in the other three lanes. The reported benefits, summarized in Table C-5, show savings of 17 to 21 percent by buses and 22 to 39 percent by other vehicles. On St Paul Street, bus travel time was reduced from 3 9 min to 1.6 min after the bus lane was established. Corresponding values for Charles Street were reported as 3 6 min before and 2 7 min after the establishment of bus lanes

Effectiveness is reported as difficult to determine. The Baltimore Transit Company (now the Metropolitan Transit Authority) found no reason to make adjustments in their schedules, and, therefore, there was no reduction in number of runs and savings in operating costs. When the lanes were first installed, savings in travel time amounted to one-third. However, recent observations suggest that the effectiveness of the lanes may have diminished because of limited enforcement.

3. BUFFALO BUS PRIORITY LANES

Buffalo, N.Y, has about 24 million square feet of floor space in its downtown area. A major college expansion, along with the potential development of a new town, has increased the feasibility of a rapid rail line connecting the downtown with its northeast spine Until recently, bus priority treatments received relatively little attention.

An exclusive bus lane, about 600 ft long, exists on both sides of Church Street in the CBD (Fig C-4). This treatment, installed in late 1969, is a normal curb bus lane and operates 24 hours a day seven days a week. About 10 buses (five bus routes) use it during the peak hour A 6-in. raised

TABLE C-4

BUS LANE SURVEY, HOWARD STREET, BALTIMORE, MD[a]

VEHICLE TYPE	TIME	NO VEH	PASS. FAC-TOR	NO PASS	PASS REQ[b]	DEFICIT OR AVG.	% OF PASS.	
							REQ[b]	ACTUAL
			(*a*) Morning Survey					
Non-Transit	7:30–8:30 AM	472	1.6	755	—	—	—	—
	7:00–10·00 AM	1268	1 6	2029	—	—	—	—
Transit	7.30–8:30 AM	30	26 4	792	516	+276	33⅓	51
	7:00–10·00 AM	80	23 6	1888	1306	+582	33⅓	48
			(*b*) Afternoon Survey					
Non-Transit	4:00–5·00 PM	414	1 6	662	—	—	—	—
	4 00–6:00 PM	788	1 6	1261	—	—	—	—
Transit	4:00–5:00 PM	26	21 6	562	408	+154	33⅓	46
	4 00–6·00 PM	54	22 9	1237	833	+404	33⅓	49

Source Baltimore Department of Transit and Traffic

[a] From Franklin St to Fayette St, June 25, 1963, five-lane street, two-way with three lanes SB, traffic normal

[b] Required by warrant

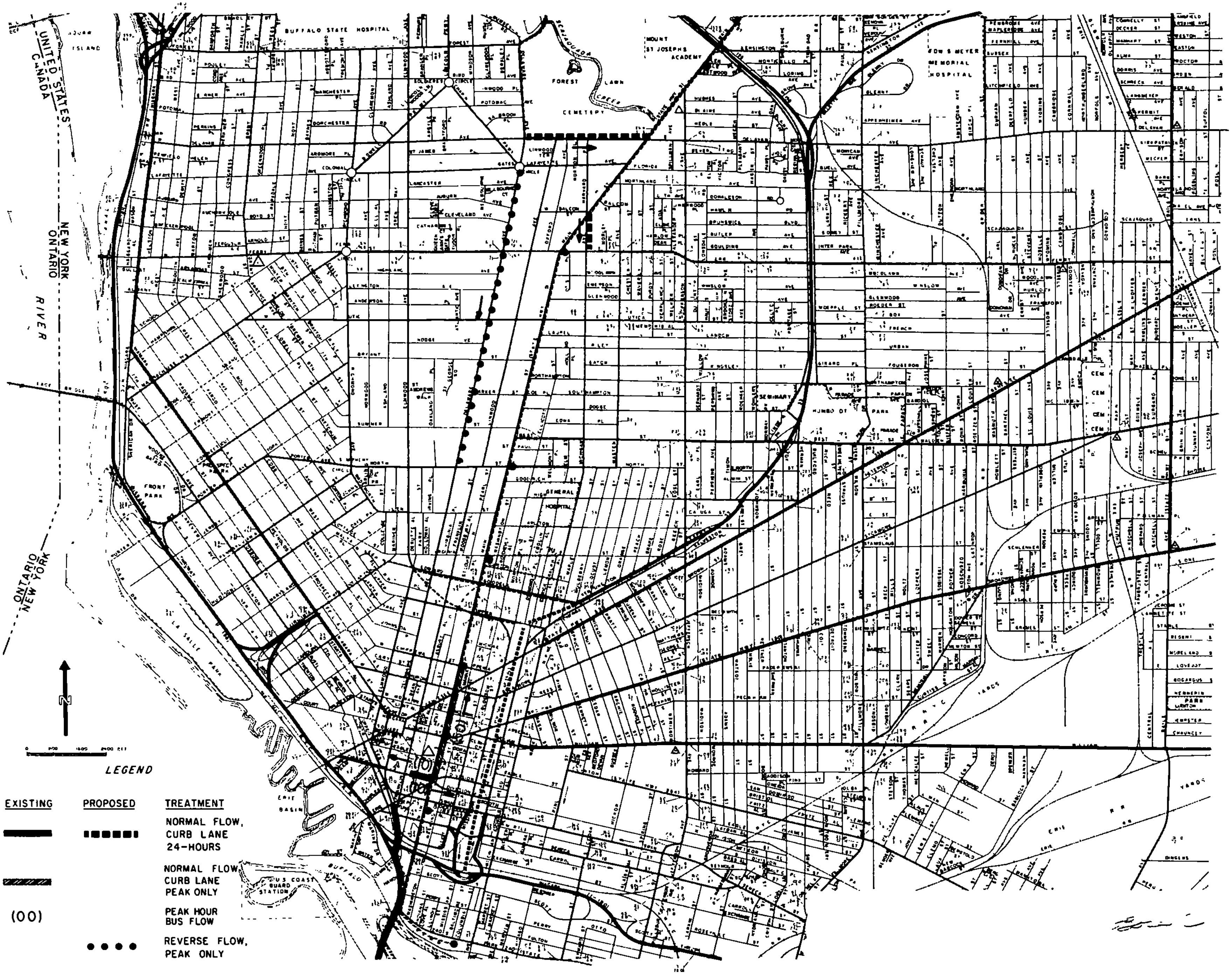


Figure C-4 Existing and proposed bus priority treatments, Buffalo, N Y concrete curb protects the lanes from intrusion by other traffic and allows buses to stop without interference. The protected lanes, each 10 ft wide, have a maximum capacity of four buses It is one of the few examples of physically separated normal-flow bus lanes in the United States.

Another bus lane runs for about 3,600 ft on the east side of Main Street in the CBD This lane is in effect from 4 30 to 6 30 PM six days a week (Sunday excepted) It carries about 50 buses during the peak hour

Three other streets are currenly being considered to carry bus lanes Michigan, Delavan, and Delaware Avenues. The first two treatments would be normal curb lanes, they would be about 1,200 and 3,600 ft long, respectively, and would operate 24 hours a day The proposed bus lane on Delaware Avenue would be a contra-flow bus lane, 1 7 miles long; it would operate in the morning rush hours only, along the west side on approaches to the CBD

A traffic operations study completed during 1972 recommended an electronic signal system that would give buses extended green time at about 40 intersections in the downtown area to increase speeds and service levels.

4. CHARLOTTE BUS PRIORITY LANES

Central Charlotte (N.C) employes about 35,000 people, placing it in the group of cities that with continued downtown growth affords promise for bus priority treatments

Proposed bus priority lanes in downtown Charlotte are shown in Figure C-5. They represent a typical application of curb bus lanes in medium-sized city centers The bus lanes would traverse the two main streets along which major retail stores and commercial office buildings are located. They reflect a public policy statement relative to improved transit.

Curb bus lanes on Trade and Tryon Streets in the downtown area would serve about 30 to 40 buses each peak hour These bus lanes would carry 1,000 people in the peak hour as compared with 700 to 800 people carried in each highway lane. Two lanes each way for automobile travel also would be provided

5. CHICAGO BUS PRIORITY TREATMENTS

Chicago, Ill., was a pioneer in bus priority innovations as well as freeway-transit coordination The geographical coverage and diverse nature of the city's preferential bus treatments are shown in Figure C-6

Washington Street Median Bus Lane

The Washington Street median bus lane was established in June 1956 The lane extends 0.6 miles from Wacker Drive to Michigan Avenue (Fig. C-7). Buses on seven routes operate eastbound in the center lane of a 5-lane one-way eastbound street 48 to 50 ft wide (Figure C-8). About 110 buses use the lane in the peak hour.

Background

TABLE C-5

REPORTED BENEFITS OF TRANSIT LANES, BALTIMORE, MD

VEHICLE TYPE	INCREASE IN SPEED (%) AM RUSH	PM RUSH
Transit	21	17
Other	39	22

Source Baltimore Department of Transit and Traffic (1958)

The installation was based on extensive studies by the Chicago Street Traffic Commission, the Corporation Counsel, the City Departments of Streets and Public Works, and the Chicago Transit Authority (*C-3*). Prior to bus lane installation, Washington Street carried 15,000 automobiles into the CBD in a 12-hr period, and 760 buses carried 19,000 passengers in the same period.

During the peak hour some 90 buses (on five routes) operated on the street Two routes previously operated next to the south curb, three others operated in the middle of the roadway, stopping to discharge and receive passengers at safety islands

Field studies and engineering analyses indicated that it was feasible to reserve a lane for exclusive use by buses Calculations showed that it was possible to save 2 min running time per bus between Wacker Drive and State Street (the first six blocks of the transit lane), corresponding to a saving of three vehicle-hours during the peak hour (90 buses)

The analyses further indicated that greater time savings could be realized by reserving a lane for buses in the middle of the street. Exclusive use of a center lane does not affect access to abutting properties, does not conflict with turning movements at intersections, and does not rely on active enforcement of "no standing" regulations in the curb lanes

City authorities recognized that under center-line operations all passengers are required to cross a portion of the street to a loading platform or safety zone rather than loading from the sidewalk. This, however, was a long-established streetcar loading practice

The City's legal department prepared a brief regarding the creation of separate lanes for mass transit vehicles. The brief indicated that the City Council has the right (eminent domain) to establish lanes for mass transit vehicles, provided such regulations (a) are reasonable, (b) promote public safety, convenience and welfare, and (c) benefit the public at large (*C-3*)

Location and Design

The general redesign of Washington Street to accommodate the bus lanes is shown in Figure C-9 Prior to establishment of the transit lane traffic moved in four lanes, with a passenger loading zone in the center of the street. After establishment of the transit lane, four lanes were still provided, plus a bus lane and a passenger loading zone The bus lane is 9 ft wide, the loading area is about 5 ft wide, and the traffic lanes range from 8½ to 10 ft in width.

Wooden passenger loading platforms with guardrail and splash shields (Fig C-10) were installed in November 1956

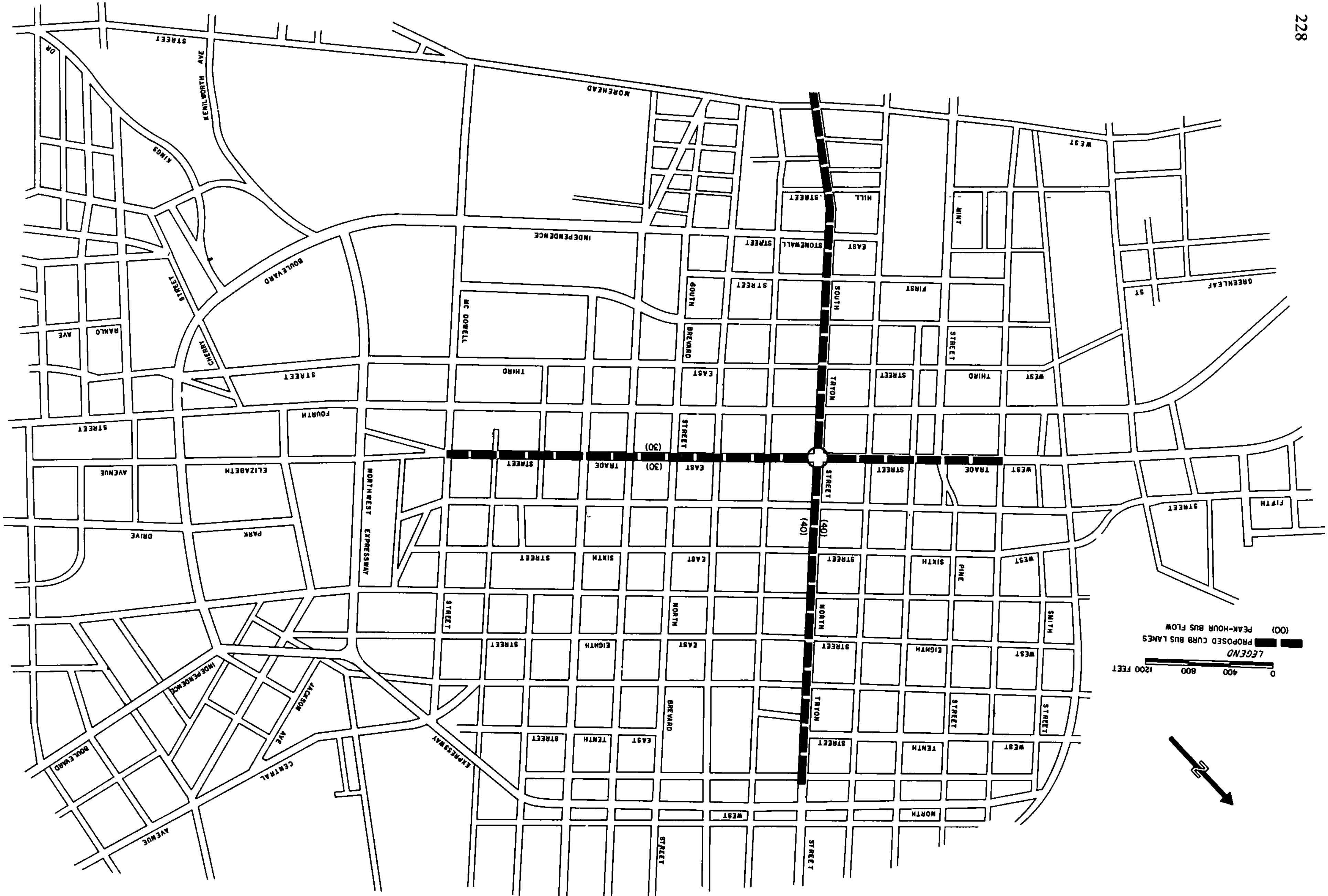


Figure C-5 Proposed bus lanes, Charlotte, N C

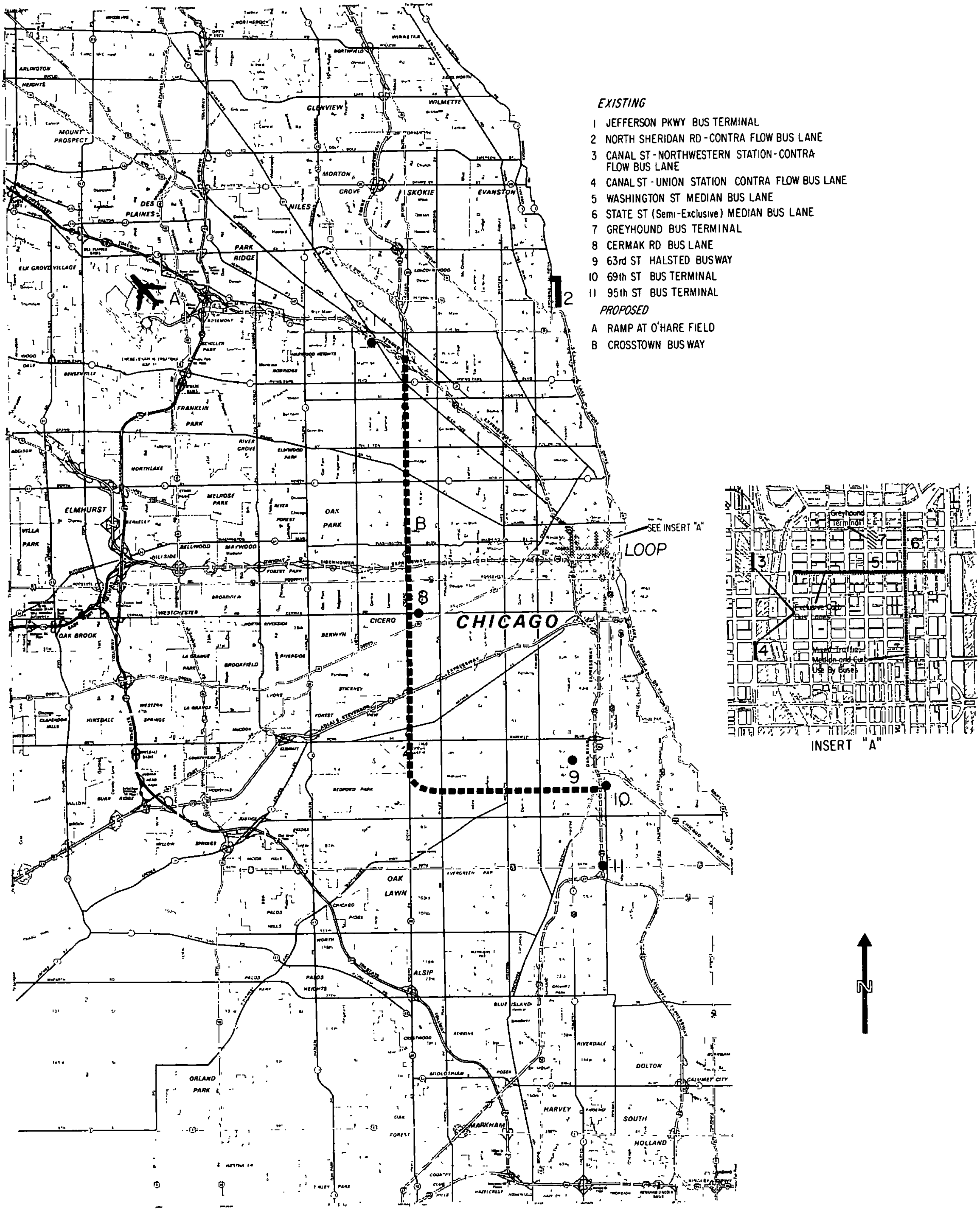


Figure C-6 Bus priority treaments, Chicago, Ill

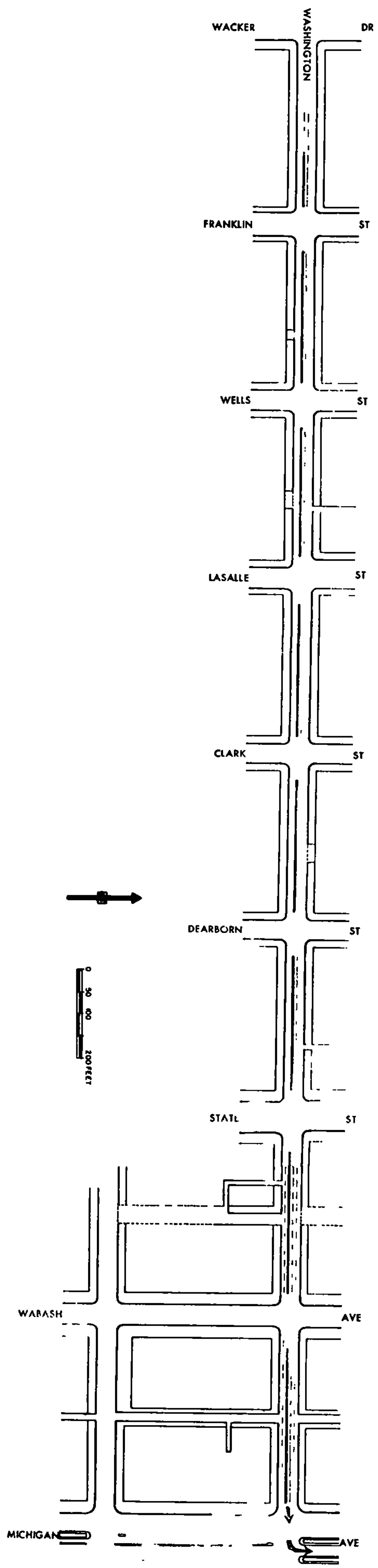


Figure C-7 Washington Street median bus lane, Chicago, Ill

at State Street, the heaviest passenger stop, and subsequently at other locations. Passenger loading platforms 5 ft wide and 128 ft long are installed at the near sides of the intersections The traffic side of the platforms is equipped with a pipe safety rail and splash guard for protection of bus patrons. The 4½-ft clearance from the guardrail to the island edge was the widest permissible in the 48-ft curb-to-curb width of street. Loading platforms at intersections other than State Street were subsequently removed because of vehicle collision conflicts, insufficient lane width, and maintenance problems.

The current lane marking plan is shown in Figure C-11 Street lane lines are solid white. Double yellow lines mark the left side of the bus lane, and a painted median (yellow) segregates the right side and passenger loading areas from auto traffic Pavement legends read DO NOT ENTER, BUS ONLY. Stanchions further define pedestrian loading areas

Benefits

The Chicago Transit Authority (CTA) indicates that the "bus lane has proved highly successful in promoting a faster and more orderly traffic flow not only for buses, but also for all traffic using Washington Street." Surveys conducted some ten years ago found that average bus running times were improved by about 14.5 percent in the morning rush period, 28.3 percent during the day, and 15.4 percent in the evening rush period. The average running times of vehicular traffic were reported to have remained essentially the same with no loss in efficiency. No change in vehicular volumes occurred.

A special (CTA) study in June 1971 found that in the afternoon rush hour the average bus travel times between Wacker Drive and State Street (0.5 mile) were 4 3 min on Washington Street as compared with 6 3 min for the same distance on Randolph Street, a parallel facility It was possible to eliminate one bus run during peak hours because of this saving. Assuming a value of $3.00 per hour, the time savings to travelers during morning and evening peak hours are worth about $250,000 annually.

Significance

The Washington Street bus lane represents a pioneering effort in reserving for buses a median lane unobstructed by parking or loading vehicles Inaugurated in 1956, it preceeded the Baltimore bus lane installation The problems of safe pedestrian boarding and alighting and of other vehicles weaving across the bus lane have been successfully solved

Canal Street Contra-Flow Bus Lanes

Two contra-flow bus lanes are found along Canal Street in Chicago at Northwestern and Union Stations Canal Street is a one-way northbound street on the west side of the business district

At Northwestern Station

The contra-flow bus lane at Northwestern Station between Randolph and Washington Streets is shown in Figures C-12

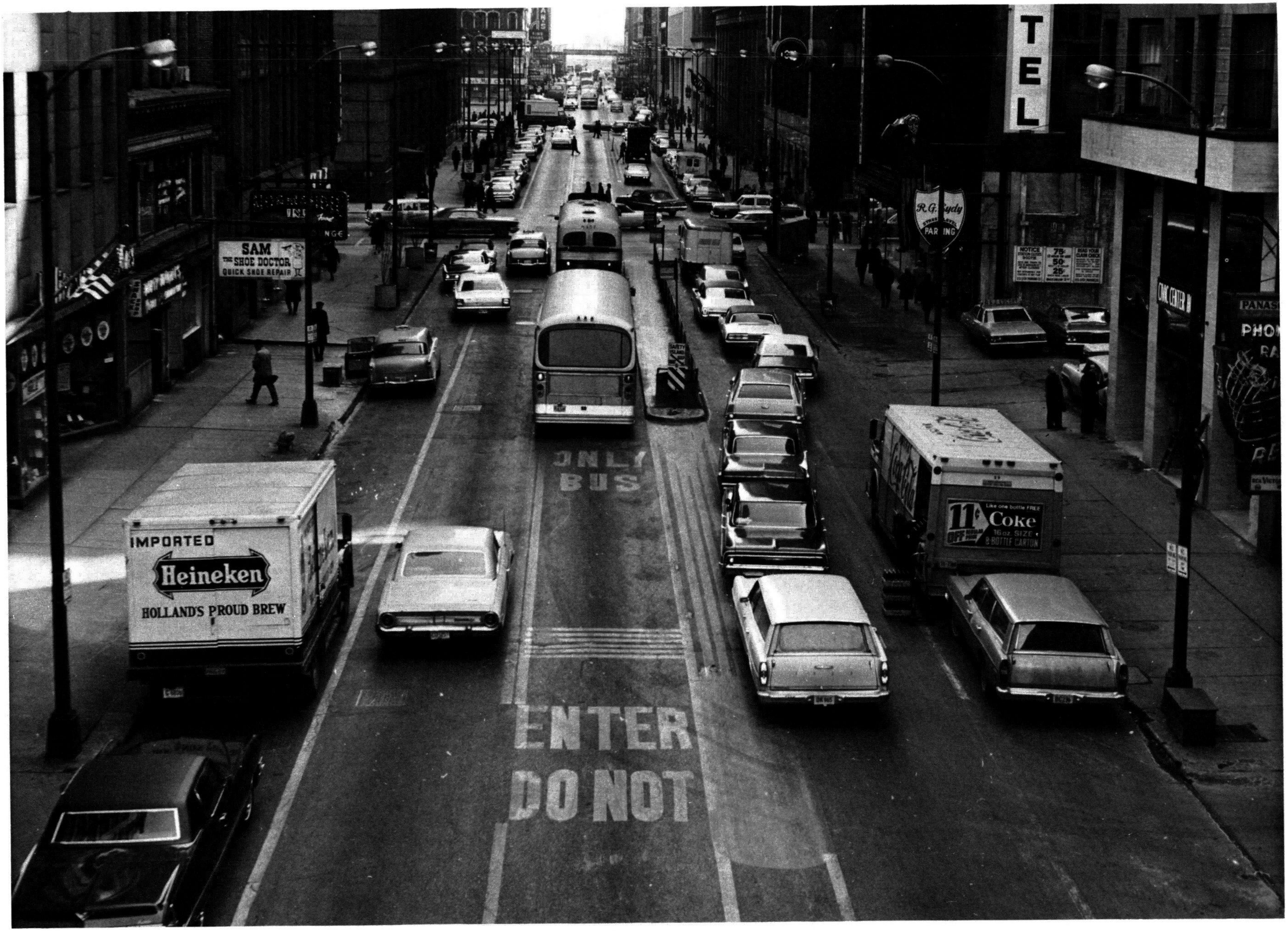


Figure C-8. *Typical view, Washington Street bus lane, Chicago, Ill.*

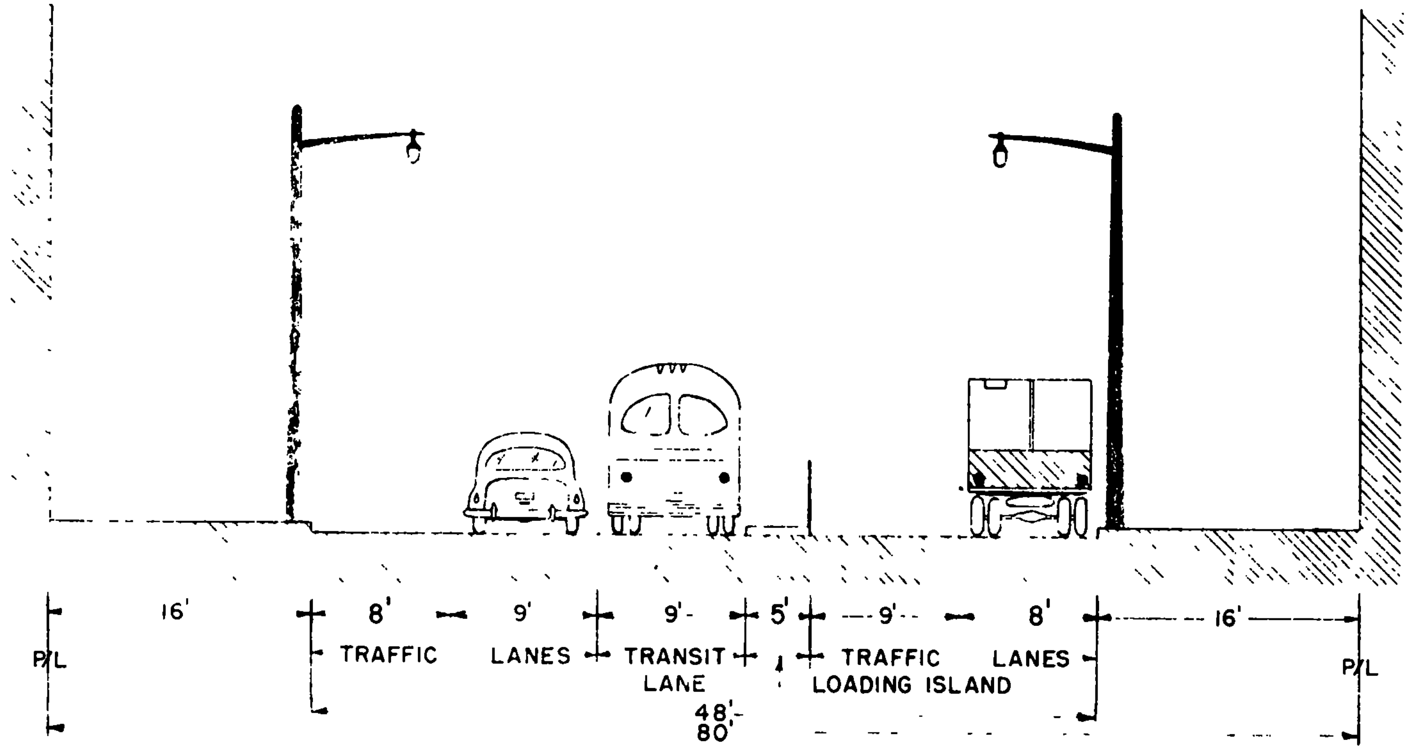


Figure C-9 Typical cross section, Washington Street bus lane, Chicago, Ill

and C-13. This lane was established in 1964 to serve some 3,000 passengers each rush period, eliminate 1,500 pedestrian mid-block crossings each morning, and eliminate approximately 2,500 mid-block crossings in the evening peak period

The lane allows buses to pick up and discharge passengers at the station entrances Before its installation, bus riders had to cross the street between the railroad station and bus stop, the large number of mid-block pedestrian crossings created undesirable congestion and hazards in peak periods. The contra-flow lane has created neither traffic hazards nor undue congestion. Only three pedestrian accidents were reported from 1965 to 1967.

Five bus routes use this lane to pick up and deliver approximately 6,500 Chicago and Northwestern passengers daily. Eighty buses use the lane each peak hour Passenger interchange takes place under a canopy at the station's suburban entrance with overhead illuminated signs, controlled by a CTA supervisor to identify which route is loading in each berth. Between 7·00 AM and 7:00 PM use of the lane averages about 20 buses per hour

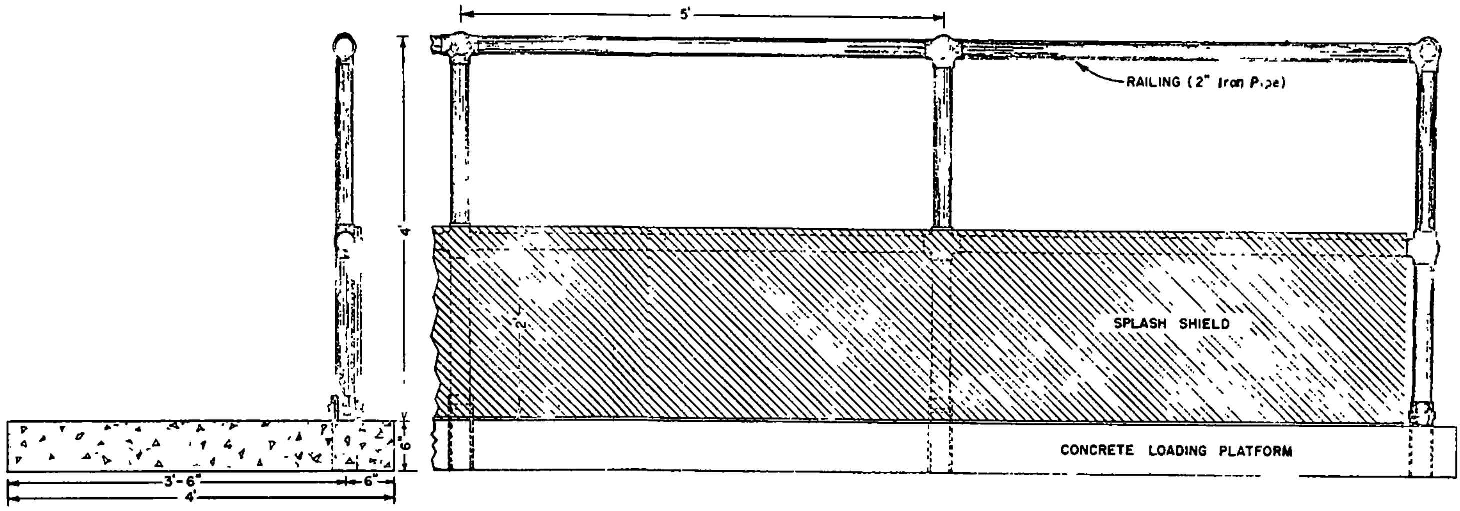
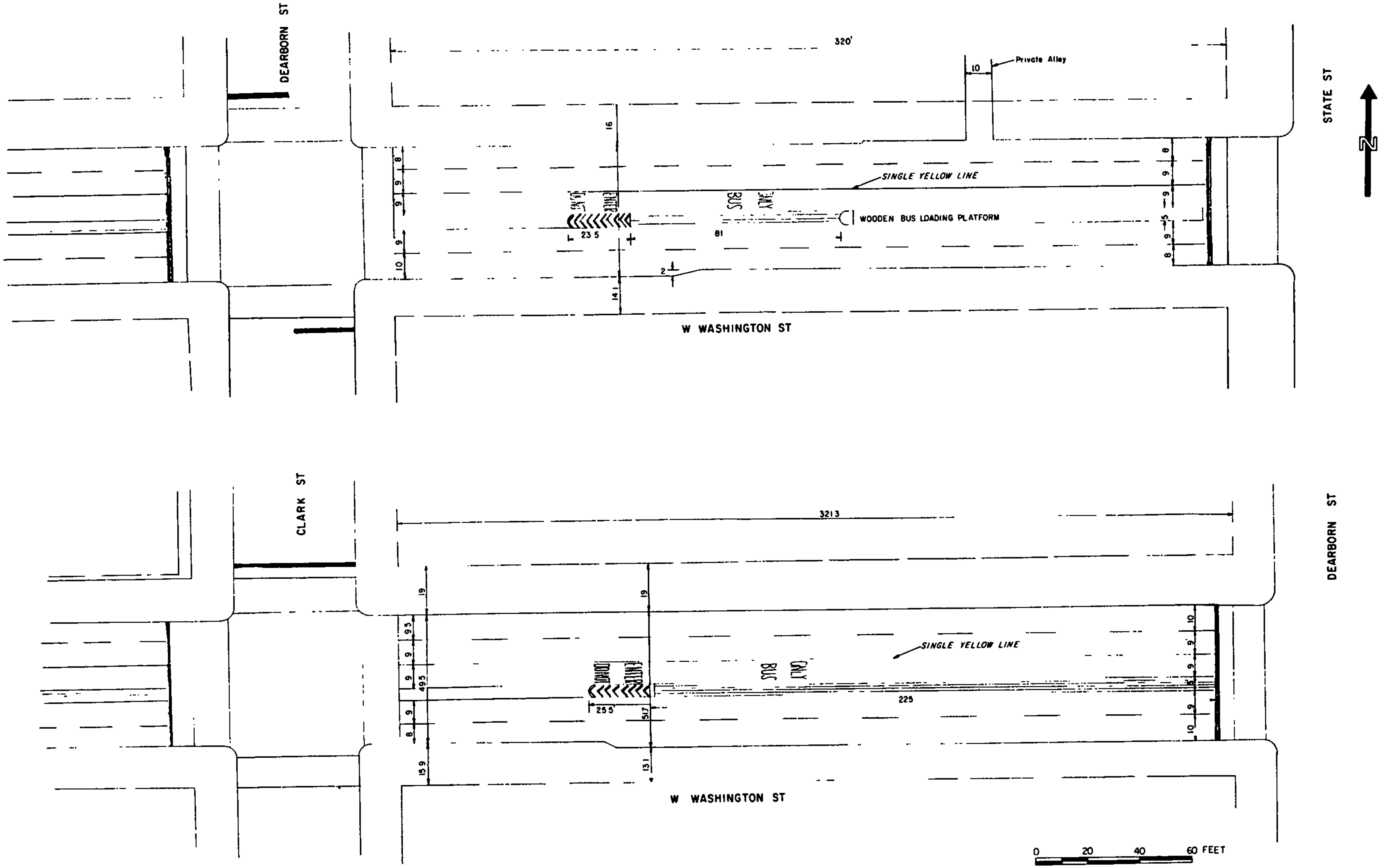


Figure C-10 Typical passenger loading island detail, Washington Street bus lane, Chicago, Ill



SOURCE City of Chicago
Bureau of Street Traffic

Figure C-11 Lane marking plan, Washington Street bus lane, Chicago, Ill.

Figure C-12. Canal Street contra-flow bus lane at Northwestern Station, Chicago, Ill.

The exclusive lane is separated from northbound traffic by a 2-ft-wide concrete "jiggle bar." (Initially, delineation was by means of a painted double yellow line). A mast arm-suspended sign reading BUS LANE, DO NOT ENTER was erected over the lane. At the north entrance of the bus lane signs reading ONE-WAY point to the usual northbound direction of Canal Street, and the south exit signs read NO LEFT TURN EXCEPT BUSES

On leaving the contra-flow lane, buses are required to turn left across northbound traffic on Canal Street. A special left-turn signal indication controls these bus movements. However, a police officer is regularly assigned to this intersection to assist turning buses as well as pedestrian crossings.

At Union Station

During May 1969 a southbound contra-flow bus lane was installed on Canal Street for 385 ft between Adams Street and Jackson Boulevard. Fifty-five buses on four bus routes use the lane during the peak hour. Buses serve approximately 6,700 boarding and alighting commuters daily at Union Station.

Figures C-14 and C-15 show this treatment. The bus lane is protected by a concrete median that separates southbound buses from northbound traffic. A fence along the median also prevents mid-block pedestrian crossings. Southbound buses turning left into Jackson Boulevard conflict with northbound traffic, this conflict could be eliminated by revising the signal controls to allow a special bus phase

Significance

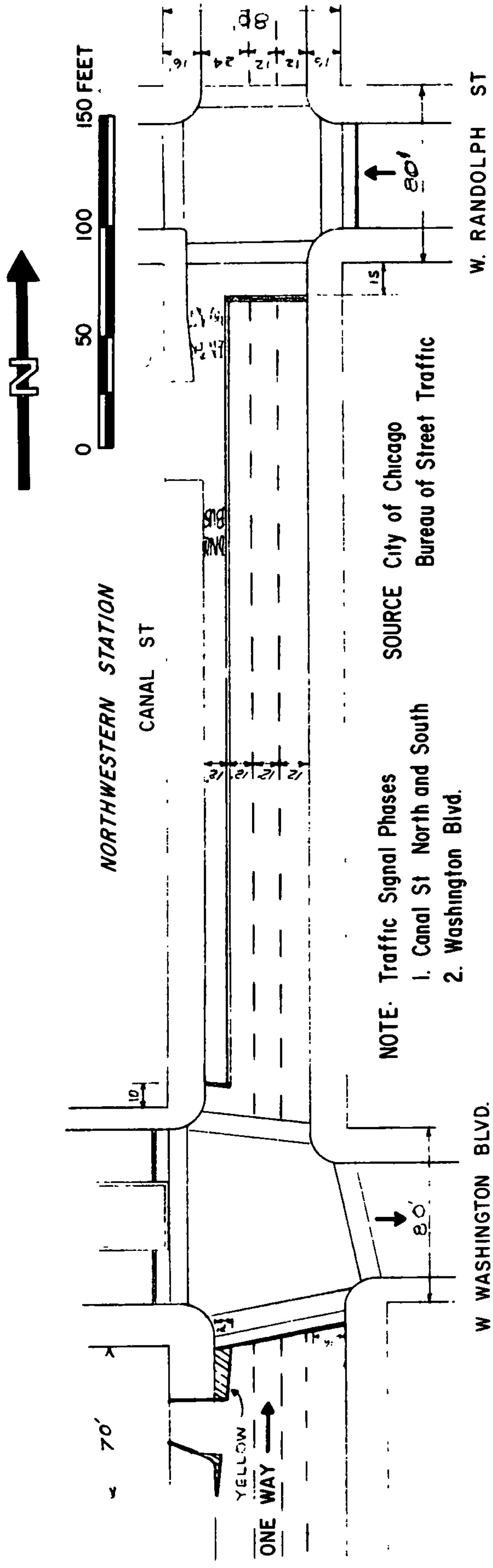
The two contra-flow lanes facilitate bus services operating as shuttles within the Chicago Loop district, providing downtown collection and distribution for line-haul commuter railroads Pedestrian safety is improved without reducing the level of service or safety for other traffic

Cermak Road Bus Lane and Signal

The westbound turn-around on the Cermak Road bus route requires a U-turn to be made at the intersection with 47th Avenue To separate buses from other traffic, an exclusive bus turn-around lane has been constructed in the north parkway area, and a special bus-only signal phase has been provided (Fig C-16) The signal phasing is designed to minimize vehicular delay. About 12 buses use this facility in the peak hour. This treatment clearly illustrates the application of conventional traffic engineering techniques to improve bus flows.

State Street Bus Lanes

On State Street in the Loop, buses operate both in the center lane and along the curb lanes Neither lane is exclusive, however, peak-hour bus flows represent approximately 25 percent of the total one-way vehicular volume and account for 90 percent of the peak person-flow Buses operating in both lanes make near-side stops. During special events an exclusive southbound lane is provided.



NOTE: Traffic Signal Phases
1. Canal St North and South
2. Washington Blvd.

SOURCE City of Chicago Bureau of Street Traffic

Figure C-13. Lane marking plan, Canal Street contra-flow bus lane at Northwestern Station, Chicago, Ill

Figure C-14. Canal Street contra-flow bus lane at Union Station, Chicago, Ill.

Lake Shore Drive Contra-Flow Bus Lane

A contra-flow bus lane is operated for special events on ten-lane Lake Shore Drive (Fig. C-17). The lane operates southbound for 0.6 miles between Balboa Drive and Soldiers Field In many respects the lane is functionally similar to the contra-flow lanes operated on the Long Island Expressway and I-495 in the New York Metropolitan Area However, Lake Shore Drive is a limited-access, traffic-signal-controlled facility, rather than a freeway Access to the lane is controlled by policemen stationed at the Balboa Drive entrance and by traffic lanes at the exit. The lane is also defined by traffic cones. (A similar-type treatment for bus departures from special events is being considered in design plans for the proposed New Jersey Sports Complex in the Hackensack Meadows near New York City)

Halsted and 63rd Bus Streets, Englewood

Englewood is the second-largest retail shopping center in the City of Chicago The Englewood Conservation Plan developed bypass roadways and peripheral parking around the retail core in an attempt to reduce the number of autos in the area and improve its quality as a pedestrian environment. Afternoon peak-hour traffic is approximately 700 vehicles southbound on Halsted Street and 250 vehicles on 63rd Sreet

The 63rd and Halsted Street busways, 990 and 1,320 ft long, respectively, traverse the heart of the shopping core (Figs C-18 and C-19). The busways are about 22 ft wide; narrowing the roadways enabled the sidewalks on both streets to be widened and plantings to be introduced In many respects, these treatments were the prototype for Minneapolis' Nicollet Mall. There are approximately 40 buses in the peak hour (total, both directions) on each bus street

North Sheridan Road Contra-Flow Bus Lanes

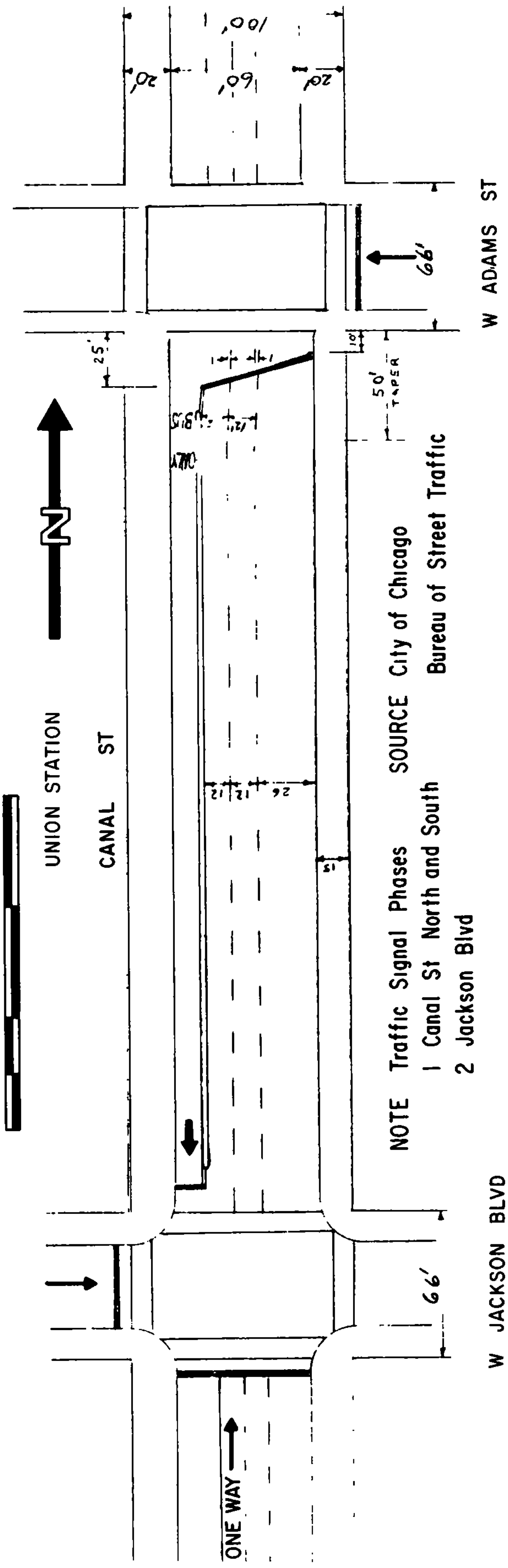
Peak-hour contra-flow bus and local traffic lanes were instituted on North Sheridan Road in 1939, as part of the Lake Short Drive reversible roadway operations plan Lanes are currently in operation between North Hollywood and Devon Avenues, a distance of 1 mile

The method of lane use is shown in Figure C-20. During the morning peak hour (when southbound auto traffic approximates 2,500 vehicles), there are three 10-ft southbound lanes and one 10-ft contra-flow (northbound) lane for buses and local traffic The procedure is reversed in the evening. Approximately 40 buses use the lane during each peak hour.

Lane designation is by slip-type traffic signs, which are unhinged by maintenance personnel during peak hours These signs are subject to vandalism and are currently being replaced to more effectively keep through auto traffic from using the bus lanes.

6. CLEVELAND BUS PRIORITY TREATMENTS

Cleveland, Ohio, has two bus priority treatments A contra-flow bus zone operates in Public Square (Fig C-21) and a reserved lane along Ninth Street serves events at Municipal Stadium (Figs. C-21 and C-22).



NOTE Traffic Signal Phases
1 Canal St North and South
2 Jackson Blvd

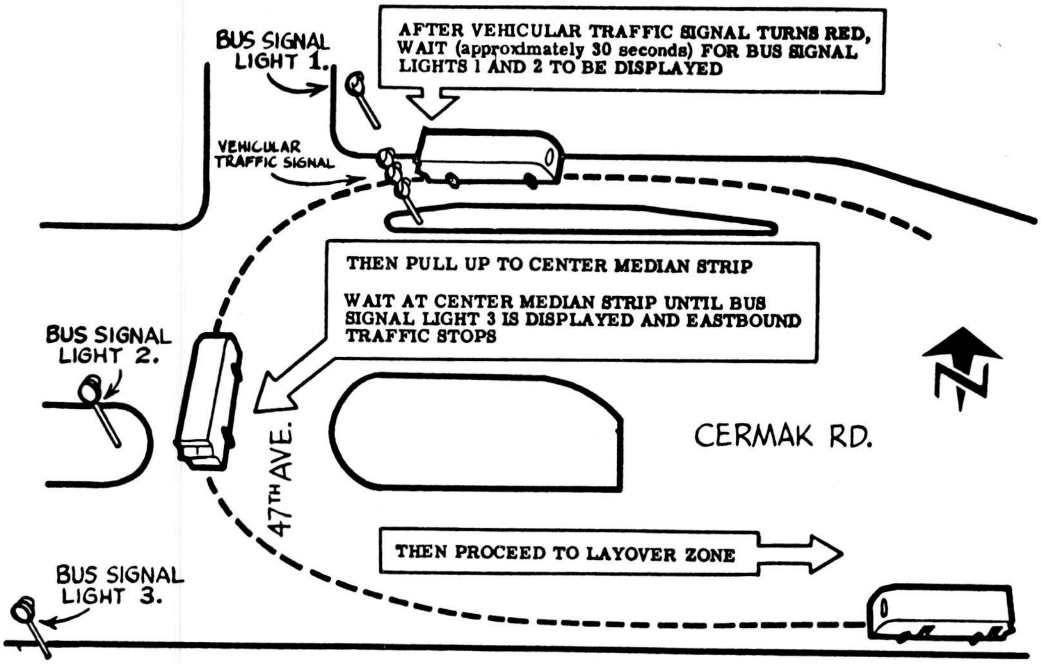
SOURCE City of Chicago
Bureau of Street Traffic

Figure C-15 Lane marking plan, Canal Street contra-flow bus lane at Union Station, Chicago, Ill

Public Square has been a major transfer and terminal point since street-railway operations. It accommodates transfers between bus and rapid transit routes as well as between bus lines. Automobile traffic is routed counterclockwise around the perimeter of the Square. A multilane, contra-flow bus zone is designated along key sections of roadway in a clockwise direction.

The reserved Ninth Street bus lane operates normal-flow

BUS TURNING PROCEDURES FOR CERMAK RD. BUSES AT 47TH AVE.


AFTER VEHICULAR TRAFFIC SIGNAL TURNS RED, WAIT (approximately 30 seconds) FOR BUS SIGNAL LIGHTS 1 AND 2 TO BE DISPLAYED

THEN PULL UP TO CENTER MEDIAN STRIP

WAIT AT CENTER MEDIAN STRIP UNTIL BUS SIGNAL LIGHT 3 IS DISPLAYED AND EASTBOUND TRAFFIC STOPS

THEN PROCEED TO LAYOVER ZONE

Figure C-16. Cermak Road bus lane and signalization, Chicago, Ill.

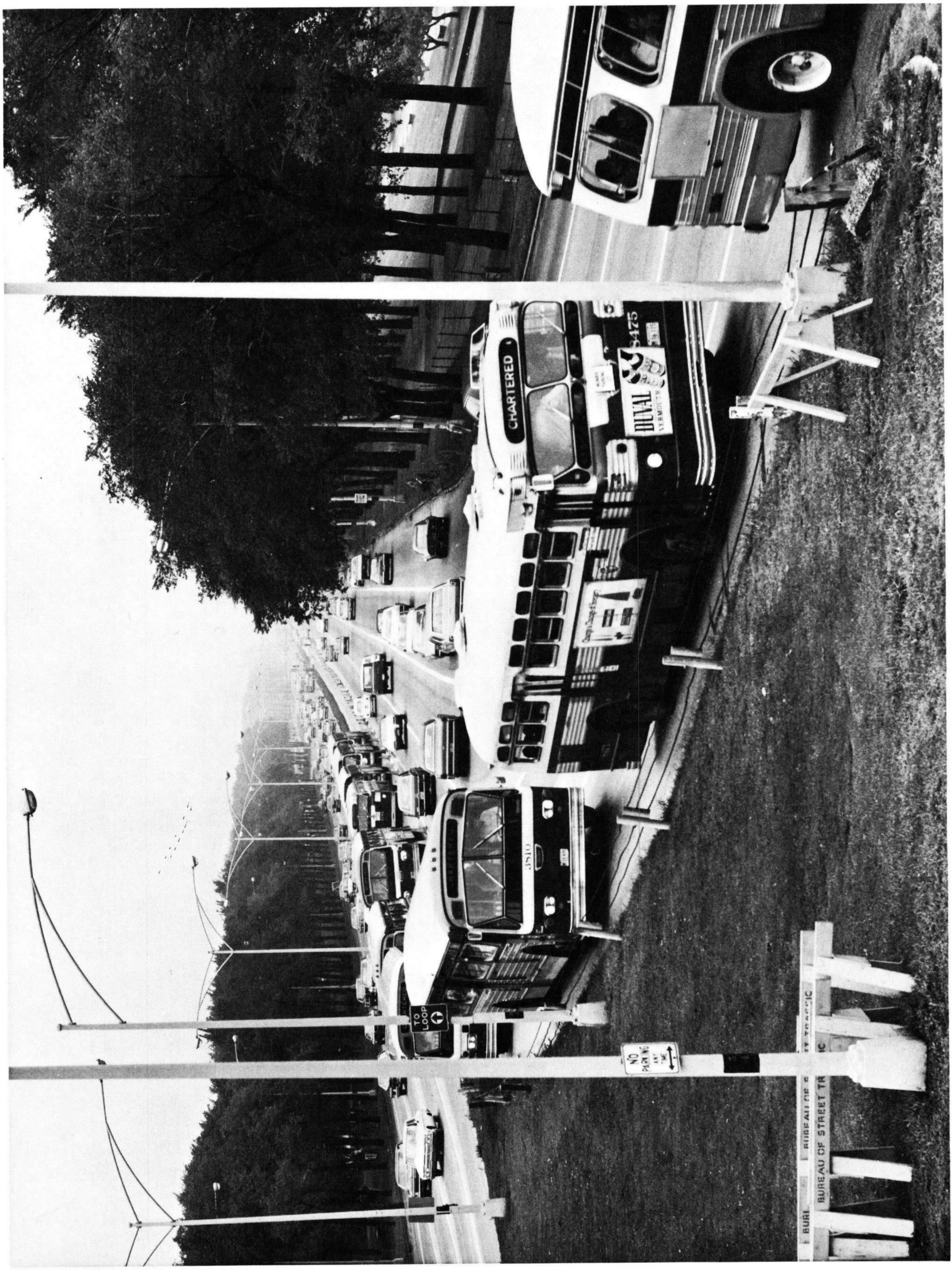


Figure C-17. Special events contra-flow bus lane, Lake Shore Drive, Chicago, Ill.

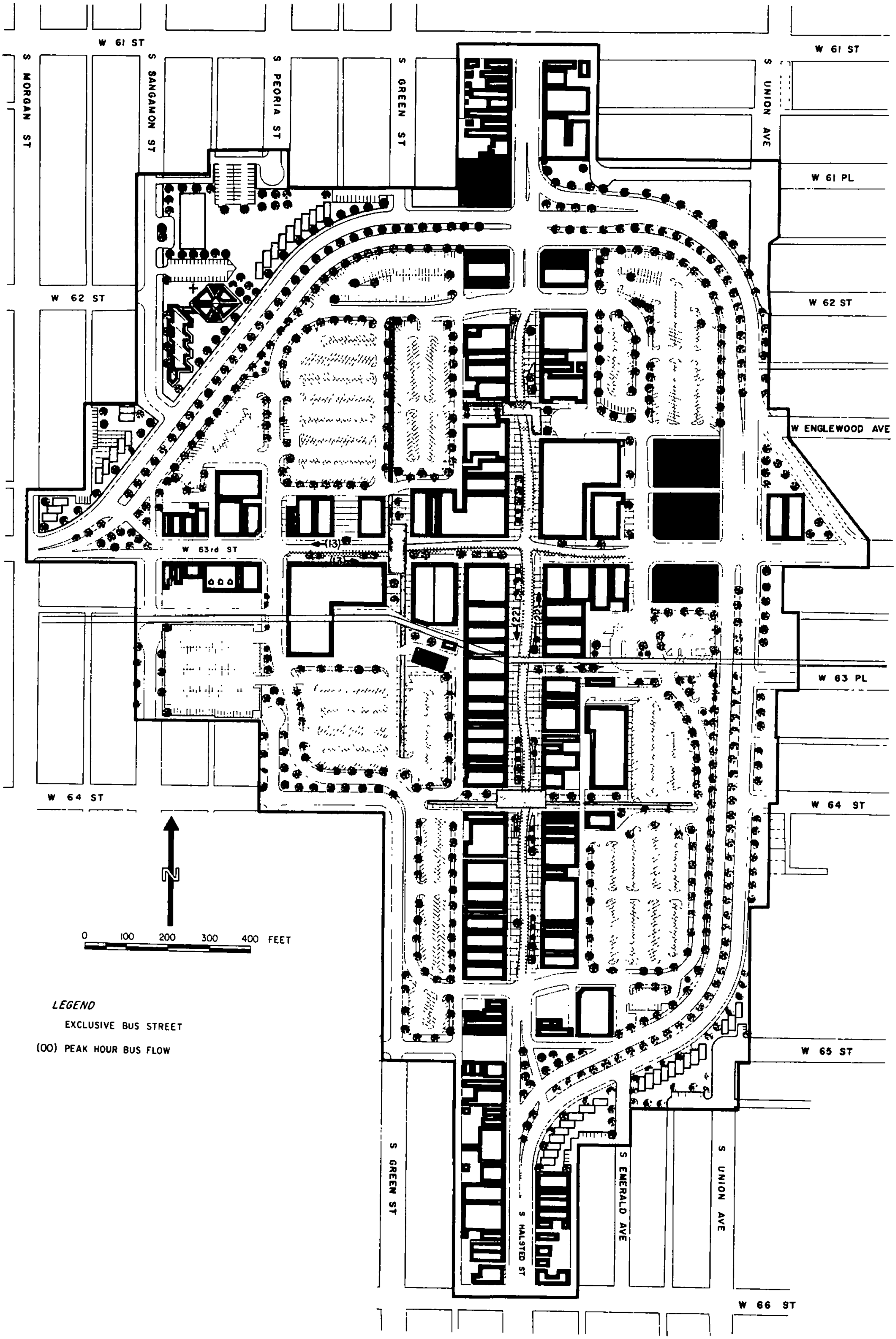


Figure C-18 Halsted and 63rd bus streets, Englewood, Chicago, Ill

Figure C-19. Halsted bus street, Englewood, Chicago, Ill.

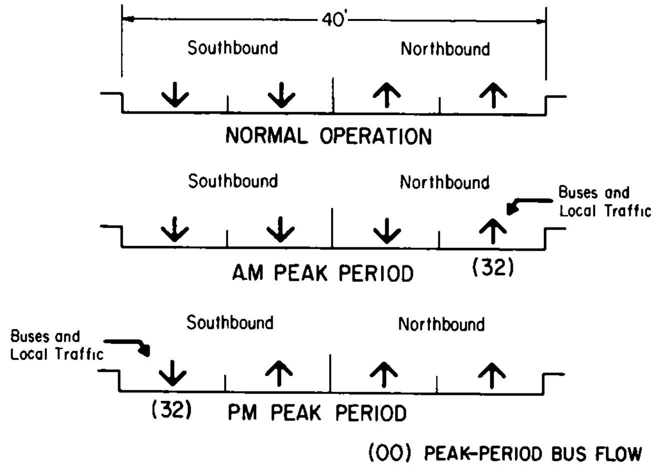


Figure C-20. Operational scheme, peak-period contra-flow bus and local traffic lanes, N Sheridan Road between N Hollywood and Devon Avenues, Chicago, Ill

along the curb. The lane, initiated September 1971, extends into a large parking lot east of and adjacent to the Cleveland Municipal Stadium at Lakeside Avenue It is placed in operation about 2 hours before game time. About 140 buses use the bus lane during a 2-hour period.

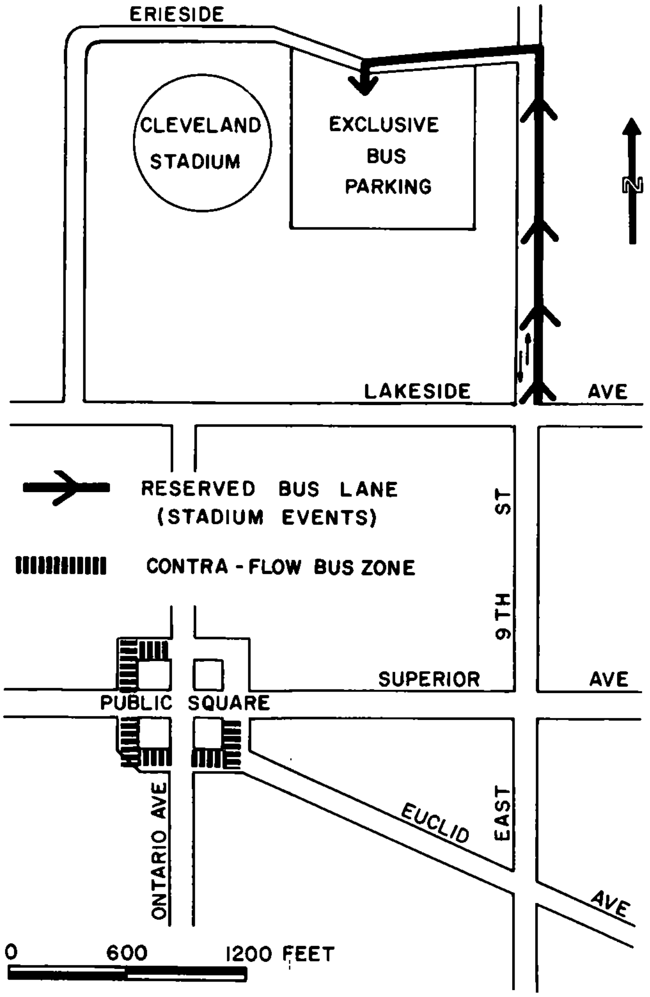


Figure C-21 Bus priority treatments, Cleveland, Ohio

7. DALLAS BUS PRIORITY TREATMENTS

The Dallas (Tex) Transit System fleet consists of 440 air-conditioned buses, all acquired within the last six years The system carries approximately 30 million revenue passengers yearly. Of the 285,000 vehicles that enter and leave the Dallas CBD on a typical weekday, 4,000 (1 3 percent) are transit buses, yet they account for 17 percent of all daily person-trips to the CBD. Bus passengers account for 12,000 of the Dallas CBD's maximum accumulation of 64,000 persons

Most of the city's 58 bus lines converge in the downtown area Main, Elm, and Commerce Streets, the city's east-west spine, accommodate about 300 buses in the peak hour Existing and proposed bus priority treatments are located on these streets (Fig. C-23)

Elm-Commerce Bus Lanes

Curb bus lanes were established on the Elm and Commerce one-way couplet in 1957. Each bus lane is approximately 0.55 miles long, and the distance between stops averages 460 ft. Near-side stops predominate, and right turns are allowed from the bus lanes. Black on white 24-by-30-in signs read CURB LANE BUSES ONLY 7-9 AM AND 4 30-6.00 PM EXCEPT SUNDAYS. Approximately 70 to 75 buses use each lane in the peak hour.

Main Street Busway Bus Lanes

Proposals have been made for a Main Street busway through the downtown area This could accommodate 100 buses each way in the peak hour, with the balance of buses operating in the Elm-Commerce bus lanes (*C-4*). Alternatively, if curb bus lanes are provided on Main Street, all vehicle turns except buses would be prohibited during morning and evening peak hours (*C-5*)

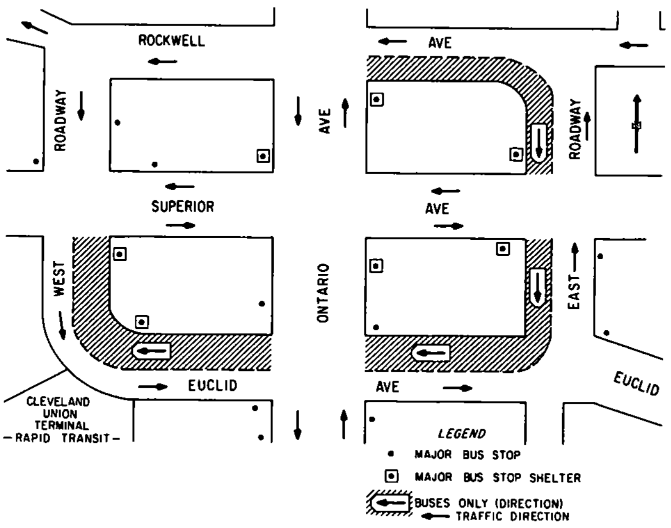


Figure C-22 Contra-flow bus zone, Public Square, Cleveland, Ohio

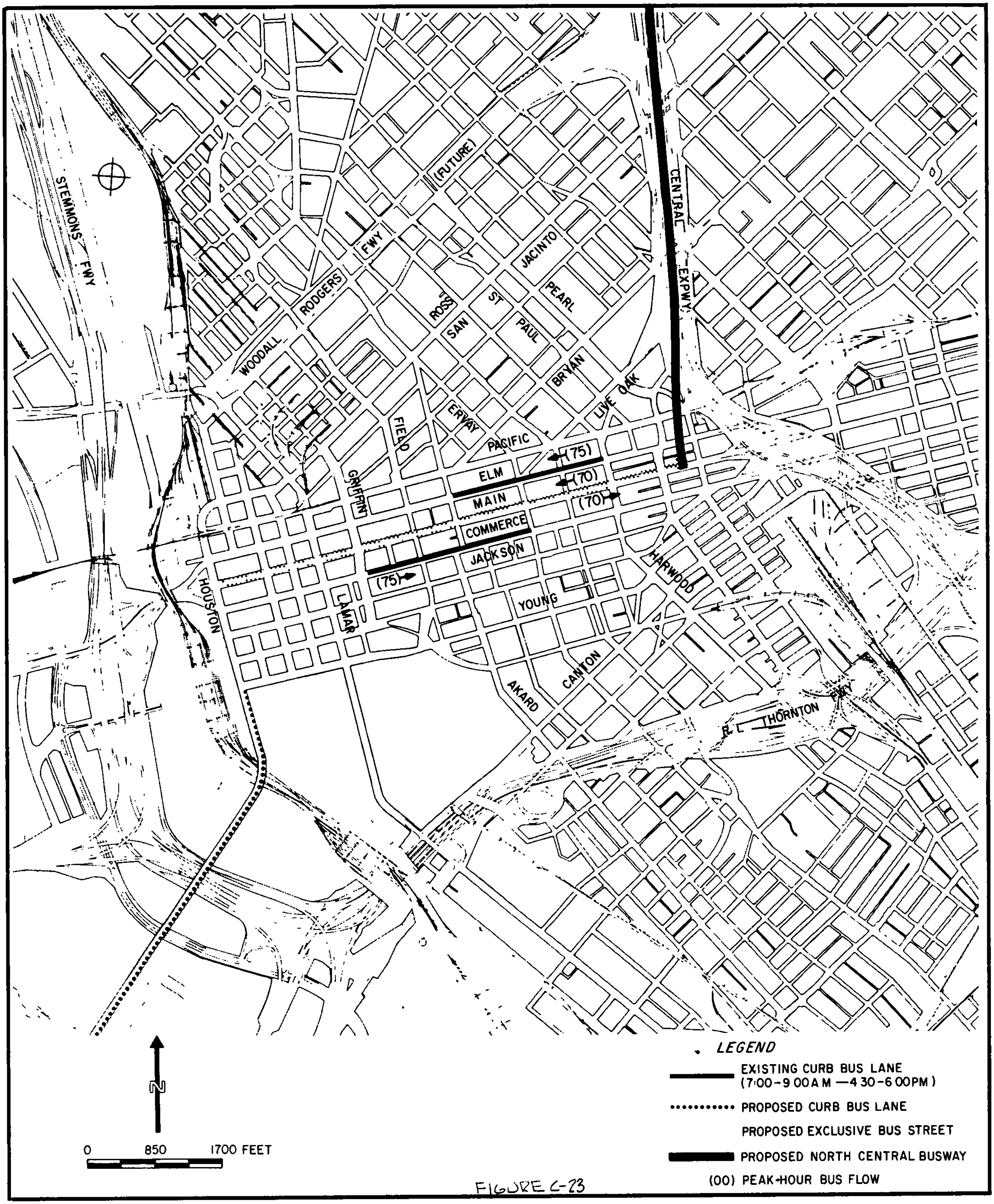


Figure C-23 *Bus priority treatments, Dallas, Tex*

Jefferson-Houston Viaduct Bus Lanes

The Dallas Immediate Action Transit Improvement Program (*C-5*), recommended exclusive curb bus lanes on (1) the Houston and Jefferson viaducts, (2) Jefferson Street from Trinity River to Young Street, AM peak-hour inbound; and, (3) Houston Street from Young Street to Trinity River, PM peak-hour outbound These lanes would give buses priority across major travel barriers.

8. HARRISBURG BUS PRIORITY LANES

The Harrisburg, Pa , Market Street bus lane, established in 1958, is one of the oldest contra-flow bus lanes in the United States The lane extends approximately one-half mile in the downtown area between Second and Fifth Streets It was initially installed as part of a downtown street routing improvement Because of the shortage of downtown streets, it was necessary to provide two-way east-west bus flow on one-way eastbound Market Street Approximately 20 buses use the lane during each peak hour, and midday bus flows range from 3 to 5 per hour. Traffic separation is by means of painted lanes and traffic cones Observance and enforcement are reported as good

Although the lane was initially opposed by merchants, it soon received acceptance. They funded minor pole relocations and corner widening to facilitate traffic operations and requested that all inbound buses from the north operate in the lane

Twice, certain merchants were able to convince traffic authorities to return Market Street to a two-way operation between First and Fifth Streets Both times, however, after about two weeks, most merchants requested the return of the exclusive contra-flow bus lane Except for these periods, it has been in effect continuously since 1958

The lane has functioned for nearly 15 years, even though the maximum bus flow has not exceeded 20 buses per hour This operation suggests that bus and street circulation requirements may be as important as the number of buses *per se*

9. HARTFORD BUS PRIORITY TREATMENTS

Downtown Hartford, Conn., contains approximately 20 million square feet of floor space and provides jobs for about 30,000 workers. When current development plans and the State Office complex are included, employment approaches 50,000 Accordingly, considerable emphasis has been placed on improved public transport.

Various bus priority proposals for downtown Hartford are shown in Figure C-24. Curb bus lanes have been proposed along streets with major bus flow at locations where traffic congestion occurs A Main Street busway was proposed in the City Plan of 1971 to improve amenity and service in the retail core This bus street concept clearly illustrates how buses can penetrate commercial areas with automobiles diverted to peripheral streets In this context, the bus street is prototypical for similar bus malls in other cities.

10. HOUSTON BUS PRIORITY TREATMENTS

Rapid Transit Lines, a private company, provides bus service in Houston, Tex The company's 375 buses carry 32 million passengers annually over 750 route-miles at a base fare of $0 45, plus an additional $0 05 per zone up to five zones. There is a special student fare of $0.20

Arterial-Bus Priority Concept

In the past, the transit company expressed comparatively little interest in bus lanes on freeways, because Houston's freeways are poorly located relatively to transit corridors. They preferred placing bus lanes on arterial streets. In 1970 the company developed a comprehensive plan for arterial street bus lanes This plan (Fig. C-25) is similar to proposals advanced more than a decade ago in St. Louis, Mo.

The proposed Suburbia Limited services would incorporate 14 express bus lines, radiating up to 12 miles from downtown Each bus route would serve two or three park-and-ride terminals. Some 37 terminals were proposed, 12 would be at drive-in theatre lots and 25 at city parks, where ample parking would be available (and where parking peaks normally occur on evenings and weekends). The peak-ride locations were selected according to population and employment concentrations Eight terminals would be located within 5 miles of downtown, 20 within a 5- to 10-mile radius, and nine beyond 10 miles (*C-6*)

Buses would be scheduled to run express between the terminals and the CBD One hundred and twelve buses would be used in peak-demand periods, as compared with a present system-wide use of 330 buses in peak hours. They would provide service over 188 5 route-miles, with 29 miles of street having either reserved curb lanes for buses in peak hours or a reserved bus lane in the middle of the street (Table C-6) These routes have sufficient capacity in peak hours to assure reliable operation. The transit operator believes that once the lanes are reserved for buses, additional measures (such as traffic signal preempts) may not be needed.

The system's current average running speed is 13 mph. The proposed system is expected to achieve speeds of 19 to 21 mph

At drive-in theatre lots used for park-and-ride, the company would encourage theatre owners to collect a moderate all-day parking fee, with the owner responsible for security. The theatre parking area would be available at night for regular use. At selected city parks, parking would presumably be free, and only existing parking spaces would be used.

Main Street Bus Lanes

Curb bus lanes were established on Main Street between Franklin and Leeland Avenue (14 blocks) in the downtown area in 1971 The curb lanes are reserved for buses and right-turning cars from 7 00 AM to 6.00 PM daily (Fig. C-26).

Eleven bus lines, involving 1,270 daily bus trips, including shoppers' special service, use the lanes. About 10 percent of all daily bus trips are made in each peak hour

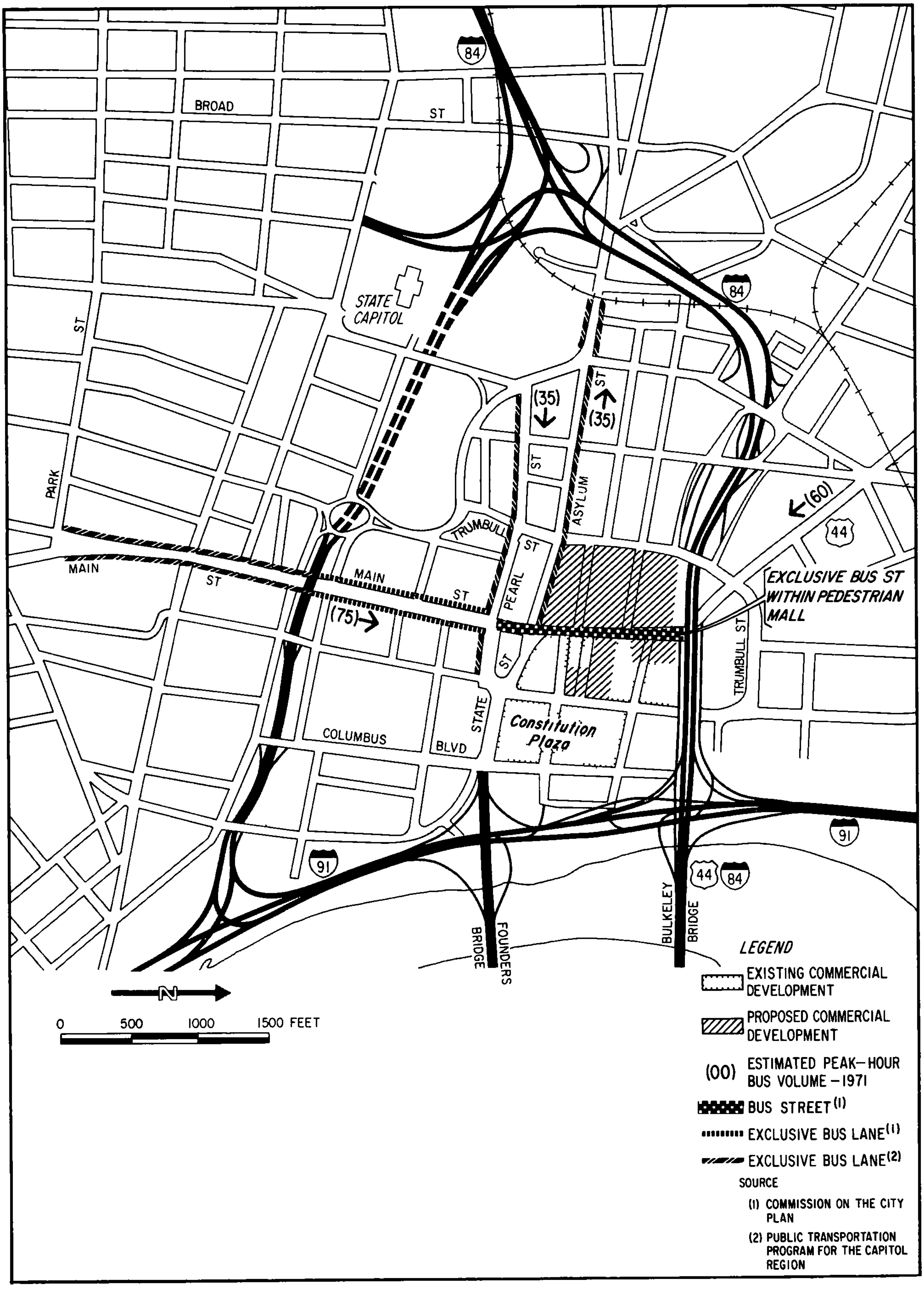


Figure C-24 Proposed bus priority treatments, Hartford, Conn.

Peak-period bus occupancy averages 46 persons Thus, each bus lane has a peak-hour occupancy of about 3,000 people.

The bus lanes have increased bus speeds on Main Street, permitting better schedule adherence No detailed data on the speed increases are available

11. KENT BUS-ACTUATED TRAFFIC SIGNALS

A demonstration project was conducted in Kent, Ohio, (population 28,000) to determine the impact of a bus-traffic signal priority system on auto and bus movements The study was conducted by Kent State University for the Urban Mass Transportation Administration

Project Location

The project was located along a 0 4-mile section of East Main Street (State Route 59) This narrow four-lane street borders Kent State University on the north. It carries 18,000 vehicles on a typical 12-hr weekday, and peak-hour volumes (total, both directions) approach 2,000 vehicles.

The five-block study area extends from Midway Drive to Hilltop Drive (Fig C-27). Three signalized intersections (Hilltop-Linden, Terrace, Midway) were controlled by uncoordinated signals prior to the demonstration

Bus Service

The Campus Bus Service runs 27 buses, 18 of which operate throughout the day. The other buses are used for special purposes only, such as field trips or reserve vehicles in case of breakdown. No fares are charged. Five bus routes carry nearly 20,000 passengers on each school day. Nearly 1,100 persons are carried on each vehicle per day, a rate of productivity that is reported comparable to large cities such as Baltimore and Philadelphia Bus headways average about 3 min eastbound and 5 min westbound along East Main Street.

Traffic Control Changes

Prior to the experiment independent fixed-time controllers operating on an 80-sec cycle controlled the three intersections Signal progression was random and all traffic experienced delays.

To improve the level of traffic service, the three controllers were interconnected. The green phases on Hilltop, Terrace, and Midway Drives were converted to semi-actuated operations with the signals normally set for East Main Street traffic. Pedestrian-actuation push buttons were installed at Terrace and Midway, the traffic controller at Hilltop Drive was automatically set to give at least 13 sec of green time in each cycle to that side street to accommodate heavy pedestrian flows The minimum green time on the other side streets depended on whether or not pedestrian push buttons were actuated.

Two-phase operation was provided at all three intersections with a maximum side-street green time of 20 to 24 sec. A minimum green time for East Main was established as the overriding warrant

A bus signal priority system was installed after the signals were coordinated. This gave the bus operator additional green time on East Main when he activated the signal by means of a foot-pedal in the bus. When the cycle was green for East Main, the bus driver would extend the signal for about 7 sec When the signal was red for East Main, the controller returned to green as soon as the minimum side street green time (usually 10 sec) had elapsed.

Evaluation

Travel time and delay studies conducted before and during the demonstration project are summarized in Table C-7. The major reductions in vehicle travel times resulted from coordination of the traffic signals. Average auto speeds increased from about 20 mph to 23 mph as a result of traffic signal interconnection

Bus preemption of traffic signals resulted in about a 10 percent increase in bus speeds—from 12.0 to 13.3 mph eastbound on Main Street These speed gains were accomplished with only a minimum reduction in auto speeds Part of this decrease was attributed to slightly increased traffic on side streets

Automobile waiting times on side streets were not noticeably affected by the bus priority system when traffic was light. However, during peak 5-min periods automobile queuing increased on side streets. The peak-hour queues on traffic entering Main Street from Terrace Drive increased from 6 to 19 as a result of traffic signal changes.

The study suggests that bus travel times can be reduced through improved traffic signal control equipment and timing. It also suggests that driver-controlled signal preempts are technically feasible and can function within the broader framework of over-all signal network coordination

12. LOUISVILLE BUS PRIORITY LANES

Bus priority treatments in Louisville, Ky , represent early action projects implemented as an outgrowth of the Louisville Urban Corridor Demonstration Program (*C-7*) They focus on improved mobility in the South Corridor of the city (Fig C-28).

Existing Contra-Flow Bus Lanes

Contra-flow bus lanes were installed on Second and Third Streets north of Avery Avenue in October 1971. The east curb lane on Third Street accommodates northbound buses from 7 00 to 9.00 AM; the west curb lane on Second Street serves southbound buses from 4:00 to 6:00 PM. Parking, stopping, and standing are prohibited in these lanes. The lanes are delineated by yellow pavement markings.

Route Characteristics

Three express bus lines use the lanes and operate on a combined 5-min headway The Iroquois Park buses (Route 4) depart from a new 175-car parking lot at New Cut Road and Kenwood Drive. The International Harvester buses (Route 2) begin at that plant. The third route operates from Auburndale. All three routes operate only during the morning and evening rush hours The express service costs the Louisville Transit Company about $1.00 per bus-mile to operate.

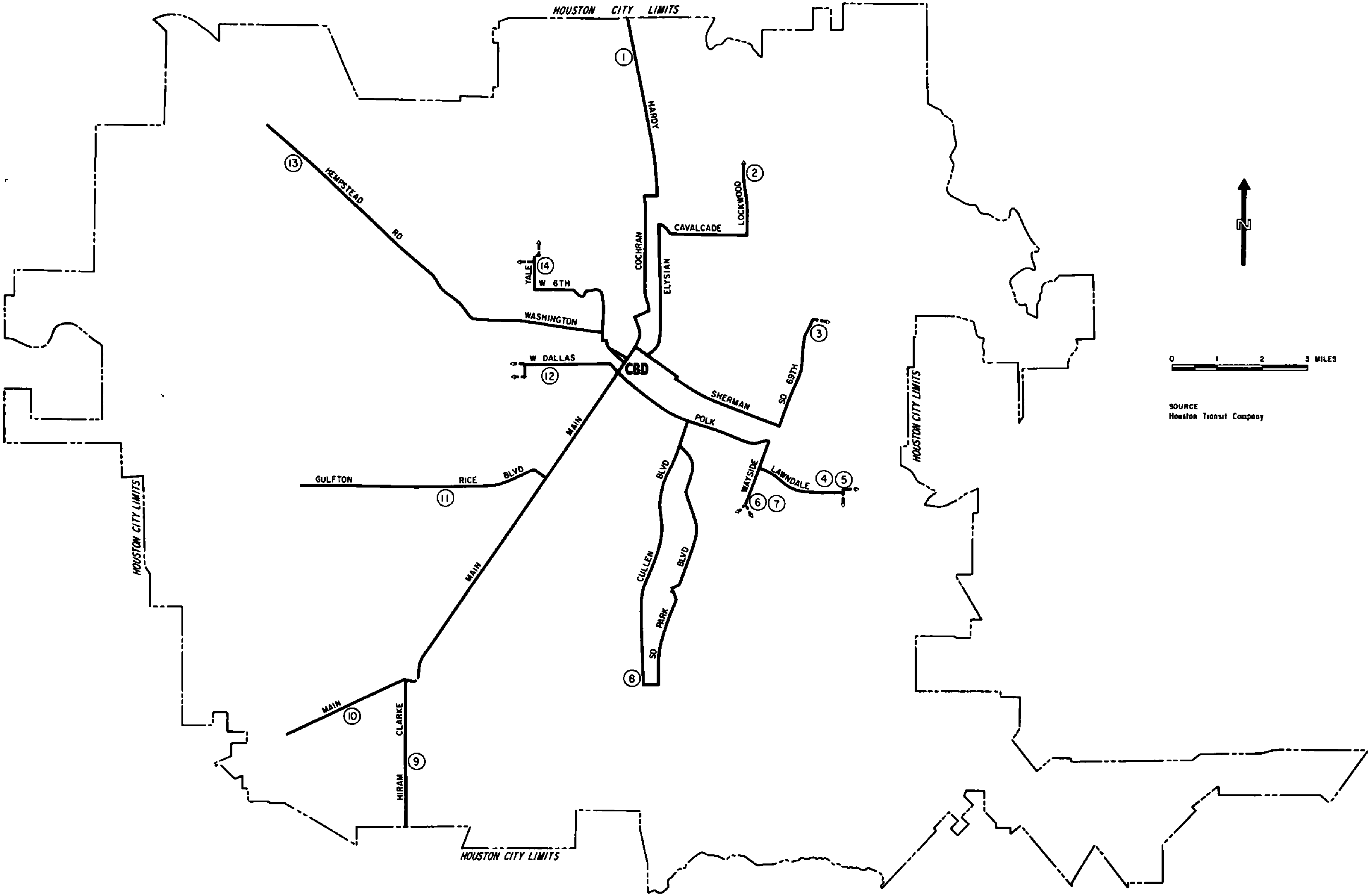


Figure C-25. Proposed arterial curb bus lanes, Houston, Tex.

TABLE C-6

PROPOSED ARTERIAL STREET BUS PRIORITY LANES, HOUSTON, TEX

ROUTE AND PROPOSED STREET	FROM	TO	LENGTH OF RESERVED BUS LANES (MI)
1 Cochran	Brooks	North Loop	3.35
2 Elysian	Commerce	Cavalcade	3 00
3 Sherman	Commerce	69th	3 20
4–8 Polk	Fannin	Wayside	3 70
9–11 Main	Texas	Hiram Clark	9 60
12 West Dallas	Main	Dunlavy	2 10
13 Center Street [a]	Houston Ave	Hempstead Hwy	3 00
14 Houston Ave	Reisner	White Oak	1 00
All			28 95

Source Ref (C-6)

[a] Street would need major improvements

Use Characteristics

The typical bus rider, before the express service began, was a women without a car who traveled to and from work. Post evaluation studies showed that express bus riders were diverted from (a) local bus service and (b) the automobile Most riders were women; however, many had cars available for their trip.

Express ridership increased from 9,800 in November 1971 to 12,000 in March 1972. Local service, however, declined from 15,600 to 11,300 persons during this same period. Monthly revenue ranged from $4,900 to $4,800, costs were constant at about $11,500 per month.

The 175-space Iroquois Park parking lot is used by about 44 vehicles. About two-thirds of all park-ride patrons use this lot.

Safety

Two accidents occurred with the expess bus operation. In both cases there were no personal injuries and the automobile driver was cited for failure to yield the right-of-way.

Benefits

The extended express bus service in conjunction with the peak-hour contra-flow bus lanes has reportedly produced a 25 percent time savings between the CBD and the park-and-ride facilities. Preliminary patronage data indicate that the express bus service carries about 250 adult riders on a typical day, of which 160 were previously automobile riders and 90 are transfers from other bus routes. About one-half of all passengers are carried on the Iroquois Park route.

Proposed Bus Lane Extensions

The Urban Corridor program proposed extensions of the contra-flow bus lanes southerly on the Third-Fourth Street one-way couplet. (1) northbound contra-flow lanes would be provided on the Fourth Street-Oakdale Avenue connection between Southern Parkway and Brandeis Avenue, and (2) southbound contra-flow lanes would be provided on Third Street between Avery and Oakdale Avenues.

The following street routing changes would be implemented in conjunction with the bus lanes.

1. Third Street would become one-way northbound for cars between Oakdale and Brandeis Avenues, with curb parking prohibited from 4:00 to 6:00 PM daily

2 Fourth Street would become one-way southbound be-

Figure C-26. Signs and markings, Main Street bus lane, Houston, Tex

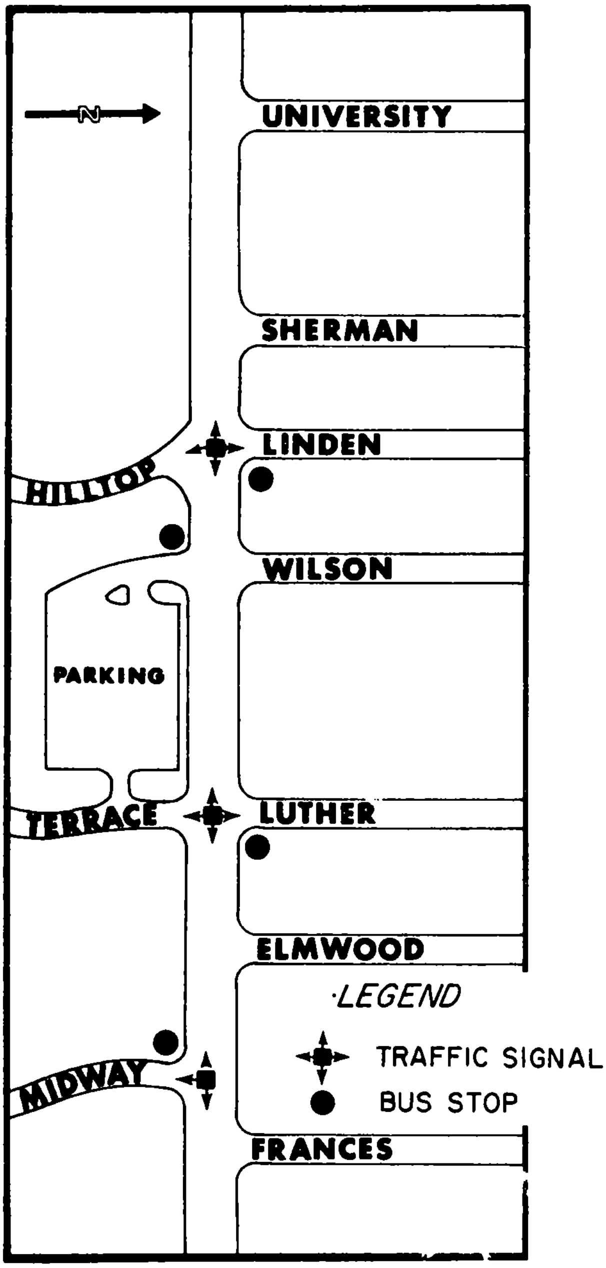


Figure C-27 Bus priority signals, Kent, Ohio

tween Brandeis and Oakdale Avenues, with curb parking prohibited from 7 00 to 9 00 AM daily

3 Oakdale Avenue would become one-way southbound between Fourth Street and Southern Parkway, with curb parking prohibited from 7 00 to 9 00 AM daily

Lane availability analyses indicate that these changes would not alter the number of northbound and southbound traffic lanes available to traffic For example, between Brandeis Avenue and the Third Street-Southern Parkway-Oakdale Avenue intersection, four lanes exist in both directions (two lanes north on Third Street and Fourth Street, two lanes south on Third Street and Fourth Street). Conversion of Fourth Street to southbound and Third Street to northbound between these two points does not alter the lane availability (four lanes north on Third Street, four lanes south on Fourth Street)

The success of this project depends on Eastern Parkway being extended westward from Third to Fourth Street and becoming a one-way connection between the two arteries The project also depends on proper transition between Second and Fourth Streets at Brandeis Avenue Although the Eastern Parkway extension is the critical roadway improvement, it is also crucial to general transit service Maximum 1975 peak-hour (directional) volumes would approximate 1,700 vehicles on Third and Fourth Streets if these projects were implemented

The cost of reversing 1.5 miles of bus lanes on the Fourth Street-Oakdale Avenue connection between Southern Parkway and Brandeis Avenues and on Third Street between Avery Avenue and Southern Parkway is estimated at $9,200 (Table C-8).

The corridor program recommends placing bus-actuated traffic signals at various points in the city. Funding was provided for installation of 13 remote-actuation devices and 13 transmitters as part of the Early Implementation Program An additional 26 intersections are suggested for bus-actuated signals along major arterials such as Taylor Boulevard, Fourth Street, Southside Drive, Seventh Street, Berry Boulevard, and Park Boulevard About 350 new BUS

TABLE C-7

COMPARATIVE BUS AND CAR TRAVEL SPEEDS, KENT, OHIO[a]

		AVERAGE SPEED (MPH)			AVERAGE DELAY (SEC)		
LOCATION	DIST (MI)	BEFORE	INTER-CON-NECTED SIGNALS	BUS PRIORITY SIGNALS	BEFORE	INTER-CON-NECTED SIGNALS	BUS PRIORITY SIGNALS
Buses on East Main, EB	0 4	N A	12 0	13 3	N A	22 0	13 0
Buses on Hilltop and East Main, EB	0 3	8 2	8 5	9 0	32 5	28 5	17 0
Autos on East Main, EB	0 4	19 5	24 5	23 7	N A.	N A	N A
Autos on East Main, WB	0 4	20.8	22 7	21 5	N A	N A	N.A

Source Ref (*C-30*)

[a] All measurements taken eastbound except as noted, delay recorded at traffic signals only

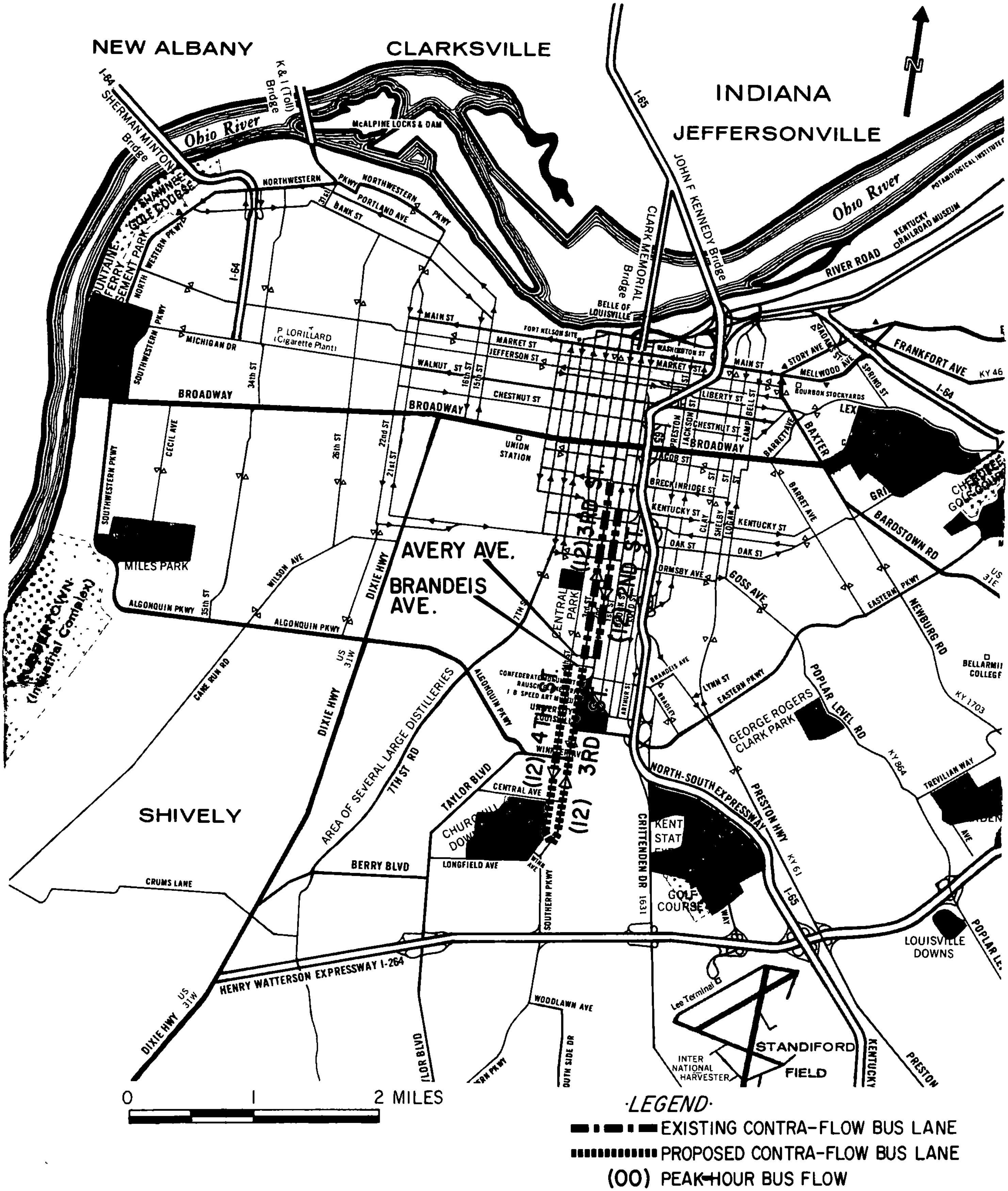


Figure C-28 Bus priority treatments, Louisville, Ky

STOP signs and the construction of about 40 bus shelters were also recommended.

Significance

The Louisville contra-flow bus lanes are significant in several important respects: (a) They extend outward along arterials and are not limited to the CBD; (b) they represent a statement of public policy toward bus use, in that peak-hour bus volumes on many sections of the route are less than 20 buses per hour; and (c) they represent the contra-flow use of a street for only part of the day.

13. MADISON CONTRA-FLOW BUS LANE

A contra-flow bus lane was installed in Madison, Wis., along 2.2 miles of University Avenue in conjunction with the inauguration of a one-way street couplet in October 1966. University Avenue was made one-way westbound; Johnson Street, parallel to it, was designated as the complementary eastbound route. The one-way street couplet and contra-bow bus lane are shown in Figure C-29.

The bus lane was located in University Avenue for two reasons: First, it provided better access to the University of Wisconsin; second, it permitted four automobile travel lanes on each street. The eastbound bus lane was separated from four lanes of auto traffic on University Avenue by a 4-ft wide concrete platform.

Use

Daily traffic volumes on the one-way couplet increased from 36,500 to 44,200 vehicles, a 21 percent gain. Simultaneously, accidents decreased 9 percent, from 270 to 220 when the years before and after the one-way pair were compared. Between November 1967 and October 1969, 26 bus lane accidents were reported, as compared with 278 other accidents on University Avenue.

The eastbound bus lane brought approximately 1,900 riders one block closer to their destinations. It also eliminated the need for these people to cross Johnson Street (24,000 vehicles per day). About 170 buses used the lane daily.

Safety

When the bus lane was placed into effect, there was little adverse public reaction to either the bus lane or the one-way operations. This changed when a serious pedestrian accident on March 11, 1967, resulted in a pedestrian losing one leg and a consequent $200,000 suit against the bus company and the city.

Legal Implications

The accident produced a sudden change in public opinion and precipitated legal questions. The Wisconsin Supreme Court held that the bus lane was illegal because it discriminated against the right of access to street by all vehicles. The Supreme Court Chief Justice ruled on October 9, 1970: "We think the trial court was correct in concluding 'free use of all highways' meant accessible to everyone. No matter how liberally we continue the police power of a City in relation to its streets, we cannot find the right to discriminate against the general public's use of a one-way lane on a street for the benefit of only buses and taxicabs. . . . If the City needs such power to discriminate in the use of a public street, it must seek it from the Legislature."

TABLE C-8

ESTIMATED COSTS, THIRD AND FOURTH STREETS CONTRA-FLOW BUS LANES, LOUISVILLE, KY.

ITEM	COST ($)
50 signs reading CURB LANE BUSES ONLY 7 AM–9 AM EXCEPT SATURDAY AND SUNDAY	1,300
50 signs reading NO PARKING 7 AM–9 AM EXCEPT SATURDAY AND SUNDAY	1,300
50 signs reading CURB LANE BUSES ONLY 4 PM–6 PM EXCEPT SATURDAY AND SUNDAY	1,300
50 signs reading NO PARKING 4 PM–6 PM EXCEPT SATURDAY AND SUNDAY	1,300
Striping approximately 3 miles of reserved bus lanes	3,000
50 Traf-flex posts to be mounted in the pavement at each intersection to prevent autos from entering the bus lane	1,000
Total	9,200

Source Ref (*C-7*)

Limited-Use Lane

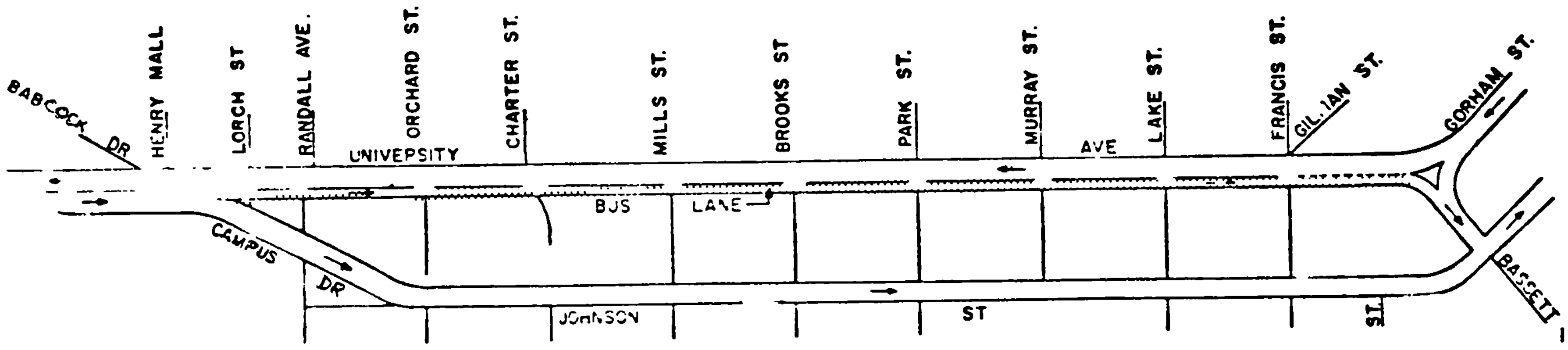
As a result of this court decision, the city converted the bus lane into a "limited-use" lane. By signs and markings, all vehicles that use the lane must enter it at its beginning (Campus Drive) and traverse its entire length to the terminus (Gilman Street).

14. MINNEAPOLIS-ST. PAUL BUS PRIORITY TREATMENTS

The Twin Cities Area Metropolitan Transit Commission (MTC) was established in 1967 and charged with preserving and expanding transit services in the Minneapolis-St. Paul, Minn., urbanized area. Initially its primary source of revenue was an annual levy of $1.00 on every motor vehicle garaged in seven contiguous counties (Amoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington; total 1970 population, 1,874,000).

The 1971 Minnesota Legislature prohibited further collection of this tax and replaced it with a general property tax of up to 2.9 mills, limiting it to incorporated "urbanized" municipalities within the seven-county area. This tax yields about $5 million yearly, based on current assessed valuation.

In September 1970 the Commission established a Transit Operating Division and took over the Twin Cities Lines, which accounts for 95 percent of the bus ridership in this area. ATE Management and Service Company, a private transit management firm, was selected to manage the Transit Operating Division. Free transit service is provided to senior citizens during nonpeak hours



SOURCE RICHARD MADRZAK, FEDERAL HIGHWAY ADMINISTRATION

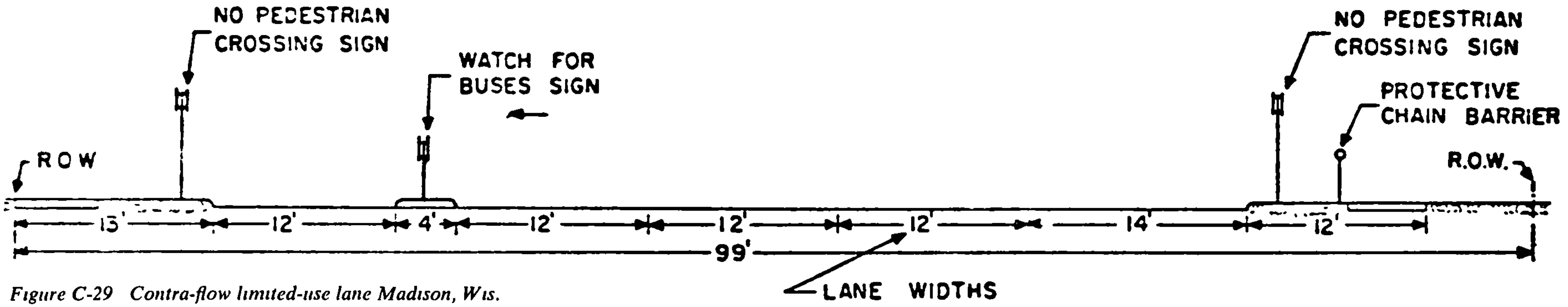


Figure C-29 Contra-flow limited-use lane Madison, Wis.

MTC now operates 630 buses. Since public ownership ot the Twin Cities Lines, service was increased and ridership gained 3 percent in 1971 Daily ridership is about 170,000 In both the Minneapolis and St. Paul central business districts, 30 percent of peak-hour person-trips are by transit

Existing and proposed bus priority treatments in downtown Minneapolis are shown in Figure C-30 A more detailed discussion of the I-35W Urban Corridor treatment in Minneapolis is presented in Appendix B.

Nicollet Mall

An eight-block section of Nicollet Avenue in downtown Minneapolis was renamed Nicollet Mall in April 1968. The street was closed to all vehicular traffic except buses, and all street space except for two bus lanes was redeveloped into pedestrian walkways, landscaping, and other amenities. Development cost about $3 8 million, of which $1.3 million was for above-ground improvements (*C-8*).

The Mall is a totally restructured area, radically redesigned for pedestrians, buses, and occasional taxis and other special-purpose vehicles. These vehicles use a two-lane, approximately 24-ft-wide serpentine roadway The rest of the right-of-way is devoted to pedestrian movements —to special facilities such as heated bus shelters and a self-service post office—and landscaping (Fig. C-31). The Mall penetrates the Minneapolis retail core.

Specific planning objectives underlying Mall development were: (1) to improve pedestrian circulation in terms of efficiency and comfort in an area of severe winter weather, (2) to improve access and encourage public transportation use by making transit more attractive, by relocating bus lines to provide more direct service to the retail area, by creating good pedestrian access, and by generally reducing traffic congestion; (3) to promote the retail area and the central business district by building on the image of Nicollet Avenue as the prime retail center of the Upper Midwest, and (4) to encourage private investment The transitway was an integral part of these objectives However, it is clear that general economic and environmental considerations were key factors in implementing the Mall.

Initially, conventional transit buses used the Mall. In March 1971 a QT (Quick Transit) bus service was added, involving acquisition of air-conditioned 12- to 17-passenger minibuses, for a total cost of $177,120, with a two-thirds capital grant from UMTA Two bus lines provide both north-south service on the Mall and east-west service throughout the CBD core area for a $0 10 fare, which includes free transfers between the two QT lines.

The north-south QT bus operates from 9 00 AM to 6 00 PM daily except Sunday, and until 9:30 PM Monday and Thursday evenings The east-west crosstown QT bus runs from 7 00 AM to 6:00 PM Monday through Friday Patronage on the Mall line ranges from 12,000 passengers per week during summer and early fall to 18,000 during busy shopping weeks Patronage on the Fourth and Fifth Street lines remains relatively constant at 3,500 to 4,000 passengers per week (Table C-9).

Including the QT buses, Nicollet Mall carries 64 buses in each direction during each peak hour Despite the absence of other vehicular traffic, bus speeds are slowed by pedestrians, who make frequent mid-block crossings

Proposed Contra-Flow Bus Lanes

Plans are under way to develop contra-flow bus curb lanes on two one-way streets (South Marquette and South Second Avenues) parallel to Nicollet Mall The two streets penetrate the office core, and would improve bus service to and from I-35W, where ramp metering with bus priority bypass lanes is planned The bus-only lanes would use the

TABLE C-9

PASSENGER TRENDS ON BUSES, MINNEAPOLIS, MINN.

		TOTAL PASSENGERS CARRIED		
ITEM	PERIOD	MALL	4TH–5TH	TOTAL
Weekly average, 1st six weeks	3/8/71 — 4/17/71	11,650	3,294	14,944
Weekly average, next nine weeks of operation (after change in service)	4/19/71 — 6/19/71	12,071	3,760	15,831
Weekly average, 1st 15 weeks (90 days)	3/8/71 — 6/19/71	11,902	3,574	15,476
Weekly average, 2nd 15 weeks	6/21/71 — 10/3/71	10,862	3,632	14,494
31st week total	10/4/71 — 10/9/71	12,561	3,897	16,458
32nd week total	11/11/71 — 10/16/71	18,307	2,874	21,181
33rd week total	10/18/71 — 10/23/71	15,316	3,255	18,571
34th week total	10/25/71 — 10/30/71	—	—	N/A
35th week total	11/1/71 — 11/6/71	18,278	3,553	21,831
36th week total	11/8/71 — 11/13/71	13,260	3,169	16,429
37th week total	11/15/71 — 11/20/71	14,816	3,332	18,148
38th week total	11/22/71 — 11/27/71	11,470	2,937	14,407
39th week total	11/29/71 — 12/4/71	17,060	3,855	20,915

Source Ref (*C-29*)

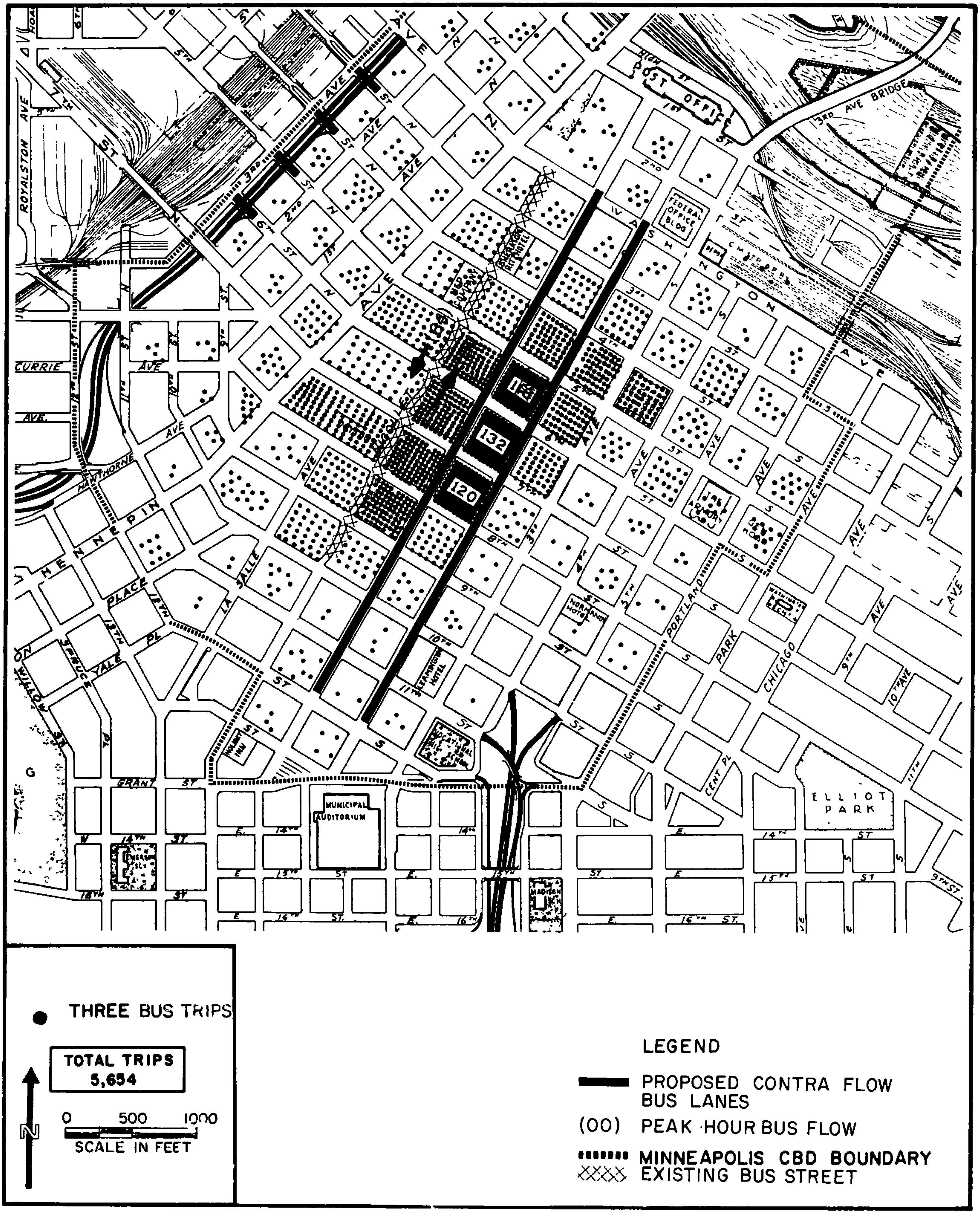


Figure C-30. Bus priority treatments, Minneapolis, Minn

Figure C-31. Nicollet Mall, Minneapolis, Minn.

far left lane on each street, for a contra-flow operation. Concrete curbs would be installed, along with special overhead signs, to separate the bus lanes from other traffic lanes, with the raised curbs interrupted at cross streets.

A plan is being developed to encourage mid-block crossings by pedestrians, including installation of mid-block traffic signals. This will reduce intersection delays to buses, as left turns by other vehicles would be allowed at intersections, and pedestrian crossings could delay left-turning vehicles and conflict with bus movements in the reserved lanes.

Linked to these proposals is a program involving use of electronic devices on buses so that signals can be adjusted automatically to favor bus movements. However, because traffic signal preemption by buses may create traffic problems for other vehicles, the program will be delayed until a fully computerized traffic signal system, already approved by the city (through the Federal TOPICS program), is installed by mid-1973. A similar reserved-bus-lane plan is under study for the St. Paul CBD.

Park-and-Ride Facilities

The Commission owns three park-and-ride lots, and serves five others located at shopping centers. They are not well patronized; the average is about 50 bus patrons daily, including the kiss-and-ride patrons. They are not being promoted at present; they lack passenger shelters and desired features, such as pay telephones. Future plans call for extensive development of such facilities, concurrent with substantial improvements in transit speeds.

Bus-Pool Project

The Minnesota Highway Department has applied to UMTA for a $29,260 grant for a demonstration project involving purchase of five microbuses, each with 10- to 12-passenger capacity, as a test of a bus-pool system for Highway Department employees. The project would involve $27,000 for vehicles, and $2,260 as an initial operating subsidy.

The project involves a fixed daily charge for all riders except the driver, who would pay no fee and who would have two or more designated substitute drivers available from his particular rider group to fill in during periods of illness or other occasions when the regular driver was not available.

Round trip costs would depend on trip length: on a round trip up to 10 miles the daily fee would be $0.83; up to 20 miles, $0.90; up to 100 miles, $1.45.

The proposal, developed by the Transit Liaison Section of the Minnesota Highway Department, is expected to prove financially self-supporting, including full repayment of the cost of vehicles Riders for each vehicle would be selected on the basis of convenience of their home locations to the bus route.

15. NEWARK BUS PRIORITY LANES

Newark, N J., was one of the first cities in the United States to install exclusive bus lanes. In December 1956 the city established two transit lanes, one exclusively for buses, on Market Street between Mulberry and Washington Streets. The 0 34 miles of Market Street bus lanes were established in the westbound direction during the evening peak hours. The curb lane was designated exclusively for buses; the adjacent lane was 90 percent occupied by buses; a third westbound lane was assigned to other traffic, including bus routes that could not be diverted. During the evening peak hour, 95 bus trips on eight bus routes operated westbound on this street in all lanes.

Prior to the bus lane arrangement it took an average of 12 min to travel 0 9 mile from the Pennsylvania (now Penn Central) Station to the junction of West Market Street and Springfield Avenue

When the bus routes were divided into two lanes, an average running time of 10 min was required to traverse the area, representing an improvement of about 16 percent. This time saving, in turn, was translated into a saving of one bus on each of four routes.

Installation of a revised bus lane strategy, based on findings of a flow optimization study (*C-9*), achieved further improvements. The reorganization of bus stops along Market Street resulting from this study is shown in Figure C-32. This plan abandoned the second lane for buses and designated for bus loading operations the entire 3½ blocks of the curb lane between Beaver Street and a far-side stop at Washington Street. The second lane was designated for use by buses moving through the area, allowing buses to bypass buses loading and unloading passengers. The need for bus bypass capability resulted from the variations in loading practices and times of Public Service Coordinated Transport and private bus operations.

Buses were assigned to stops so that groups of buses having common destinations would use the same stops. An attempt was made to allocate buses equally among available stop positions, with each bus assigned at least two stops in the 3½-block area. The revised treatment, initially implemented in May 1969, is still operating. Buses save an additional 1 min in peak periods.

The 200 buses that move westbound in the 2-hour period accommodate more than 10,000 people. A saving of approximately 1 min per person and a time value of $2.00 per hour produces an annual saving of approximately $87,000. This does not include operating benefits experienced by the bus companies. The actual costs to implement these improvements were negligible, involving only a few signs, some pavement markings, a brief driver education period, and some engineering.

16. NEW ORLEANS BUS PRIORITY TREATMENTS

New Orleans Public Service, a privately owned company providing transit, electric, and gas service to the city, operates 459 transit buses, plus 35 streetcars (St. Charles Avenue line). With a population of 593,000, New Orleans has the lowest transit fare of any U.S. city of comparable size—a $0 15 basic fare, no zone fares, and a free transfer to a total of five different lines in the same general direction.

The transit system averages 251,000 passengers per bus per year, highest in the U.S. (Milwaukee's 217,000 average is the second highest). The system recently requested an increase of $0.05 in the $0.15 base fare and the $0 20 express fare. Most residences are within one-quarter mile of a transit route, and headways in peak hours are usually between 1½ and 6 min.

Approximately one-third of the 240,000 person trips to the CBD from 7:00 AM to 7:00 PM are by public transport; 16,000 of the 42,000 PM peak-hour persons leaving the CBD (40 percent) travel by transit.

Canal Street Busway

Canal Street, New Orleans' famed 130-ft-wide thoroughfare, is the focus of the city's transit system. There are more than 700 daily two-way bus trips on portions of Canal Street (592 local, 136 express). This street carries 30,000 people into and out of the CBD daily. Each peak hour, 40 to 50 Canal Street buses carry 2,500 people in the peak direction of travel (Fig. C-33).

In 1966, the Canal Street streetcar line, which operated in the 40-ft-wide Neutral Ground, was converted to bus operations. The center section of the 1½-mile Neutral Ground was repaved, and a 24-ft-wide road was marked for buses only Permanent yellow thermoplastic markings delineated a double center line, and also edge lines. White plastic markings defined bus stops and pedestrian crossings (Fig C-34).

Buses leave the center mall and use regular traffic lanes to the west of Claiborne Avenue. Elimination of streetcar tracks on the median reservation to the west of the CBD made it possible to establish two additional traffic lanes However, it eliminated the horiontal separation of cars and transit.

Because of frequent traffic signals and stops, average speeds along Canal Street are 9 mph as compared to 9.9 mph for the over-all system.

The Canal Street busway also provides the downtown a potential for eventually linking with a freeway-oriented bus rapid transit system.

A bus rapid transit concept developed in 1963 (*C-10*) would use Canal Street for downtown distribution. The Neutral Ground, in combination with a widened Poydras Street, would provide the principal downtown distribution for express bus services. These facilities would distribute most passengers within short walking distances of destinations. Buses would operate express over freeways within a 20-min time zone from downtown, stopping at arterial streets or at outlying park-and-ride areas.

Other Concepts

A Regional Planning Commission study is under way for Jefferson, Orleans, and St Bernard Parishes, with a combined 1970 population of 982,000. Emphasis is on bus rapid transit, preferential bus access to metered freeways

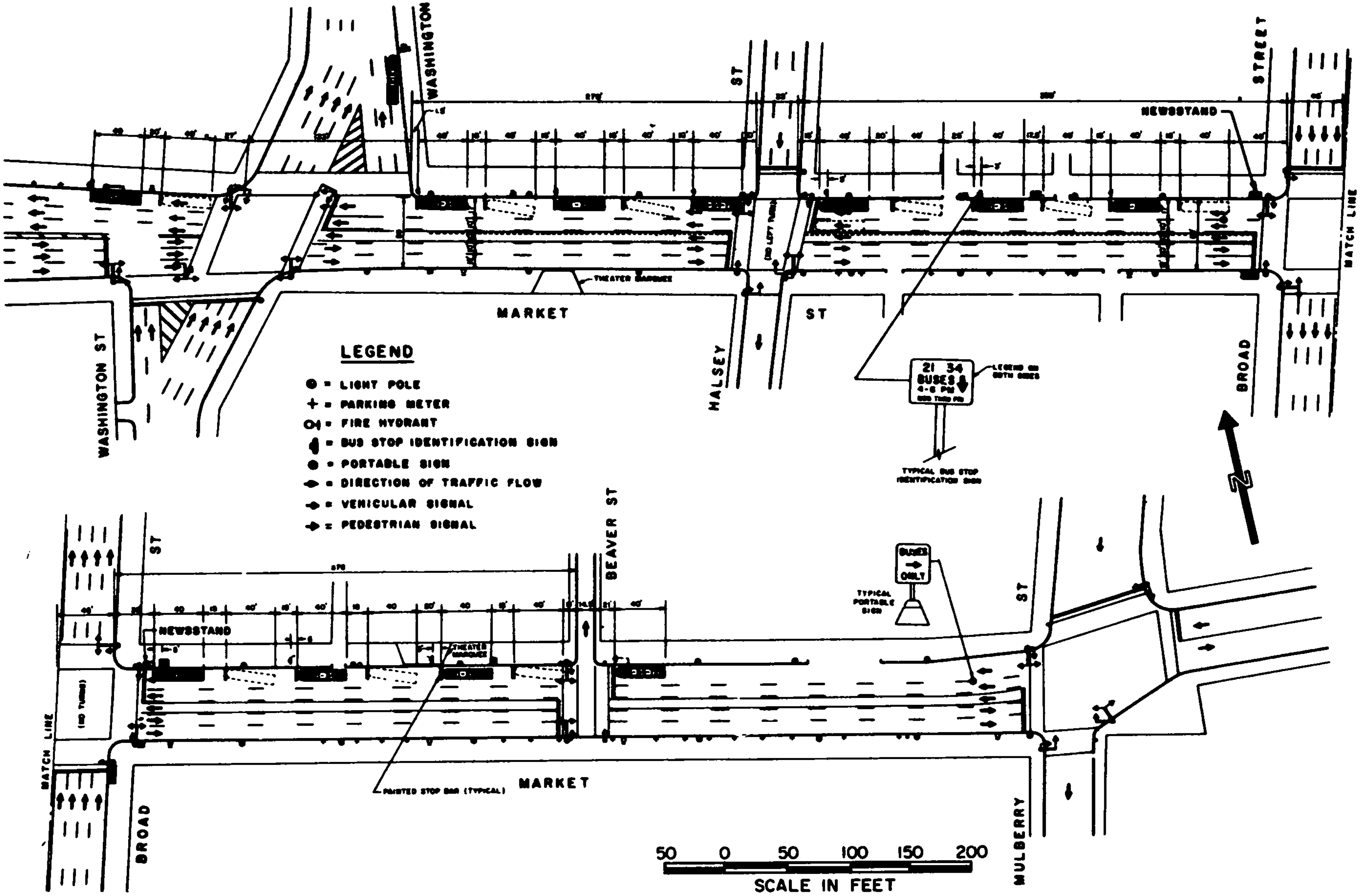
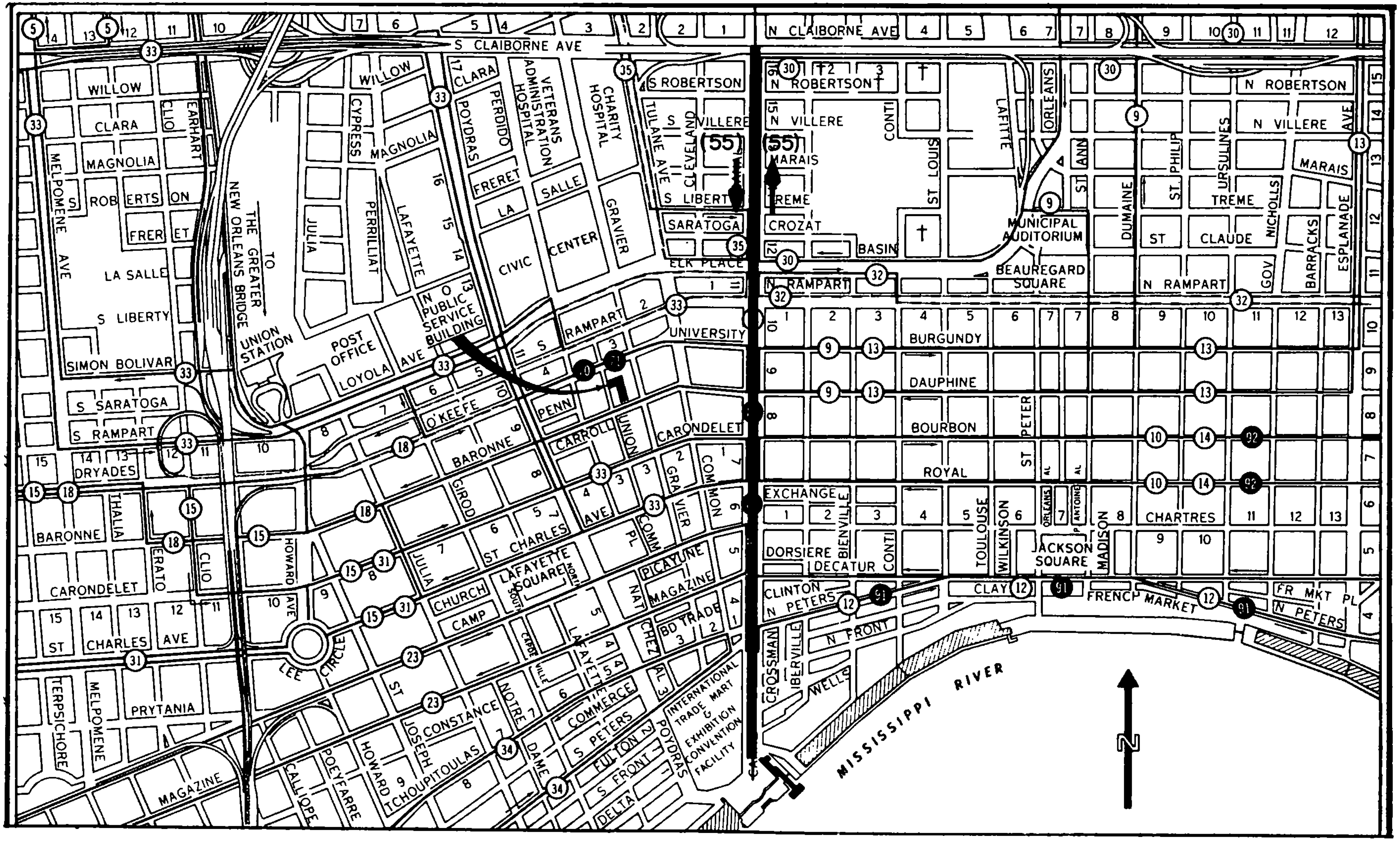


Figure C-32. Bus lane experiment, Market Street, Newark, N J.



0 ¼ ½ ¾ 1 Mile

SCALE

Figure C-33. Location of Canal Street busway, New Orleans, La

LEGEND

▬ NEUTRAL GROUND BUS STREET

←(00) PEAK-HOUR BUS FLOW

Figure C-34. Typical view, Canal Street busway, New Orleans, La.

or busways, and use of drive-in theatres for park-and-ride lots during the daytime.

Related to this is a proposal for a park-and-ride facility across the Mississippi River in the western part of Jefferson Parish connecting with Canal Street bus lanes. Currently, a passenger ferry crosses there. The new plan calls for a bus ferry, with buses then entering Canal Street.

17. NEW YORK CITY BUS PRIORITY TREATMENTS

The New York Metropolitan area has the largest concentrations of bus use and bus priority treatments in the United States. Some 4,000 publicly operated buses carry 2.7 million passengers daily over 1,100 miles of route; 800 privately operated buses (double the bus fleet of Dallas or Atlanta) carry another 165,000 passengers each day.

Description

Bus priority treatments began in 1963 In June 1972 there were 15 miles of curb bus lanes or bus zones on 11 streets in the five boroughs. Most treatments, however, were in midtown Manhattan. Figure C-35 shows the general locations of Manhattan arterial bus priority treatments and their relationship to the I-495 and Long Island Expressway contra-flow AM peak-hour bus lanes.

The locations, lengths, regulation, and use of bus priority treatments are summarized in Table C-10. Curb bus lanes are found on Fifth, Madison, First, and Second Avenues, as well as 42nd and 57th Streets in Manhattan, Hillside Avenue in Queens; Victory Boulevard in Richmond; and Livingston Street in Brooklyn. The lanes range from 0.7 to 2.5 miles in length.

There are two basic types of controls: (1) Bus zones (on Fifth and Madison Avenues) prohibit stopping of vehicles between 7:00 AM and 7:00 PM, although other vehicles are allowed to travel in these zones, but cannot park, make deliveries, or stand longer than to pick up or discharge a passenger; (2) bus lanes allow only buses and right-turning vehicles in the curb lanes, which operate during the morning and evening peak hours. All exclusive bus lanes are 10 ft wide. However, the streets on which bus lanes are provided vary in width, because they include both one and two-way operations.

Control Methods

The reserved bus lanes are designated by 36 × 30-in. signs with blue bus symbols and black letters on white background. They are placed beside curb lanes, except on Victory Boulevard in Richmond and Hillside Avenue in Queens, where the signs are placed on special mast arms. Solid yellow lines further delineate the bus lanes.

Use

Peak-hour bus volumes range from 60 per hour on 42nd Street, Lexington Avenue, and Third Avenue to more than 120 buses per hour on Fifth Avenue and Hillside Boulevard. Midday bus volumes range from 15 to 100 per hour. The 12-hr bus zones on Fifth and Madison Avenues carry about 80 to 100 buses per midday hour.

The peak-hour bus volumes on six-lane Hillside Avenue appear to be the highest on any surface street in the United States. During a typical 1972 PM peak hour, the two-way Hillside Avenue volume east of 179th Street approximated 290 buses, of which 170 were westbound and 120 east-

TABLE C-10

BUS LANES AND BUS ZONES, NEW YORK CITY

BOROUGH	STREET	DIRECTION OF TRAFFIC	LIMITS	DISTANCE (MI)	TYPE TREATMENT	PERIOD	HOURLY BUS VOL	
							PEAK	BASE
Manhattan	Fifth Ave.	S.B.	34–86th St.	2.50	Bus zone	7 AM–7 PM	120[a]	96[a]
	Madison Ave	N.B	34–59th St.	1.12	Bus zone	7 AM–7 PM	96[a]	79[a]
	First Ave.	N B.	34–72nd St.	1.90	Bus lane	7–10 AM 4–7 PM	96	48
	Second Ave	S.B	34–72nd St.	1.90	Bus lane	7–10 AM 4–7 PM	96	48
	42nd St.	Two way	3rd–8th Ave.	1.00	Bus lane	7–10 AM 4–7 PM	60	15
	57th St.	Two way	8th Ave – Queensbor. Br.	1.20	Bus lane [b]	4–7 PM	60	5
	Lexington Ave	S.B	34–59th St.	1.12	Bus lane	7–10 AM 4–7 PM	60[a]	30[a]
	Third Ave.	N.B.	34–59th St.	1.12	Bus lane	7–10 AM 4–7 PM	60[a]	30[a]
Brooklyn	Livingston St.	Two way	Flatbush Ave.– Boerum Pl.	0.68	Bus lane	7–9 AM 4–7 PM	77	57
Richmond	Victory Blvd.	Two way	Forest Ave – Bay St	1.00	Bus lane	7–9 AM 4–7 PM	106	33
Queens	Hillside Ave.	Two way	Francis Lewis Blvd.–167th St	2.00	Bus lane	7–9 AM 4–7 PM	170	37

Source New York City Transit Authority (1971)

[a] Does not include express buses operated by private companies.

[b] Eastbound only

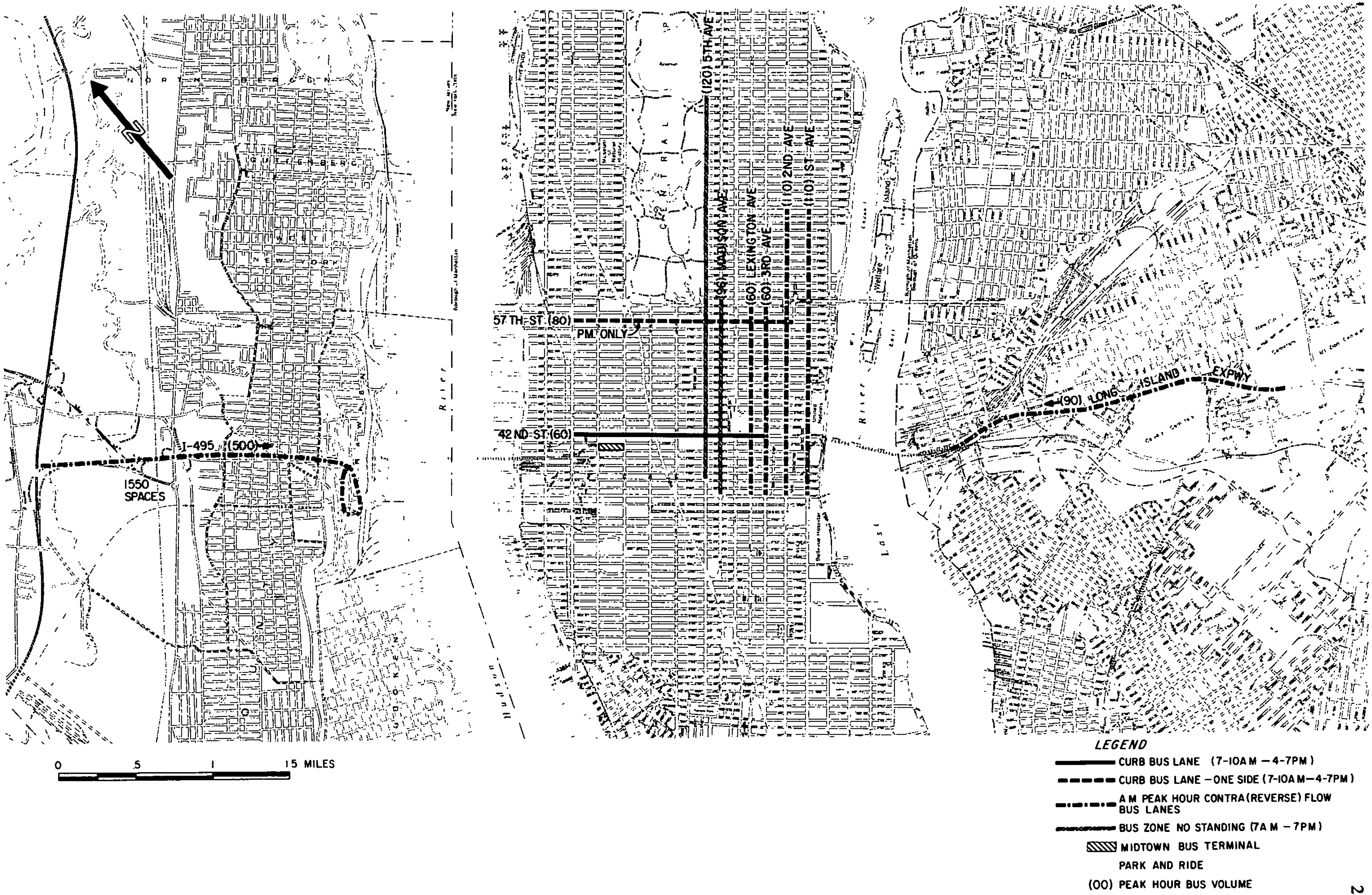


Figure C-35 Bus priority treatments, New York City.

bound from 5 30 to 5 30 PM (Table C-11). Automobile traffic on the six-lane street was 600 to 700 cars per hour each way. This section of Hillside Avenue, east of 179th Street, is within the area of exclusive bus lanes, which extend from Francis Lewis Boulevard to 167th Street, approximately 2 miles The roadway is six lanes wide, with three lanes in each direction. The westbound curb lane is used during the morning peak hours and the eastbound curb lane is used as an exclusive bus lane during the evening peak hours.

Traffic counts were taken at the terminus of subway routes E and F, approximately 10 miles from midtown Manhattan Buses function as an extension to the subways, carrying riders east to Queens and Nassau Counties. Buses include MTA and county bus routes

Bus stops are located at close intervals along the curb, necessitating some maneuvering for position. Generally, there is only minimum "leap-frogging" and delay Buses use the center lane as well as the exclusive bus lane because of the many bus stops and minimum headways. No major delays were noted for automobiles and buses.

Reported Benefits

The New York City Transit Authority reports that there has been no significant change in the number of passengers carried since the inception of exclusive bus lanes. As the bus lanes constitute only a small part of the route length involved, there has not been an appreciable reduction in running times.

Before-and-after studies conducted by the New York City Department of Traffic are summarized in Table C-12. These studies represent typical benefits; statistical significance tests were not made. They show travel time reductions ranging from 22 to 42 percent.

1. The Fifth Avenue bus zone reduced bus running times by 22 percent and the number of bus stops by 34 percent. The bus companies report a total saving of 10 hr on a typical day. The maximum improvement in bus travel time occurred about 3:30 PM, when travel time was reduced from 11 min 8 sec to 6 min 29 sec; and the number of bus stops was reduced from 8 to 3.

2. The Madison Avenue bus zone reduced midday (10.00-11 00 AM) travel times from 11 min 16 sec to 6 min 19 sec, a gain of 40 percent.

3. On Second Avenue (southbound), average travel time was reduced 22 percent and on First Avenue (northbound) 29 percent Average running time on Second Avenue was reduced from 10 min 30 sec to 8 min 12 sec, on First Avenue the reduction was from 9 min 6 sec to 6 min 30 sec On each of these streets there are more than 200 Transit Authority buses in each peak 3-hr period.

It has been the Transit Authority's experience that the success of the curb bus lanes depends on enforcement of regulations. Avenues from which commercial traffic is banned produce a more successful bus operation.

TABLE C-11

EXISTING BUS AND AUTOMOBILE VOLUMES, HILLSIDE AVENUE AT 179TH ST., NEW YORK CITY

	VEHICULAR VOLUME [a]					
	EASTBOUND			WESTBOUND		
TIME PERIOD (PM)	BUS	AUTO	TOTAL	BUS	AUTO	TOTAL
4:00–4:15	19	178	197	20	85	105
4:15–4:30	21	152	173	19	93	112
4:30–4:45	22	126	148	20	108	128
4:45–5:00	20	164	184	23	120	143
5:00–5:15	25	202	227	26	135	161
5:15–5:30	39	182	221	21	150	171
5:30–5·45	35	163	198	27	158	185
5:45–6:00	41	159	200	40	167	207
6:00–6:15	44	155	199	26	136	162
6·15–6:30	51	150	201	29	105	134
Peak-hour volume.						
5.00–6.00	150	706	856	114	610	724
5·30–6:30	171	627	798	122	566	688

Source Field counts conducted on Tuesday, Feb 23, 1972, by Wilbur Smith and Associates

[a] Some auto volumes interpolated from adjacent 15-min counts

18. PHILADELPHIA BUS PRIORITY LANES

Bus priority treatments in Center City Philadelphia are shown in Figure C-36. Preferential curb lanes for buses exist on the Ben Franklin Bridge and on East Market Street. There are no exclusive bus lanes or bus streets.

East Market Street, like State Street in Chicago, provides both median and curb bus lanes. The volume of buses dominates westbound street use; consequently, this direction largely functions as exclusive bus lanes during peak periods.

During the peak AM hour, there are 143 westbound buses and 463 westbound cars, and 54 eastbound buses and 364 eastbound cars (Table C-13). During this peak hour, 90 percent of the westbound person-movement on Market Street is by bus.

The high westbound bus volumes result from TNJ (Transport of New Jersey Public Service) buses operating westbound on Market Street. Approximately 120 TNJ buses operate in the curb lane in the peak hours, while SEPTA (Southeast Pennsylvania Transit Authority) buses use the median lane. In actuality, TNJ buses preempt the curb lane, even though other vehicles are legally permitted in it.

TABLE C-12

REPORTED BENEFITS OF BUS LANES, NEW YORK CITY

	BUS TRAVEL TIMES (MIN·SEC)			
STREET	BEFORE	AFTER	DECREASE	CHANGE (%)
Fifth Ave.	11:8	6:29	4:39	42
Madison Ave	11:10	6:19	4:51	40
First Ave.	9:6	6:30	2:36	29
Second Ave.	10:30	8:12	2:18	22

Source New York City Department of Traffic (1971)

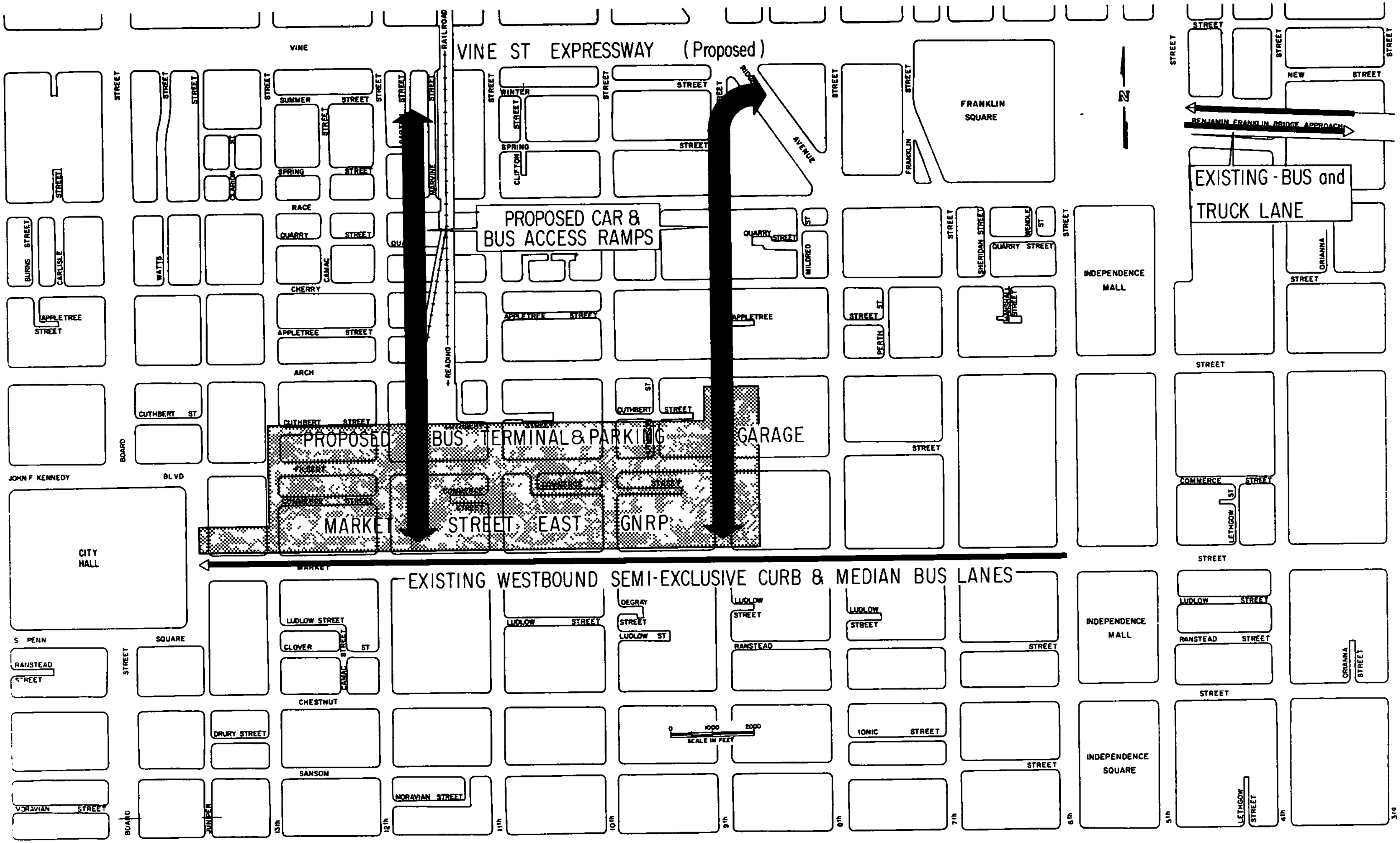


Figure C-36. Bus priority treatments, Philadelphia, Pa

TABLE C-13

CHARACTERISTICS OF PM PEAK-HOUR TRAFFIC VOLUMES, EAST MARKET STREET, PHILADELPHIA, PA[a]

TIME (PM)	TRAFFIC VOLUME											
	WESTBOUND				EASTBOUND				TWO-WAY TOTAL			
	BUSES[b]	AUTO	TOTAL	% BUSES	BUSES	AUTO	TOTAL	% BUSES	BUSES	AUTO	TOTAL	% BUSES
4 30–5:00	67	243	310	21.6	19	176	195	9 8	86	419	505	17.1
5:00–5.30	76	220	296	25 7	35	188	223	15 7	111	408	519	21.4
5 30–6.00	43	166	209	20 6	21	183	204	10 3	64	349	413	15 5
6·00–6·30	30	139	169	17 8	14	129	143	9.9	44	268	312	14 1
4 30–6:30	216	768	984	21 9	89	676	765	11 6	305	1,444	1,749	17 4

[a] Data collected during October 1971 by Wilbur Smith and Associates, for four lanes westbound and two lanes eastbound
[b] Occupancy, 35 to 40 passengers per bus

The traffic operations plan in effect along Market Street accommodates the high imbalance in bus volumes (Fig. C-37). During normal operations there are three lanes each way, during the evening rush hour, four lanes are provided westbound The lane arrangement is given in Table C-14.

Five-foot concrete loading islands provide refuge for pedestrians boarding westbound SEPTA buses. A chain-link fence on the islands serves to protect pedestrians from cars in the adjacent lane

The volume of buses and the arrangement of lanes along Market Street is conducive to the designation of exclusive bus lanes. The street affords an excellent potential for bus priority treatments.

19. PROVIDENCE BUS PRIORITY TREATMENTS

Bus priority treatments in downtown Providence, R.I, are shown in Figure C-38. They include bus service through the East Side Tunnel and downtown curb bus lanes on Washington and Weybosset Streets. There is also a special channelization west of the tunnel that provides contra-flow bus travel from the tunnel exit toward downtown Providence.

TABLE C-14

LANE USE, EAST MARKET STREET, PHILADELPHIA, PA, 1972

LANE[a]	MAJOR USE	LANE DIRECTION	
		MIDDAY	PM PEAK PERIOD
1[b]	TNJ	WB	WB
2	Cars	WB	WB
3	SEPTA buses	WB	WB
4	Cars	EB	WB
5	Cars	EB	EB
6[c]	SEPTA buses	EB	EB

Source Field survey (1972)
[a] From north to south [b] North curb [c] South curb

East Side Tunnel

The East Side Tunnel was opened on August 19, 1914, for streetcar operation. The tunnel replaced an unsafe cable-assisted operation (15 percent grade) on College Hill with a low-grade direct route free from traffic interference. It facilitated substantial high-value residential development on the East Side of Providence.

The tunnel was converted to bus service in 1948. Although trolley buses represented 75 percent of the tunnel traffic immediately after conversion, the tunnel has been used exclusively by diesel buses since 1954. It is approximately 2,160 ft long, has height of 17 ft 6 in., a width of 25 ft, and an average grade of 4 8 percent. The costs for the tunnel itself were reported at $164,000.

The tunnel is self ventilating; no special ventilation is provided Although carbon monoxide levels are not hazardous and exposure is brief, passengers are subjected to diesel exhaust odors on uphill trips because the natural velocity of air through the tunnel is about the same as that of a bus going up the 4.8 percent grade. Despite this condition, which resulted from the replacement of electric trolley buses, a comparison of 1951 and 1956 studies indicates that the East Side transit routes lost a smaller percentage of their patronage than the transit system as a whole (*C-11, C-12*).

Four Rhode Island Public Transit Authority bus routes currently use the tunnel, making 300 to 400 trips per day and about 18 trips each way in the peak hour. These routes are. (1) Six Corners-Rumford (East Providence) via Tunnel, (2) Butler-Tunnel; (3) Elmgrove via Tunnel; and (4) Hope-Tunnel.

The Authority would like to abandon the tunnel to reduce its maintenance costs. The tunnel carries a maximum of approximately 750 persons per hour in the peak direction, about 15 percent of its capacity. However, abandonment would mean a return to steep gradients or indirect routings, reducing the level of service to transit users.

Downtown Bus Lanes

Approximately 0.5 miles of curb bus lanes were installed on the Washington-Weybosset one-way street couplet in

1968 Nearside bus stops are provided and spaced about 500 ft apart Right turns are permitted from the bus lane. The bus lanes resulted from recommendations set forth in a 1956 transit and traffic report (*C-13*) They are marked with a solid white line the length of the street, and posted with signs reading BUS LANE NO PARKING The lanes have helped bus flows, which approximate 60 buses each way in the peak hour. However, because of inadequate enforcement, buses sometimes leave the lanes to maintain schedules

20. ST. LOUIS BUS PRIORITY TREATMENTS

The Bi-State Transit System, created in 1963, has a fleet of 960 buses, of which 730 are in active service on an average day. The system and its predecessor companies have been innovators in express transit service, park-and-ride lots, and bus priority proposals.

Park-and-Ride Bus Service

In 1953, the city and the transit system established a 1,000-car park-and-ride facility in Forest Park This lot, perhaps the first bus-oriented park-and-ride facility in the U.S., is located about 5 miles west of the CBD. It was designed to reduce downtown congestion by diverting motorists to buses.

Parking is provided free. Fares for the express bus trip to the city center are $0 50 each way, and the journey takes about 17 min Some air-conditioned buses are used.

The lot was initially used by some 2,000 cars per day. Current statistics show that about 1,000 vehicles use it each day. Completion of the Daniel Boone Expressway (US 40) into the CBD diverted motorists from the lot and contributed to the decline in its patronage.

Arterial Bus Lanes

In 1957, the St Louis Public Service Company proposed implementing the first U S bus priority proposals on radial arterial streets (*C-14*). Reversible lanes were recommended on three six-lane radial arteries to provide extra capacity during rush hours The report further recommended exclusive bus use of the curb lanes in the flow direction during rush hours and the closing of certain local streets that connected with the flow direction.

A similar proposal was outlined in the 1971-75 transit improvement program (Fig. C-39) (*C-15*). Curb lanes would be reserved for buses along four major arterial routes in the flow direction of travel during peak hours. The four routes—Natural Bridge, Florissant, 12th; Lindell, Olive; Southwest, Vandeventer, Market; and 12th, Gravois—parallel existing freeways. Bus routes that would use these arterial lanes are summarized in Table C-15.

Downtown Bus Priority Lanes

Downtown bus priority proposals are shown in Figure C-40. Peak-period curb bus lanes are proposed along Market, Olive, Washington, 6th, 7th, 8th, and 9th Streets, and Locust Street is proposed as a PM peak-period bus street Some of these bus lanes (e.g., 6th, 7th, and Washington Streets) were recommended more than a decade ago (*C-16*).

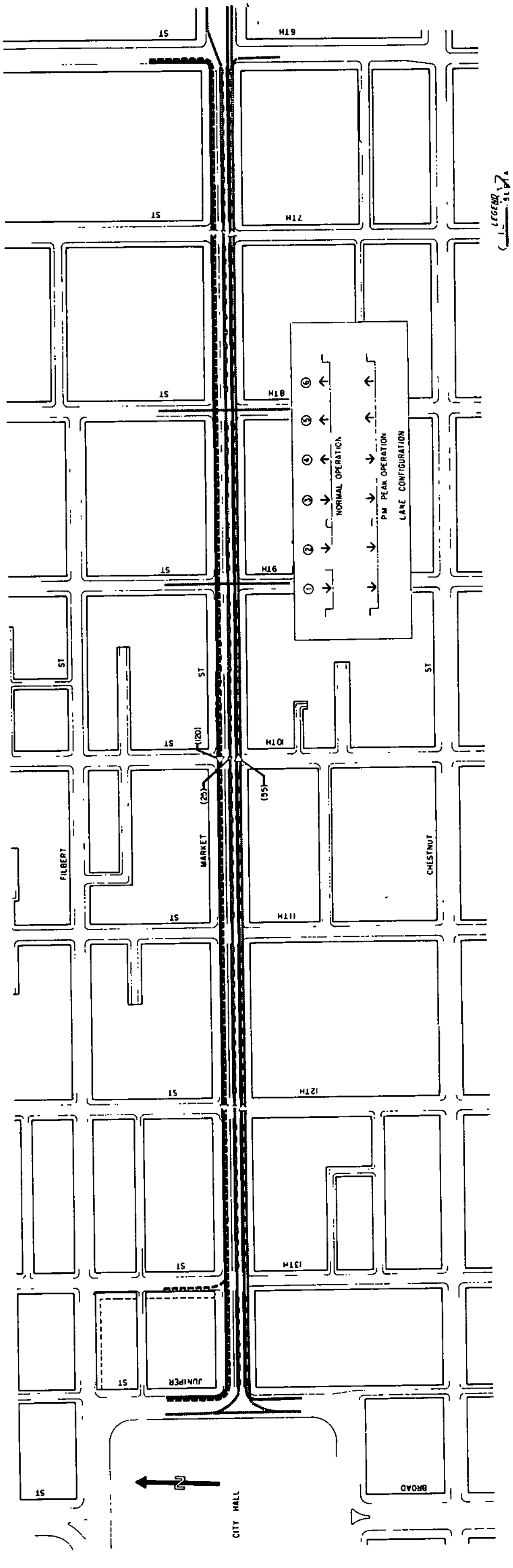


Figure C-37 Bus operations, Market Street, Philadelphia, Pa.

Figure C-38. Bus priority treatments, Providence, R.I

Locust Street would become a westbound peak-period bus mall between Broadway and 11th Street. Thirteen local lines and eight express lines would use the four-lane street. The operating plan would be as follows

1. Present roadway lane markings would be used.
2. Metered parking on the south side of Locust Street would be removed in the PM peak period.
3 Local buses would operate in the north curb lane Passengers would load from the sidewalk. Principal loading positions for the local buses would be in the present far-side stops (no change)
4. Express buses would operate in the south lane. Passengers would board from the center of the street (two lanes). The principal loading position for the express buses would be near-side of the intersection (6th to 11th inclusive) unless there is a variance or delay in loading, in which case buses would load in the entire block
5. No automobiles would be permitted in the street. The two center lanes would include barricades that would read DOWNTOWN BUS MALL and DO NOT ENTER.
6. After 6:00 PM automobile traffic would be allowed to use Locust Street. The local buses would remain at the north curb.
7. Under the plan there would be no regular scheduled bus lines on Pine Street between 4th Street and 12th Street, thus freeing Pine Street for other vehicles.
8. During the peak hour about 35 local and 65 express bus trips are expected in both lanes on Locust Street (more than 4,000 passengers). This volume of buses would occupy practically all of the usable space available (Table C-16).

The Locust Street bus mall proposal would exclude taxis as well as cars. Accordingly, it was opposed by the taxi drivers union (teamsters) and its implementation, originally scheduled for a 90-day experimental period starting September 1971, was deferred. Taxicabs would add an estimated 30 vehicles to the north curb lane, which they would share with local buses.

21. SAN ANTONIO BUS PRIORITY LANE

Downtown San Antonio, Tex., has one of the few contra-flow bus lanes in the United States. A 1,200-ft contra-flow bus lane was established on Alamo Plaza between Commerce and Houston Streets in March 1968, coinciding with the Hemisphere opening.

The relation of the bus lane to downtown bus routing patterns is shown in Figure C-41. Five bus lines use the two-block lane for about 260 trips daily. They use the lane to allow efficient return from Houston to Commerce Streets. Each peak hour the lane is used by 30 buses carrying about 1,600 passengers.

Physical configuration of the bus and car lanes is shown in Figures C-42 and C-43. There are three moving and

TABLE C-15

BUS LINES TO USE PROPOSED ARTERIAL CURB BUS LANES, ST LOUIS, MO

BUS LINE	PARALLEL EXPRESSWAY
1. 12th-Gravois Artery:	
Affton Express	I-70, Mark Twain
Carondelet	
Cherokee	
Gravois	
Lemay Express	
Shrewsbury Express	
Southampton Express	
South Grand Express	
South Side Express	
Watson Road Express	
2 Market-Vandeventer-Southwest Artery:	
Big Bend Express	US 40, Daniel Boone
Brentwood Express	
Clayton Road Express	
Forest Park	
Kirkwood Express	
Lindenwood	
Lindenwood Express	
Manchester Road Express	
3 Olive-Lindell Artery:	
Clayton Road Express	US 40, Daniel Boone
Park-Ride	
Lindell	
Lindell Express	
McPherson	
Olive	
4 12th-N. Florissant-Natural Bridge Artery:	
City Limits	I-55
Ferguson	
Lucas Hunt	
Natural Bridge	
Natural Bridge Express	

Source Ref (*C-15*)

TABLE C-16

ANTICIPATED PEAK-HOUR BUS VOLUMES, PROPOSED LOCUST BUS STREET, ST. LOUIS, MO [a]

NORTH CURB, LOCALS		SOUTH CURB, EXPRESSES	
LINE	NO OF TRIPS	LINE	NO. OF TRIPS
Delmar-Forsyth	5	Effton	8
Forest Park [b]	4	Big Bend [b]	3
Hodiamont	3	Brentwood [b]	5
Lee	6	Clatyon Road	3
Lindell	5	Park-Ride	2
McPherson	2	Kirkwood [b]	6
Olive	5	Lemay	4
Wellston	6	Lindell	6
		Manchester Road [b]	3
		Shrewsbury [b]	8
		Southampton	3
		South Side	9
		Watson Road [b]	6
Total 8 lines	36	Total 13 lines	66

Source Ref (*C-15*)

[a] Average local headway = 100 sec, average express headway = 55 sec, combined average headway (102 trips) = about 35 sec Estimated use during maximum afternoon peak hour (4 15–5 15 PM)

[b] Moved from Pine Street

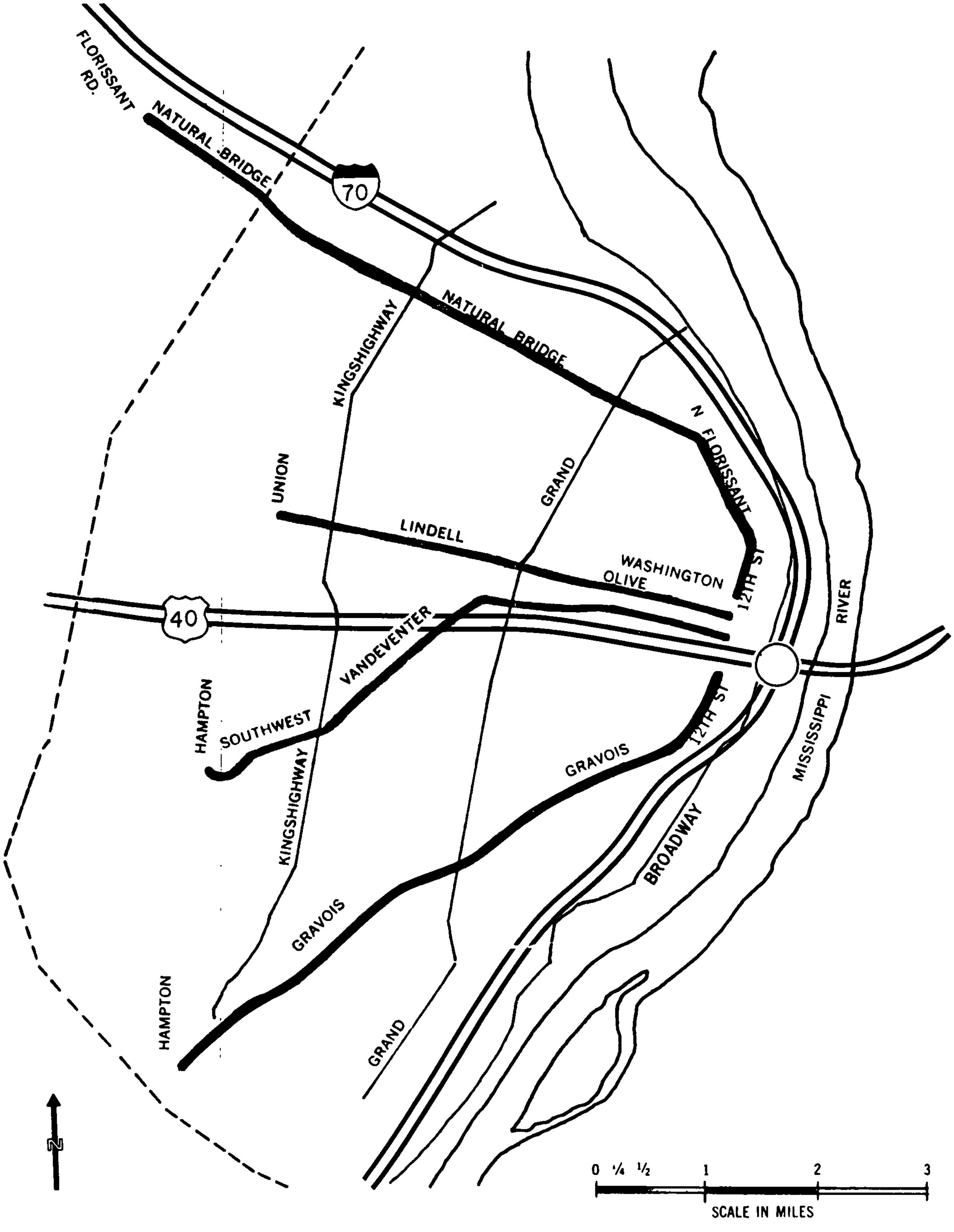


Figure C-39 Proposed arterial bus lanes, St Louis, Mo

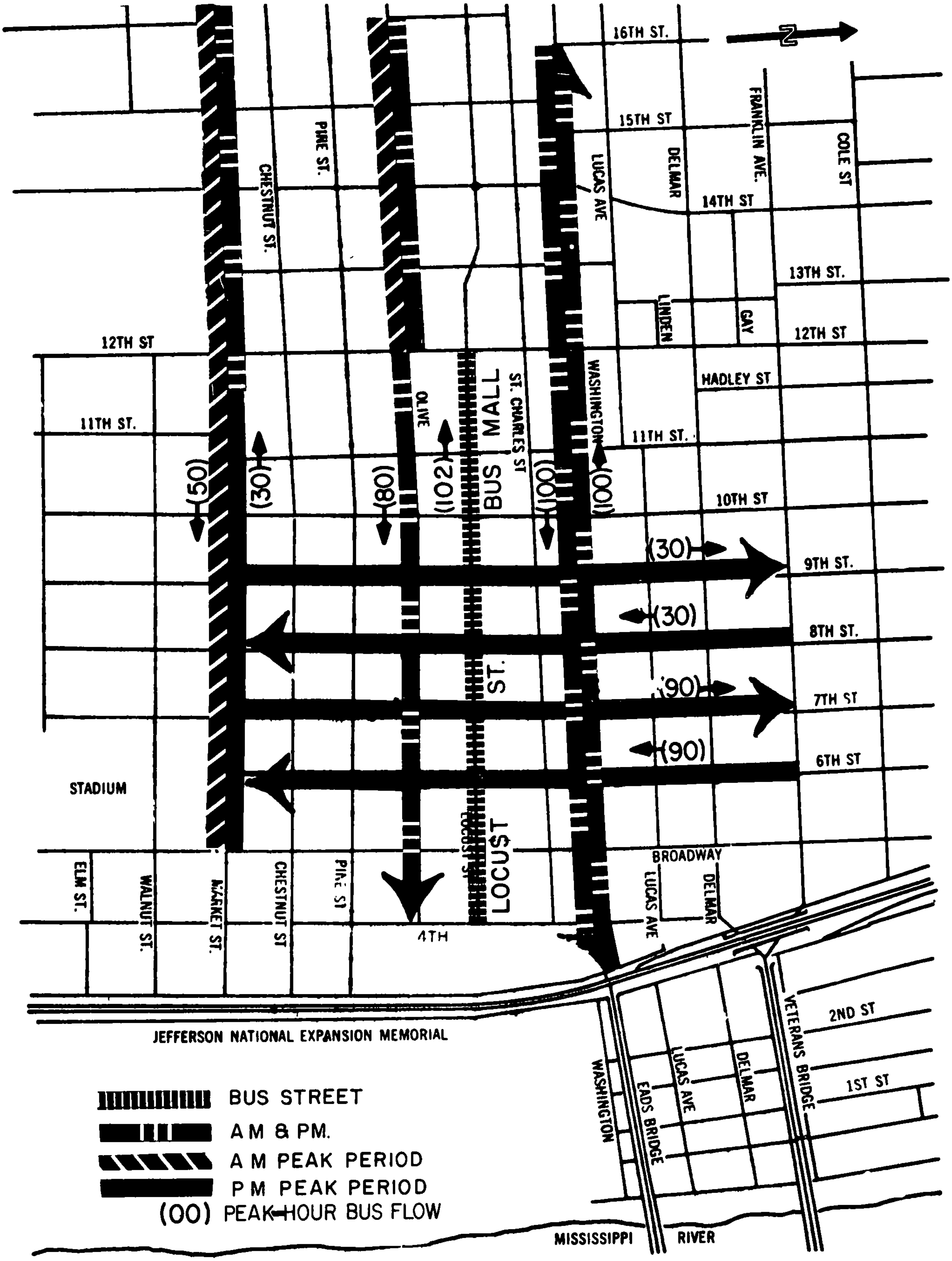


Figure C-40 Proposed bus priority treatments, St Louis, Mo

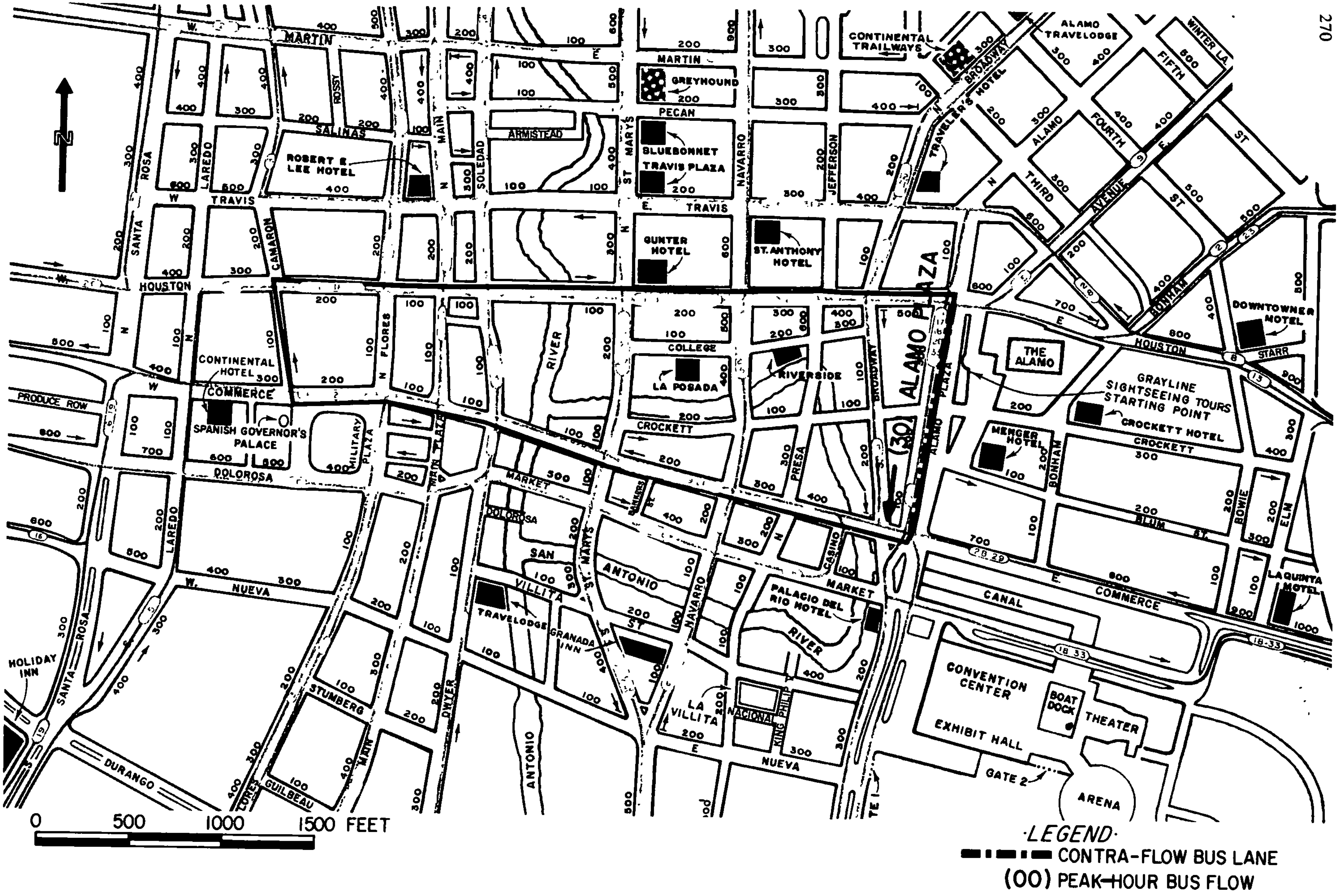


Figure C-41 Contra-flow bus lane, San Antonio, Tex

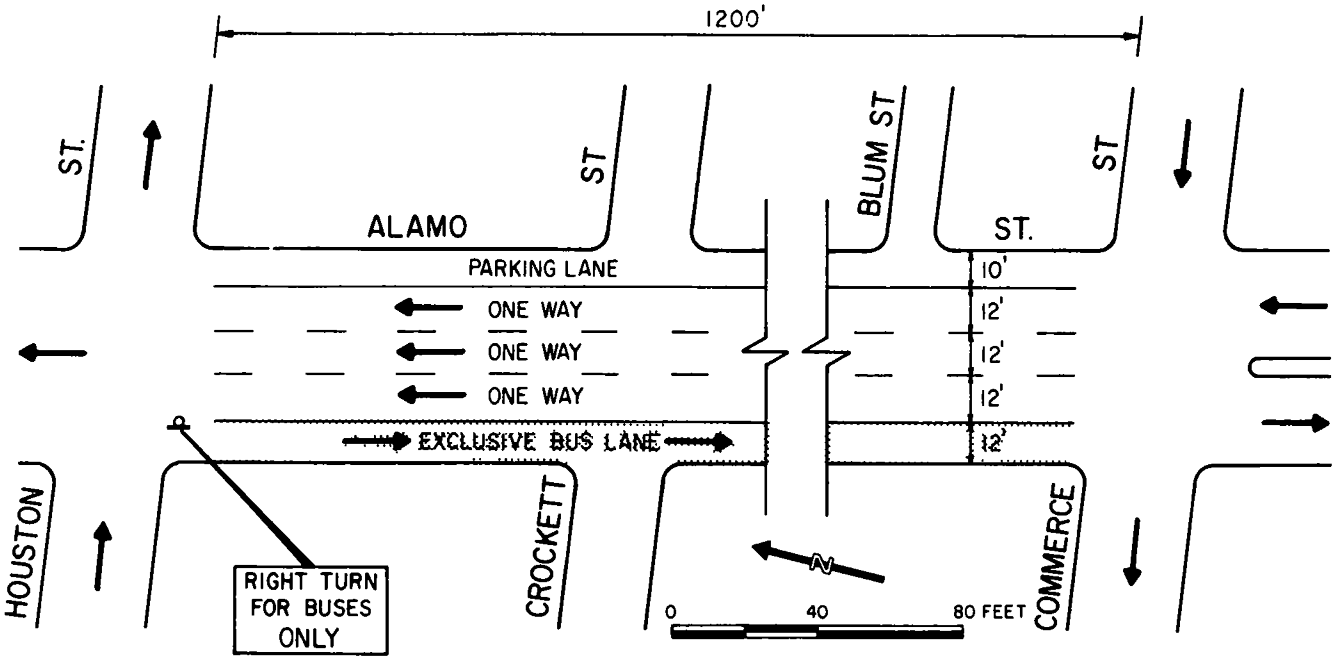


Figure C-42 Typical lane use, contra-flow bus lane, Alamo Plaza, San Antonio, Tex

one parking lane in addition to the contra-flow bus lane on 60-ft-wide Alamo Plaza

22. SAN FRANCISCO BUS PRIORITY LANES

Downtown San Francisco, Calif., contains 83 million square feet of floor space and employs 270,000 persons. Each day it attracts 326,000 persons, of which 45 percent arrive by transit. During the peak hours transit accounts for about 55 percent of the total CBD person-travel. Most of these downtown trips use the City's Municipal Railway (MUNI) bus, trolley-bus, and streetcar routes.

Market Street Operations

Market Street is the focus of the city's transit lines, as well as the Bay Area Rapid Transit System. The two median lanes and many sections of curb lanes are preempted by transit vehicles.

A track in each lane is used by 60 streetcars per hour in the peak period. In addition, certain bus routes use this lane and stop at streetcar loading platforms. Left turns from Market Street are prohibited at all hours, and non-transit vehicles are directed to keep to the right of the loading islands. Cars, trucks, and other vehicles generally do not use the median lanes to avoid being trapped behind buses or streetcars

Market Street has a transit passenger volume of more than 15,000 persons per hour, of which more than half use buses or trolley buses This is presently the highest observed hourly transit volume on any surface street in the United States, and it exceeds peak hourly one-way volumes (though at a lower speed) found on rapid transit lines in Cleveland, Chicago (Eisenhower Expressway), and Philadelphia (Lindenwold Line).

Downtown Bus Priority Lanes

The downtown street system contains two separate local street grids that converge at Market Street to form many complex five-way intersections. To alleviate this condition, the downtown one-way street system was expanded, additional tow-away zones were installed, higher fines for parking violations were adopted, and special peak-hour bus lanes were initiated in 1971.

The network of downtown bus priority lanes is shown in Figure C-44; Table C-17 summarizes their extent, hours of operation, and use. Peak-hour bus lanes are located along 55 blocks of five one-way streets (Clay, Sacramento, Sutter, Geary, O'Farrell). Peak-hour utilization ranges from about 25 to 65 buses.

The lanes are located along curbs and can also be used by vehicles making right turns. They are delineated by a solid white double lane line ONLY BUS and BUS STOP pavement markings and post-mounted signs reading TOW AWAY LANE FOR BUSES AND RIGHT TURNS ONLY further identify lane use. Typical pavement marking and signing plans are shown in Figures C-45 and C-46.

Benefits

The coordination of bus lanes with general traffic improvements produced substantial benefits to both autos and buses Studies by the Municipal Railway and Department of Public Works indicated the following travel time savings·

1. In the area north of Market Street consisting of Bush, Sutter, Post, Geary, and O'Farrell Streets, AM peak-hour speeds increased by 10 percent; midday speeds increased by 22 to 25 percent, and PM peak-hour speeds increased by 22 to 36 percent (Table C-18).

2 The greatest improvements were reported on Geary

Figure C-43. Typical view, Alamo Plaza bus lane, San Antonio, Tex.

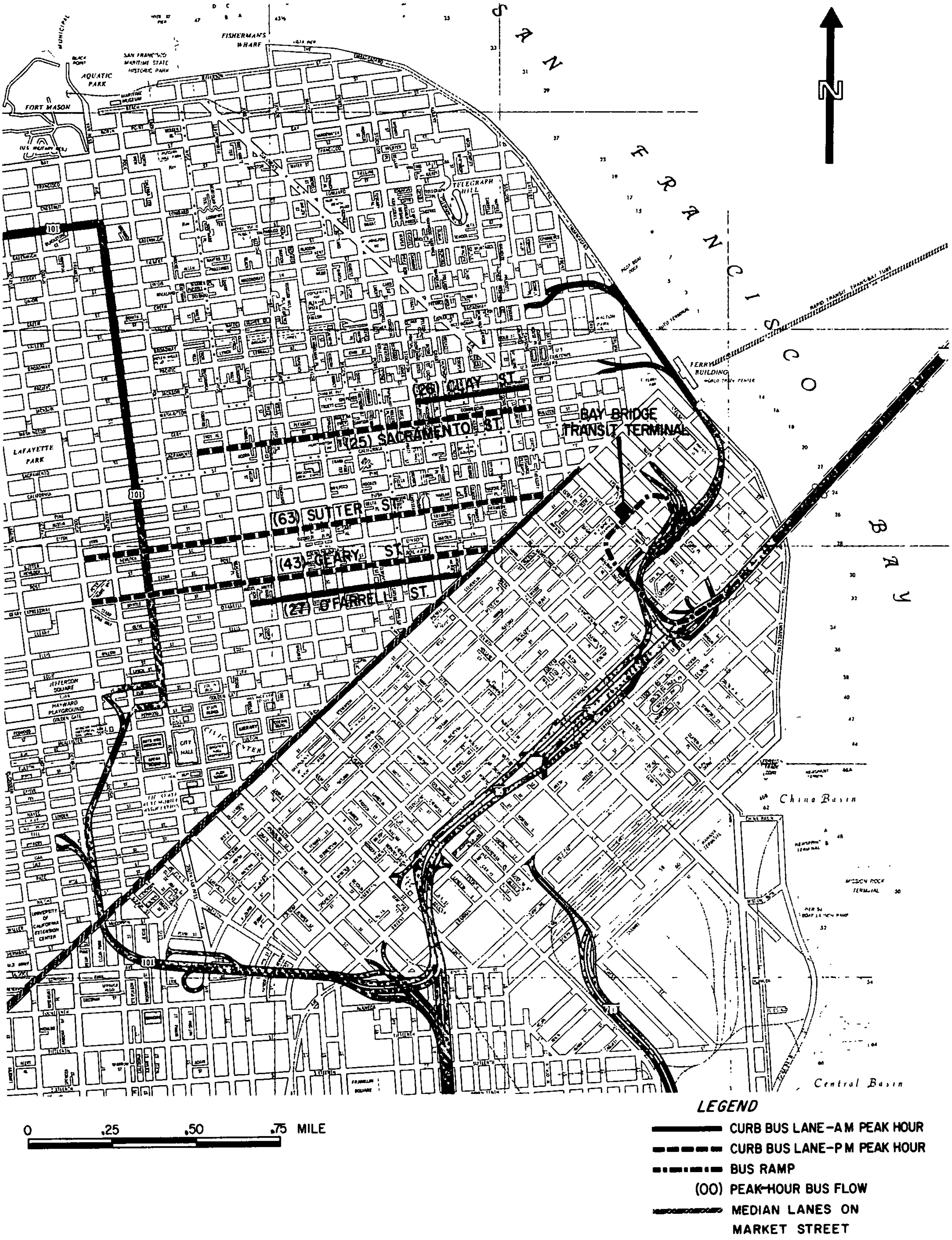


Figure C-44 Bus priority treatments, San Francisco, Calif

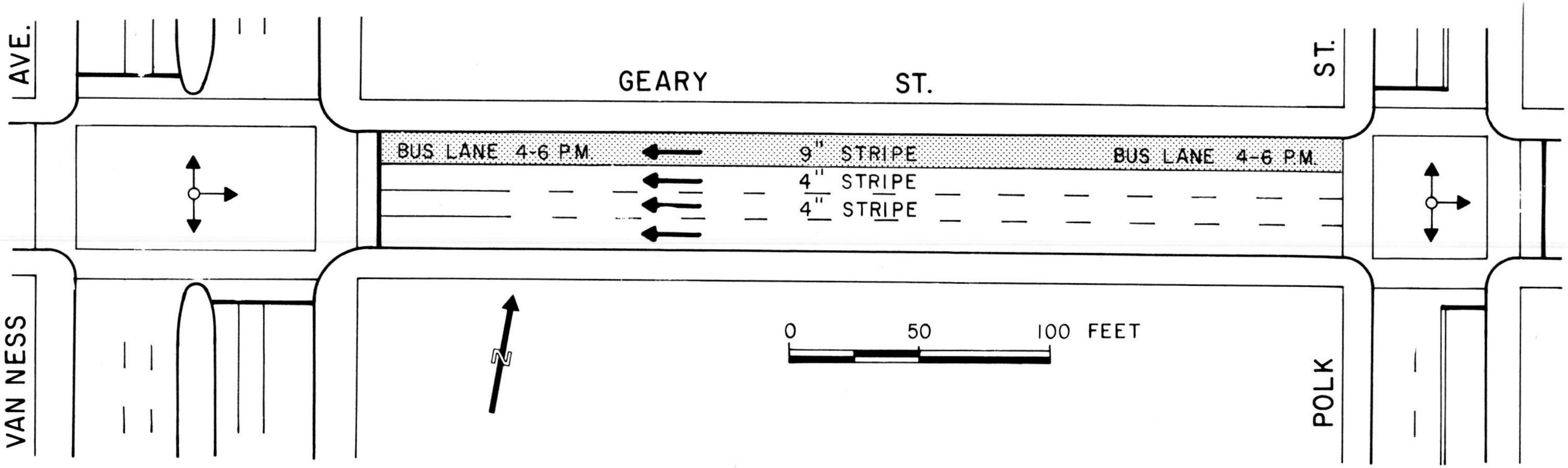


Figure C-45. *Typical lane markings, Geary Street bus lane, San Francisco, Calif.*

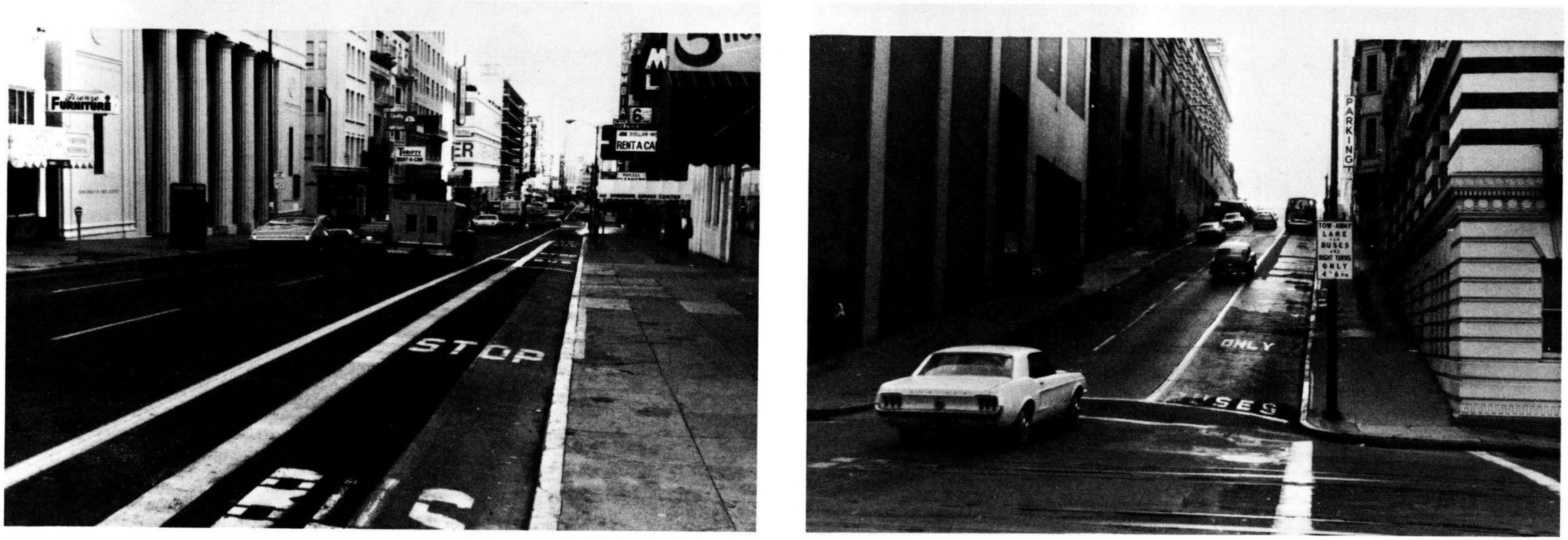


Figure C-46. *Typical views of bus lanes, San Francisco, Calif.; O'Farrell Street (left) and Sacramento Street (right).*

TABLE C-17

EXCLUSIVE BUS LANES, SAN FRANCISCO, CAL

STREET WITH SPECIAL BUS LANE[a]	LIMITS	BLOCKS	PERIOD	BUS USE 2-HR PERIOD[b]	BUS USE PEAK HOUR
Clay	Stocton-Battery	5	7–9 AM	37	11 (7–8 AM) 26 (8–9 AM)
Sacramento	Larkin-Drum	15	4–6 PM	44	19 (4–5 PM) 25 (5–6 PM)
Sutter	Gough-Market	15	4–6 PM	117	54 (4–5 PM) 63 (5–6 PM)
Geary	Gough-Market	13	4–6 PM	73	43 (4–5 PM) 30 (5–6 PM)
O'Farrell	Hyde-Market	7	7–9 AM	49	22 (7–8 AM) 27 (8–9 AM)

Source Division of Traffic Engineering, San Francisco Dept of Public Works (1971)

[a] One-way street, auto and truck right turns allowed

[b] AM peak = 86 buses, PM peak = 234 buses

and Sutter Streets, which were converted from two-way to outbound one-way streets. (Post Street was reversed from one-way outbound to one-way inbound to provide balance.) Traffic on Geary moved 105 percent faster during off-peak hours and 46 percent faster during the evening peak. On Sutter Street, the increases were 13 and 38 percent, respectively.

3. South of Market Street, Howard Street was made one-way outbound, resulting in a 45.6 percent increase in evening peak speeds. Folsom Street became one-way inbound and had a 19 percent AM speed increase.

4. Even though Mission Street remained two-way, its average speed increased by 20 percent. This apparently resulted from eliminating left-turn movements and from diversion of traffic to Howard and Folsom Streets.

The Municipal Railway studied running times on the Geary Line (No. 38) between Gough and Market Streets before and after the new one-way streets and special bus lanes were introduced. Average travel time for inbound buses was reduced by 16 percent (from 12.7 to 10.6 min) between 11 00 AM and 4·00 PM, and 20 percent (from 10.6 to 9.9 min) from 4 00 to 7.00 PM.

Outbound buses moved 22 percent faster between 11:00 AM and 4.00 PM (times reduced from 13.8 to 10.8 min). Between 4:00 and 7.00 PM, average travel times were reduced by 14 percent (from 11.6 to 9.9 min).

The Municipal Railway reported that buses were better able to maintain schedules. This was evidenced by a sharp decrease in the number of buses turned back before reaching their terminals. "Turnbacks" reduced from 76 to 20 on four lines observed during a one-week period

Significance

Bus speeds were increased by the institution of a one-way traffic flow pattern. This improvement permitted more effective timing of traffic signals and generally increased vehicular speeds. The reported bus travel time improvements are significant in terms of driver productivity, but are unlikely to affect modal split. A greater inducement to transit riding, perhaps, is the city tax on off-street parking fees in downtown San Francisco.

TABLE C-18

CHANGES IN AUTOMOBILE SPEEDS RESULTING FROM BUS LANES AND ONE-WAY STREETS, SAN FRANCISCO, CALIF.[a]

TIME OF DAY	SPEED (MPH) BEFORE	SPEED (MPH) AFTER	CHANGE (%)
7.30–8:30 AM			
Inbound	14 8	16 4	10.2
11 00 AM–4:00 PM			
Inbound	12.2	13.7	22.3
Outbound	9.8	12 2	25.0
4·30–5:30 PM			
Inbound	11.8	14.4	21.5
Outbound	8 6	11.7	36.0

Source San Francisco Municipal Railway, San Francisco Dept of Public Works (1971)

[a] Data collected north of Market St

23. SAN JUAN BUS PRIORITY TREATMENTS

In San Juan, Puerto Rico, the Metropolitan Bus Authority (AMA) operates 42 bus routes consisting of more than 500 route-miles. The system owns 360 buses, of which 300 are in scheduled service. These buses carry 66 million passengers annually.

The city's geography and development pattern require that most buses and automobiles traverse the Fernandez Juncos-Ponce de Leon-Munoz Rivera "spine" in traveling through San Juan Antiguo, Santurce, Rio Piedras, and Hato Rey Prior to the extension of Las Americas Freeway

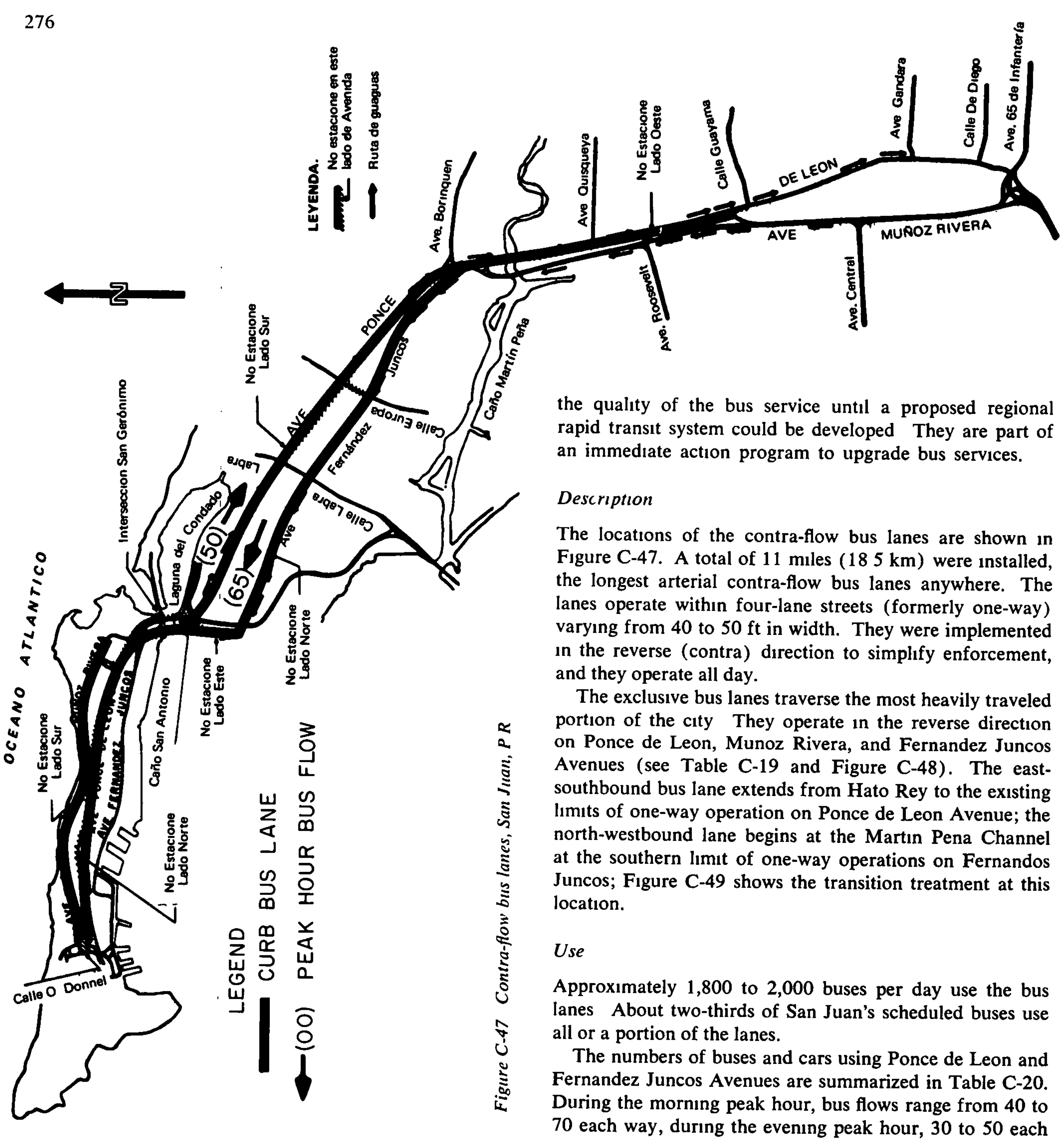


Figure C-47 Contra-flow bus lanes, San Juan, P R

into Santurce (May 1971) this arterial street spine carried more than 100,000 cars per day.

Contra-Flow Bus Priority Lanes

In May 1971, a pair of contra-flow bus lanes was established along Munoz Rivera, Fernandez Juncos, and Ponce de Leon Avenues in old San Juan, Santurce, and Hato Rey. The lanes were installed cooperatively by the Puerto Rico Planning Board, the Department of Public Works, the Puerto Rico Highway Authority, the Metropolitan Bus Authority (AMA), the San Juan Police Department, and the municipalities of San Juan after the Las Americas Freeway extension into Santurce reduced auto traffic along the arterial street spine The lanes were intended to improve the quality of the bus service until a proposed regional rapid transit system could be developed They are part of an immediate action program to upgrade bus services.

Description

The locations of the contra-flow bus lanes are shown in Figure C-47. A total of 11 miles (18 5 km) were installed, the longest arterial contra-flow bus lanes anywhere. The lanes operate within four-lane streets (formerly one-way) varying from 40 to 50 ft in width. They were implemented in the reverse (contra) direction to simplify enforcement, and they operate all day.

The exclusive bus lanes traverse the most heavily traveled portion of the city They operate in the reverse direction on Ponce de Leon, Munoz Rivera, and Fernandez Juncos Avenues (see Table C-19 and Figure C-48). The east-southbound bus lane extends from Hato Rey to the existing limits of one-way operation on Ponce de Leon Avenue; the north-westbound lane begins at the Martin Pena Channel at the southern limit of one-way operations on Fernandos Juncos; Figure C-49 shows the transition treatment at this location.

Use

Approximately 1,800 to 2,000 buses per day use the bus lanes About two-thirds of San Juan's scheduled buses use all or a portion of the lanes.

The numbers of buses and cars using Ponce de Leon and Fernandez Juncos Avenues are summarized in Table C-20. During the morning peak hour, bus flows range from 40 to 70 each way, during the evening peak hour, 30 to 50 each way. Buses carry about 60 percent of the peak direction peak-hour person movement in this corridor.

Costs

Implementation costs were initially estimated at $80,000 for construction and $20,000 for publicity. Costs of data collection, analyses, reports, and contingencies were estimated at $55,000 (Table C-21). Subsequent data indicate actual costs of $25,000 for construction and $22,000 for traffic controls.

Benefits

Prior to the installation of the bus lanes, peak-hour delays were common. On AMA line No. 1 between Rio Piedras

Figure C-48 Typical view, Avenida Ponce de Leon contra-flow bus lane, San Juan, P R

and San Juan, for example, schedules called for a 55-min running time However, during the rush hours the running time approached 80 min.

Results of before and after studies conducted by the Metropolitan Bus Authority are given in Table C-22. Routes operate the entire distance of the exclusive lanes and also operate considerable distances (40 percent or more) under normal mixed-traffic conditions. Each run is scheduled for about 45 min, compared with more than an hour prior to the exclusive lane operation. As a result, buses could not meet schedules prior to installation of the bus lanes.

An inspection of time runs at different periods of the day indicates little difference between peak and off-peak periods Generally, about 20 to 30 min is saved on each round trip for those routes that extensively use the exclusive lanes On portions of the route that remain the same, over-all bus speeds increased 30 to 50 percent.

Second-Stage Bus Priority Treatments

Second-stage projects recommend extending the exclusive bus lanes to the proposed Capetillo Terminal in Rio Piedras. No implementation date had been established as of January 1972

The proposed second-phase projects would integrate street, terminal, and transit improvements, as follows.

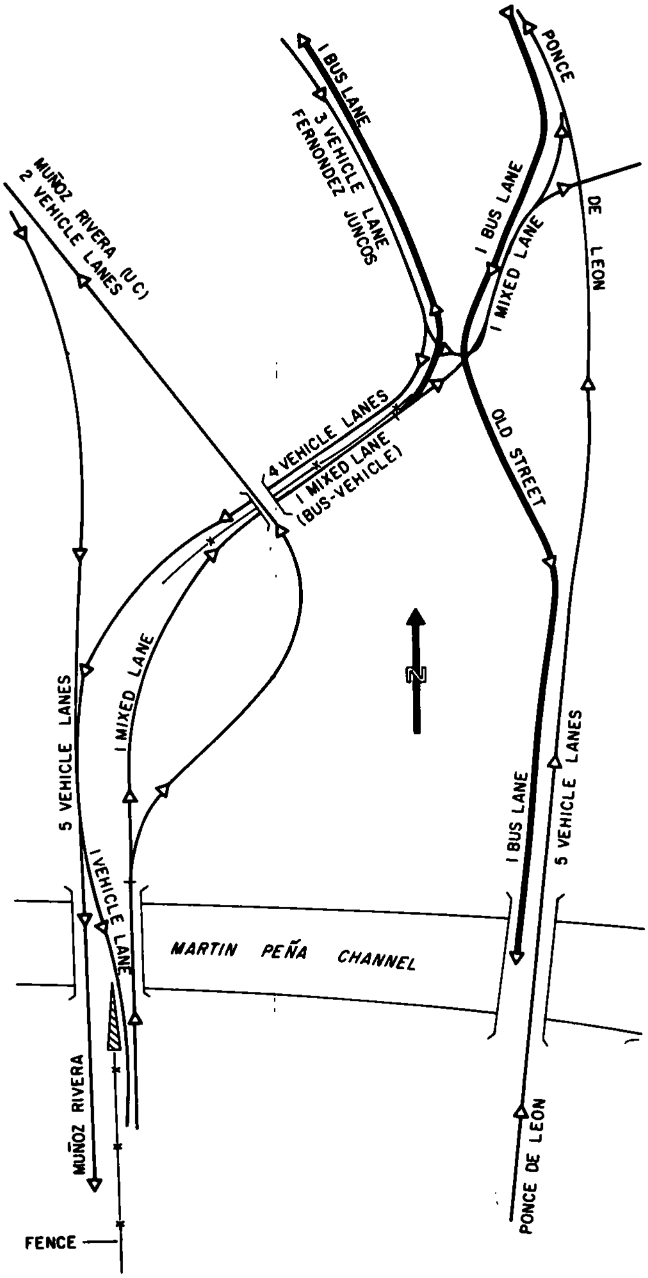


Figure C-49 Details of transition, contra-flow bus lanes, San Juan, P.R

1 Convert Ponce de Leon Avenue to one-way northbound traffic from Hato Rey to Gandara Avenue in Rio Piedras.

2. Provide an exclusive northbound bus lane in six-lane Munoz Rivera Avenue adjacent to the west side of the median (i.e., contra-flow).

3. Construct a barrier-type median in Munoz Rivera Avenue from University Avenue in Rio Piedras to the Martin Pena Channel.

4. Construct bus stops in the Munoz Rivera Avenue median, including bus shelters

5. Extend Gandara Avenue from University Avenue to Colley Toste Street.

TABLE C-19

EXISTING CONTRA-FLOW BUS LANES, SAN JUAN, P R

AREA	STREET	LIMITS	DIRECTION
San Juan Antiguo	Munoz Rivera—Ponce de Leon	Plaza Colon—San Antonio Channel	Eastbound Westbound
Santurce	Ponce de Leon—Fernandez Juncos	San Antonio Channel—Martin Pena Channel	Eastbound Westbound
Hato Rey	Ponce de Leon	Martin Pena Channel—Betances Avenue	Southbound

Source Ref *(C-17)*

TABLE C-21

ESTIMATED COSTS, CONTRA-FLOW BUS LANES, SAN JUAN, P.R

ITEM	ESTIMATED COSTS ($)
1. Signing	10,000
2 Pavement marking	8,000
3 Traffic control signals	6,000
4. Minor street constr	30,000
5. Access to MBA	11,000
6 Planning and design	15,000
Subtotal	80,000
7 Publicity	20,000
Subtotal	100,000
8. Data collection	25,000
9. Anal , eval , reports	15,000
10 Contingencies	15,000
Total	155,000

Source Ref *(C-18)*

TABLE C-22

BUS TRAVEL TIMES,[a] CONTRA-FLOW BUS LANES, SAN JUAN, P.R , 1971

ROUTE NO	ROUTE MILES	DIRECTION OPERATED	ELAPSED TIME (MIN)	SPEED (MPH)	
				USING EXCLUSIVE LANE	PRIOR TO EXCLUSIVE LANE
1	8 4	N-W	39.8	12 6	8.4
		S-E	45.5	11.0	8.4
9	8.6	N-W	40 6	12.7	8.6
		S-E	48.7	10 6	8.6
25	8.8	N-W	40.2	12.8	8.8
		S-E	38 0	13.9	8.8
35	8.4	N-W	41.1	12.2	8 4
		S-E	46.0	10.9	8.4

Source San Juan Metropolitan Bus Authority (AMA) (1971)

[a] Travel times between Old San Juan and Rio Piedros (Capetillo)

TABLE C-20

VEHICLE COUNTS, CONTRA-FLOW BUS LANES, SAN JUAN, P R [a]

LOCATION	6 00 AM TO 10 00 PM		AM PEAK HOUR 7·30– 8 30		PM PEAK HOUR 5·00– 6 00		OFF-PEAK HOUR 10:00– 11.00 AM		OFF-PEAK HOUR 2 00– 3 00 PM	
	CARS	BUSES	CARS	BUSES	CARS	BUSES	CARS	BUSES	CARS	BUSES
Ave. Fernandez Juncos·										
At Parque	20,676	720	1,288	67	1,808	36	1,453	45	1,447	41
At Roberto H. Todd	19,411	782	853	61	769	55	855	55	866	40
Ave Ponce De Leon										
At De Diego	26,373	665	2,556	39	1,985	40	1,094	43	1,193	20
At Parque	24,003	443	1,805	49	1,359	32	1,386	44	1,615	13

Source Puerto Rico Highway Authority and Dept of Public Works (1971)

[a] Traffic southeast bound, buses northwest bound

6 Widen University Avenue and Colley Toste Street

This phase also calls for improved transit surveillance, purchase of new buses, and construction of a major Capetillo transportation terminal in Rio Piedras.

Costs for this program have been estimated at $1.3 million for street and traffic improvements; $0.1 million for a public education program; $2.6 million for improved bus service, and $0.5 million for surveys, analyses, reports, and contingencies. Costs for the terminal have been estimated at $8 million.

Significance

The San Juan contra-flow bus lanes produced important time savings to bus riders at minimum cost The time savings, although influenced in part by opening of a new expressway, are comparable to those achieved by expressway priority treatments and by many rail rapid transit lines. This project clearly demonstrates how arterial street bus improvements can be achieved effectively and suggests an approach to bus priority lanes on one-way street couplets.

24. TORONTO BUS PRIORITY LANES

The Toronto Transit Commission (TTC) is responsible for all public transportation within the 240-sq-mi area of Metropolitan Toronto, Ontario. It operates 2 subway routes, 11 streetcar routes, and 90 bus routes, including several trolley bus lines. Approximately 80 percent of the bus routes connect with the subway system.

Some of the heaviest bus flows converge at the Eglinton Avenue terminal of the Yonge Street subway. This terminal accounted for 17 percent of the total morning peak-hour subway passenger volume in 1971 Accordingly, the Municipality of Metropolitan Toronto, in conjunction with the TTC, installed an eastbound bus lane on 3.2 miles of Eglinton Avenue in 1972. This lane operates between Bathurst and Yonge Streets during the morning peak period, and between Yonge Street and Brentcliffe Road during the evening peak period (Fig. C-50)

Traffic Characteristics

Eglinton Avenue eastbound between Bathurst and Yonge Streets serves 5,000 bus passenger-miles and 2,600 automobile passenger-miles during the 7:00 AM to 9.00 AM weekday period. There are 9,500 bus passenger-miles eastbound on Eglinton Avenue between Yonge Street and Brentcliffe Road from 4·00 PM to 6:00 PM each weekday, as compared with 5,300 automobile passenger-miles. Thus, buses serve about 56 percent of the eastbound peak-period person movement.

Eastbound 1971 car and bus speeds between Bathurst and Yonge Streets are summarized in Table C-23. The average eastbound AM peak-period automobile speed averaged 13 2 mph as compared with 8.4 mph for buses. During the PM peak period between Yonge Street and Brentcliffe Road, the eastbound automobile speeds averaged 10.5 mph as compared with 9.5 mph for buses

Design Concept

Eglinton Avenue is 50 to 54 ft wide. The bus lane was achieved by re-marking the street for three eastbound lanes, and designating the south curb lane for buses. This plan did not reduce the number of lanes devoted to through automobile movement. The cost for signs, pavement markings, and removal of channelizing islands was approximately $50,000.

To provide a satisfactory level of vehicular service within the limits of the reserved bus lane, the stopping of private vehicles was prohibited on the north side of Eglinton Avenue between Bathurst Street and Brentcliffe Road from 7.00 AM to 9:00 AM and from 4:00 PM to 6:00 PM. On the south side of Eglinton Avenue stopping is prohibited between Bathurst and Yonge Streets from 7:00 AM to 9·00 AM; and between Yonge Street and Brentcliffe Road from 4 00 PM to 6:00 PM.

Anticipated Benefits

Toronto transportation planners estimate that the eastbound reserved bus lane on Eglinton Avenue saves each transit

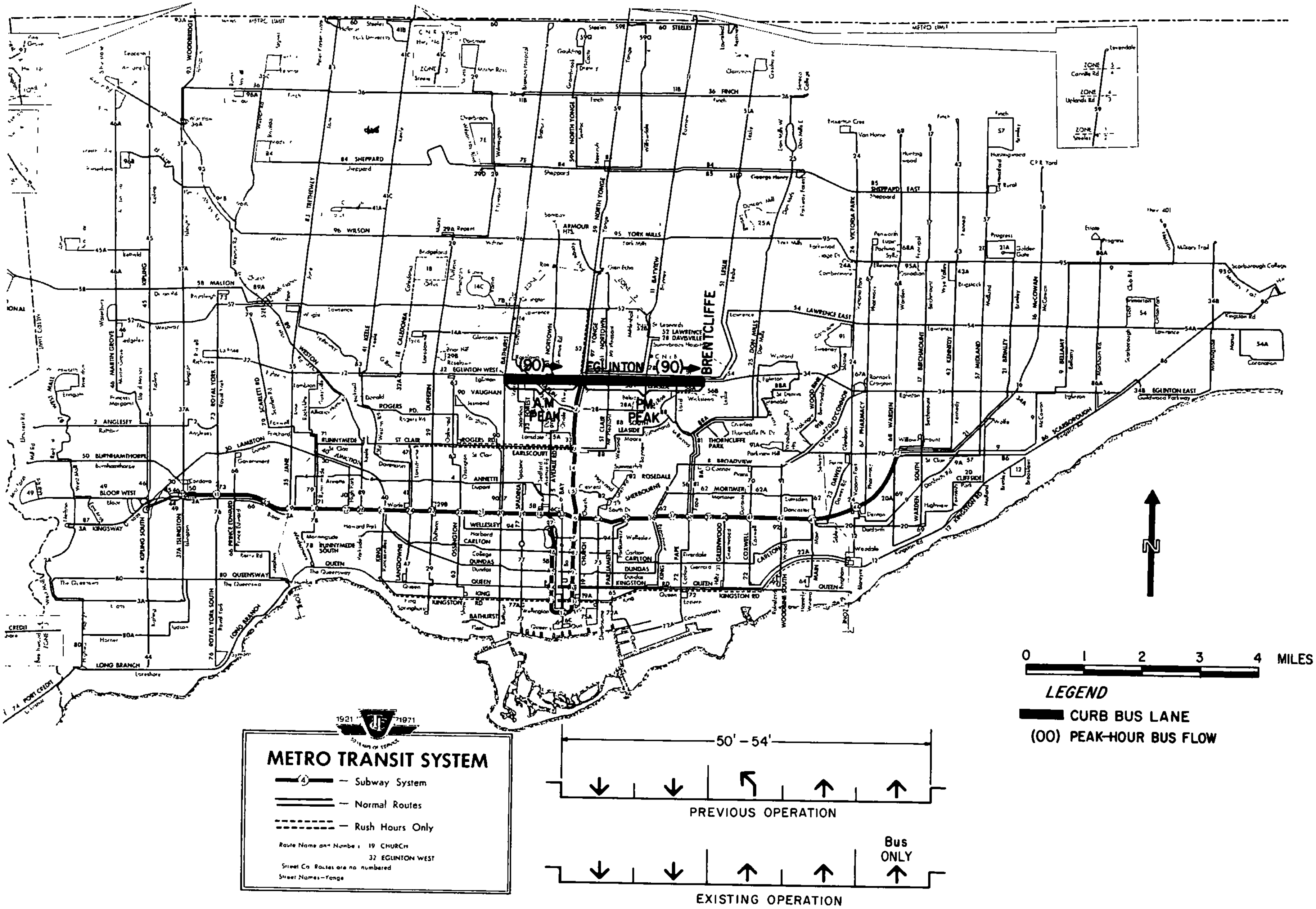


Figure C-50 Eglinton Avenue bus lane, Toronto, Ont

TABLE C-23

TRAVEL CHARACTERISTICS, EGLINTON AVENUE, TORONTO, ONT

			VEHICLE CHARACTERISTICS						
			PRIVATE			TRANSIT			
								DELAY DUE TO	
LOCATION	TIME PERIOD	DIRECTION OF TRAVEL	AVG. SPEED (MPH)	TOTAL AVG TRAVEL TIME (MIN)	DELAY DUE TO EXISTING TRAFFIC CONDITIONS (MIN)	AVG SPEED (MPH)	TOTAL AVG TRAVEL TIME (MIN)	EXISTING TRAFFIC CONDITIONS (MIN)	BOARDING AND DISCH. PASS (MIN)
Bathurst St	AM peak period	EB	13.2	6 4	2 1	8 4	9 9	1 5	1.7
to Yonge St.	7 00 to 9:00 AM	WB	14.4	5 8	2 2	—	—	—	—
Yonge St	PM peak period	EB	10.5	11.4	2 9	9.5	12 6	3 8	1 0
to Brentcliffe Rd	4 00 to 6·00 PM	WB	12.5	9 6	3 6	—	—	—	—

Source Municipality of Metropolitan Toronto, Dept of Roads and Traffic (1971)

passenger up to 4 min in the morning peak period in the Bathurst-to-Yonge section. In the Yonge-to-Brentcliffe section, each transit passenger saves up to 6 min travel time in the evening peak

The losses in travel time for Eglinton Avenue motorists resulting from the reserved bus lanes were estimated to be. (1) 2 min per vehicle-trip eastbound and 4 min per vehicle-trip westbound in the Bathurst Street to Yonge Street section during the AM peak period; and (2) 3 min per vehicle-trip eastbound and 5 min per vehicle-trip westbound in the Yonge Street to Brentcliffe Road section during the PM peak period.

During other periods of the day, similar reductions in the over-all level of vehicular service were expected as a result of implementing a permanent five-lane section of pavement The loss of existing left-turn lanes at major signalized intersections within the proposed reserved bus lane area may also increase vehicular travel time. A further prohibition of left turns would tend to eliminate most of the anticipated auto delays This would involve a trade-off between bus operating benefits and circuitous travel for vehicles turning left, including additional travel in residential neighborhoods.

25. VANCOUVER BUS PRIORITY TREATMENTS

Downtown Vancouver, B.C , is a peninsula on a peninsula with an employment of 90,000 and a residential population of 40,000 Burrard Inlet on the north, False Creek on the south, and an extensive network of rail facilities on the east limit the gateways to downtown and emphasize reliance on public transport for the journey to work.

Bus Use Patterns

The British Columbia Hydro-Electric Company (B.C Hydro) operates a fleet of more than 400 diesel and trolley buses, with 325 vehicles in service during peak periods. During the evening rush hour some 250 buses carry 17,000 of the 45,000 people leaving the CBD

Major bus concentrations are found on a few downtown streets (Fig C-51). Bus flows are somewhat more concentrated than in other downtown areas because of the limited number of water crossings Peak-half-hour bus volumes approach 50 vehicles on Hastings and Granville Streets. The principal points of bus delays are also found in the retail-commercial core (Fig C-52).

Bus Priority Treatments

Existing and proposed bus priority treatments (Fig C-53) were designed to (1) alleviate major locations of downtown bus delay, and (2) improve transit identity in the downtown commercial core.

Georgia Street Bus Lane

A PM peak-hour curb bus lane was installed in 1967 on six-lane west Georgia Street, the major artery leading to the Lion's Gate Bridge across Burrard Inlet. The lane, which allows right turns by cars, extends for six blocks along the north curb from Burrard to Pender Streets This area experiences major congestion because of the convergence of traffic on the approach to the three-lane bridge (the bridge provides two lanes outbound in the evening).

Installation of the bus lane reduced bus travel times 30 percent (from 6 4 to 4 5 min) in the section of street covered by the regulation. A 12 percent patronage increase was reported for the four months following installation of the bus lane. In 1971, the B C Hydro reported a time saving of about 20 percent in the lane.

Inbound during the morning, there is also a preferential bus entry lane onto the Lion's Gate Bridge from North Vancouver.

Proposed Treatments

The Greater Vancouver Regional Planning District has proposed that Granville Street be converted into a bus mall. This downtown street has the heaviest bus volumes and penetrates the retail and commercial core It is paralleled by two one-way streets with direct entry to the eight-lane Granville Bridge This arrangement, similar to that pro-

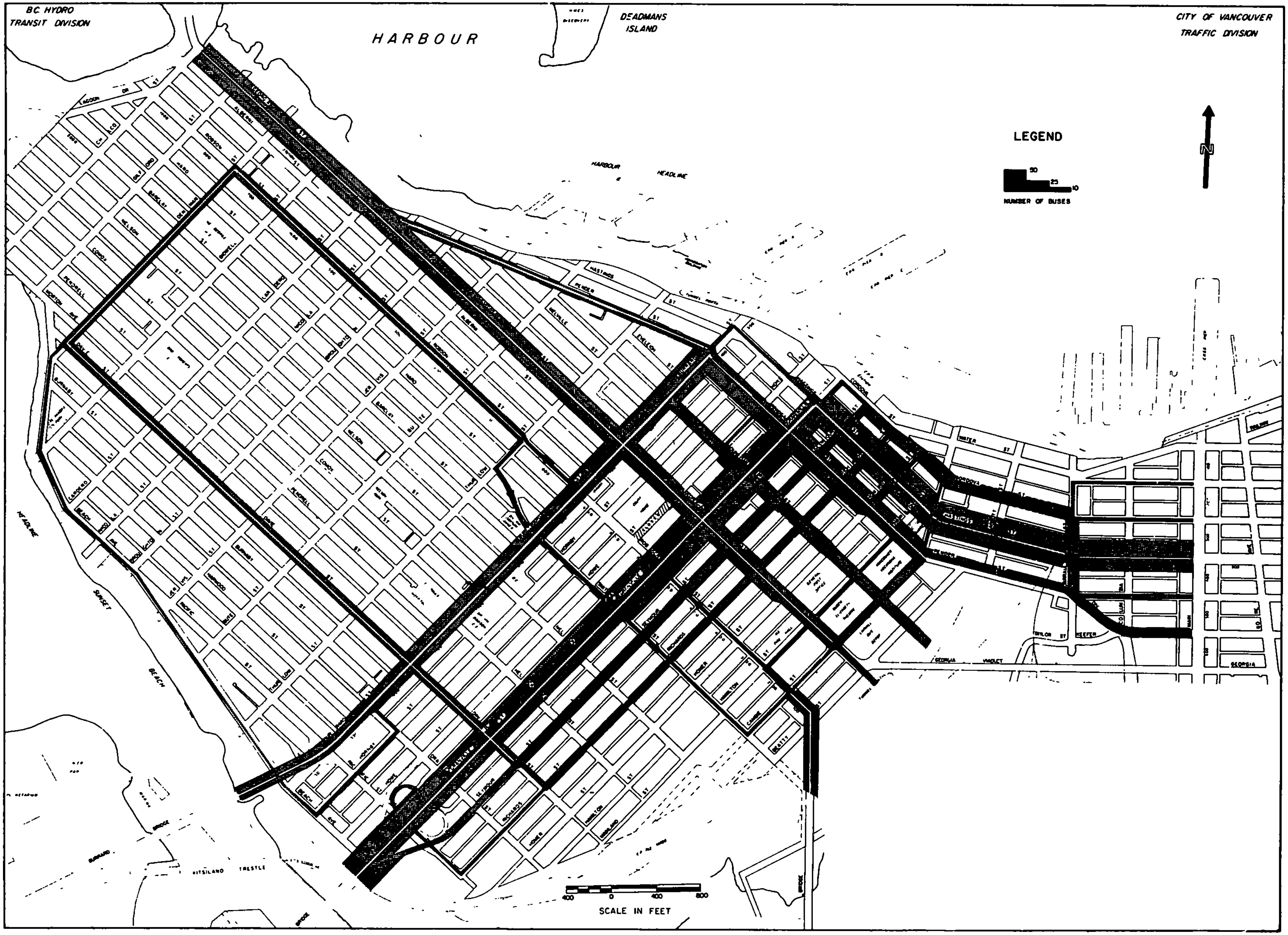


Figure C-51   Evening peak-30-min bus flows, Vancouver, B.C

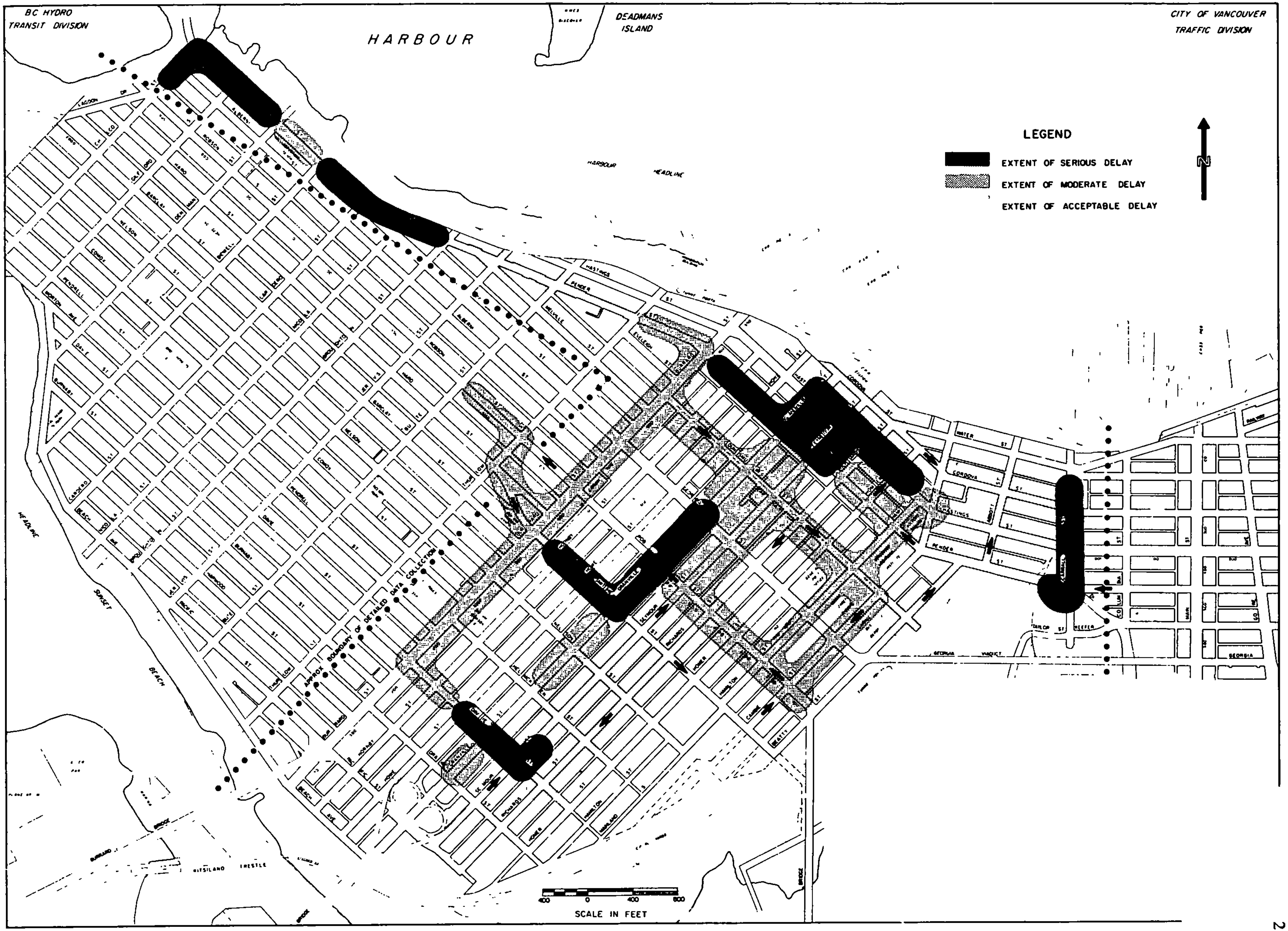


Figure C-52 Evening peak-hour bus delays, Vancouver, B C

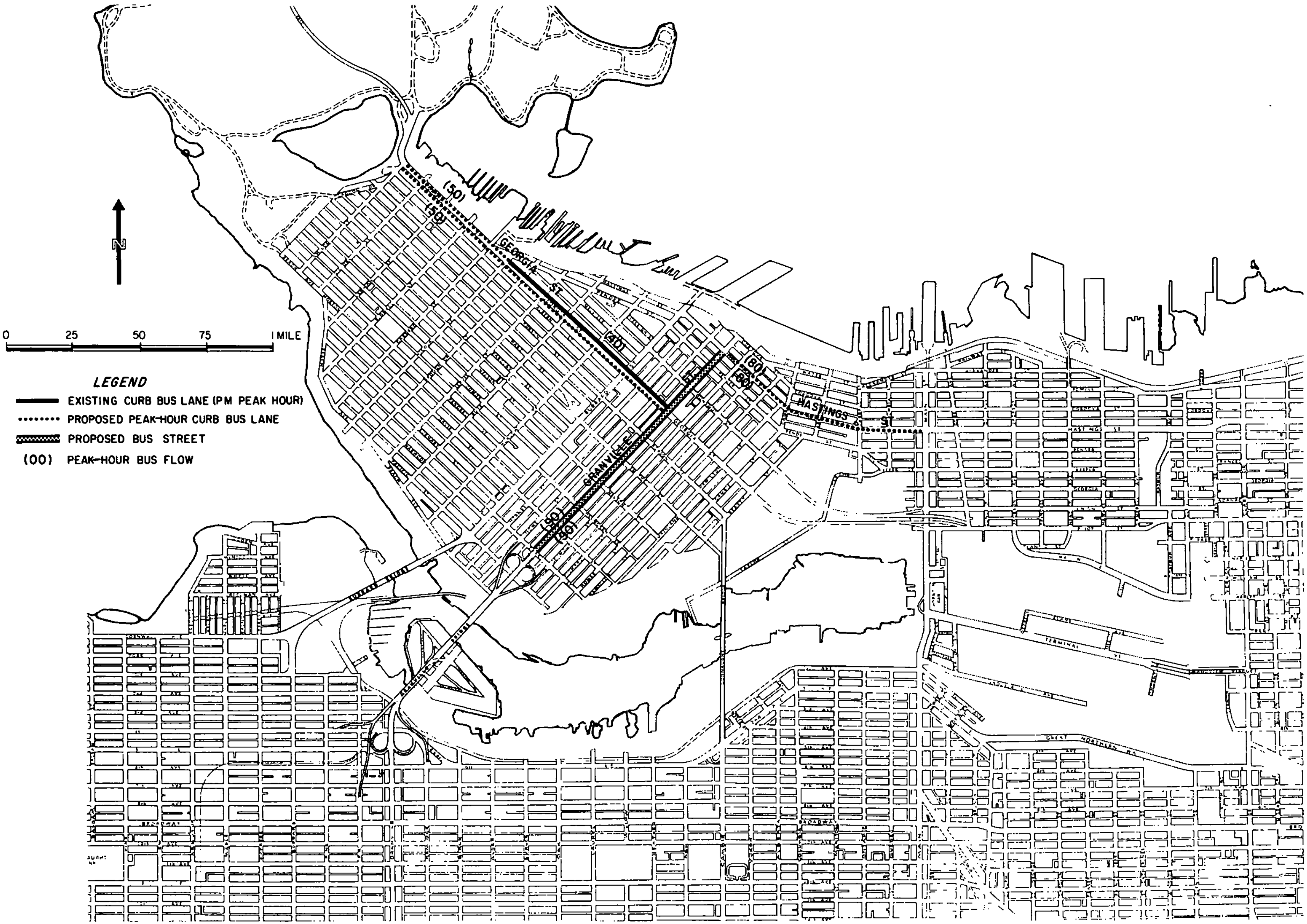


Figure C-53. Bus priority treatments, Vancouver, B C posed for Main Street in Dallas, allows auto traffic to be readily diverted to parallel one-way streets

Bus priority lanes have been proposed along Hastings Street between Granville and Main Streets in the downtown area This street has the second heaviest downtown bus flows and serves an important part of the retail shopping core

A proposed extension of the existing curb bus lane on Georgia Street west to Stanley Park would give buses an exclusive route between the downtown core and the Lion's Gate Bridge approach

26. WASHINGTON BUS PRIORITY LANES

The first bus priority lane in Washington, D.C., was instituted in May 1957. Since then the District of Columbia Department of Highways and Traffic (D.C DOT) has established many other bus lanes

Bus Use Patterns

The role that buses play during peak-period person movements is best shown by 1970 cordon counts (Table C-24). Buses represented less than 1 percent of the total vehicle flow, but carried almost 17 percent of the people inbound crossing the District Line cordon during the 2-hour morning peak period At the Anacostia and Potomac River cordon line, buses carried 22 to 25 percent of the inbound person movement.

Peak-hour CBD cordon data developed a decade ago show major bus concentrations on Connecticut, Massachusetts, Wisconsin, Georgia, Pennsylvania, New York, and Constitution Avenues, and on Capitol, 14th, 16th, H, I (Eye), and K Streets These conditions prevail today.

Legal Authority

The legal authority for establishing bus priority lanes is contained in Part II, Article XXXVIII, Section 176, of the D.C Code, as follows

> The traffic lane closest to the right hand curb on the following streets shall, during the times set forth below, except on Saturdays, Sundays and Holidays, be reserved for the use of buses, provided, however, that other vehicles may enter or leave the bus priority lane for the purpose of taking on or discharging a passenger or to make a right turn unless such turn is otherwise prohibited by an official traffic control device
>
> Vehicles other than buses entering the bus priority lane to make a right turn shall be permitted to enter only within the same block as the right turn.
>
> The burden of proof shall be upon the driver of a vehicle other than a bus entering such lane to show that he entered for the purpose of taking on or discharging a passenger or of making a right turn.
>
> Buses are not restricted solely to the bus priority lanes; they are permitted to by-pass right turning or loading vehicles

Taxis and cars are permitted in the bus lanes to pick up and discharge passengers. Although not specifically mentioned, mail trucks are also permitted to stop in bus lanes during peak periods.

Bus lanes are established, marked, and signed by the D.C. Department of Highways and Traffic through coordinated efforts with the four major bus companies, the Washington Metropolitan Area Transit Commission, and the Metropolitan Washington Council of Governments. Maintenance is the responsibility of the highway department.

Existing Bus Lanes

Existing bus lanes are located along 7th, 9th, 13th, 14th, 16th, H, and I (Eye) Streets in the CBD. Bus lanes also extend northerly along 16th Street to U Street (see Table C-25 and Fig. C-54). Bus lanes generally operate Monday through Friday (excluding holidays) from 7·00 to 9.30 AM and from 4·00 to 6.30 PM.

The Department of Highways and Traffic uses 60 buses per hour as the minimum volume warrant for a bus lane. Most bus lanes carry 60 to 120 buses per hour All are along curbs in the direction of auto movement; there are no contra-flow lanes.

Controls

Distinctive red, white, and blue signs advise motorists of lane use (Fig C-55) The Department of Highways and

TABLE C-24

PEAK-PERIOD TRANSIT USE, WASHINGTON, D C[a]

	VEHICLES				PASSENGERS			
LOCATION	TRANSIT BUSES	AUTOS	TOTAL[b]	% BUSES	TRANSIT BUSES	AUTOS	TOTAL[b]	% BUSES
Potomac River bridges	435	38,846	39,281	1 11	17,810	61,898	79,708	22 34
Western Ave[c]	81	19,863	19,944	0 41	1,999	28,238	30,237	6.61
Eastern Ave[c]	236	51,558	51,794	0 46	5,786	76,982	82,768	6.99
Anacostia River bridges	413	35,368	35,781	1 16	20,432	60,505	80,937	25 24
Total	1,165	145,635	146,800	0 79	46,027	227,623	273,650	16 82

Source Ref (*C-19*)

[a] Data collected between 7 00–9 00 AM during May 1970

[b] Transit buses and autos only, excludes trucks and other types of buses (school, charter, military, intercity)

[c] City line

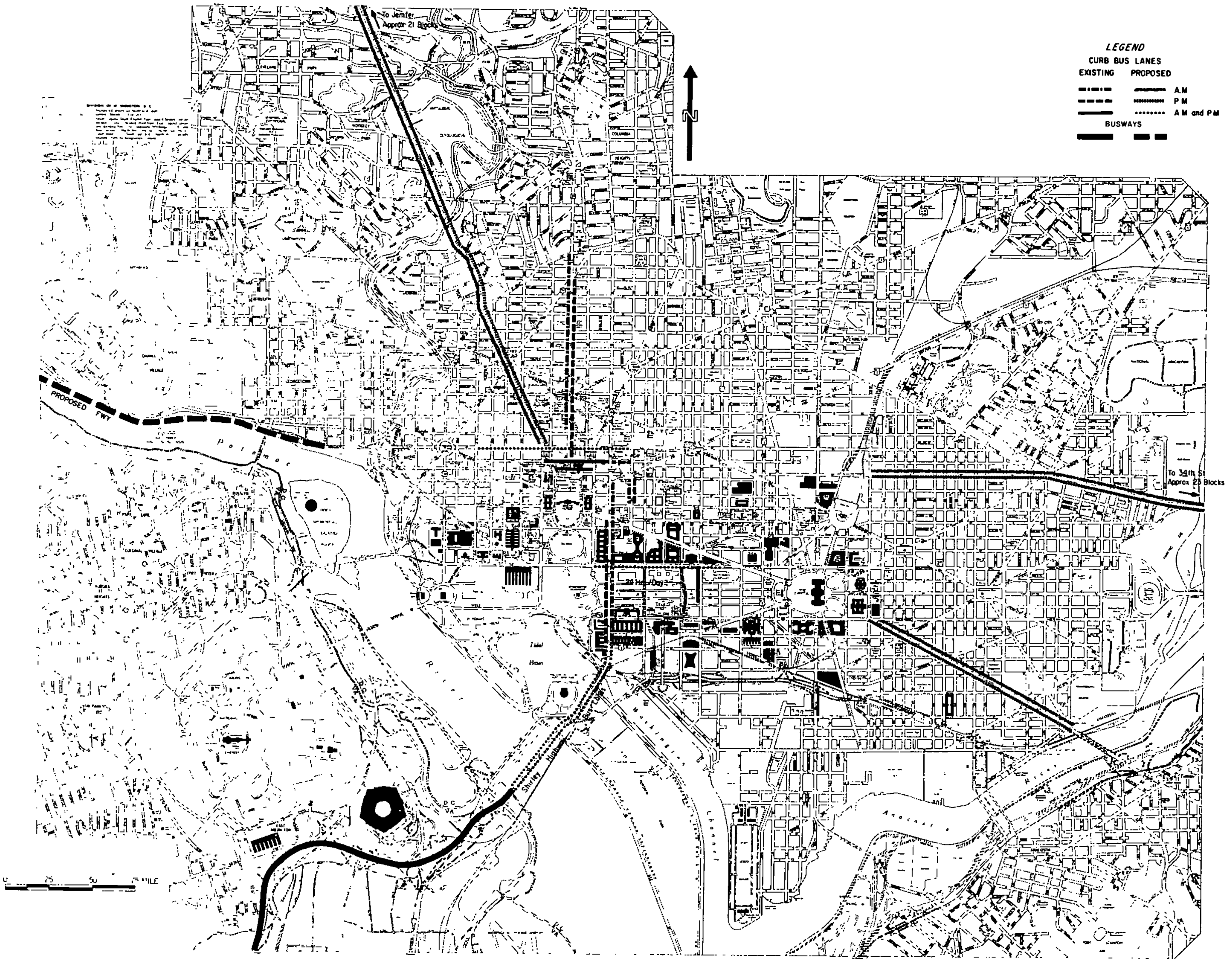


Figure C-54 Bus priority treatments, Washington, D C

TABLE C-25

EXISTING BUS LANES, WASHINGTON, D C

STREET	FROM	TO	LENGTH (BLOCKS)	DESCRIPTION
14th	D St., S W	New York Ave., N.W	13	AM; east side of street, two-way street.
	Pennsylvania Ave , N.W.	D St., S.W	10	PM, west side of street, two-way street
7th	Pennsylvania Ave.	Independence Ave	6	AM and PM, west side of street, two-way street
16th, N W.	Eye St , N W.	U St , N.W.	15	PM east side of street
	Florida Ave , N W.	L St , N W	15	AM; west side of street, two-way street.
13th	F St , N W.	H St , N W.	2	AM, west side of street, PM; east side of street.
Eye, N W	17th St , N.W	14th St , N.W	5	AM and PM, south side of street
	14th St , N.W	13th St , N W	2	PM only, one-way EB street
H, N W	14th St , N W	Connecticut Ave , N.W	4	AM and PM, north side of street, one-way WB street
9th St [a]	Constitution Ave	Bus turnout south of Independence Ave	6	Reserved at all times; one-way SB street

[a] Expressway

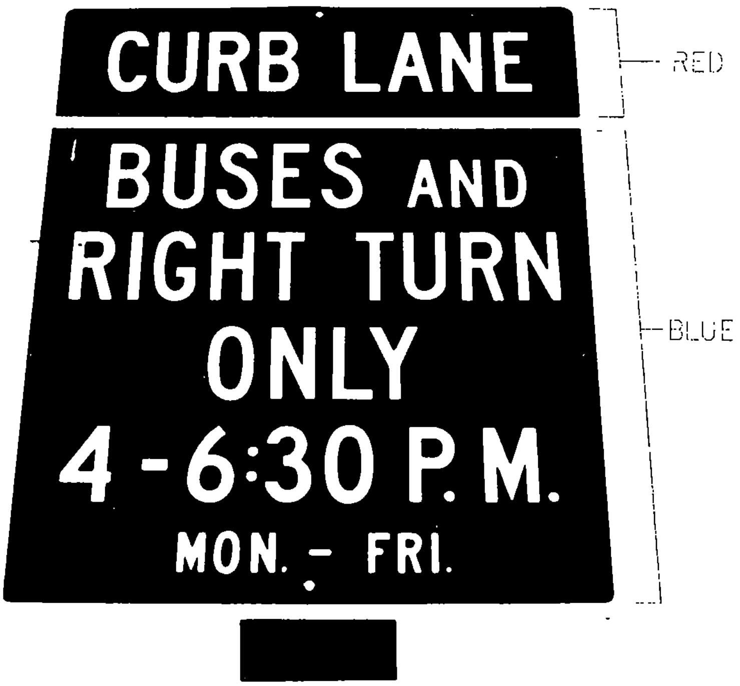


Figure C-55 Typical bus lane sign, Washington, D C

Traffic utilizes unique pavement markings to further advise motorists of the bus lane restrictions (Fig. C-56).

Control Effectiveness

A before-and-after study at the intersection of Constitution Avenue and 14th Street in 1971 evaluated the effectiveness of the bus lane pavement markings in achieving driver compliance (i e., having only right-turning cars use the bus lane). Sufficient time elapsed between the two sets of counts for drivers to familiarize themselves with the markings.

The results are summarized in Table C-26. Two characteristics are clear. First, the decline of more than 500 vehicles during a comparable 2-hour period can be attributed, in part, to the diversion of motorists from cars to the Shirley Highway express bus service during the six-month lapse between counts, about 50 peak-period bus trips were added to that service between June and October 1971 Second, both the number and percentage of driver violations fell markedly between the two counts. This suggests that the pavement markings, in combination with the signs, were more effective than the signs alone in advising motorists to keep out of the curb lane except to make right turns

Current Proposals

The District of Columbia Department of Highways and Traffic is planning to extend bus lanes along six radial arterial streets (Table C-27). These proposals (January 1972) are especially significant because they involve a city-wide approach to bus priority lanes It is important to note that on each street there are at least two other lanes in the peak direction of auto travel; in no instance are cars restricted to only one lane of traffic Signing and pavement markings would be the same as that for the existing bus lanes

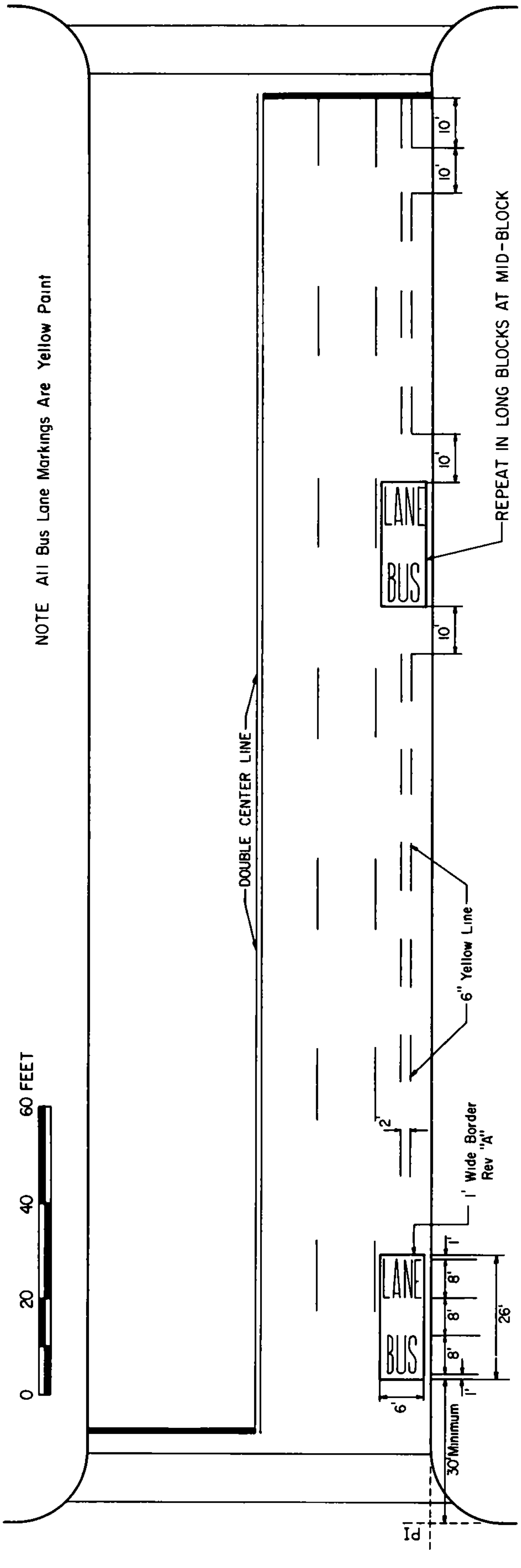


Figure C-56. Typical bus lane pavement markings, Washington, D C

TABLE C-26

COMPARATIVE TRAFFIC CONDITIONS, 14TH STREET AND CONSTITUTION AVENUE, WASHINGTON, D C

ITEM	BEFORE [a]	AFTER [b]
Total traffic, all lanes	2,844	2,327
Illegal thru traffic in bus lane	261	92
Violations (%)	9	4
Right turns legally permitted	311	300
Legal turns (%)	11	13

Source D C Dept of Highways and Traffic (1971)
[a] April 1971 between 7 00–9 00 AM
[b] October 1971 between 7 00–9 00 AM

Traffic Signal Preemption

The District of Columbia has installed traffic signal controllers at 41 intersections in the downtown area to allow bus preemption The green phases of selected traffic signals will be extended by approaching bus drivers. The computerized bus priority-signal control system was planned to be operational by early 1973.

Significance

The public has accepted the idea of bus lanes and cooperation is good Although delivery vehicles, mail trucks, or parked cars occasionally block bus lanes, buses are usually able to bypass the obstacles

The priority bus lanes on 14th Street were specifically designed to reduce travel times within the District. This was a major delay point during initial express bus operations from Shirley Highway. However, no substantial savings have been reported in this area.

The proposed arterial bus lanes represent an important step forward Inasmuch as the probability of marginal conflicts is less along arterials than in the downtown, violations should be fewer. The greater travel distances should achieve significant time savings for buses and bus passengers.

27. DERBY TRAFFIC MANAGEMENT PLAN

In 1970, a traffic management plan was introduced in Derby, an historic central England market and manufacturing community of 270,000 (Fig. C-57). A clockwise loop of one-way streets discourages motorists from entering or traversing the downtown area. The clockwise street pattern, plus a natural barrier, the Derwent River, precludes car travel through the city center.

To retain direct bus routings and to prevent circuitous detours, buses were afforded certain operating advantages Portions of two streets (Wardwick and Queen) were developed as contra-flow bus lanes; Market Street in the downtown was designated as a bus only street; and normal-flow curb bus lanes were installed on short sections of three other streets

This project, sponsored by the Ministry of Transport, is designed to measure the travel time benefits achieved by buses and automobiles as a result of restricting unnecessary traffic in the central area and establishing bus priorities.

TABLE C-27

PROPOSED BUS PRIORITY LANES, WASHINGTON, D.C

STREET	FROM	TO	LENGTH (BLOCKS)	DESCRIPTION
Constitution Ave , N.W.	6th St	15th St.	6	AM and PM; north and south sides of street, two-way street.
K St , N.W.	13th St	21st St	10	AM and PM; south side of main roadway; only during metro construction on Eye St ; two-way street with service lanes
Connecticut Ave , N W.	K St	Jenifer St	52	AM, west side of street, PM, east side of street; two-way street.
Pennsylvania Ave , S E	2nd St	Sousa Bridge	15	AM, north side of street, PM, south side of street; two-way street
Benning Rd , N E.	34th St. 15th St	Bladensburg Rd 34th Street	14 14	AM, north side of street; PM, south side of street, two-way street
H St , N E	Florida Ave	2nd St	13	AM, north side of street, PM, south side of street; two-way street

Source D C Dept of Highways and Traffic (Jan 1972)

28. DUBLIN BUS PRIORITY LANE

A curb bus lane was installed on 2.1 miles of an arterial route leading into downtown Dublin, Ireland, during March 1971. Dublin's current population approximates 900,000. This lane and three short feeder lanes extend through the Fairview area, as shown in Figure C-58. The lanes operate in the westbound direction during the morning peak hours, 8 00 to 9·30 AM.

The Dublin City Bus Service believed that a bus priority lane would help reduce traffic congestion by diverting people to buses. During the peak period, 12,500 people commute to the city center along this route (3,700 by car, 8,800 by bus). Thus, even before installation of the lane buses dominated person-flow. The average frequency of bus service was 21 sec, the equivalent of nearly 180 buses per hour

The lane was reserved for buses, taxis, and emergency vehicles It was 10 ft wide, located adjacent to the curb, and marked by 4-ft white lines with 10-ft gaps. Cars and cyclists requiring to turn left were permitted to enter the lane at predetermined locations. Bus fares were reduced slightly during the experiment, and 30 buses were added along the route

Results of a week-long bus lane experiment are summarized in Table C-28.

1. Bus travel times were reduced from 10.6 to 8.2 min
2. Bus service regularity was increased. About 72 percent of the buses operated within the scheduled headway, as compared with 54 percent before.
3. An increased number of persons used the bus service; daily passengers increased 13 percent (from 8,900 to 10,070).
4. Automobile travel times increased from 10.0 to 12.6 min (26 percent)
5 Automobile traffic volumes were reduced, perhaps because of the reduced space available and increased use of buses. Car volumes at Newcomen Bridge were reduced from 2,446 to 1,664
6. The over-all journey time per person (bus and car) was reduced from 10.4 to 9.3 min, equivalent to a 10 percent over-all reduction in person-delay.

Figure C-59 shows how bus speeds increased from 4 5 mph to 9 mph as a result of the experiment. Even more significant was the reduction in the range or variance of bus travel times (Fig. C-60).

The decrease in car traffic during the peak hour may have resulted from a staggering of work trips. Some additional bus passengers may have been attracted from a parallel rail commuter line

In a related context, the Public Transportation Study, released in October 1971, recommended a 1991 plan of high-speed bus routes (*C-21*). The routes would operate within new town areas and on three radial routes to the city center. They would include busways, bus lanes, and bus streets.

One busway would extend to Tallaght, a planned new town southwest of the city; another would serve Leopardstown, a third would serve northwestern areas. Two additional busways would operate within residential communities, both located to the west of Dublin Altogether, more than 40 miles of busways were recommended.

A 15-mile network of bus routes on priority lanes would extend radially outward from Dublin to connect with the

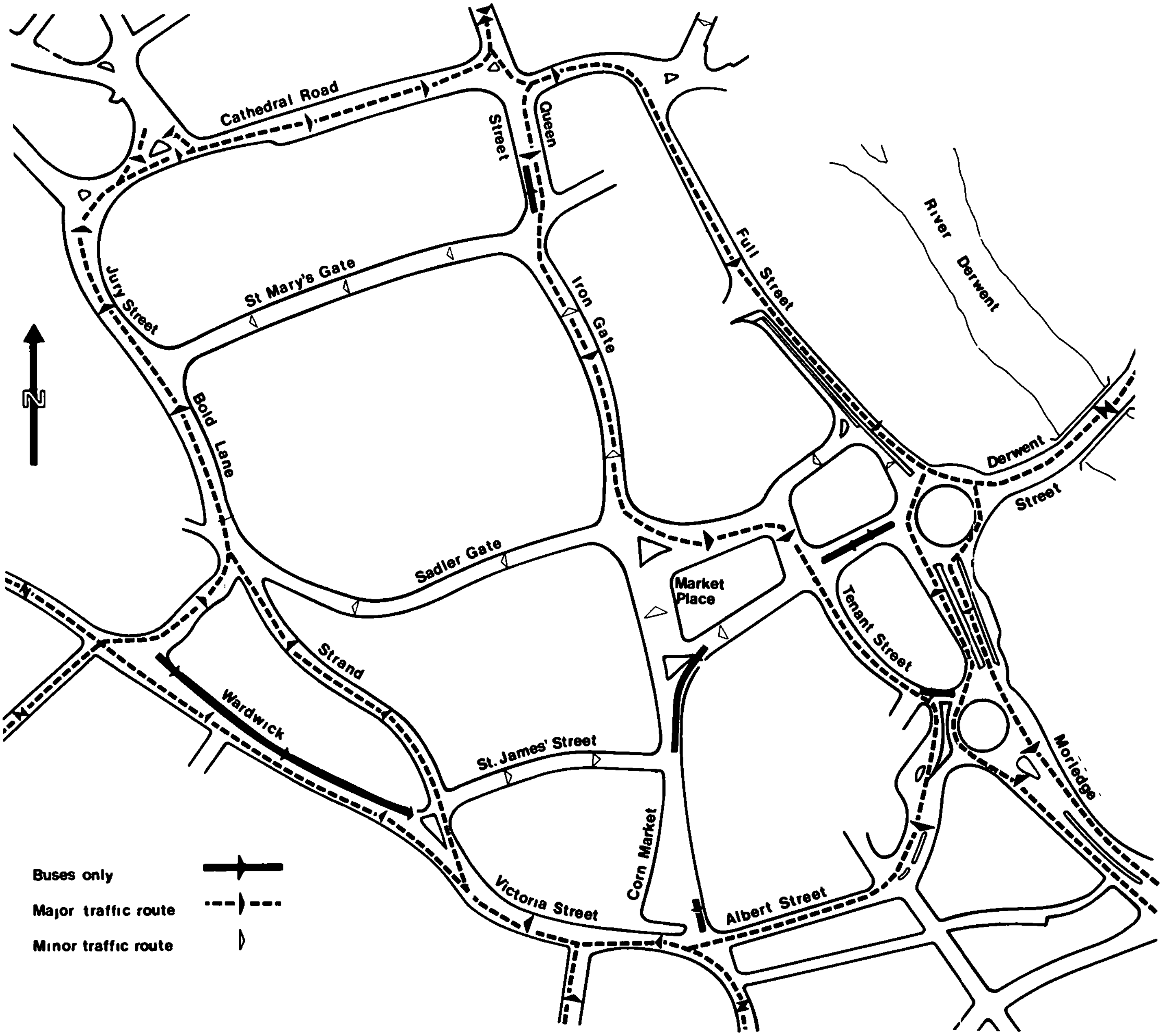


Figure C-57 Traffic flow and bus priority treatments, Derby, England.

proposed busways and the airport A central bus terminal, a network of priority bus lanes, and bus-actuated traffic signals also were proposed for central Dublin.

29. LEICESTER BUS PRIORITY AT A TRAFFIC SIGNAL

An experiment in Leicester, England, was designed to test the practicality of giving buses priority at an isolated traffic signal in a city of about 450,000 This project was one of the Bus Demonstration Projects studies by the Ministry of Transport in 1969.

The intersection of Humberstone Gate (5 lanes wide) and Charles Street (6 lanes wide) in the CBD was chosen for analysis, because a new signal was needed at this location. Buses making right turns into Charles Street were experiencing difficulty due to heavy conflicting traffic during the peak period. Accordingly, a third phase was added to the traffic signals; when actuated by the buses, this reduced the green time for the other two phases. The bus right-turn green time was held constant at 16 sec (see Fig C-61) This phase is similar to actuated left-turn phases at intersections in the United States.

A device installed under each bus automatically actuated a detector loop placed in the roadway about 100 ft before the signal on each side of Humberstone Gate. Once the signal was actuated, the following signal phases were compensated for the reduced green time by extending their green signal time to prevent excessive vehicle delay from occurring in the next cycle. The net effect was to shorten the normal signal cycle whenever there was a bus in the

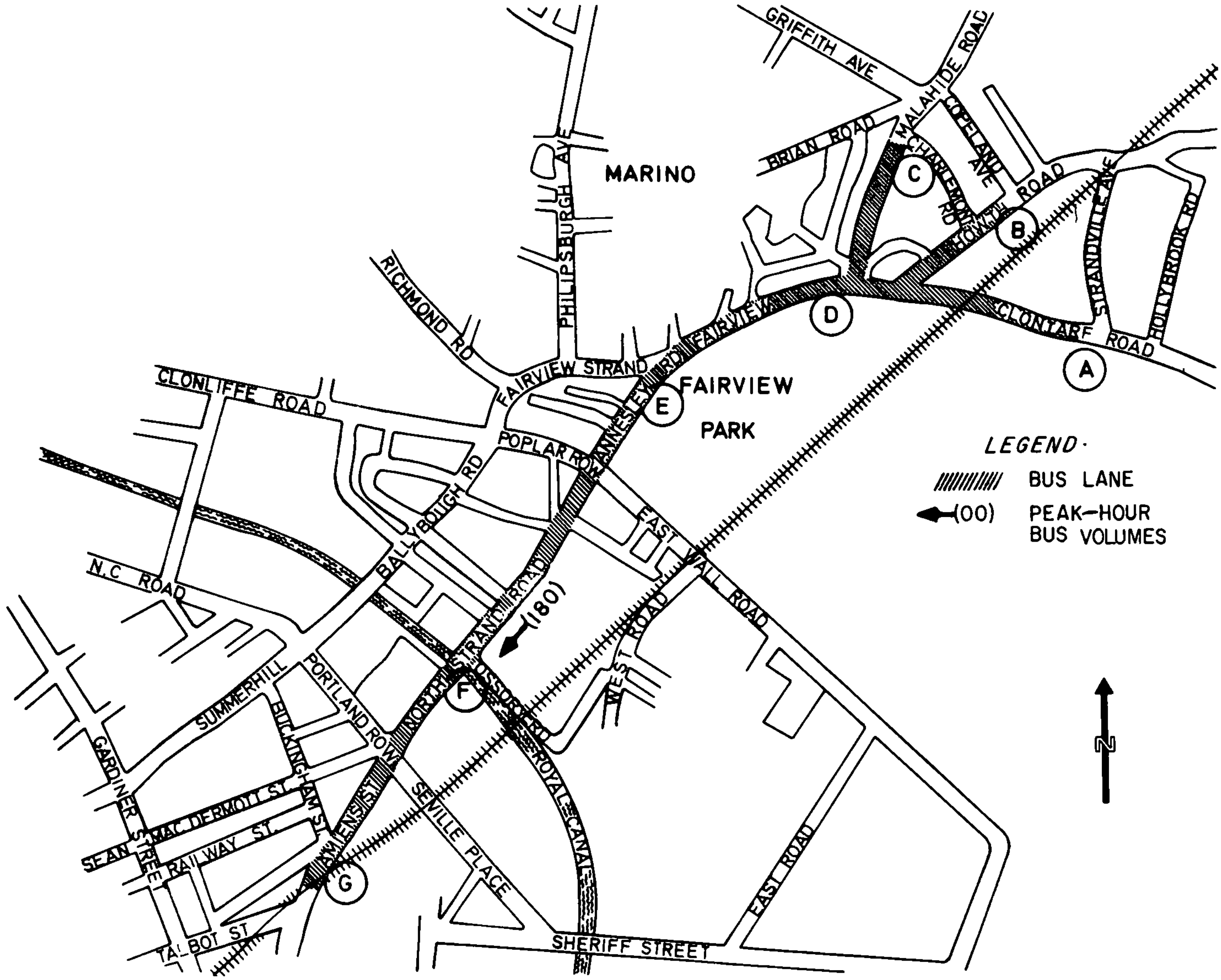


Figure C-58 Bus lane, Fairview, Dublin, Ireland

right-turn storage lane, simultaneously increasing the percentage of the cycle allocated to right turns. Other vehicles were allowed to make right turns with the buses

Altogether 20 buses were fitted with signal-actuating transponders and were given a designated travel route that normally passed through the studied intersection twice. A typical round-trip journey took 6 min.

Before-and-after studies showed that the buses making right turns saved only 7 sec per trip. More important, however, the distribution of long trip times (those longer than 1 min) was reduced from 47 to 36 percent (Fig. C-62).

The studies indicated that the loops were placed too close to the intersection Hence, whenever buses queued beyond the loops, the loops could not detect their presence, and in some cases buses did not have enough time to clear the intersection. Moreover, a bus approaching on the cycle following a signal actuation by another bus would suffer additional delay from the ensuing longer cycle. Although total bus time savings per trip were small, bus consistency and regularity seem to have improved Use of this type of bus-actuated signal showed that it is easily adaptable to a mixed-flow operation However, the variation in cycle length resulting from this test would not be applicable in an interconnected signal system.

30. LONDON BUS PRIORITY TREATMENTS

The Greater London Council (GLC), the metropolitan government of the London, England, urbanized area (population 7,400,000), has implemented a number of bus priority lanes. The GLC has complete responsibility for arterial roads within its jurisdiction and also controls London Transport bus and rail transit operations Bus priority projects in the central part of the city are shown in Figure C-63

TABLE C-28

BUS LANE EXPERIMENT RESULTS, DUBLIN, IRELAND

	8.00–9·30 AM			8.45–9.15 AM		
ITEM	BEFORE	AFTER	EFFECT (%)	BEFORE	AFTER	EFFECT (%)
Total passengers [a]	12,615	12,510	—	4,280	4,524	+5.7
Bus passengers [a]	8,900	10,070	+13.1	2,980	3,730	+25.0
Car passengers [a]	3,715	2,440	−34 2	1,300	794	−38 7
Car occupancy	1.52	1 46	—	1.52	1.46	—
No. of cars [a]	2,446	1,664	−32 0	855	544	−36.4
Trip time (min): [b]						
Buses	10 6	8 4	−20.8	13.1	8 7	−33 5
Cars	10 0	12 6	+26 0	12 9	13 0	—
Total travel time (hr):						
Bus [c]	1,573	1,410	—	650	541	—
Car [d]	619	512	—	281	172	—
Bus and car	2,192	1,922	—	931	713	—
Avg trip time per person (min)	10 4	9.3	−10.6	12 9	9 8	−24 0

Source Ref (*C-20*)

[a] Newcomen Bridge [b] Average trip time along bus lane length (1¼ miles) [c] Number of passengers times average bus trip time [d] Number of passengers times average car trip time

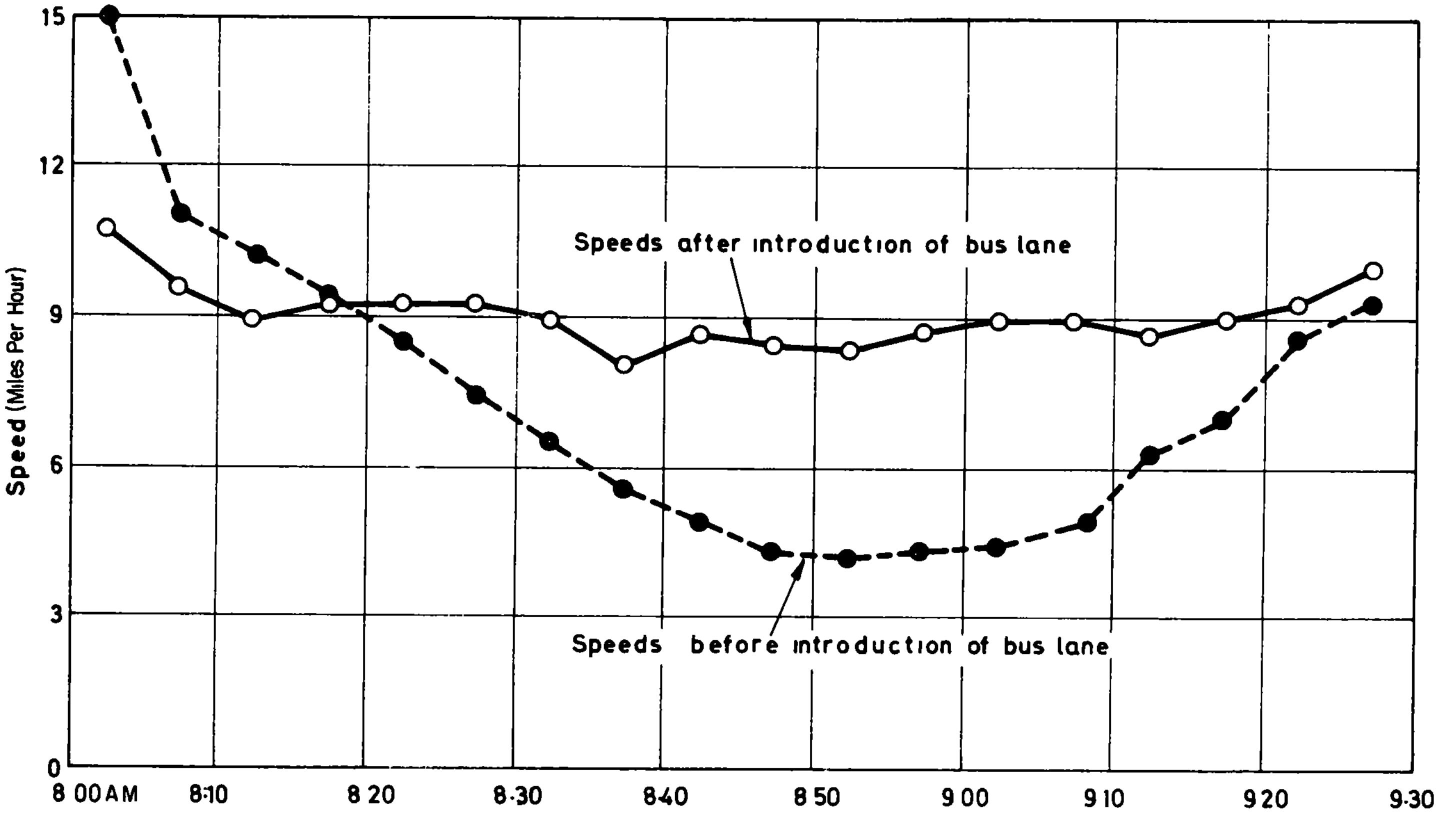
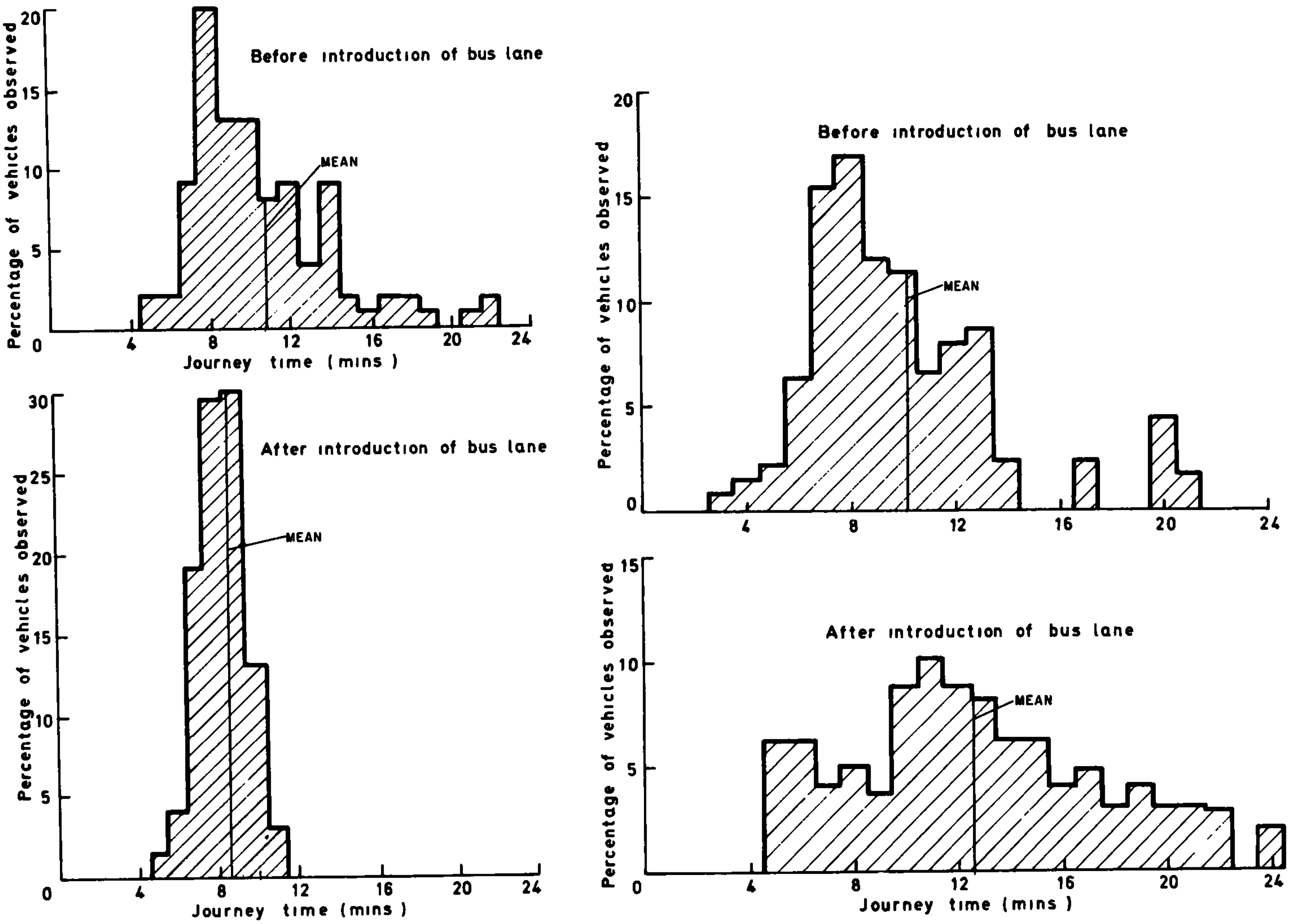


Figure C-59 Comparison of bus speeds, Fairview bus lane, Dublin, Ireland.



DISTRIBUTION OF BUS JOURNEY TIMES

DISTRIBUTION OF CAR JOURNEY TIMES

Figure C-60 Distribution of bus and car journey times, Fairview bus lane, Dublin, Ireland

Planning Guidelines

Broad guidelines were established by the GLC for implementing bus lanes, as follows.

1. A bus lane is considered where there are at least 50 buses and/or 2,000 people in the peak hour.
2. New bus lanes should not produce a significant disbenefit to other traffic. (This is not easy to achieve in practice.)
3. Bus lanes should generally stop 200 ft short of an intersection. (This enables buses to advance through the intersection in one signal cycle and automobiles can move into the lane to turn, while the over-all intersection capacity is retained.)
4. Bicyclists and emergency vehicles are allowed to share the bus lane where there is no conflict with pedestrians. Taxis are allowed to use the lane where they will not create major conflicts with other traffic.
5. Buses are not restricted to bus lanes and can use adjacent lanes.

Albert Embankment Bus Lane

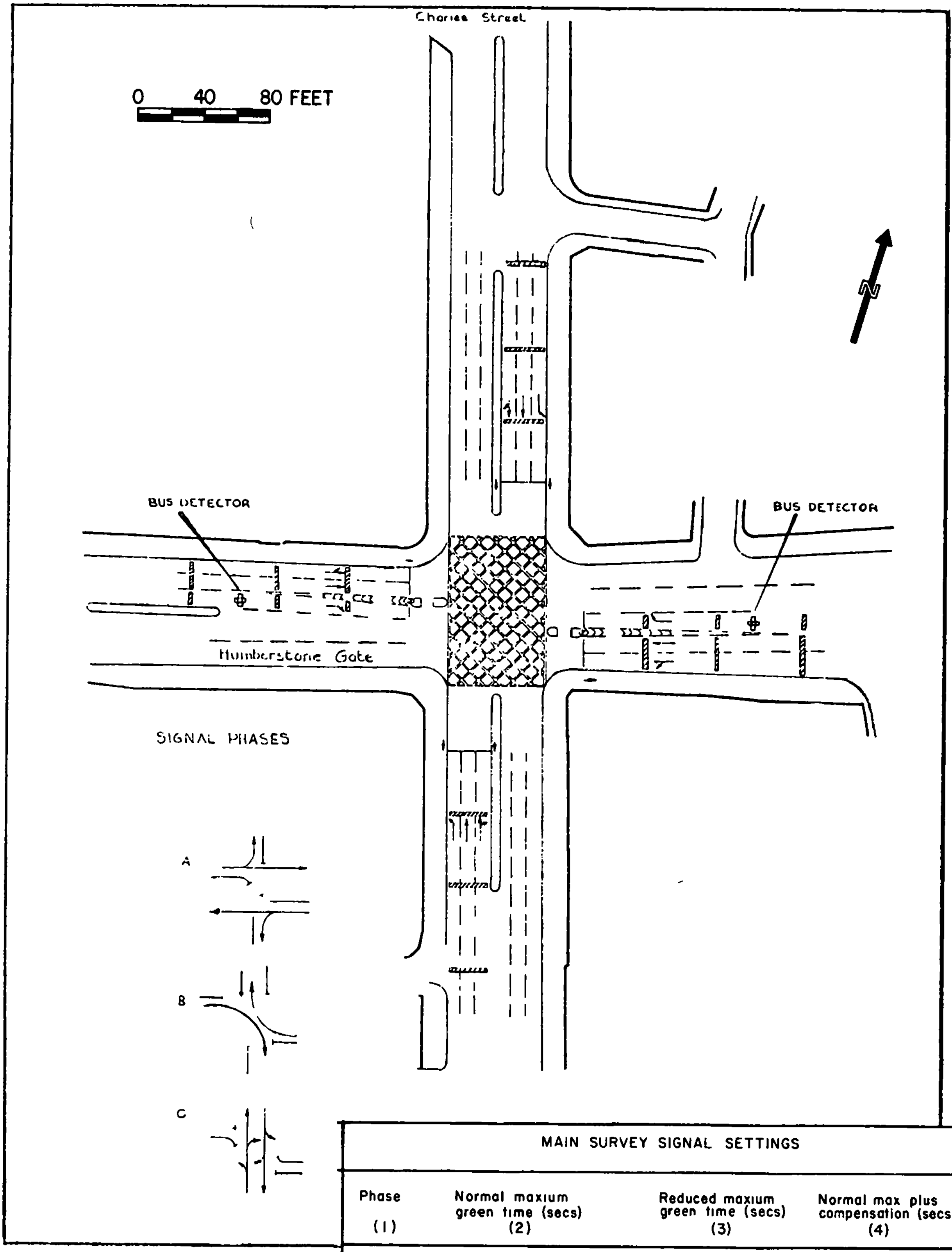
A normal-flow curb lane was introduced on Albert Embankment in May 1971. This 10-ft-wide lane is about 1,200 ft long, serves about 55 buses per hour, and operates from 8.00 to 10.00 AM on weekdays. Some 1,700 other northbound vehicles use the two adjacent lanes. Enforcement is good, and the reported savings per bus trip average 1.5 min.

Brixton Road Bus Lane

The Brixton Road bus lane was introduced in June 1969. The 10-ft-wide bus lane is 1,140 ft long and operates from 7.00 to 9:30 AM on weekdays (Fig. C-64). It is London's only bus lane where auto traffic in the same direction is limited to one lane, the two-way roadway is four lanes wide.

The bus lane carries 105 buses in the peak hour; the adjacent lane is used by 1,400 vehicles in the peak hour.

Results of before and after studies are summarized in Table C-29. Over-all vehicular flows and travel times were unchanged. Buses, however, saved 2.5 min per journey



MAIN SURVEY SIGNAL SETTINGS

Phase (1)	Normal maxium green time (secs) (2)	Reduced maxium green time (secs) (3)	Normal max plus compensation (secs) (4)
A	26	16	30
B	16	16	16
C	40	34	40
Total	82	66	86

Figure C-61 Bus priority signals, Leicester, England

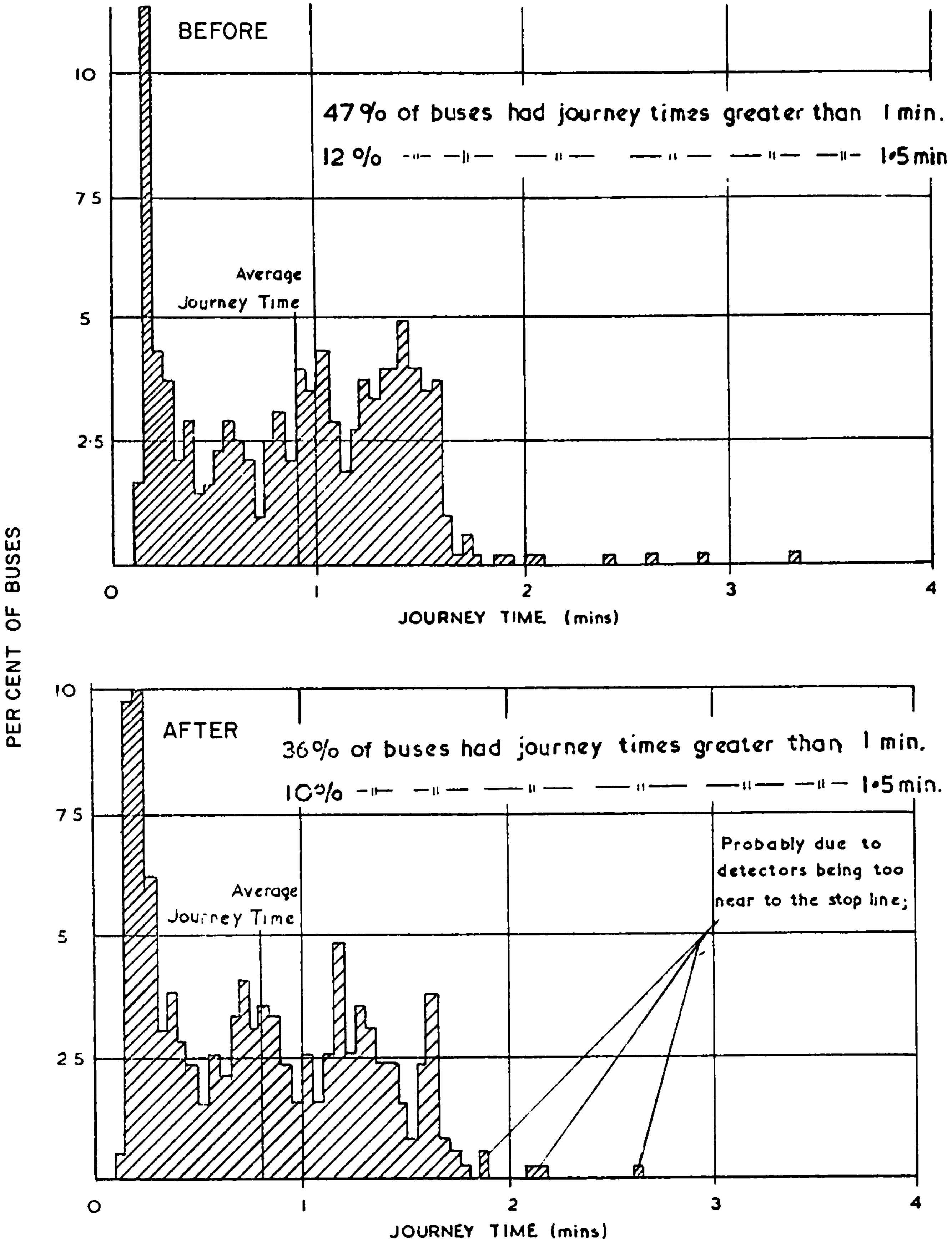


Figure C-62. Distribution of bus journey times, Leicester, England

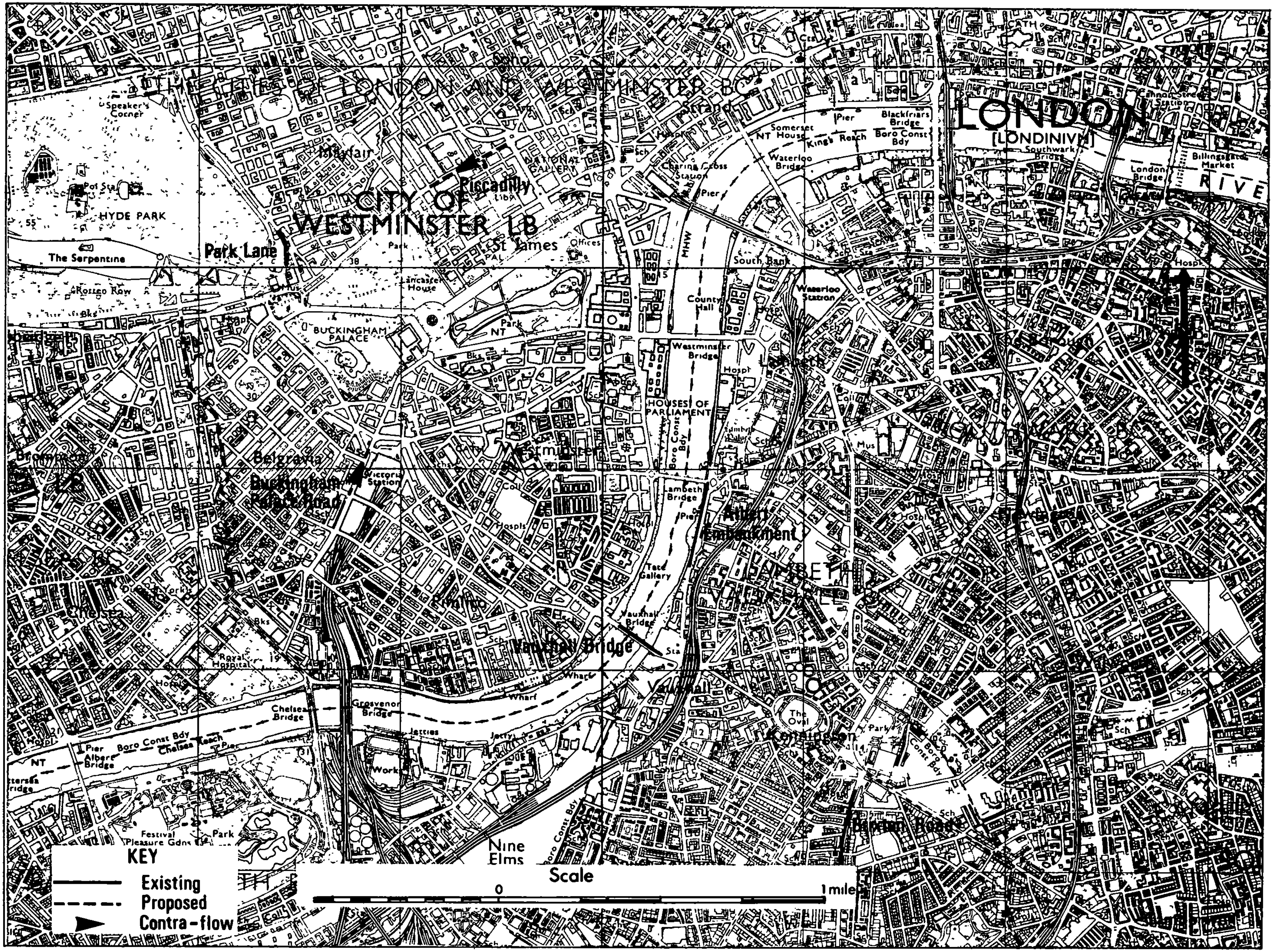


Figure C-63 Bus lanes, London, England

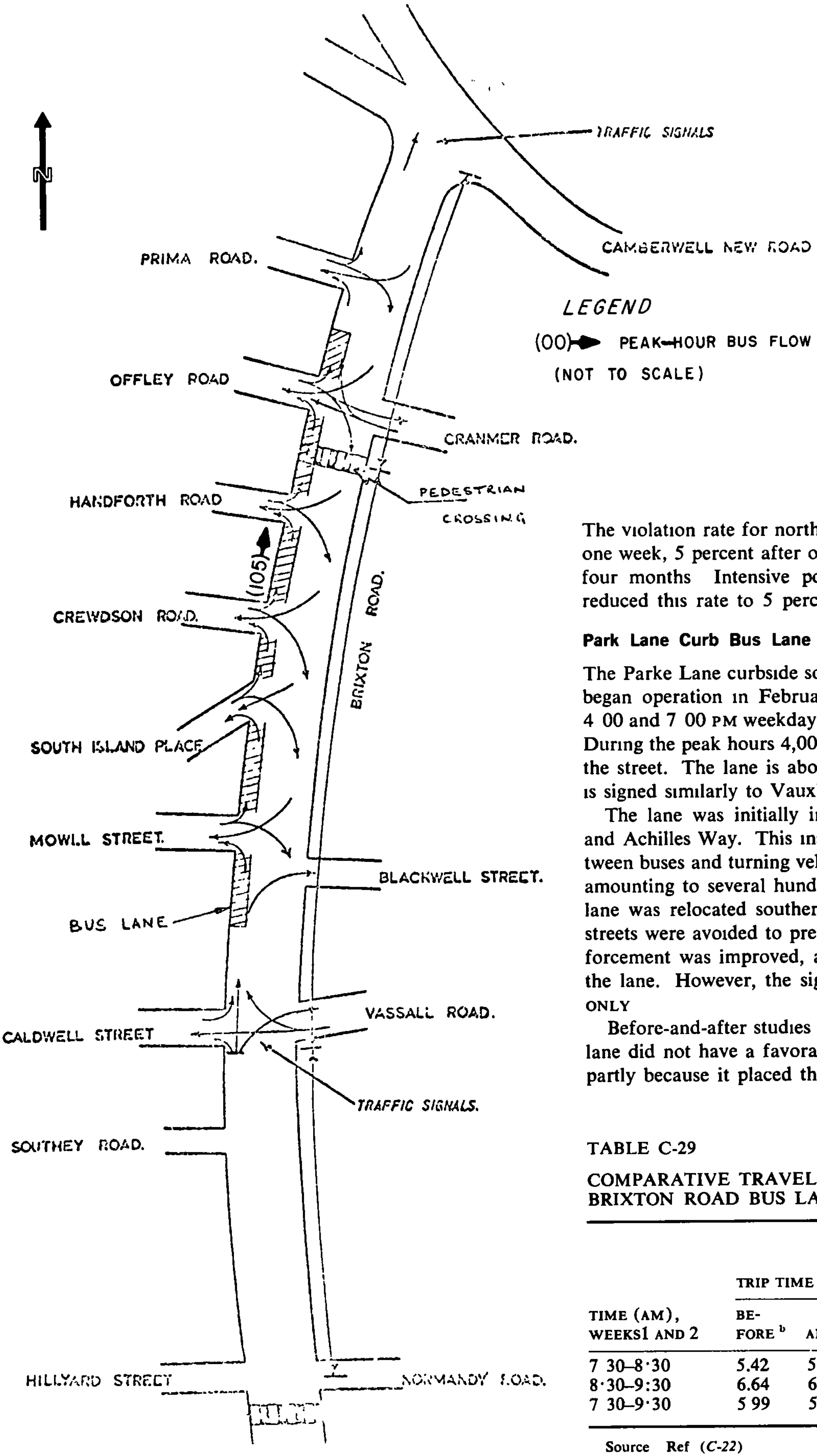


Figure C-64 Brixton Road bus lane, London, England.

The violation rate for northbound flow was 1 percent after one week, 5 percent after one month, and 15 percent after four months Intensive police enforcement subsequently reduced this rate to 5 percent.

Park Lane Curb Bus Lane

The Parke Lane curbside southbound bus lane (Fig. C-65) began operation in February 1968 and operates between 4 00 and 7 00 PM weekdays, carrying 160 peak-hour buses. During the peak hours 4,000 other southbound vehicles use the street. The lane is about 550 ft long, 10 ft wide, and is signed similarly to Vauxhall Bridge (Fig. C-65).

The lane was initially installed between Curzon Street and Achilles Way. This installation produced conflicts between buses and turning vehicles Violations were common, amounting to several hundred each hour. As a result, the lane was relocated southerly from Hertford Place Cross streets were avoided to preclude traffic conflicts, police enforcement was improved, and taxis were permitted to use the lane. However, the signing was designated for BUSES ONLY

Before-and-after studies indicated that the 550-ft revised lane did not have a favorable effect on bus running times, partly because it placed them in a poor position to weave

TABLE C-29

COMPARATIVE TRAVEL TIMES
BRIXTON ROAD BUS LANE, LONDON, ENGLAND

TIME (AM), WEEKS1 AND 2	TRIP TIME (MIN) [a] BEFORE [b]	AFTER [c]	VIOLATIONS [d] 1ST AFTER SURVEY	2ND AFTER SURVEY	3RD AFTER SURVEY
7 30–8·30	5.42	5.16			
8·30–9:30	6.64	6.10			
7 30–9·30	5 99	5 50	28	144	390–470

Source Ref (*C-22*)
[a] All vehicles except buses [b] 1,465 vehicles per hour [c] 1,400-1,440 vehicles per hour [d] Immediately after implementation

across traffic in the Hyde Park Corner complex. Violations of the bus lane became frequent because (1) it was not physically separated and (2) it reduced the total vehicular capacity of Park Lane.

Although a special enforcement program could have reduced violations, it appeared unlikely that total person-travel times (including that of bus users) would be improved. Therefore, the Greater London Council is considering further modifications to improve bus operations in the heavily utilized Marble Arch-Victoria corridor

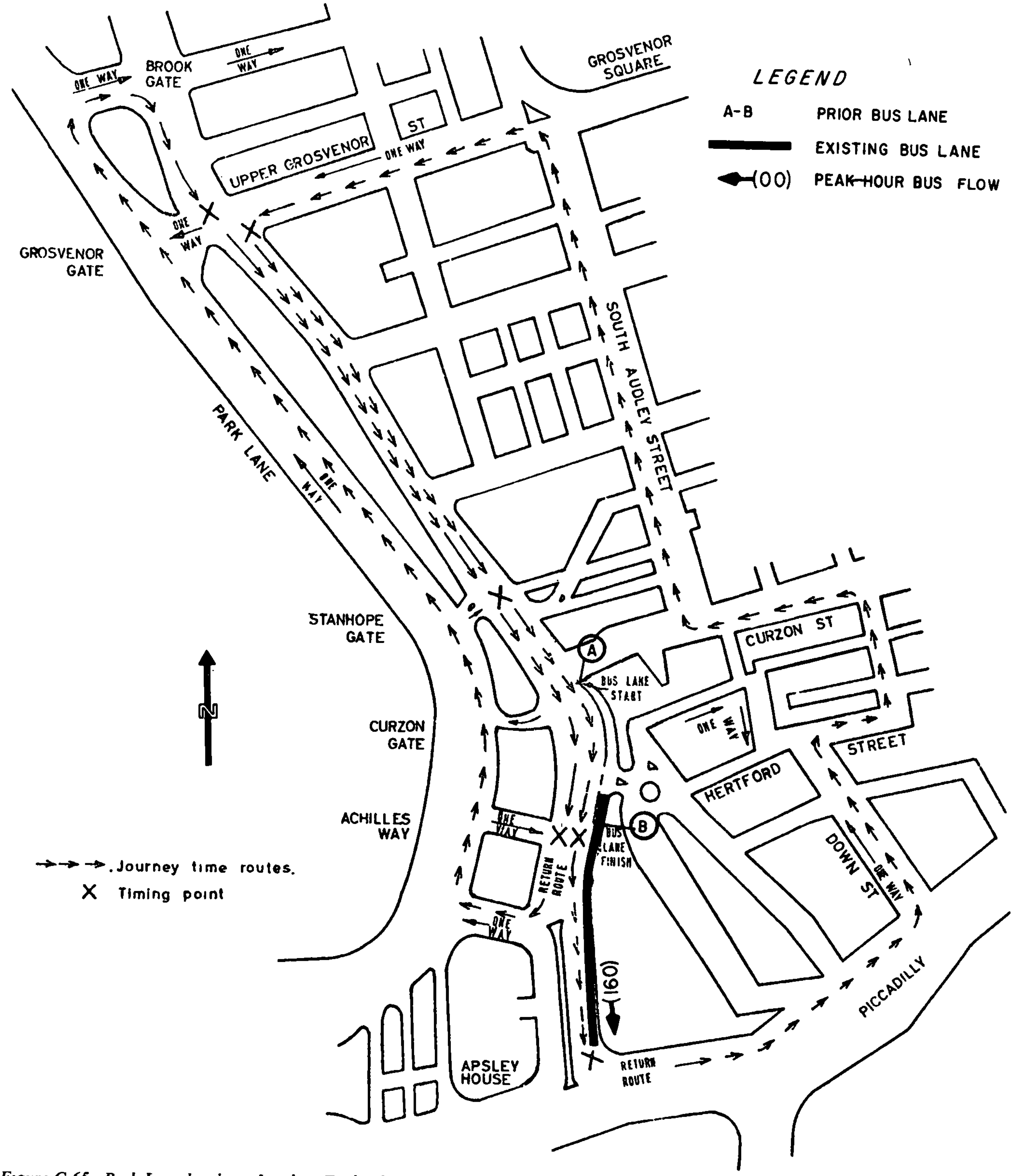


Figure C-65 Park Lane bus lane, London, England

Tottenham High Road Contra-Flow Bus Lane

The 10-ft-wide contra-flow bus lane in Tottenham High Road is located (Fig. C-66) in Northern London and forms part of a traffic management scheme for a large area. The lane was introduced in April 1970, operates southbound 24 hours a day, is 2,700 ft long, and carries approximately 70 buses per peak hour (Fig. C-67). It is separated from the three opposing traffic lanes by a 4-ft concrete island that permits the adjacent lane (at certain times) to be used for loading and unloading Pre-existing bus turnouts have been retained so that buses can stop for crew change if necessary. There are six openings along its length for turning operations (Fig C-68).

Average savings of 2 4 and 1.2 min in the peak morning and evening hours, respectively, have been reported for each bus. Compliance is excellent. The cost of signals, signing, and islands was estimated at $400,000.

This bus lane is a good example of bus priority treatment incorporated into a general traffic improvement scheme (similar to a TOPICS project in the U.S.) It preserves the advantages of direct bus routing and access to shopping frontage in an outlying community center, and it keeps bus operations from being adversely affected by the introduction of one-way operations.

Vauxhall Bridge Median Bus Lane

London's only median normal-flow bus lane, 1,120 ft long, existed on Vauxhall Bridge between February 1968 and April 1972. It operated southbound (4:00 to 7·00 PM) on weekdays along with two other lanes on the five-lane bridge The lane carried approximately 100 peak-hour buses There were no bus stops on the bridge.

The 10-ft wide lane was marked by a painted broken white stripe (more restrictive than the usual English lane striping, but not prohibitive) on each side BUS LANE was printed on each end, along with a lane directional arrow (Fig. C-69).

The Vauxhall Bridge bus lane was discontinued in April 1972 because of construction, but will be reinstituted late in 1973 as a southbound auto and bus lane.

Use Characteristics

Car and bus journey times before and after the bus lane was installed are given in Tables C-30 and C-31. Automobile journey times were reduced slightly as peak-hour traffic increased from about 1,750 to 1,900 vehicles. Bus journey times were reduced from 3.4 to 1.4 min. Average savings to buses on specific routes ranged from 1.5 to 3.7 min per journey.

Peak-hour traffic violations in the bus lane are summarized in Table C-32 The violation rate approximated 10 to 12 percent, as compared with 5 percent in the month immediately after its installation. Enforcement was reported to be difficult, largely because of the bus lane location in the center of the road and the lack of overhead signs.

Significance

The improvements in traffic flow probably came from restriping the bridge for five lanes (three outbound, two inbound), rather than from the bus lane itself.

The capacity of the bridge is limited by signalized intersections at each end, with Millbank on the north and Vauxhall Cross (a channelized, signalized gyratory complex of many intersecting streets) on the south Long queues build up from the latter intersection in the evening peak The bus lane allows buses to bypass these queues to a certain extent and functions in a manner similar to the temporary bus bypass lane on the lower deck of the San Francisco-Oakland Bay Bridge upstream from the Yerba Buena Island traffic signal.

The recent opening of the Victoria Tube to Brixton has provided rail rapid transit parallel to many bus routes using the Vauxhall Bridge, and bus passenger volumes are reported below 1969 levels. The lane, therefore, can be opened to autos as well as buses without adverse effects on bus operation

Camden Bus Lane Network

The Department of Housing and Communication of the London Borough of Camden proposed a network of bus priority lanes in that borough This proposed network of normal-flow curb bus lanes is shown in Figure C-70

The plan would cost $200,000 to $320,000 to implement. The net benefits were estimated at $500,000 to $1,000,000. Bus travel savings would be substantial; speeds of car trips would fall 20 to 30 percent; and some 7 to 10 percent of the car trips would be diverted

This proposal is significant in that it represents a systematic areawide approach to bus priorities.

Piccadilly Proposed Contra-Flow Bus Lane

Since Piccadilly was made one-way in 1961, westbound buses were diverted to a parallel street (Pall Mall) about ¼ mile to the south This adds substantially to bus mileage and reduces passenger potentials by routing buses onto a street with less intensive lane use (*C-24*). Accordingly, a contra-flow bus lane (0 30 mile) has been proposed for the south side of the one-way portion of Piccadilly. Plans call for using a 4-ft raised concrete curb to separate this lane from the remaining three lanes of traffic. A short northbound bus lane on the western side of Regent Street for about one block would join with the Piccadilly bus lane.

An estimated 100 buses and 2,800 passengers would use the bus lane in the peak hour. Buses are expected to reduce their travel time by 3 5 to 4 min per trip.

Some streets crossing Piccadilly will require special bus turn signals to let buses turn left This, in turn, will reduce the crossing time available for pedestrians Although no systems analysis has been made on street capacity, lane balance considerations suggest that little or no automobile delay will be experienced The additional signing necessary at Piccadilly Circus would, however, conflict with the Greater London Council's goal of reducing the number of signs and general clutter in this area. Provisions for servicing offices on the south side of Piccadilly need resolution prior to installing the bus lanes.

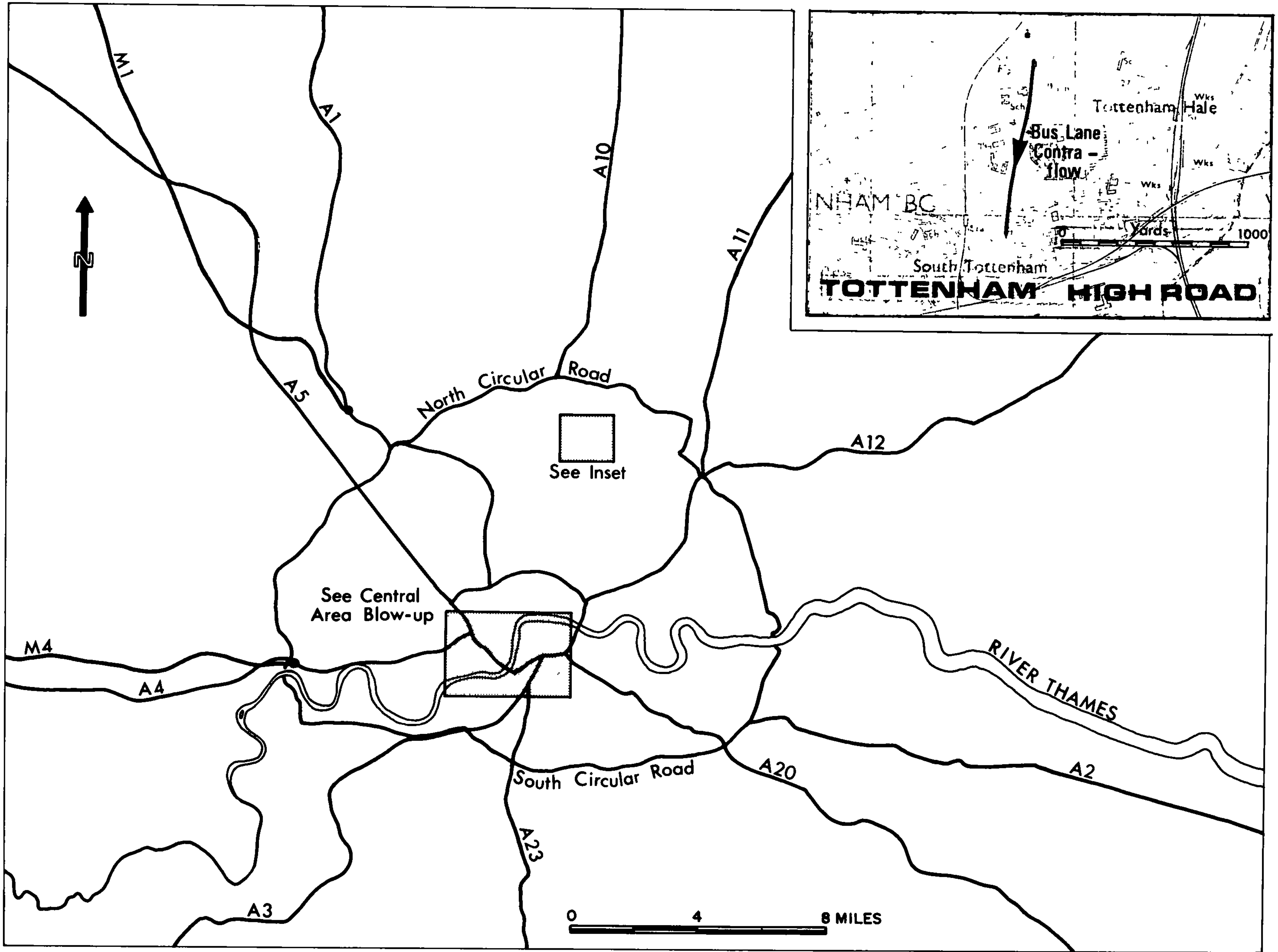


Figure C-66. Location map, Tottenham High Road contra-flow bus lane, London, England.

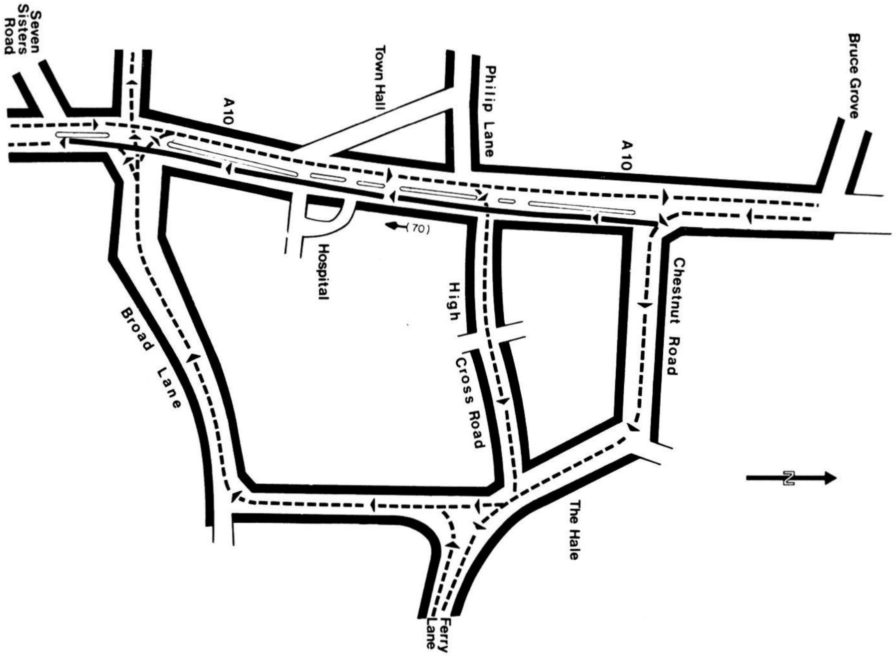


Figure C-67. Tottenham High Road contra-flow bus lane, London, England.

Figure C-68. Typical views, Tottenham High Road contra-flow bus lane, London, England.

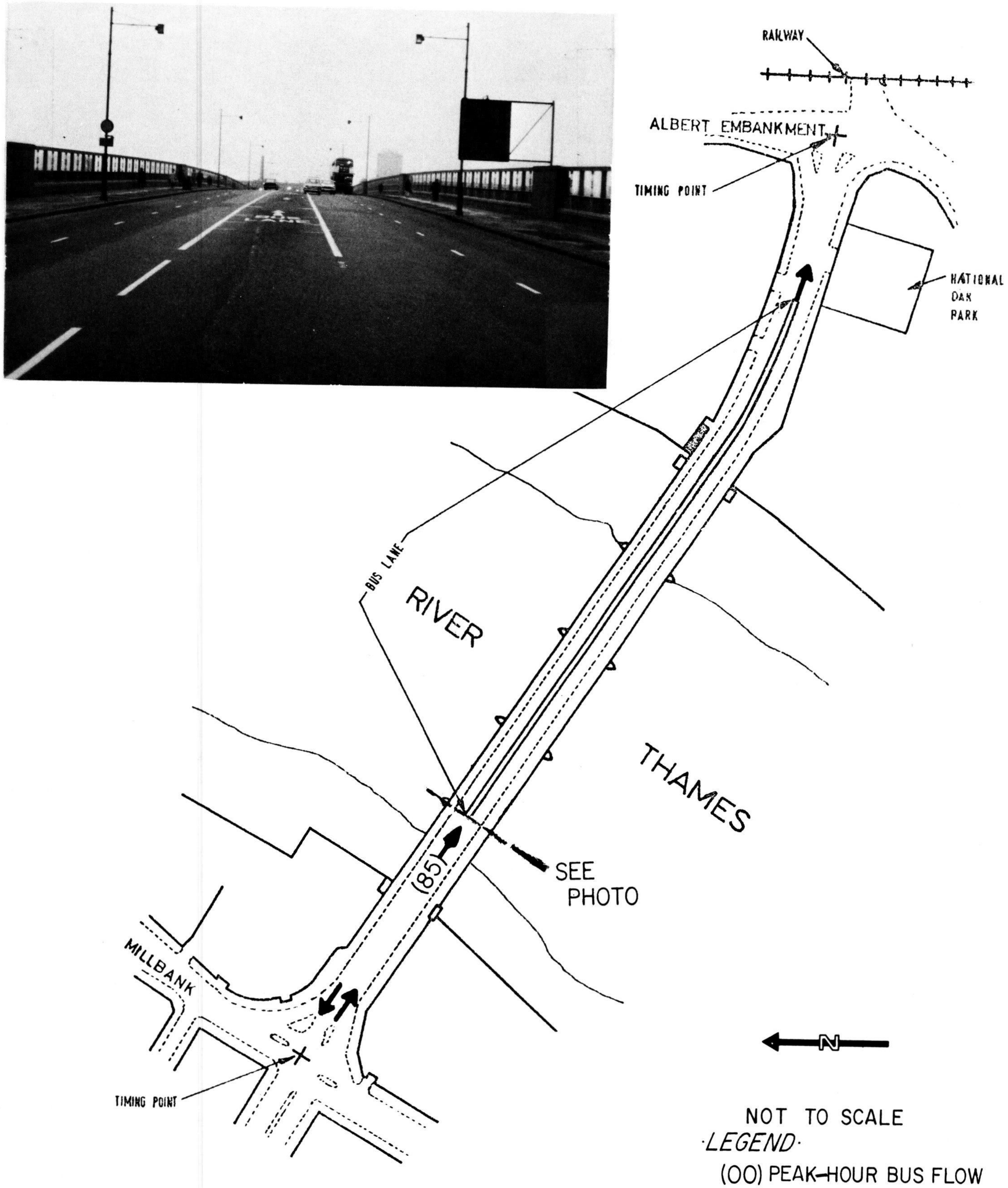


Figure C-69. Vauxhall Bridge median bus lane, London, England.

TABLE C-30

TRAVEL TIMES FOR VEHICLES OTHER THAN BUSES, VAUXHALL BRIDGE BUS LANE, LONDON, ENGLAND

DATE	DAY OF WEEK	TRIP TIME (MIN-SEC)			NO. OF TRIPS	MEAN SPEED (MPH)	TRAFFIC VOLUME (VPH)
		MIN	MAX	AVG.			
		(*a*) Before Study					
30 Oct 67	Monday	1–30	4–23	2–48	6	6.48	1,919
31 Oct 67	Tuesday	2–00	5–20	3–46	11	4.84	1,846
1 Nov 67	Wednesday	3–41	18–38	9–46	8	1 86	1,275
2 Nov. 67	Thursday	2–34	8–24	4–20	12	4 20	1,702
3 Nov. 67	Friday	2–40	4–37	3–28	12	5.25	1,924
30 Oct - 3 Nov	Period	1–30	18–38	4–41	49	3 88	1,738
6 Nov. 67	Monday	1–55	3–49	2–47	12	6 53	2,001
7 Nov 67	Tuesday	1–10	4–25	3–14	12	5.62	1,914
8 Nov. 67	Wednesday	1–00	4–25	2–58	12	6 13	1,868
9 Nov. 67	Thursday	1–29	5–57	4–06	12	4 43	1,742
10 Nov 67	Friday	1–01	5–21	3–38	12	5 00	1,962
6-10 Nov	Period	1–00	5–57	3–21	60	5 44	1,897
		(*b*) 12-Month After Study					
24 Mar. 69	Monday	0–45	3–28	1–51	12	9 82	1,975
25 Mar. 69	Tuesday	0–47	2–44	1–43	12	10 59	1,931
26 Mar. 69	Wednesday	0–48	2–05	1–21	12	13 47	1,932
27 Mar 69	Thursday	0–54	2–50	1–34	12	11 60	1,922
28 Mar 69	Friday	1–01	2–56	2–00	12	9 09	2,140
24-28 Mar	Period	0–45	3–28	1–42	60	10.91	1,980

Source Ref (*C-23*)

31. READING TRAFFIC MANAGEMENT PLAN

Reading, England, located about 25 miles west of London, is a major manufacturing center with a population of about 178,000. The municipality has operated several highly successful bus priority treatments (Fig. C-71). A 0 57-mile contra-flow bus lane was installed on King's Road in June 1968. Three additional contra-flow lanes and a traffic management plan for the city center were introduced in 1970 This plan combines bus streets in the city center with reserved bus lanes along radial roads to facilitate a through-run of considerable length that is only insignificantly affected by traffic congestion.

TABLE C-31

BUS TRAVEL TIMES, VAUXHALL BRIDGE BUS LANE, LONDON, ENGLAND[a]

BEFORE STUDY, 1967		AFTER	12-MONTH AFTER STUDY, 1969	
DATE	TRAVEL TIME (MIN)		DATE	TRAVEL TIME (MIN)
30 Oct.	3 5			
31 Oct	3 8			
1 Nov.	(7.7)		24 Mar.	1 6
2 Nov.	4.2		25 Mar.	1.4
3 Nov.	3.2		26 Mar.	1.3
6 Nov.	2.5		27 Mar	1.4
7 Nov.	2.9		28 Mar	1.6
8 Nov	2 7			
9 Nov.	3.9			
10 Nov.	3.6			
Average	3 4[b]	1.6		1 4

Source Ref (*C-23*)

[a] Travel times are between Millbank and Albert Embankment (southbound) 5 15-6 15 PM

[b] Does not include Wednesday, Nov 1

TABLE C-32

NUMBER OF VEHICLES OTHER THAN BUSES USING VAUXHALL BRIDGE BUS LANE, LONDON, ENGLAND

TIME (PM)	NO. OF VEHICLES				
	MON 24TH	TUES. 25TH	WED. 26TH	THURS. 27TH	FRI. 28TH
5:15–5·30	16	79	45	72	91
5·30–5:45	73	62	69	48	78
5·45–6:00	84	40	30	66	110
6:00–6·15	34	48	34	40	92
5.15–6:15[a]	207	229	178	226	371

Source Ref (*C-23*)

[a] Average = 242

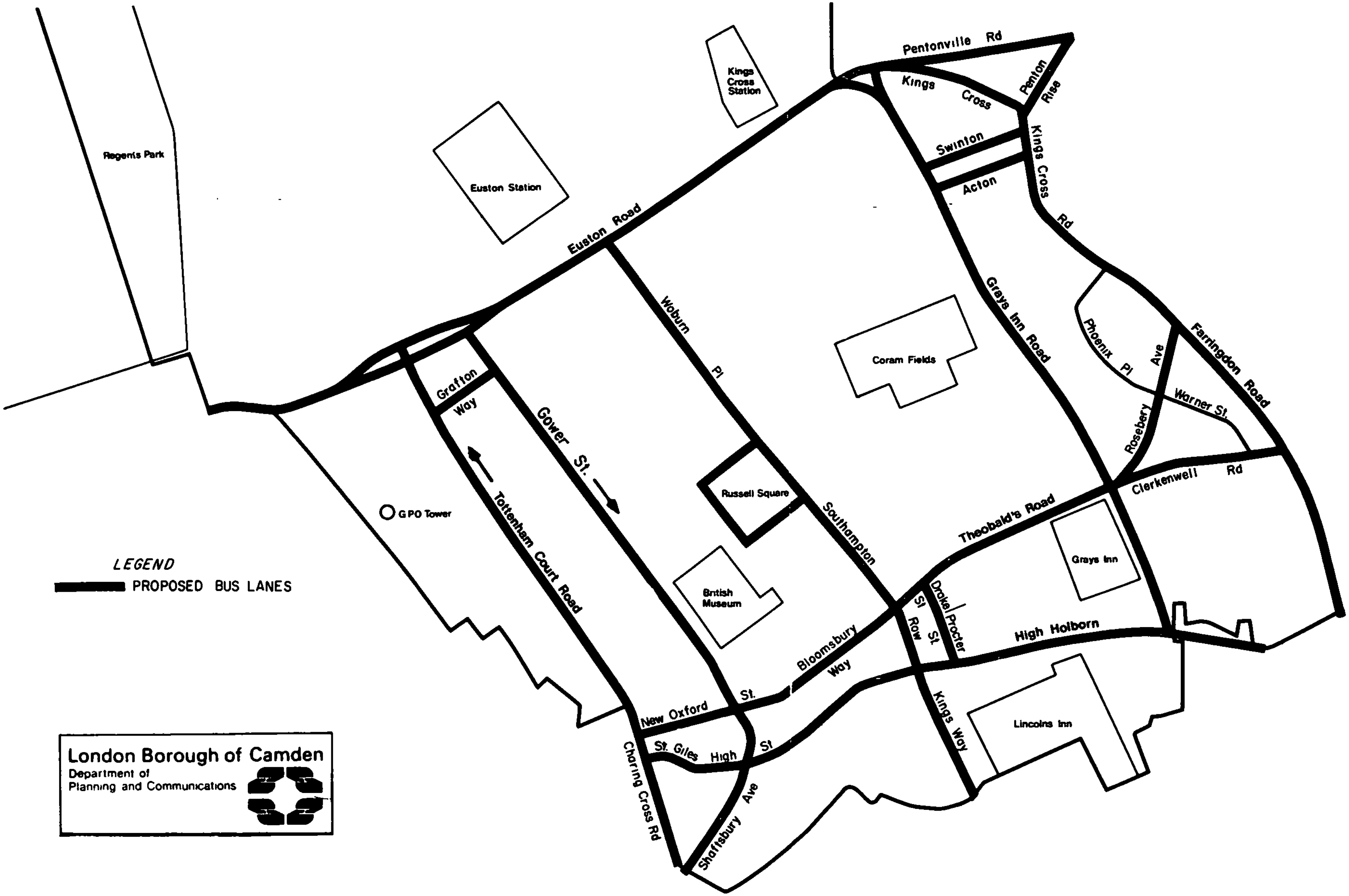


Figure C-70 Existing bus routes, proposed bus lanes, Borough of Camden, London, England

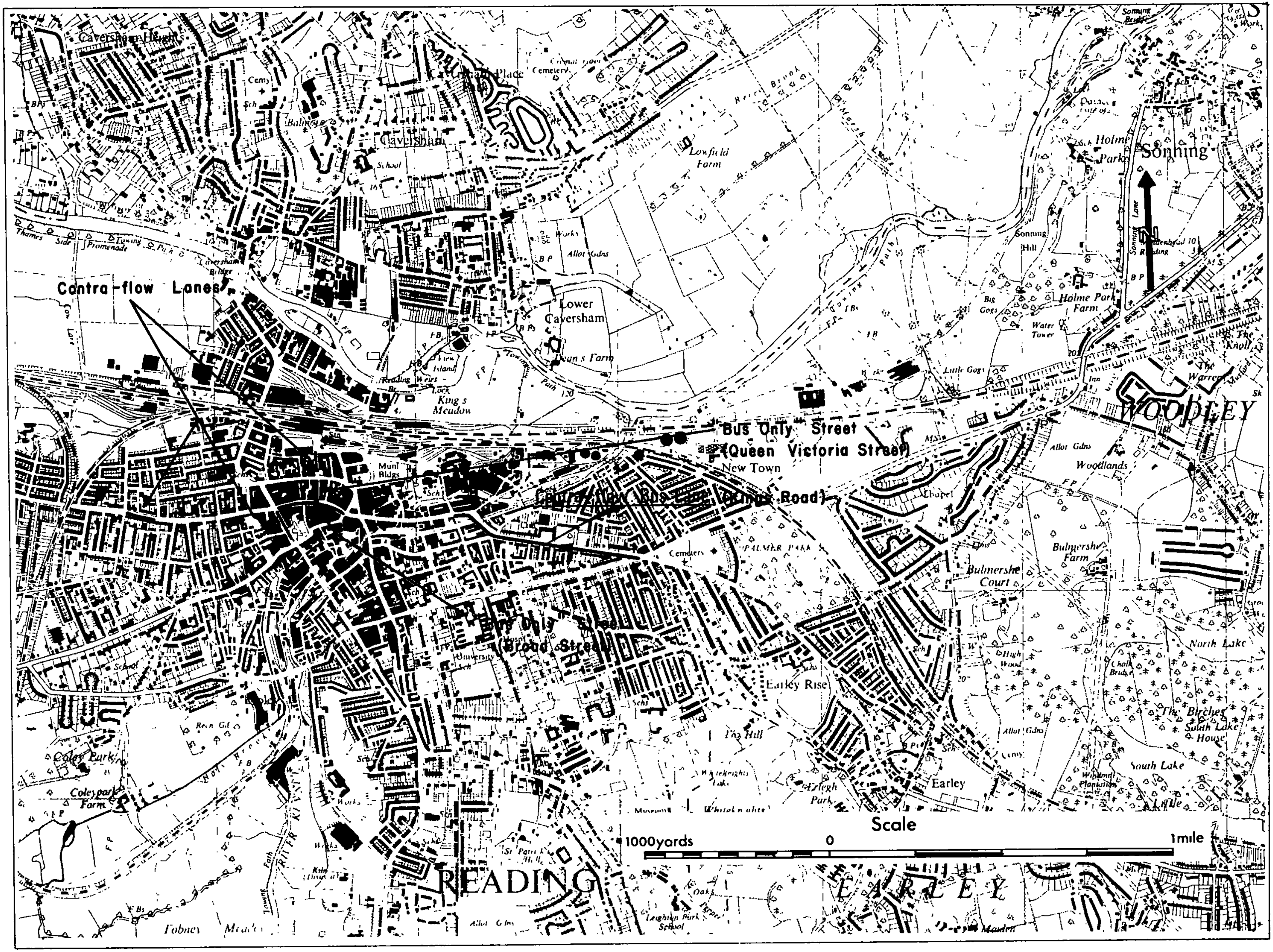


Figure C-71. Location map, traffic management plan, Reading, England

King's Road Contra-Flow Bus Lane

The King's Road contra-flow bus lane was implemented as part of a one-way operations plan to make bus service more attractive and avoid circuitous routing away from activity centers. At first only Municipal Corporation buses were allowed access to the lane, but since April 1969 buses of Thames Valley Traction Company also use the lane. Other vehicles were diverted to London Road and Watlington Street to conform to the one-way system installed with the bus lane The over-all plan is shown in Figure C-72; typical views of the bus lane are shown in Figure C-73.

Controls and Operations

Continuous double white lines segregate the bus lane from the rest of the street along with signs at the junctions reading NO ENTRY EXCEPT FOR BUSES. Curbside stopping is restricted at all times and loading operations are only permitted in off-peak periods. During off-peak periods, service vehicles are allowed to enter the bus lane by crossing the double-white lines in the direction of the main one-way flow Buses using the contra-flow lane when these vehicles are present are permitted to use the other lanes to pass.

Benefits

Two studies were conducted to assess the impact of the lane on traffic. The first was made late in 1968 when the reserved lane was still used only by Corporation buses. The second was made in 1969 several months after the lane was allowed to carry additional buses.

The changes in traffic volumes along King's Road resulting from the one-way street routings are summarized in Table C-33. Forty-eight buses used the contra-flow lane in the peak hour and about 450 in a 12-hour period

Approximately 10,000 passengers were carried on Corporation buses before and after the treatments. However, the number of bus-miles operated decreased about 2 percent, suggesting a small improvement in service efficiency Curtailments of trips (resulting from extreme congestion) were reduced.

Reported improvements in bus travel times are given in Table C-34. Both east- and westbound buses operated significantly faster over King's Road during the peak period. Off-peak speeds also show some reductions in trip times.

Violations on the King's Road contra-flow bus lane are summarized in Table C-35. Over-all, infractions accounted for less than 1.5 percent of total vehicular traffic.

Significant differences exist between the first and second "after" studies. Far fewer infractions occurred in the second study, this may be attributed to drivers becoming more acquainted with local street conditions. Some offenders traveled in the same direction as buses, to take "short cuts." Many, however, were overtaking other vehicles while using the bus lane, often as a result of a particular vehicle that stopped along the curb In response, other vehicles moved one lane over to keep from slowing down

An over-all reduction in accidents was reported since the bus priorities were implemented. The decrease approximated 29 percent over-all, and was 50 percent for bus passengers (Table C-36).

Additional Bus Streets

Additional contra-flow bus lanes were subsequently implemented in Reading, as well as the conversion of Broad and Queen Victoria Streets into all-bus streets Both of these streets are narrow, and penetrate the retail core (Fig C-74). Bus routes were restructured as part of the over-all street-use plans.

32. SOUTHAMPTON TRAFFIC MANAGEMENT PLAN

Southampton (population 375,000), a shipping port on the English Channel in Southern England, will be the focus of a unique experiment that is designed to minimize peak-hour vehicular travel times Bitterne and Bursledon Roads, which together form a major east-west radial, will be equipped with electronic signals and restrictive signings, connected to a central control and programmed to improve vehicular operating speeds, particularly for buses, to the CBD throughout the day.

TABLE C-33

TRAFFIC FLOW, KING'S ROAD CONTRA-FLOW BUS LANE, READING, ENGLAND[a]

		SECT 1, LONDON RD -ELDON RD						SECT 2, ELDON RD -WATLINGTON ST					
		TRAFFIC (VEH)			CHANGE (%)			TRAFFIC (VEH)			CHANGE (%)		
TRAFFIC DIRECTION	PERIOD	B	A1	A2	B–A1	A1–A2	B–A2	B	A1	A2	B–A1	A2–A1	A2–B
EB	Peak hour	925	1,536	1,995	66	30	116	1,004	1,452	1,644	45	13	64
	12-hr total	9,901	16,384	18,225	65	11	84	11,101	13,559	14,560	22	7	31
WB	Peak hour	940	18[b]	48[b]	—98	167	—95	1,141	18[b]	48[b]	—98	167	—96
	12-hr total	9,887	206[b]	456[b]	—98	31	—95	11,747	206[b]	456[b]	—98	121	—96
2-Way	Peak hour	1,865	1,554	2,043	—17	31	10	2,145	1,470	1,692	—32	15	—21
	12-hr total	19,788	16,590	18,681	—16	13	—6	22,848	13,765	15,016	—40	9	—34

Source Ref (*C-25*)

[a] B = before study, A1 = 1st after study, A2 = 2nd after study [b] Buses only

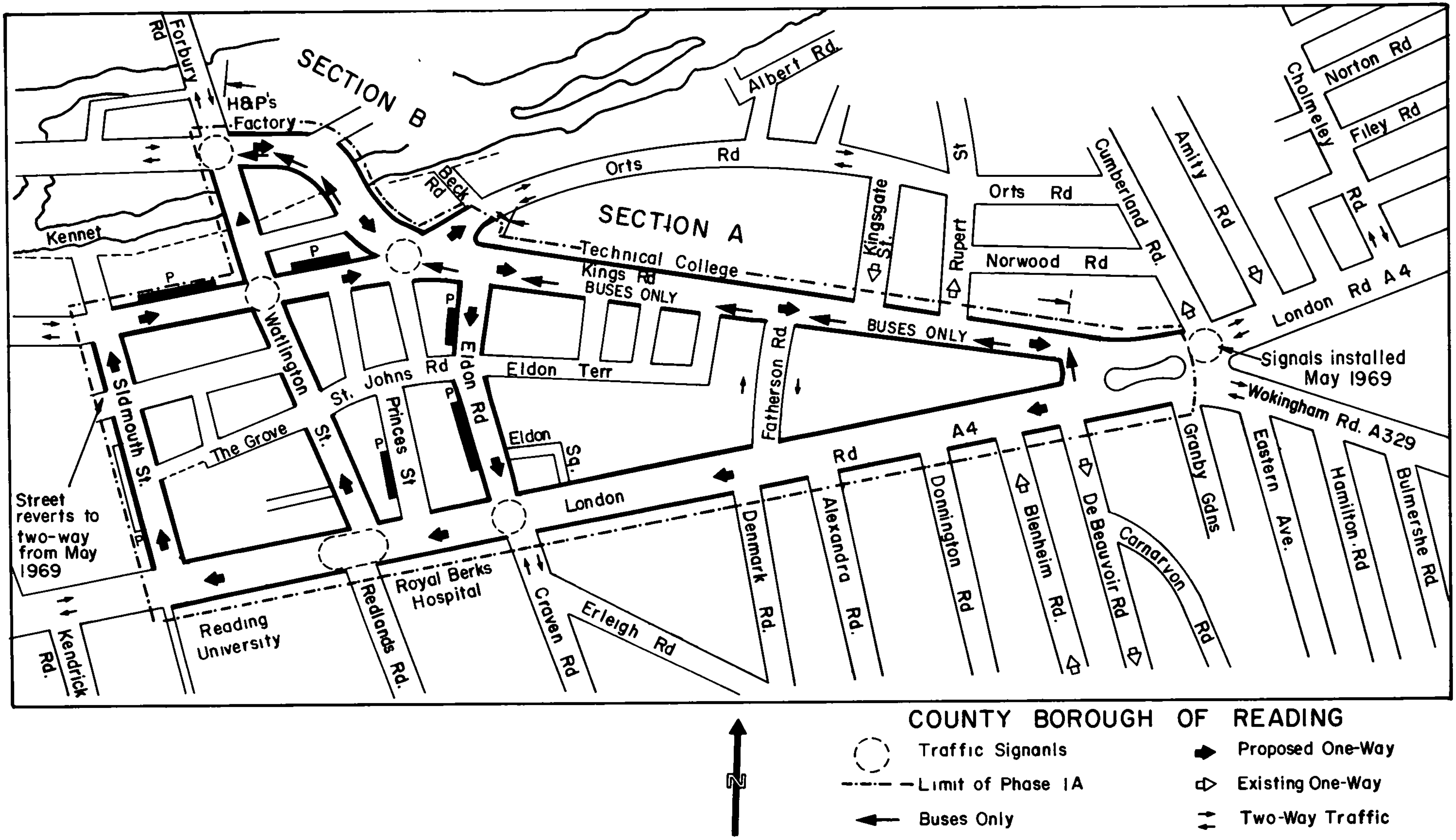


Figure C-72. Contra-flow bus lane, King's Road, Reading, England.

Figure C-73. Typical views, contra-flow bus lanes, Reading, England; St. Mary's Buffs (left) and King's Road (right).

Figure C-74. Typical views, bus streets, Reading, England; Broad Street (left) and Queen Victoria Street (right).

TABLE C-34

COMPARATIVE BUS OPERATIONS, KING'S ROAD CONTRA-FLOW BUS LANE, READING, ENGLAND[a]

	EASTBOUND						WESTBOUND					
	TRIP TIME (MIN)			CHANGE (%)			TRIP TIME (MIN)			CHANGE (%)		
PERIOD	B	A1	A2	B–A1	A1–A2	B–A2	B	A1	A2	B–A1	A1–A2	B–A2
					(*a*) Corporation Buses							
Peak	13 72	8 35[b]	7 14	—39	—14	—48	11 60	6 86	9 73[c]	—41	42	—16
Off-peak	7 28	7.16[b]	6 31	—2	—12	—14	6 46	6 34	7 12[c]	—2	12	10
					(*b*) Thames Valley Buses							
Peak	13 40	NS	5 19	NS	NS	—61	11 40	7 73[d]	7 46[e]	—32	—3	—35
Off-peak	6 93	NS	4 56	NS	NS	—34	6 14	5 77[d]	5.24[e]	—6	—9	—15

Source Ref (*C-25*)

[a] Time recorded between Cemetery Junction and Watlington St B = before study, A1 = 1st after study, A2 = 2nd after study

[b] Trip times reflect problems at the London Road junction, where improvements were still in progress

[c] Trip times show a deterioration, due mainly to the presence of Thames Valley buses in the contra-flow bus lane having separate stops, but also due partly to introduction of one-man-operated buses with their tendency to spend more time in loading operations at stops Buses are not permitted to overtake each other while in the contra-flow bus lane

[d] Via London Road and Watlington St

[e] Via contra-flow bus lane

Description

Access to the radial will be provided from side roads by a system of signals and traffic measuring devices that, when traffic approaches capacity on the major radials, will restrict side traffic from entering until flows are reduced. Certain turns will be completely curtailed; others will be permitted according to the amount of traffic. At some intersections only buses will be permitted to gain access to the major radial. In this way traffic is expected to flow smoothly once on the main route, as the volume-capacity ratio will be less than one

Some short side roads will be open only to buses and emergency vehicles, which will have special priority to enter the main stream Other access will enable buses to bypass vehicles that are waiting to enter radials Thirteen signal-controlled junctions and six pedestrian crossings are included in the plan (Fig C-75)

Bus travel times are expected to be reduced by 5 min

TABLE C-35

VIOLATIONS ON KING'S ROAD CONTRA-FLOW BUS LANE, READING, ENGLAND[a]

	VIOLATIONS (NO)[b]										PERCENTAGE OF 12-HR TOTAL FLOW	
	DRIVING WHOLLY IN BUS LANE				OVERTAKING IN BUS LANE OR DRIVING ASTRIDE DOUBLE WHITE LINE							
	EAST-BOUND		WEST-BOUND		EAST-BOUND		WEST-BOUND		TOTAL			
LOCATION	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2
London Rd - Eldon Rd	55	29	15	5	46	38	104	31	220	103	1 3	0 5
Eldon Rd - Watlington St.	2	2	8	4	9	4	13	6	32	16	0 3	0 1
Total	57	31	23	9	55	42	117	37	252	119	1 6	0.6

Source Ref (*C-25*)

[a] Pedal cycles are exempt from regulations relating to double white lines

[b] A1 = first after study, A2 = second after study

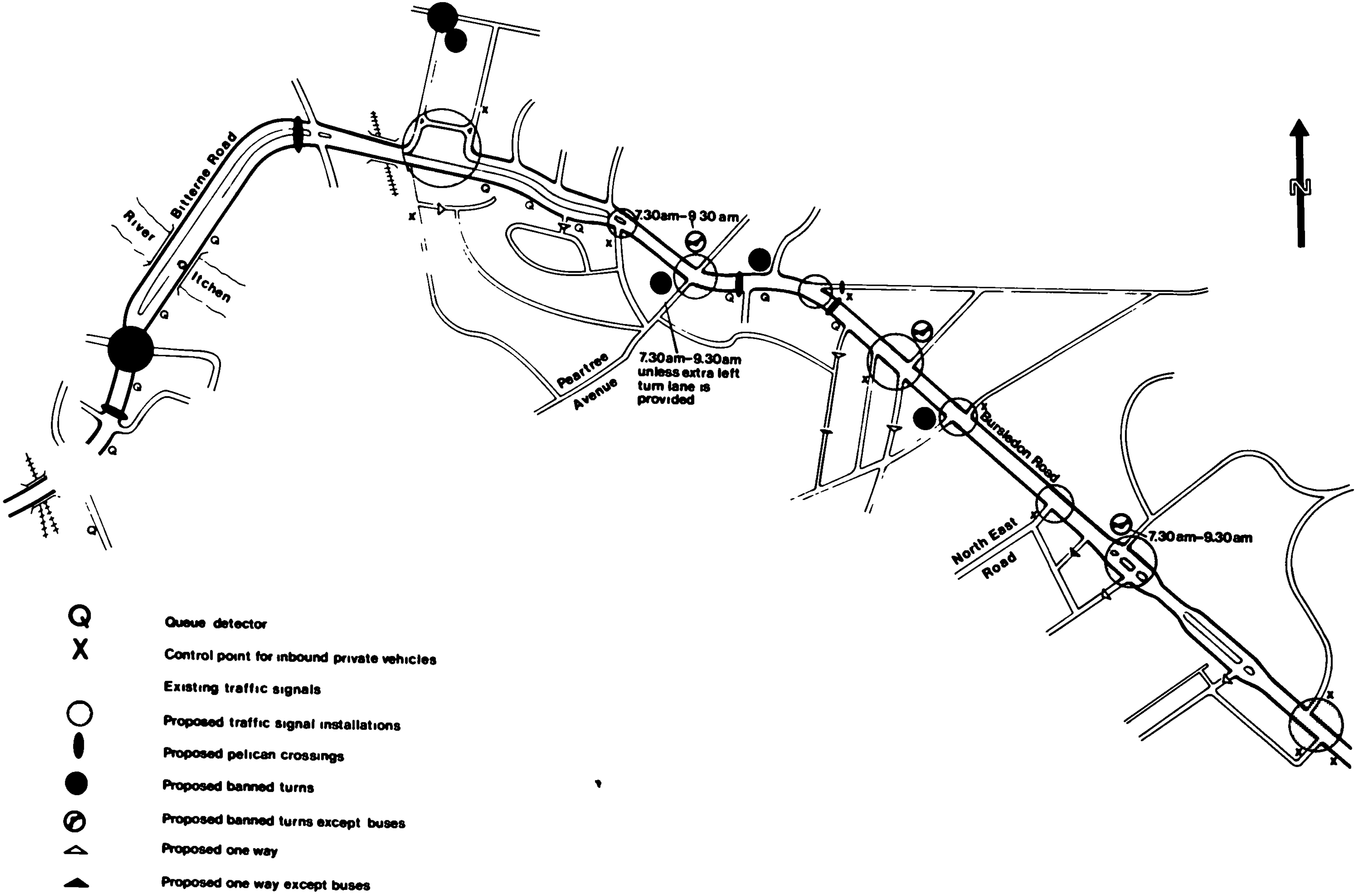


Figure C-75 Traffic management plan, Bitterne Road, Southampton, England along the 3.5-mile route, other vehicles are not expected to experience any change.

The existing peak-hour modal split of about 50 percent entering the CBD on this corridor by bus is expected to change in the long run, this may further improve the bus travel times.

Anticipated costs for this program are $260,000. The program has been approved by the Southampton City Council, and implementation was expected during the latter part of 1972. A before-and-after study will be conducted by the University of Southampton and the Transport and Road Research Laboratory.

Significance

This proposal is an imaginative approach to the granting of bus priority on arterial streets without imposing severe delays on other road users. The concept of metering turns into the arterial from side streets is analogous to ramp metering on freeways, queue bypass lanes for buses are a basic part of both concepts. In such instances the road space required exclusively for bus use is minimal, and general traffic on the through route benefits from an improved level of service.

However, the concept would appear effective only if the major cross streets are grade separated or similarly treated. Balancing capacity between the metered radial and the CBD street system also may become a problem when the plan is implemented

TABLE C-36

PERSONAL INJURIES, KING'S ROAD CONTRA-FLOW BUS LANE, READING, ENGLAND[a]

TYPE OF ACCIDENT	INJURIES (NO) BEFORE	AFTER	CHANGE (%)
Vehicles			
Fatal	2	2	—
Serious	137	129	—6
Slight	580	379	—35
Total	719	510	—29
Pedestrians.			
Fatal	5	3	—4
Serious	127	90	—29
Slight	267	197	—26
Total	339	290	—27
Bus passengers			
Fatal	0	0	0
Serious	5	1	—80
Slight	29	16	—45
Total	34	17	—50
All accidents			
Fatal	7	5	—21
Serious	269	220	—18
Slight	876	592	—32
Total	1,152	817	—29

Source Ref (*C-25*)

[a] Before period covers three-year period, June 16, 1965, to June 15, 1968, after period covers three-year period, June 16, 1968, to June 15, 1971

33. MARSEILLES BUS PRIORITY TREATMENTS

A study conducted by the Marseilles (France) Department of Transport and Traffic late in 1971 indicated that transit was used for all major trip purposes, rather than mainly for work. Twenty-eight percent of all household trips were by bus, with a high orientation to the CBD The central area of Marseilles is old, there are few new streets, and street geometrics prevent smooth traffic operations. As a result, fewer automobiles can be accommodated, and accident rates are high. An underground rail network is being built to serve the city's 1,000,000 residents; in the interim, buses provide all transit service.

Existing Bus Lanes

About 3 miles of exclusive bus lanes were instituted in Marseilles to alleviate congestion. This represents less than 1 percent of the total bus route mileage. Table C-37 summarizes the bus lanes in operation, their peak-hour bus flows before and after installation, and the increases achieved in operating speeds.

TABLE C-37

BUS LANE COMPARATIVE SPEEDS, MARSEILLES, FRANCE

STREET	BUS LANE LENGTH (FT)	BUS VOLUME[a]	SPEED (MPH) BEFORE	AFTER
Bd Longchamp	1,600	120	1–4	10
Bd Michelet-Ave du Prada	5,500	70	1–4	10
Rue de Rome[b]	2,250	70	3	8
Cours de Gouffe[b]	2,250	20	1–4	8
Rue Paradis[b]	3,250	23	1–4	11

Source Ref (*C-26*)

[a] Peak hour [b] Reverse lane

Bus Priority Experiment

A 20-day bus experiment was conducted in October 1971 A north-south bus lane was designated along a 5-mile route (between Boulevard Michelet and Boulevard de Paris) on Rue de Rome-Rue St. Ferrol, which pass through the CBD (Fig C-76) Additional buses were placed on this route to reduce the headways to about 5 min, and each route was furnished with car parking areas. The downtown street network was changed to give buses as much priority as possible

At first, Rue St. Ferrol was closed to all vehicles except buses Later, Rue de Rome was made one-way for all vehicles, and bus lanes were operated on both streets. Some side streets were made one-way to help reduce automobile delay, other streets were closed to all but delivery vehicles.

Furthermore, approximately 600 parking spaces were removed in a 20-square-block area of the downtown and special parking zones were created outside of the area. Strict police enforcement was obtained, as well as cooperation with garage owners, and a system of compensation was provided to those who had garages in the "no parking" area

Total bus use did not change, although a significant increase was found along the improved north-south bus route At predetermined days during the experiment, fares were drastically reduced to assess the sensitivity of ridership to fare levels For example, a 6 percent patronage increase was reported with a 33 percent fare reduction

Increases in bus speeds were reported with both phases

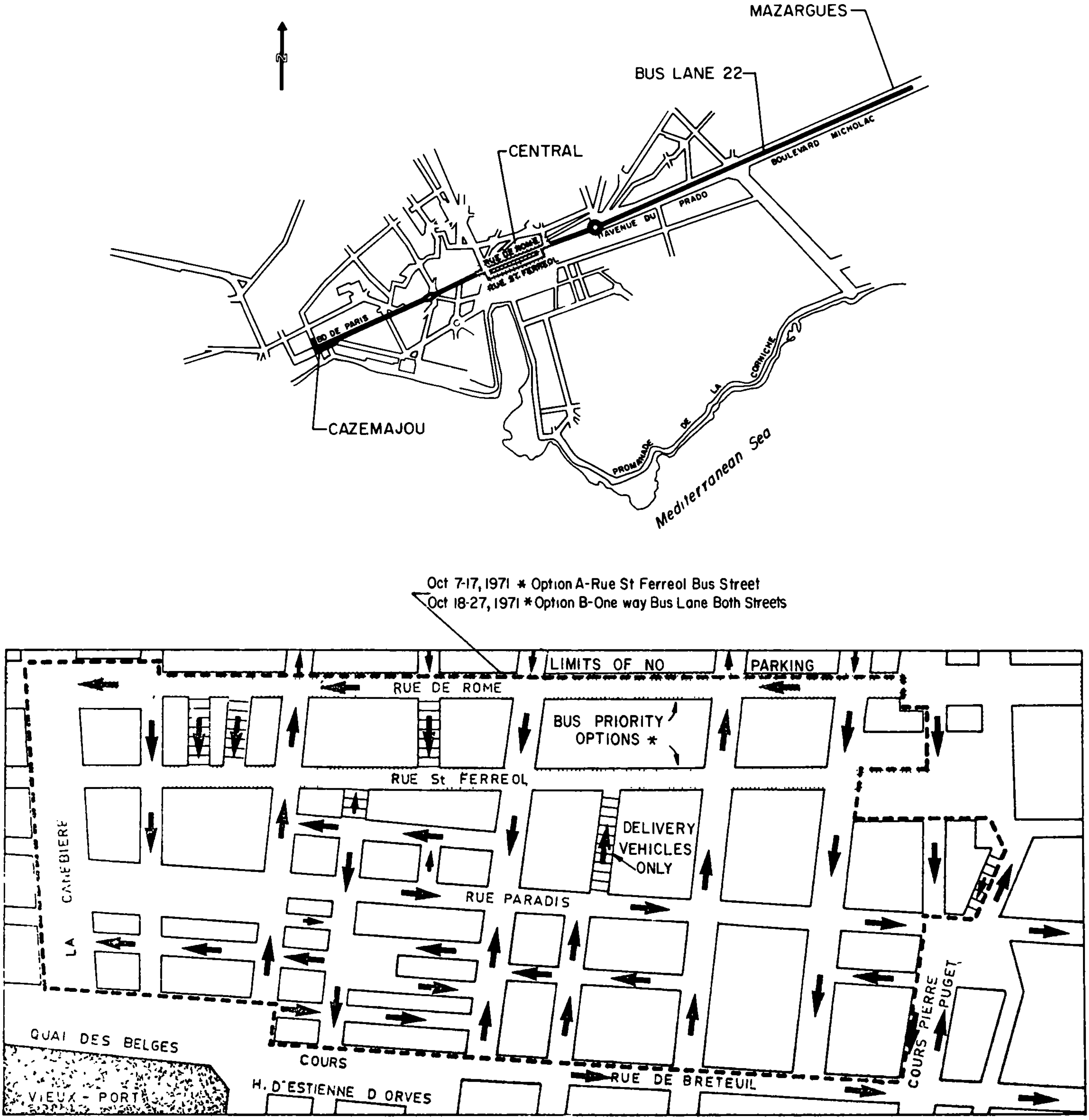


Figure C-76 Bus priority experiments, Marseilles, France of the experiment (Table C-38) These speed increases in the second phase, for example, ranged from 4 to 32 percent, varying widely by direction and route section

Data collected showed lower pollution emission and noise levels, but these findings were inconclusive and needed more verification. The experiment was judged successful by most city authorities, and the major parts were reported implemented permanently in Marseilles in February 1972

34. PARIS BUS LANES

Bus operating speeds in Paris, France, were reduced from about 18 mph in 1952 to 6 mph in 1964 and continued to decrease about 1.5 percent annually in subsequent years Accordingly, 33 bus lanes have been implemented since 1968 to increase bus operating speeds and improve schedule reliability Many of these bus lanes were implemented with the simultaneous elimination of curb parking.

Description

All exclusive bus lanes are located within the Paris city limits, many are found within the central area (Fig. C-77). The Paris bus company wants to install bus lanes in suburban areas, but the public is reported to have resisted this change.

Both normal-flow and contra-flow bus lanes are provided. These reserved bus lanes vary from about 100 to 2,700 ft in length The number of adjacent traffic lanes ranges from two to six, the number of bus lines using reserved lanes varies from 1 to 12; and the number of peak-hour bus lanes varies from 10 to about 100. Peak-hour flows of more than 35 buses are common Priority vehicles (police, fire, ambulance, taxis) may also use the bus lanes.

The bus lanes follow typical paterns. "Long" lanes (those over 900 ft) are used to prevent buses from being slowed by heavy traffic flows on major radial streets. Short and medium lanes (those under 900 ft) are used almost exclusively on bus approaches to traffic signals This procedure allows buses to clear traffic signals instead of queuing with other traffic.

Control Features

Typical views of Paris bus lanes are shown in Figure C-78. Lanes are generally marked by a solid yellow stripe on the outside, paralleled on the inside by a white dashed line that permits the buses to use other lanes On contra-flow lanes the white dashed line is omitted and passing is prohibited Each street has signs at intersections stipulating local rules for bus lane use.

Where bus lanes are adjacent to businesses, they are in effect only between 1 00 PM and 8 30 PM to allow for deliveries in the morning Otherwise they are in effect all day

Safety

Safety has been generally favorable One fatal accident occurred in 1968 shortly after the introduction of a contra-flow bus lane on Rue de Rivoli; a pedestrian was hit by a bus while crossing the street Subsequently, chains were installed along all sidewalks adjacent to the lanes, and at specific crossings islands separate the contra-flow bus lane from the other lanes No other serious accidents have been reported.

Benefits

Extensive before-and-after studies were conducted on 16 streets where bus lanes were installed. Most streets showed improved bus travel times and better service regularity. Typical bus speed increases ranged from 2 to 4 mph, in some cases automobile speeds improved, possibly because of the removal of curb parking

Results of typical before-and-after studies are summarized in Table C-39 Both the mean and the variance of the bus times were reduced, implying quicker and more reliable service.

The 33 bus lanes with their 7 miles of route represent nearly 4 percent of the total route mileage covered by the bus company Because results have been positive, it is believed that extending bus lanes may increase ridership Accordingly, plans are being prepared for adding about 30 additional bus lanes in Paris, plus several lanes in the suburbs.

TABLE C-38

BEFORE AND AFTER SPEED STUDIES, NORTH-SOUTH BUS LANE, MARSEILLES, FRANCE

		SPEED				
SECTION	DIRECTION	BEFORE (MPH)	1ST PHASE (MPH)	CHANGE [a] (%)	2ND PHASE (MPH)	CHANGE [a] (%)
North	N-S	8 2	7 5	−8.7	8 5	+4 2
	S-N	8 1	9 0	+11 1	8 9	+9 5
Central	N-S	4.7	9 3	+97 3	6.2	+32.4
	S-N	5.1	6.0	+17.7	5 5	+7 9
South	N-S	10 1	10 8	+7 4	10 6	+5.5
	S-N	10.1	10 6	+4.3	11 9	+17 1

Source Ref (*C-26*)

[a] Change from before condition

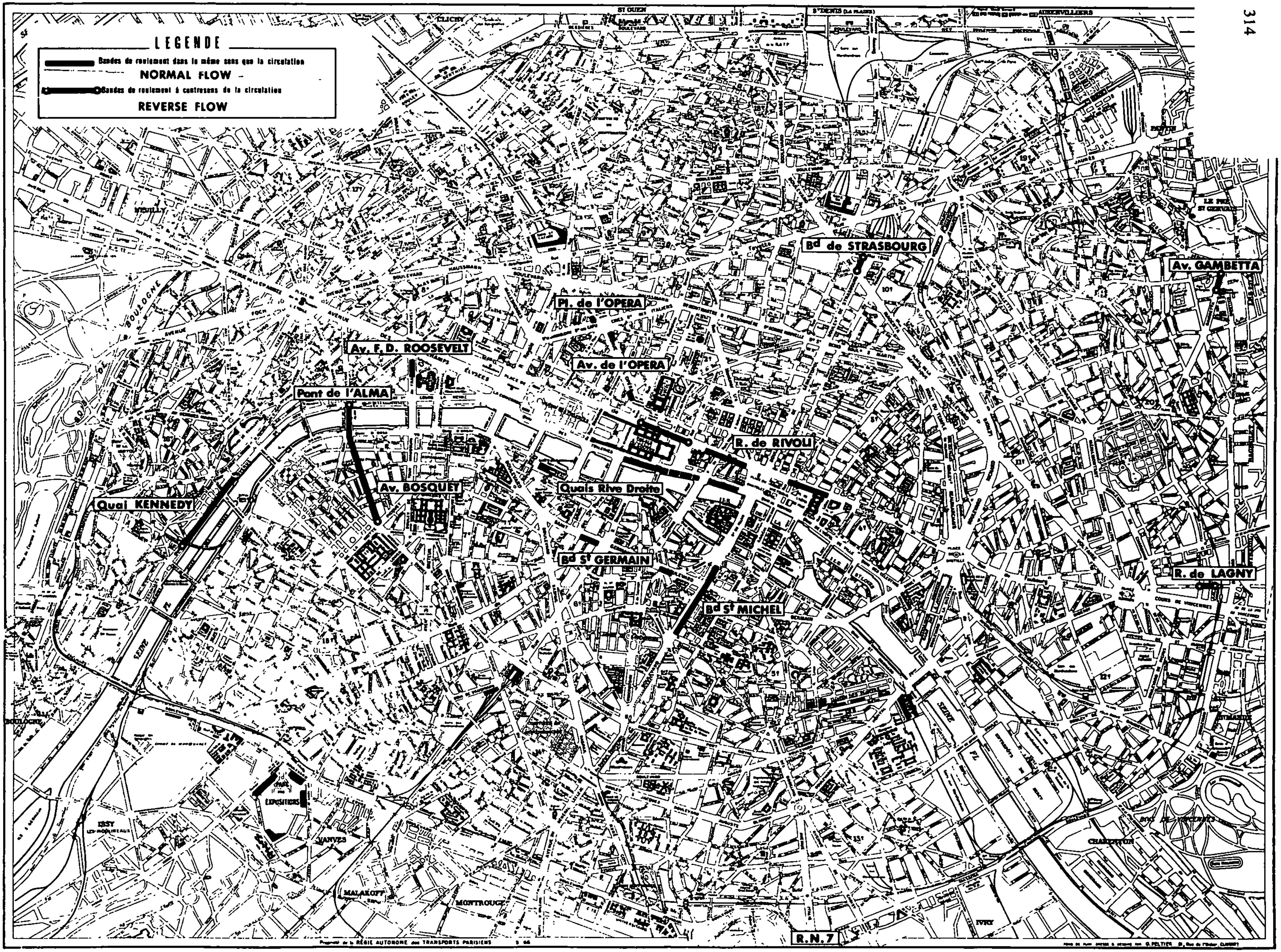


Figure C-77. Bus lanes, Paris, France.

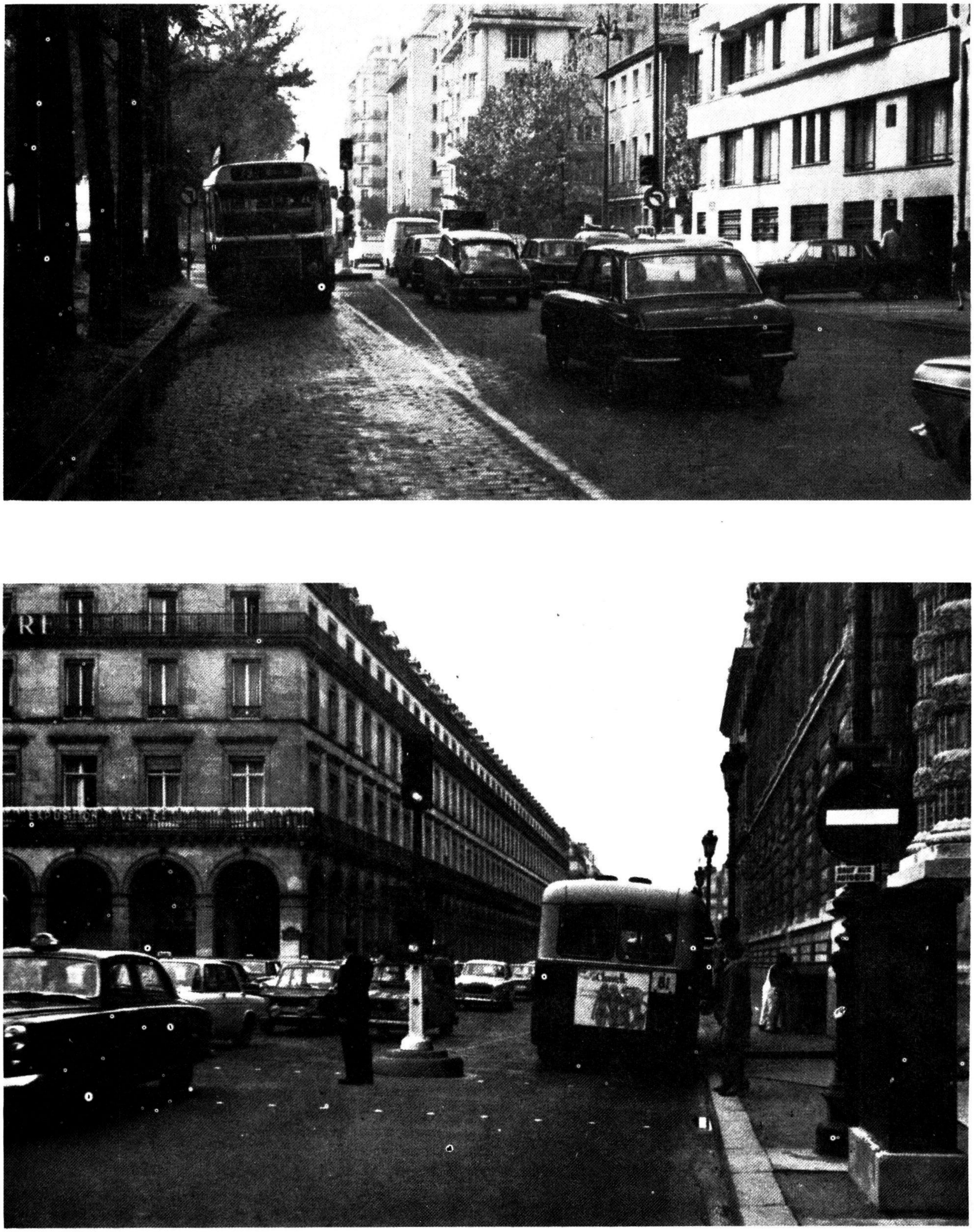


Figure C-78. Typical views, contra-flow bus lanes, Paris, France; Avenue du President Kennedy (top) and Rue de Rivoli (bottom).

TABLE C-39

COMPARATIVE TRAVEL TIMES, SELECTED BUS LANES, PARIS, FRANCE[a]

LOCATION	LENGTH (FT)	MAXIMUM NO OF BUSES AT PEAK PERIODS	OPERATING SPEEDS OF BUSES (KM/H)				AVERAGE TIME-(MIN SEC)		STAND DEV (MIN SEC)	
			SLACK PERIODS		RUSH PERIODS					
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
Right Seine Embankment	3,300	97	10 6	14 8	7 1	15 3	8 27	3 56	1 58	0 57
R N 7, Ave de Fountainebleau	2,300	92	14 0–17 0	23 0–27 0	8 5	20 0	5 06	2 12	1 35	0.45
Kremlin Boulevard, St Michel	2,200	62	9 9	13 7	6 3	9 8	6 24	4 05	2 56	0 55

Source Ref (*C-27*)

[a] Data collected by R A T P and the R A T Y M

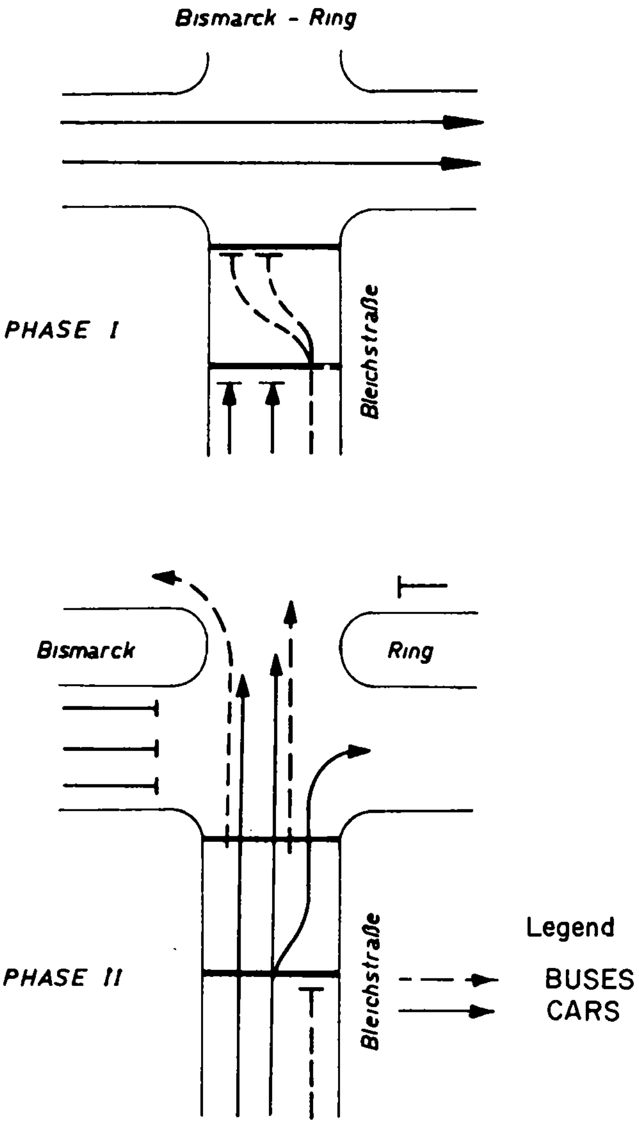


Figure C-79 Traffic signal phasing at bus lane terminal, Wiesbaden, Germany

35. WIESBADEN BUS LANES

Buses provide all public transport in Wiesbaden, Germany (population 260,000) During peak periods congestion was found to significantly reduce bus mobility. Accordingly, on September 1, 1968, curb bus lanes were introduced on Dotzheimer and Frederick Streets, a one-way street couplet These bus lanes extend ¾ mile through the CBD Commercial vehicles are allowed in the lanes from 9.00 AM to 12 00 N, and from 7 00 PM to 6:00 AM

A solid white line delineates the reserved lanes, along with the word BUS in bold white letters painted intermittently on the street Curbside signs further delineate the bus lane

At certain intersections, automobiles and buses are stopped well before the main traffic signal by "interceptor signals" placed on each side of the street (Fig C-79) This permits buses to move into the median or left lanes (in front of other vehicles) from their reserved bus lane position Buses are able to gain priority at the intersection, and are also the first to depart when the main signal permits. The 85- to 100-ft normal distance between the two signals allows storage for two buses.

Buses that used nearby streets were rescheduled to mainly operate in the two bus lanes, each street carries approximately 50 buses during the peak hour Nearly all stops in the bus lane are at intersections. This discourages lane violations by automobiles, because drivers are aware that if they are in the bus lane they may have to wait not only for bus operations but also for signal operations.

With few exceptions, the bus lanes have been respected by traffic and buses meet their schedules with regularity Insignificant travel-time delay has been incurred by automobiles as a result of this experiment, and the two bus lanes have received favorable public reaction.

36. GENOA, MILAN, ROME, AND TURIN BUS PRIORITY TREATMENTS

Major Italian cities have implemented a considerable number of bus lanes Twelve miles exist or are planned in Turin and 13 miles in Genoa. Bus lanes also exist in Rome and Milan (Figs C-80 and C-81).

Reserved lanes in Milan (population 3,365,000) are used by buses, taxis, and emergency vehicles Reserved curb

Figure C-80. Via Dante median bus lane, Milan, Italy.

lanes are delineated by two solid parallel lines white and yellow—with the white line on the outside of the lane and the yellow immediately inside. Lanes separated by physical medians are also painted with white and yellow stripes and further delineated by intermittently spaced traffic cones. Milan also has experimented in marking bus lanes with a bituminous-surface admixture that is different in color from the rest of the street.

As of November 1968 Milan had normal or contra-flow bus lanes on 38 sections of streets, as follows:

NO. OF SECTS.[a]	OPERATION AUTO	BUS	LENGTH (FT)
5	One-way	Normal-flow	150-1500
18	Two-way	Normal-flow	150-3700
10	One-way	Contra-flow	150- 930
5	None	Bus street	150- 610

[a] Some bus lanes are on both sides of the street.

37. MADRID BUS PRIORITY TREATMENTS

Madrid, Spain (population 2,900,000) is facing an accelerating increase in car ownership due to rising income levels. Presently, there is about one automobile for every 5.3 persons, or 550,000 vehicles. In an attempt to reduce the peak demands of private vehicles operating on city streets, officials initiated a three-point campaign aimed at increasing transit use: (1) decreasing bus travel times, (2) increasing bus service regularity and dependability, and (3) making bus service more convenient. Madrid's bus fleet is one of the largest in the world.

Description

The City Department of Traffic instituted a network of bus priority lanes to improve bus service. These lanes are used by large or articulated buses, regular buses, and mini-buses (which charge slightly higher fares but guarantee seats). Altogether, special CBD curb bus lanes exist on 14 sections, although several may be on the same street (Fig. C-82).

Avenida del Generalisimo

Bus lanes are located on each side of a two-way street, generally 8 lanes wide (Fig. C-83). They are 7,400 ft long and carry 83 buses and 4,000 bus passengers during the peak hour. Buses use the two outside lanes, which are generally separated from the other lanes by a raised median. This street rarely becomes congested during peak hours, and no gains have been reported in either bus or auto travel times.

Figure C-81. Corso Vitta Emanuele contra-flow bus lane, Rome, Italy.

Paseo de la Castellana

This two-way, 6-lane street is 7,600 ft long; curb bus lanes on each side (Fig. C-83) carry about 110 buses in each direction and about 4,500 passengers during the peak hour. Since its inception, buses have gained 20 to 30 sec while other vehicle travel times did not change.

Paseo del Prado

Dual reserved lanes on each side of a 820-ft, six-lane, one-way street together carry about 91 buses and 10,000 passengers. Significant time savings were noted for buses, while automobile travel time increased slightly.

Paseo de Calvo Sotelo

This curb-side bus lane is 10,170 ft long and carries 103 buses and 7,000 passengers in the peak hour. The Department of Traffic recommends removing this lane, as its impact has been generally negative. Buses have gained about 60 sec on this segment compared with "before" conditions, while automobiles have lost about 40 sec.

Onesimo Redondo

This eight-lane, one-way street has a curb-side bus lane (Fig. C-84). It is 5,905 ft long and carries 51 buses and 3,600 passengers in the peak hour. A 2.0-mph increase in travel speed occurred for both buses and autos.

Alcala

Bus lanes are located on each side of a two-way, eight-lane street 1,000 ft long (Fig. C-84). Each carries about 127 buses and 8,200 passengers per peak hour. There has been no significant change in travel times for automobiles. One lane reported slight gains in travel time; the other reported slight losses.

Infanta Isabel

This reserved lane is 1,000 ft long. It carries 98 buses and 7,600 passengers in the peak hour. Bus regularity and dependability have improved as a result of its installation. Travel times for private vehicles, however, have increased.

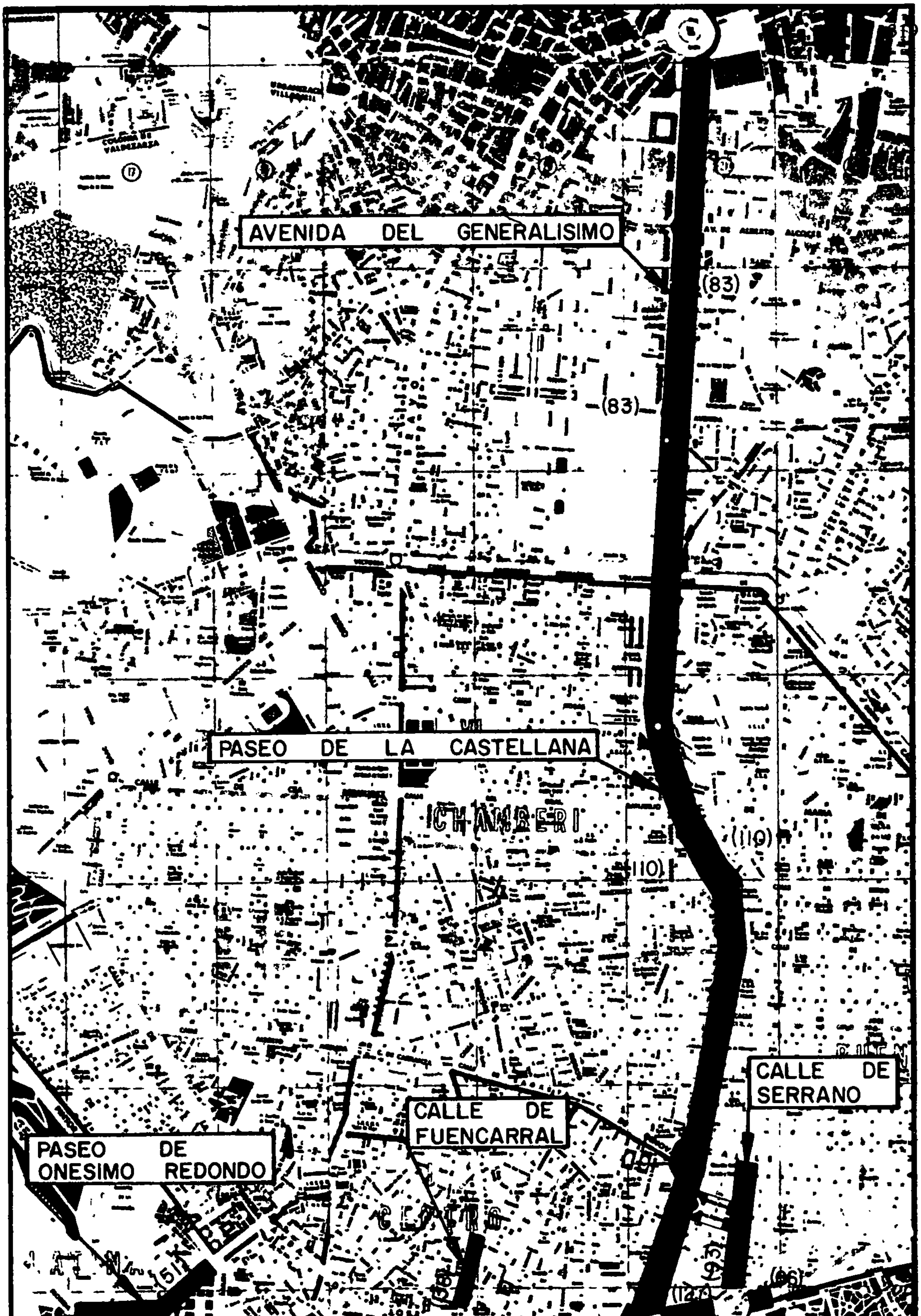


Figure C-82. Bus lanes, Madrid, Spain

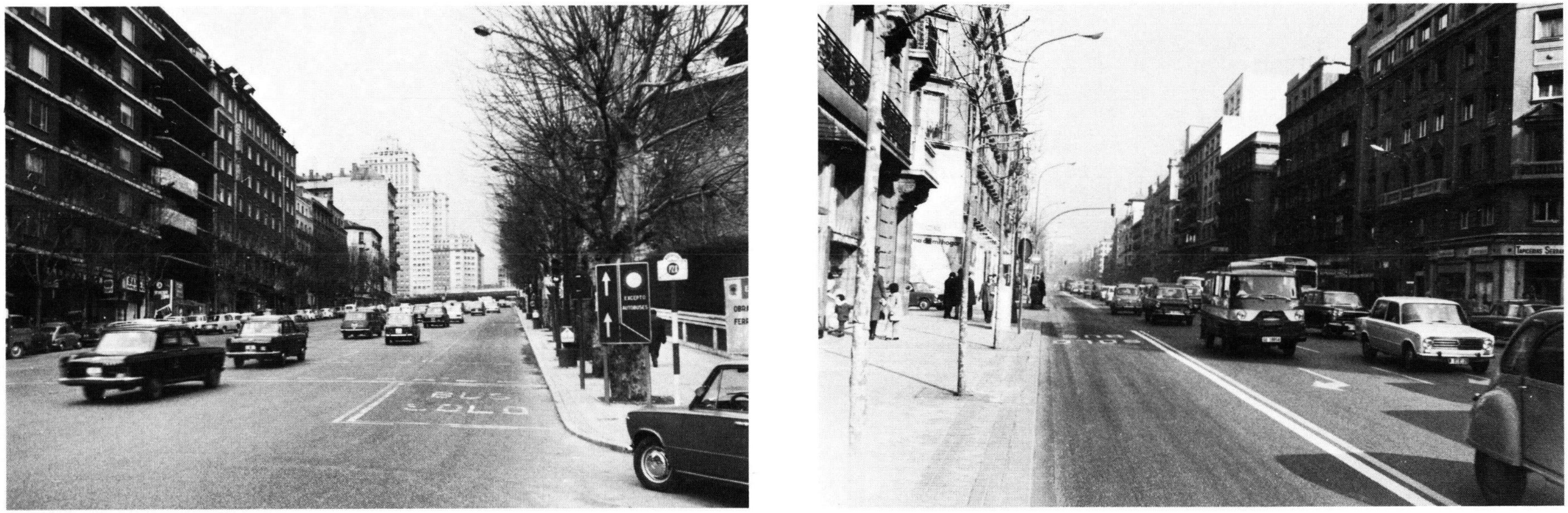
AVENIDA DEL GENERALISIMO

PASEO DEL PRADO

PASEO DELA CASTELLANA

PASEO DEL PRADO

Figure C-83. Typical views, bus lanes, Madrid, Spain.



PASEO DE ONESIMO

CALLE DE SERRANO

CALLE DE ALCALA

CALLE DE FUENCARRAL

Figure C-84. Typical views, bus lanes, Madrid, Spain.

Serrano

This one-way street, five lanes wide, has a bus lane 1,900 ft in length (Fig. C-84). It carries 93 buses and 6,300 passengers in the peak hour. Automobile travel times were observed to increase by 20 sec for each trip No benefits were observed for buses.

Fuencarral Bus Street

Fuencarral, Madrid's only bus street, is one-way and operates during the week except for Sunday. It is 900 ft long, and carries 38 buses and 1,300 passengers in the peak hour Taxis and emergency vehicles are allowed to use this facility (Fig C-84)

Significance

For Madrid as a whole, the number of bus passengers has substantially increased since bus lanes were introduced. It has not been indicated whether these are former automobile passengers (implying that other bus users from different lines may have been diverted) or the result of new growth. Altogether, 794 buses carry nearly 53,000 passengers in reserved lanes during peak hours.

38. JOHANNESBURG BUS PRIORITY SYSTEM

Since 1966 Johannesburg, South Africa (population 1,153,000) has operated a unique system of traffic control and roadway improvements designed to expedite bus movements through its downtown area Principal treatments are shown in Figure C-85.

Joubert Street was made a bus priority street This was accomplished by requiring all vehicles except buses to turn (thereby denying through movements), the removal of curb parking, the restriction of loading and unloading during the peak hours, the prohibition of car stopping, and the denial of garage rights for any new building that may be constructed along the street.

Plein Street was designated one-way east to west for two blocks (between Joubert and Rissik Streets, and between Twist and Edith Cavell Streets). Cars are permitted to turn onto it at key intersections

Edith Cavell Street was made one-way south for a short segment. Compulsory turns were instituted for automobiles at certain intersections.

Two short busways were constructed A 0 25-mile long busway extends from south of Union Grounds to the northern edge of Joubert Park paralleling Twist Street and connecting with Edith Cavell Street. Another 0.10-mile busway links Clarendon Place with Hillbrow Park. Both facilities are used only by buses

Reported benefits indicate that this system has saved up to 30 min of time for buses traveling through the area

39. STOCKHOLM BUS PRIORITY TREATMENTS

Bus and streetcar priority lanes were applied on several major streets in central Stockholm, Sweden, during the 1960's. Over-all, bus speeds generally improved, although in one case bus travel times increased When the southwestern link of the subway system was completed in September 1967, most remaining bus lanes were removed In 1968, major changes in downtown traffic patterns were introduced as a result of converting from left- to right-hand traffic.

Existing and proposed bus priority treatments in the inner city are shown in Figure C-86. Two bus lane systems and one bus street currently operate, and many more are proposed as part of a downtown bus priority system.

Kungsgatan Priority Vehicle Street

Kungsgatan, the city's principal shopping street, was closed to general traffic between Vasagatan and Sveavagen in June 1970 (Fig. C-87). In the direction toward Vasagatan, buses, taxis, bicycles, and motor bikes can use the street. In the other direction, trucks are also allowed The regulations are in effect 24 hours a day.

Tests conducted during 1970 indicate that total daily traffic along the street decreased from 22,100 to 5,000 vehicles Buses represent about 11 percent of the daily traffic; taxis, 55 percent, service vehicles, 15 percent, and bicycles-motor bikes, 20 percent. Taxi traffic has increased by 50 percent since the changes.

Buses traveling along the street have saved about 3 min No changes in bus passengers were reported.

Attitudes of various groups toward the bus street were identified. Ninety-five percent of the pedestrians using the street were positive, as compared with 60 percent of car, taxi, and truck drivers.

Skeppsbron and St. Eriksgatan Bus Lanes

Peak-hour bus lanes were installed along approximately ½ mile of Skeppsbron and St. Eriksgatan Streets in 1969 The curb lanes of both streets are used by buses, bicycles, mail trucks, and motor bikes from 7.00 to 9:00 AM and 4·00 to 6:30 PM on weekdays, and 11.00 AM to 2.00 PM on Saturdays and days preceding holidays. The layouts of both bus lanes are shown in Figure C-88; Figure C-89 shows typical signs and markings.

Peak-hour utilization of the two bus lanes is given in Table C-40. Both bus lanes carry about 200 vehicles in the peak hour, of which only 15 to 20 percent represent buses

The reserved lanes saved buses and taxis approximately 150 hr each day on Skeppsbron Street and about 50 hr each day on St Eriksgatan Street These gains are largely lost on approaches to the bus lane. Automobile travel times, and queues, have generally increased (Fig. C-90).

REFERENCES

C-1. *Atlanta Center City Transportation Project* Arthur D. Little, Real Estate Research Corp., Skidmore Owings and Merrill, and Wilbur Smith and Associates (Sept. 1970).

C-2 *Manual on Uniform Traffic Control Devices for Streets and Highways* Federal Highway Admin, U.S Dept. of Transportation (1971)

C-3 OLMSTEAD, E. E, "Chicago's Experience with an Exclusive Transit Lane." Chicago Transit Authority (1957)

C-4. *Dallas Center City Transportation Project.* Arthur

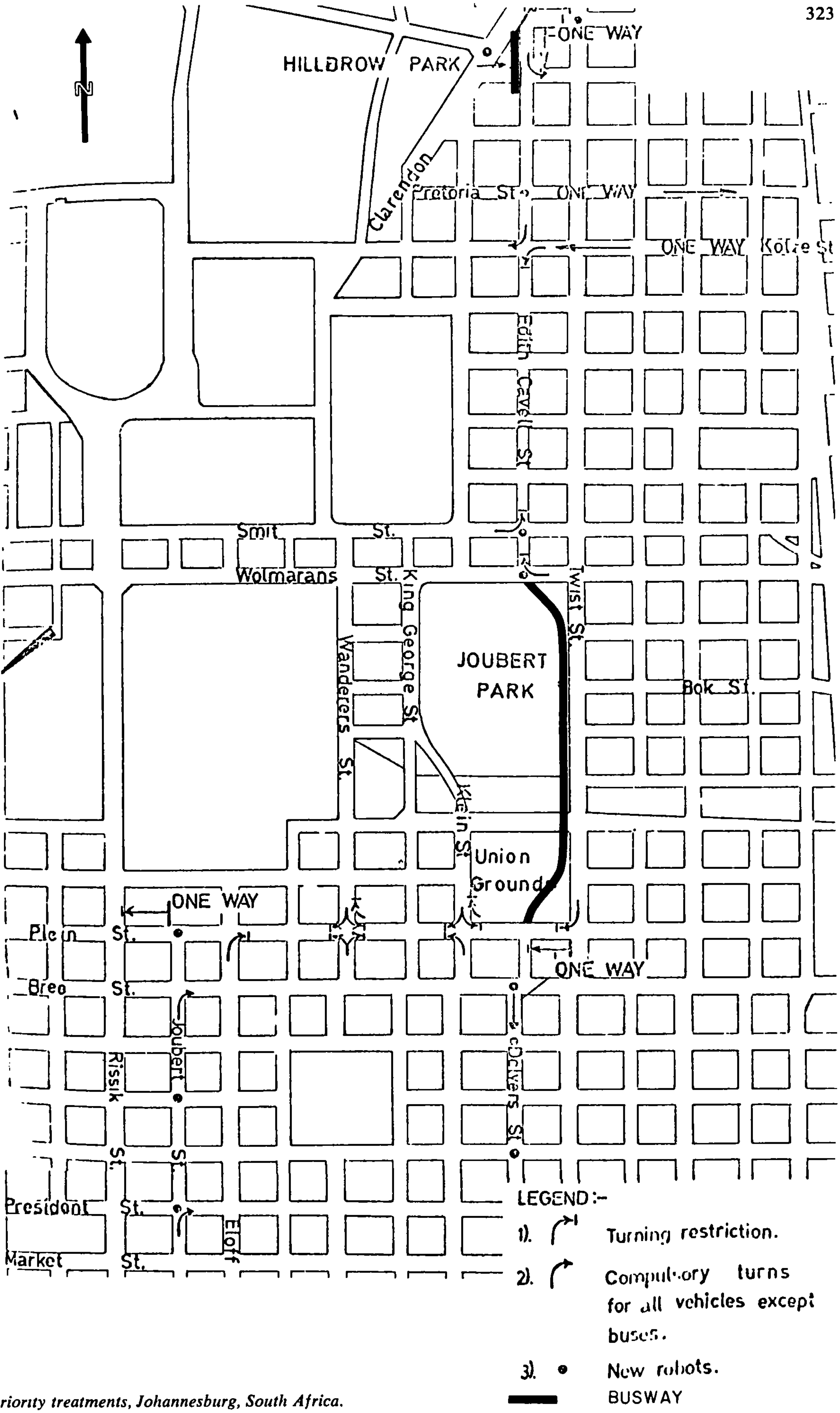


Figure C-85. Bus priority treatments, Johannesburg, South Africa.

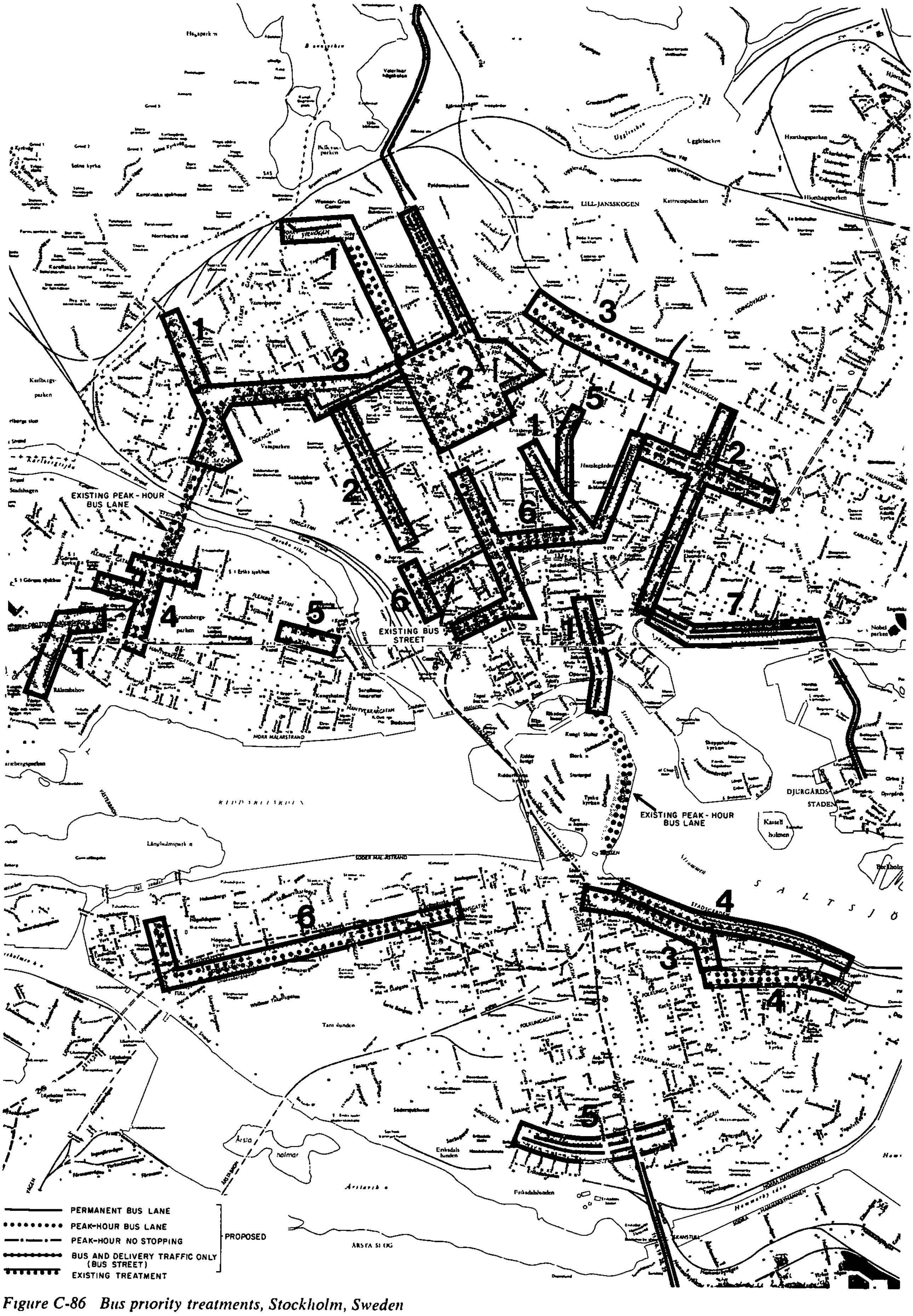


Figure C-86 Bus priority treatments, Stockholm, Sweden

D Little, Real Estate Research Corp, Skidmore Owings and Merrill, and Wilbur Smith and Associates (1970)

C-5 *Dallas Bus Operational Study Report.* Vol 2, "Immediate Action Transit Improvements." Wilbur Smith and Associates (1972)

C-6 *A Future Mass Transit Concept for Houston, Texas* Rapid Transit Lines, Inc, Houston, Tex. (Oct 1970)

C-7. *Final Report, Urban Corridor Demonstration Program, Louisville, Kentucky.* Schimpeler and Schuette Associates, prepared for Urban Mass Transit Administration (Sept. 1971)

C-8. Aschman, F T, "Nicollet Mall. Civic Cooperation to Preserve Downtown's Vitality." *Am. Inst of Planners,* Vol 1, No. 6 (Sept 1971)

C-9 Pontier, W E, Miller, P. W, and Kraft, W H, "Optimizing Flow on Existing Street Networks." *NCHRP Report 113* (1971).

C-10 "A Basic Concept for Rapid Transit Planning in the New Orleans Metropolitan Area" New Orleans Public Service Co (1963)

C-11 "A Traffic-Transit Integration Plan for Providence" Smith, Dibble and Associates (1951).

C-12. "Joint Report on Operations of United Transit Company" W. C Gilman & Co, The Roberts Organization, and Wilbur Smith and Associates (1956)

C-13. "A Study of Traffic-Transit and Trade in Downtown Providence." Wilbur Smith and Associates (1956).

C-14. "A Plan for the Improvement of Traffic and Mass Transportation in St. Louis" St. Louis Public Service Co (Sept 1955).

C-15. "Transit Improvement Program 1971-1975 The St Louis, Missouri, Illinois, Metropolitan Area." Bi-State Transit System in collaboration with W C Gilman & Co. (Jan 1971)

C-16 "St. Louis Metropolitan Area Transportation Study, 1957-70-80" W C. Gilman & Co., and Wilbur Smith and Associates (1959).

C-17. "Exclusive Bus Lanes A Demonstration Project." Dept. of Public Works, et al, San Juan, P.R. (July 1971).

C-18 Cloquell, E S. Memorandum from chairman, Puerto Rico Planning Board, to Administrator, Urban Mass Transit Admin., U.S Dept. of Transportation (July 20, 1971).

C-19. "D.C. Cordon Traffic Survey, 1970." D C Dept. of Highways and Traffic (1970)

C-20 Gahan, E., "A Bus Lane Experiment on a Major Artery in Dublin." Dept. of the Environment, Transport and Road Research Laboratory (Feb 1972).

C-21. *Transportation in Dublin.* Report of the Dublin Transportation Study (Oct. 1971).

C-22. Yates, L B, "Brixton Bus Lane Study. Interim Report for All Vehicles Except Buses." Res. Memo, Dept. of Planning and Transportation, Greater London Council (Nov. 1969).

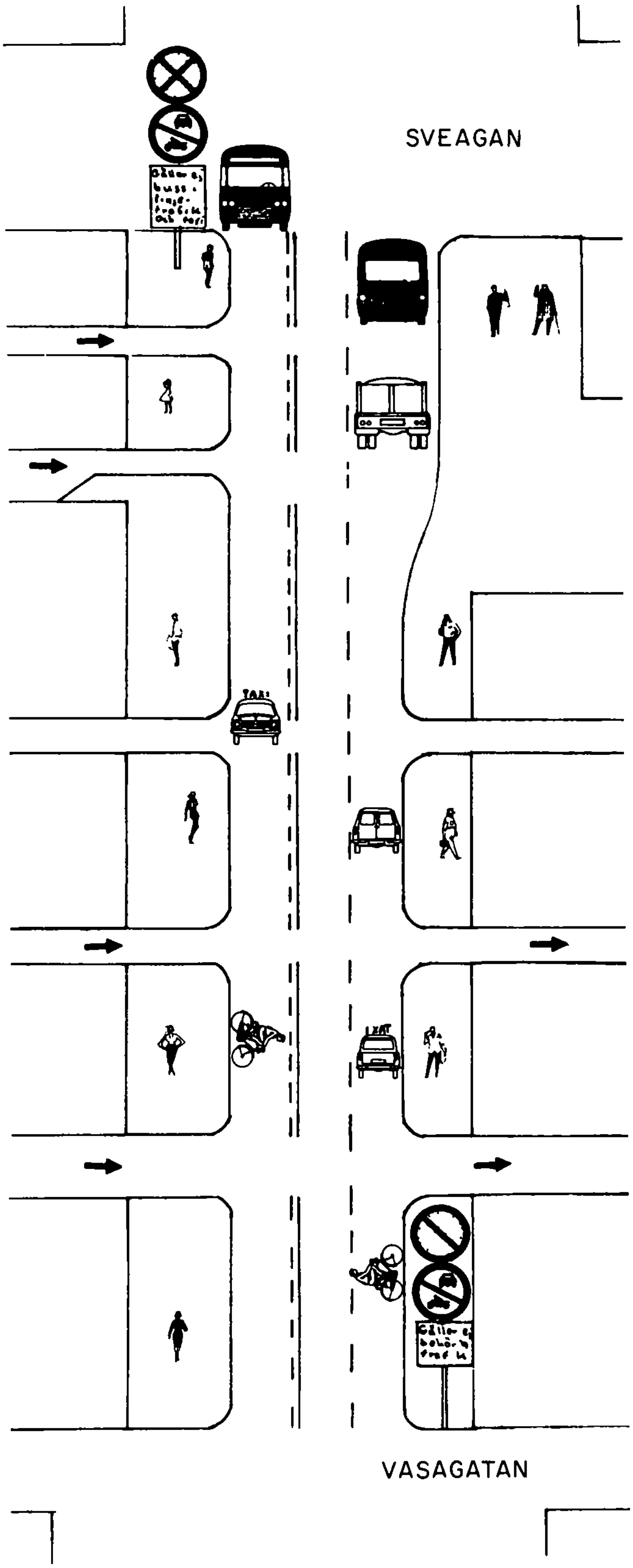


Figure C-87. Kungsgatan bus priority street, Stockholm, Sweden

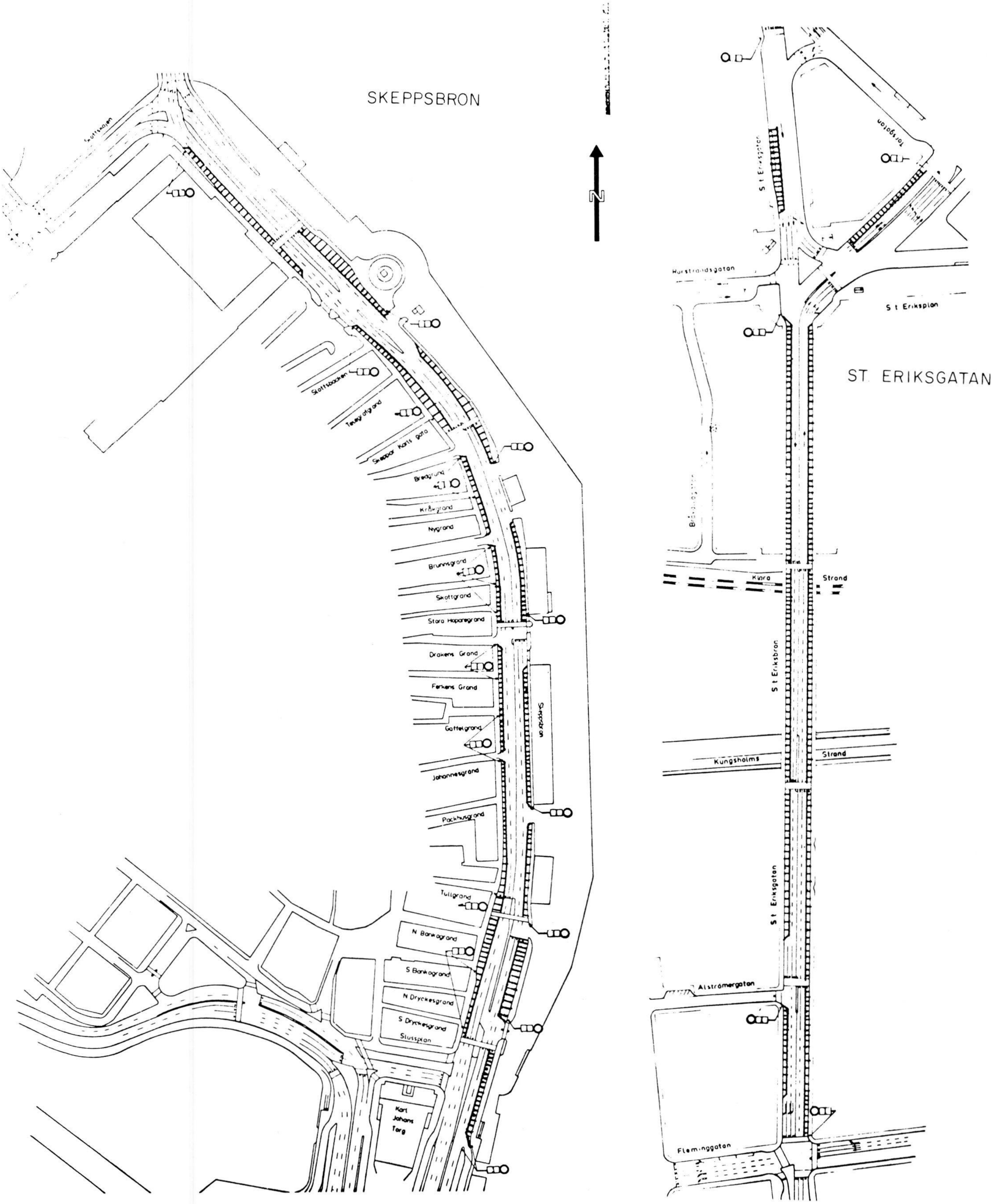
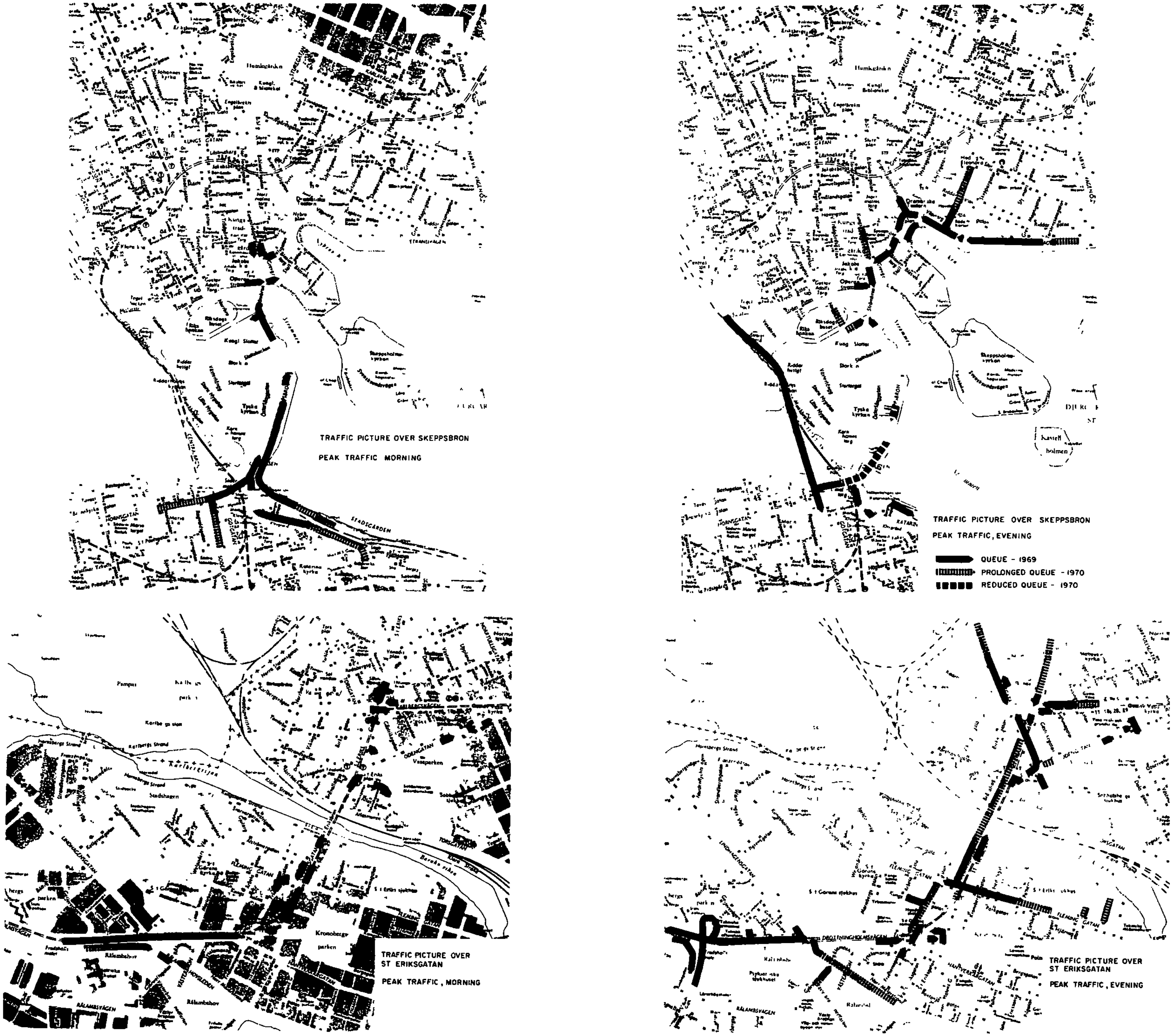


Figure C-88. St. Eriksgatan and Skeppsbron bus lanes, Stockholm, Sweden.

SIGNS FOR
RESERVED LANES

MARKING OF
RESERVED LANES

Figure C-89. Signs and markings, St. Eriksgatan and Skeppsbron bus lanes, Stockholm, Sweden.



TRAFFIC PICTURE OVER SKEPPSBRON
PEAK TRAFFIC MORNING

TRAFFIC PICTURE OVER SKEPPSBRON
PEAK TRAFFIC, EVENING

TRAFFIC PICTURE OVER ST ERIKSGATAN
PEAK TRAFFIC, MORNING

TRAFFIC PICTURE OVER ST ERIKSGATAN
PEAK TRAFFIC, EVENING

Figure C-90 Queue length changes, St Eriksgatan and Skeppsbron bus lanes, Stockholm, Sweden

C-23 Yates, L B, "Vauxhall Bridge Bus Lane 12-Month After Study." Res Memo 178, Dept of Planning and Transportation, Greater London Council (July 1969)

C-24 "Buses Both Ways in Piccadilly?" Public information circular, Greater London Council (1971)

C-25 "Reading Central Area, Comprehensive Traffic Management Schemes, Contra-Flow Bus Lane in King's Road." Traffic Advisory Unit, Reading, England (Apr 1970)

C-26 Coste, J F, "Bus Lane Experiments in Marseilles" Transportation and Traffic Dept, Marseille, France Presented at Road Research Laboratory Bus Priority Symposium (Feb 1972)

C-27. "Etude des mesures ayant pour objet de donner aux transports publics une priorite effective de circulation" 18th Technical General Assembly, Marseilles, France (May 1968)

C-28 "The Effect of Reversed Lanes for Public Transport on Skeppsbron and St Eriksgatan Streets, 1969-1970" Rep No 24, Stockholm Traffic Dept. (Apr 1971).

TABLE C-40

PEAK-HOUR USE, SKEPPSBRON AND ST ERIKSGATAN BUS LANES, STOCKHOLM, SWEDEN [a]

VEHICLE TYPE	NO VEHICLES, PEAK-HOUR HEAVY DIRECTION	
	SKEPPSBRON	ST ERIKSGATAN
Buses	36	33
Taxis	62	59
Mail cars	0	0
Other motor vehicles	33	33
Bicycles, motor bikes	114	90
All	245	197

Source Ref (*C-28*)

[a] Data collected during 1970

C-29 "Transit Annual Report" Twin Cities Metropolitan Area Transit Commission (1971).

C-30 "A Bus Priority System for Traffic Signals" Project Ohio MTD-4 (Kent State Univ), Urban Mass Transportation Admin (1971).

APPENDIX D

CASE STUDIES OF BUS TERMINALS

This appendix describes and interprets examples of bus priority treatments related to terminals. United States and Canadian experiences are discussed first, followed by significant experiences in other countries. Case studies are arranged alphabetically by city or metropolitan area for bus-related transportation terminals and mode-change facilities.

1. CHICAGO BUS TERMINALS

Chicago, Ill, has a wide variety of transportation terminals. Most are located along rapid transit lines to facilitate transfer from bus or car to rail (Fig. D-1) The Chicago Transit Authority provides 2,500 spaces at seven rapid transit terminals. These parking facilities are generally located 8 to 10 miles from the Loop, are less than 500 cars in capacity, and usually involve a $0.25 parking fee. The facilities are fully utilized, mainly by commuters, and turnover averages one car per space per day.

Greyhound Bus Terminal

The Greyhound Bus Terminal, situated at the intersection of Randolph and Clark Streets, was constructed in 1952 at a total cost of approximately $8,000,000, including office space above and retail facilities within the terminal. The bus facilities serve only long-haul buses, which are accommodated in 36 bus docks arranged around a central loading area (Fig D-2).

Physical Characteristics

Pertinent characteristics are summarized in Table D-1. The terminal is approximately 420 ft long and 180 ft wide Bus docks are located two levels below street grade, ticketing and retail services are provided one level below street grade, together with entrances to stairs and escalators leading to the bus loading level Two levels of parking are provided above the street grade There is provision for future construction of a multi-story office building over the terminal.

Access

In some respects the terminal is a smaller version of the Port of New York Authority terminal in terms of its relationship to major approach highways Bus access to the terminal is from and to Garvey Court via a short tunnel under Lake Street Garvey Court connects with the lower level of Wacker Drive at a signalized intersection. Most buses approach the terminal from the south and west, using the direct connections between Wacker Drive and the expressway system. Directional flows in the heated tunnel and ramp are separated by a walled divider.

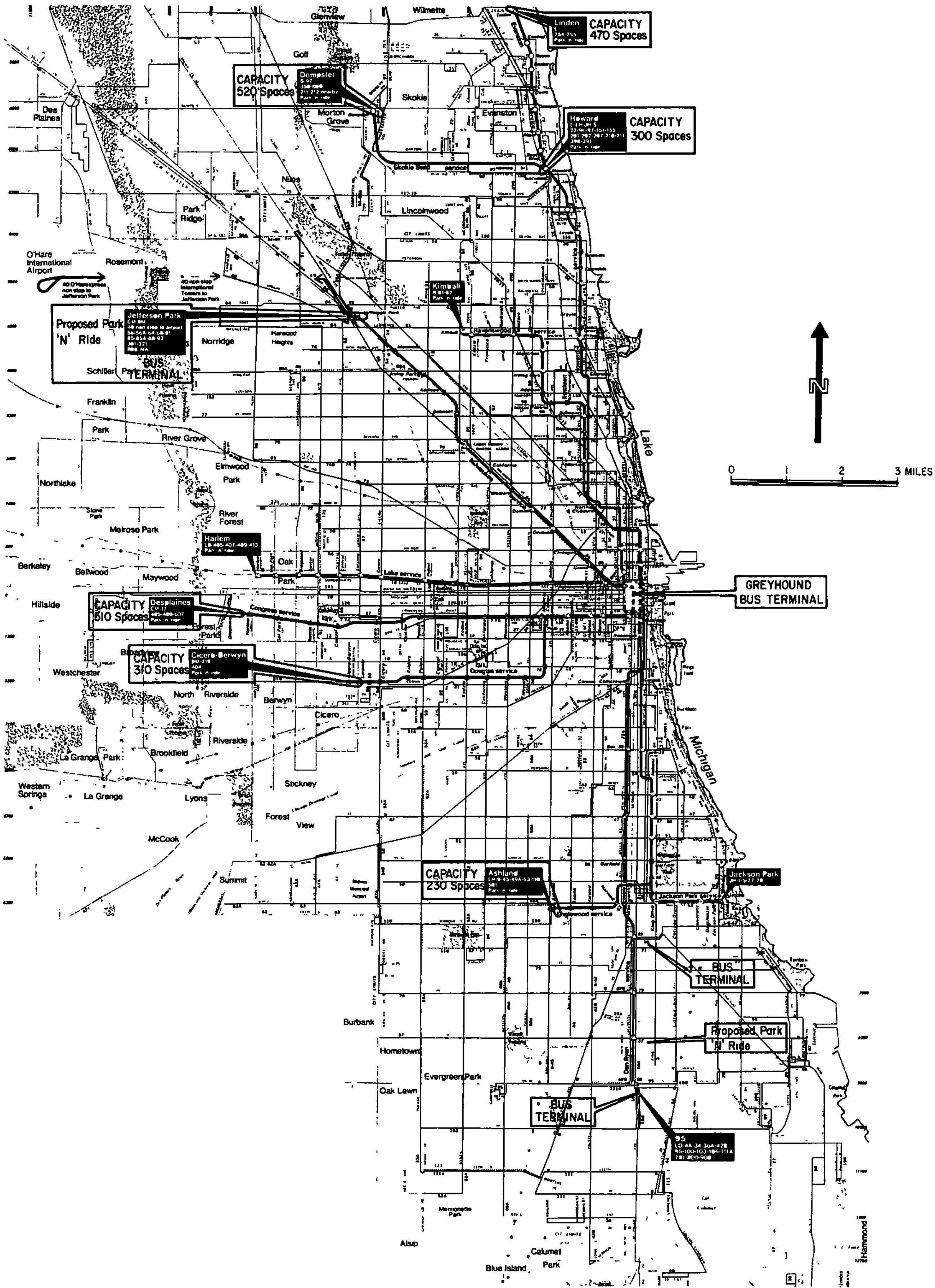


Figure D-1. Bus terminals, Chicago, Ill

Operating Characteristics

Initially, traffic signals located at the ramps were operated by a dispatcher to control bus movements. These signals are now inoperative Currently, inbound buses stop on entering the ramp and again where the ramp enters the terminal No operating problems have been reported, although in busy peak periods buses occasionally back up onto Wacker Drive.

Five bus carriers use the terminal The three intercity carriers (Greyhound, Indian Trails, and Peoria-Rockford Bus Company) have 135 scheduled departures daily. The West Suburban Transit Lines operates 12 trips daily, and the Chicago and Calumet District Transit operates 5 outbound trips The United Transit Company, a suburban carrier, previously used the terminal but now cannot because of limited terminal capacity.

There are about 25 scheduled intercity departures during the 2-hour peak period on typical weekdays. Suburban carriers add another 10 departures.

All platforms are sawtooth in pattern The first six gates serve inbound passengers; other gates serve outbound passengers. Passengers may use any of several gates for boarding an outbound bus. Three particular gates are normally used for suburban services. Intercity buses may take up to 45 min to load, because of the need to accommodate baggage and parcels.

Significance

The terminal is significant in several respects. First, it is located a few blocks from the downtown core. Second, access is provided to and from the major highways, through conventional traffic controls that also apply to other traffic. Third, buses entering and leaving the terminal have direct access to and from the expressway system, thereby avoiding downtown street operations

95th Street-Dan Ryan Bus Bridge and Terminal

The 95th Street bus bridge and terminal was constructed in 1969 as part of the Dan Ryan Expressway rapid transit extension. Construction costs approximated $1,300,000.

Physical Characteristics

The relation of the terminal to the sunken expressway is shown in Figure D-3. The terminal measures approximately 300 ft by 220 ft. Bus docks are located on the east, north, and west sides in a platform configuration that provides 19 local and three intercity bus docks; all loading is parallel to the curbs The east and west platforms are located between the expressway and frontage roads; the north platform is located on the bridge over the expressway; and the terminal itself is located over the freeway right-of-way. Passengers arriving by bus at the platforms walk a short distance to the center of the passenger concourse and then use stairways to reach the rail rapid transit platform in the expressway median Access to the terminal is provided from South Lafayette Avenue and South State Street in a north-south direction and also from 95th Street (Fig. D-4).

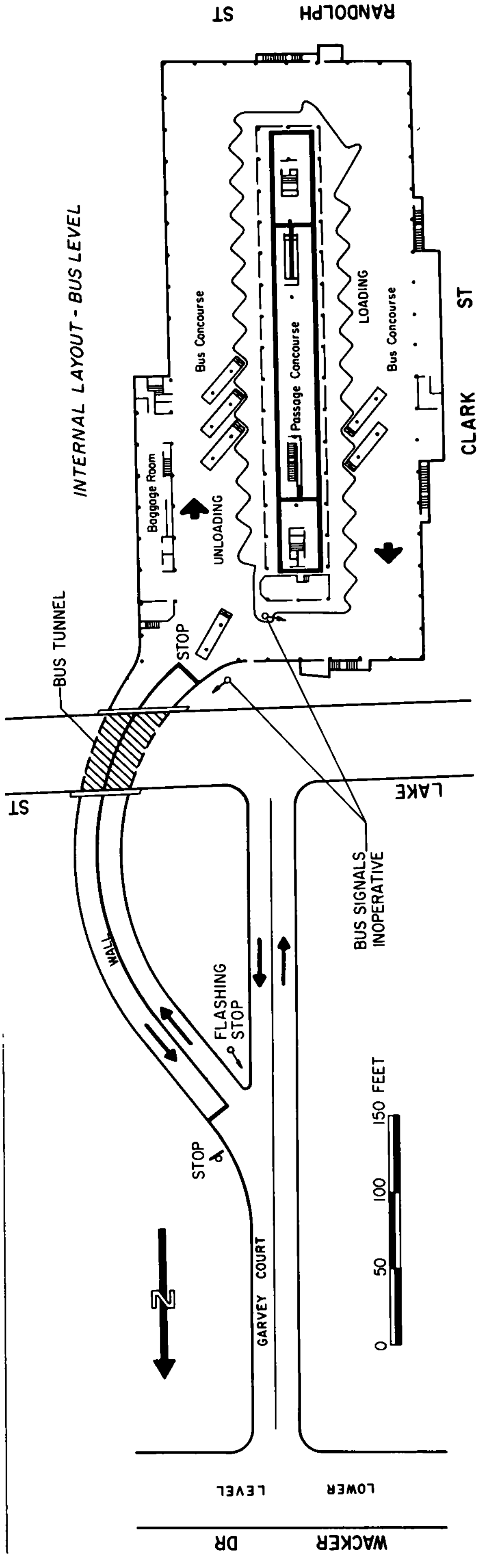
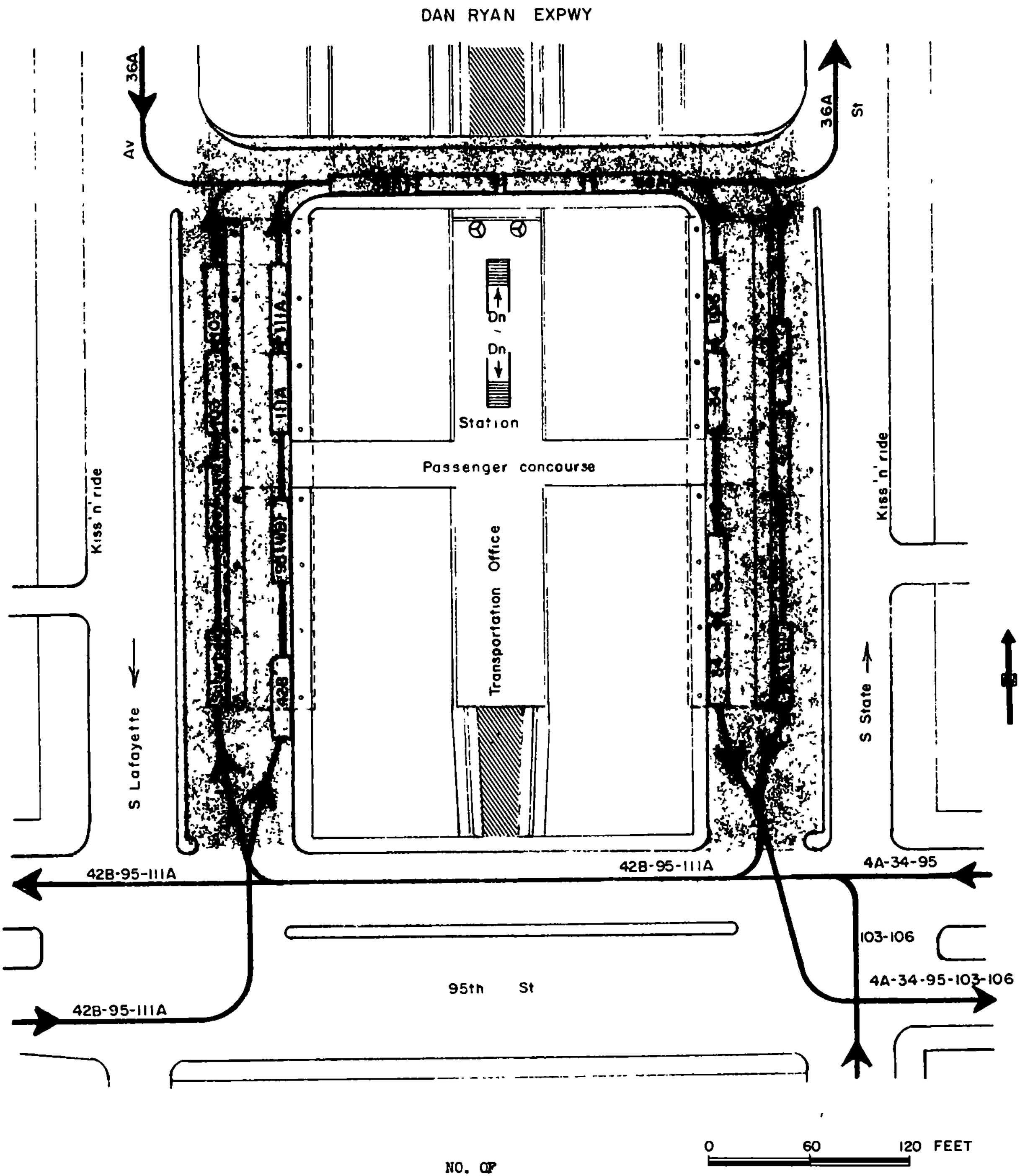


Figure D-2 Greyhound Bus Terminal, Chicago, Ill

Figure D-3. 95th Street-Dan Ryan Expressway bus bridge and terminal, Chicago, Ill.



SOURCE CHICAGO TRANSIT AUTHORITY

ROUTE		MAX. NO. OF BUSES IN TERMINAL SIMULTANEOUSLY	NO. OF BUSES IN MAX. HOUR	
			A.M.	P.M.
4A	Pullman	2	11	8
34	S. Michigan	3	20	19
36A	State	4	12	13
42B	S. Halsted	1	7	6
95	83rd-95th(WB)	1	10	10
95	83rd-95th(EB)	1	10	10
103	W. 103rd	2	11	10
106	103rd-106th	2	10	9
111A	Vincennes-111th	2	13	14
Suburban Transit Co.		1	2	2
Greyhound		2	varies	
		21	106	101

Figure D-4 Functional plan, 95th Street-Dan Ryan Expressway bus bridge and terminal, Chicago, Ill

TABLE D-1

GENERAL CHARACTERISTICS,
GREYHOUND BUS TERMINAL, CHICAGO, ILL

ITEM	DESCRIPTION
Date open	1952
Type of bus service	Mainly intercity
Construction costs	$8,000,000
Approximate dimensions	420 × 180 ft
Number of bus levels	1 bus +2 term levels
No of bus loading docks	36
No. of parking spaces	N A.
Contiguous transp facil	CTA bus and subway
Road access connections	Connection to expressways via lower level of Wacker Drive
Number of bus carriers	5

Source Field reconnaissance, Greyhound Bus Company

TABLE D-2

GENERAL CHARACTERISTICS,
95TH STREET-DAN RYAN BUS BRIDGE
AND TERMINAL, CHICAGO, ILL.

ITEM	DESCRIPTION
Date open	1969
Type of bus service	Primarily local
Construction costs	$1,300,000
Approximate dimensions	300 × 220 ft
Number of bus levels	1
No of bus loading docks	22
No of parking spaces	0
Contiguous transp facil	Dan Ryan rapid trans
Road access connections	Freeway frontage roads and arterial
Number of bus carriers	3
Number of bus routes	9 (CTA)

Source Chicago Transit Authority

Operating Characteristics

General characteristics of the terminal are summarized in Table D-2. Three bus companies operate nine routes into the terminal, with most service provided by CTA buses (Fig. D-4). The restructuring of CTA bus routes to serve the station has made the rapid transit terminal the heaviest boarding point outside of the Loop. During the rush hour about 5,000 persons on 110 buses use the facility (Table D-3) Each day approximately 20,000 to 25,000 persons enter the rapid transit at this location, most by bus.

69th Street-Dan Ryan Bus Bridge and Terminal

The 69th Street bus bridge over the Dan Ryan Expressway provides approximately four bus dock positions for passengers using the Chicago Transit Authority (CTA) buses. It was constructed in 1969 at a cost of $550,000 (Table D-4).

Physical Characteristics

The bus bridge is shown in Figure D-5 It is about 300 ft long and provides direct access from the bus loading and unloading docks via a stairway to the rapid transit platform located in the expressway median.

Operating Characteristics

The bus bridge is served by four CTA routes It serves southbound and westbound through buses as well as terminating buses It accommodates about 8,000 passengers one-way daily (Table D-5) During the peak hour it is used by 40 buses and approximately 2,000 passengers. This results in an average bus turnover during the peak hour of 10 buses per dock, and an average bus layover time of 0 17 hr.

Jefferson Park Bus Terminal

The Jefferson Park-Milwaukee Avenue bus terminal was constructed in 1970 at a cost of $1,800,000 Located next to the Chicago and Northwestern Railroad (CNW) Station and the Chicago Transit Authority Kennedy Rapid Transit

TABLE D-3

BUS AND PASSENGER CHARACTERISTICS,
95TH STREET-DAN RYAN BUS BRIDGE
AND TERMINAL, CHICAGO, ILL

	ACTIVITY CHARACTERISTICS [a]		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers [b]	20,000	5,000	25
Number of buses [b]	N A	110	—
Average bus occupancy	—	45.5	—
No. of bus loading docks	22	22	—
Avg. bus turnover per dock	—	5	—
Avg bus layover time (hr)	—	0 20	—

Source Chicago Transit Authority

[a] N A = not available

[b] One-way movements

TABLE D-4

GENERAL CHARACTERISTICS,
69TH STREET-DAN RYAN BUS BRIDGE
AND TERMINAL, CHICAGO, ILL.

ITEM	DESCRIPTION
Date open	1969
Type of bus service	Local
Construction costs	$550,000
Approximate dimensions	300 × 48 ft
Number of bus levels	1
No of bus loading docks	4
No of parking spaces	0
No of bus carriers	1 (CTA)
Contiguous transp facil	Dan Ryan rapid transit
Road access connections	Freeway frontage roads and arterial

Source Chicago Transit Authority

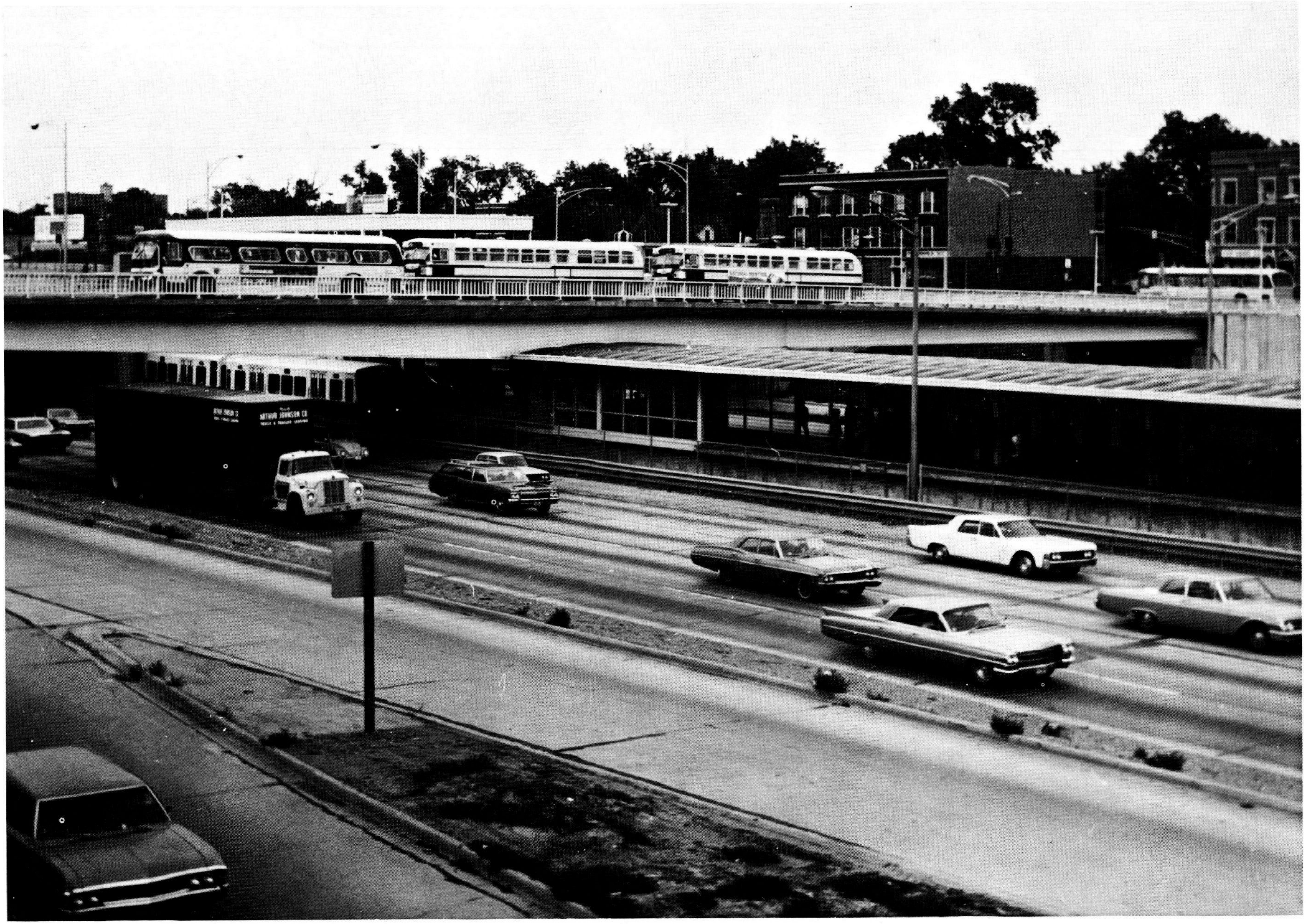


Figure D-5. 69th Street-Dan Ryan Expressway bus bridge and terminal, Chicago, Ill.

TABLE D-5

BUS AND PASSENGER CHARACTERISTICS, 69TH STREET-DAN RYAN BUS BRIDGE AND TERMINAL, CHICAGO, ILL

	ACTIVITY CHARACTERISTICS [a]		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers [b]	8,000	2,000	25
Number of buses [b]	N A	40	—
Average bus occupancy	N A	50	—
No of bus loading docks	4	4	—
Avg bus turnover per dock	—	10	—
Avg bus layover time (hr)	—	0 10	—

Source Chicago Transit Authority
[a] N A = not available
[b] One-way movements

Terminal, a single bus level terminal provides 14 bus dock positions for local and intercity bus carriers Proximity to the Kennedy Expressway indicates a continuation of CTA's policy of using median transit facilities within expressway rights-of-way

Physical Characteristics

The general design concept of the terminal is shown in Figure D-6, the bus berthing plan is shown in Figure D-7 The terminal is divided into south and north sides; island-type platforms are provided. A pedestrian way connects the rapid transit terminal and Chicago and Northwestern trains with the bus terminal Escalators and stairs are provided from the pedestrian tunnel to the CNW platforms Covered facilities are provided throughout most of the terminal area, thereby enhancing passenger comfort in an area with severe winter weather

TABLE D-7

BUS AND PASSENGER CHARACTERISTICS, JEFFERSON PARK-MILWAUKEE AVENUE BUS TERMINAL, CHICAGO, ILL

	ACTIVITY CHARACTERISTICS [a]		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers [b]	12,000	3,000	25
Number of buses [b]	N A	140	—
Average bus occupancy	N A	21 4	—
No of dock positions	14	14	—
Avg bus turnover per dock position	—	10 0[c]	—
Avg bus layover time (hr)	—	0 10[c]	—

Source Chicago Transit Authority
[a] N A = not available
[b] One-way movements
[c] Twenty-eight buses are in terminal at one time, this is the equivalent of 28 docks, or a turnover of 5 and an average layover of 0 20 hr

TABLE D-6

GENERAL CHARACTERISTICS, JEFFERSON PARK-MILWAUKEE AVENUE BUS TERMINAL, CHICAGO, ILL

ITEM	DESCRIPTION
Date open	1970
Type of bus service	Primarily local
Construction costs	$1,800,000
Approximate dimensions	600 × 340 ft
Number of bus levels	1
No of bus loading docks [a]	14
No of parking spaces	1,800 proposed
Contiguous transp facil	Kennedy rapid transit and CNW R R
Road access connections	Arterial
Number of bus carriers	3
Number of bus routes	11 (CTA)

Source Chicago Transit Authority
[a] Loading positions, actually, each can accommodate several buses

Operating Characteristics

The terminal is used by 11 CTA bus routes, one suburban carrier, and Greyhound (Table D-6) A maximum of 28 buses occupy the terminal at any one time During the morning peak hour, approximately 3,000 inbound bus passengers in about 140 buses use the facility In conjunction with the 14 bus dock positions provided, this results in an average bus turnover per position of approximately 6 min (Table D-7)

2. CLEVELAND PARK-AND-RIDE FACILITIES

The Cleveland (Ohio) Transit System (CTS) has been an innovator in providing bus-rail transfer and park-and-ride facilities along its 18-mile rapid transit line. More than 50 CTS bus lines interchange at the line's 17 stations Special off-street bus terminals and some 7,000 parking spaces have been provided at nine stations since the line first opened in 1955 (Fig. D-8). Parking capacities range from 500 to 2,000 spaces, and there is one space for every four inbound riders

General Description

Convenient interchanges have also been important objectives of passenger station design Initially, bus loops were provided, such as those found at the Windermere Station (Fig D-9) This configuration does not permit the rear doors of buses to remain parallel with the curb, and passengers were inconvenienced when disembarking

This condition, plus "leapfrogging" of newly arrived buses having to pull around buses stopped for loading, was solved by adoption of special sawtooth loading platforms in the 1958 extension of the rapid transit to West Park Designed for high-volume bus movements, the West Park facility has a center-island bus facility (Fig. D-10). Arriving coaches discharge their passengers along the left side of the island, where two entrances to the station are provided. The bus roadways are completely separate from the automobile passenger drop-off roadway outside the terminal proper

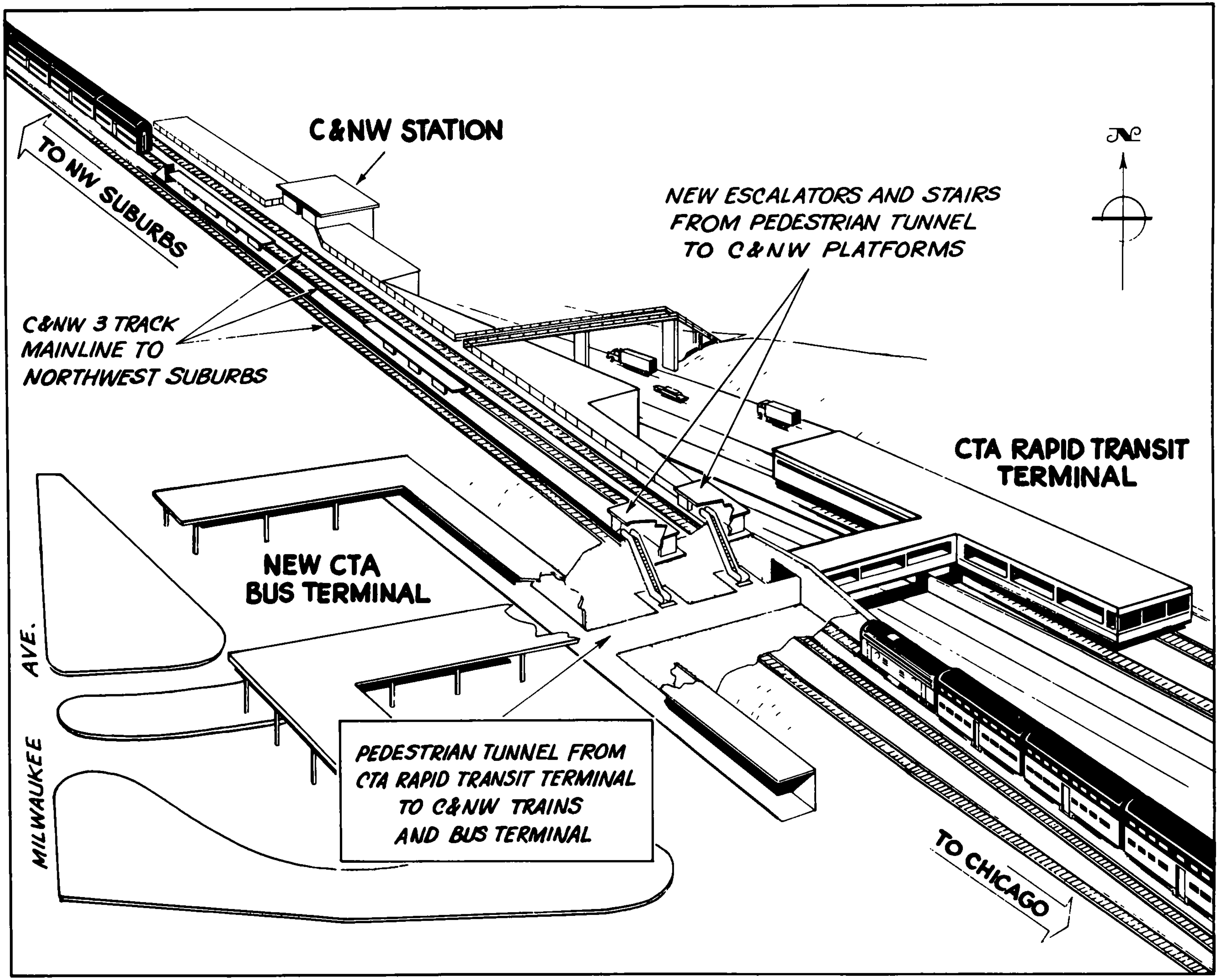
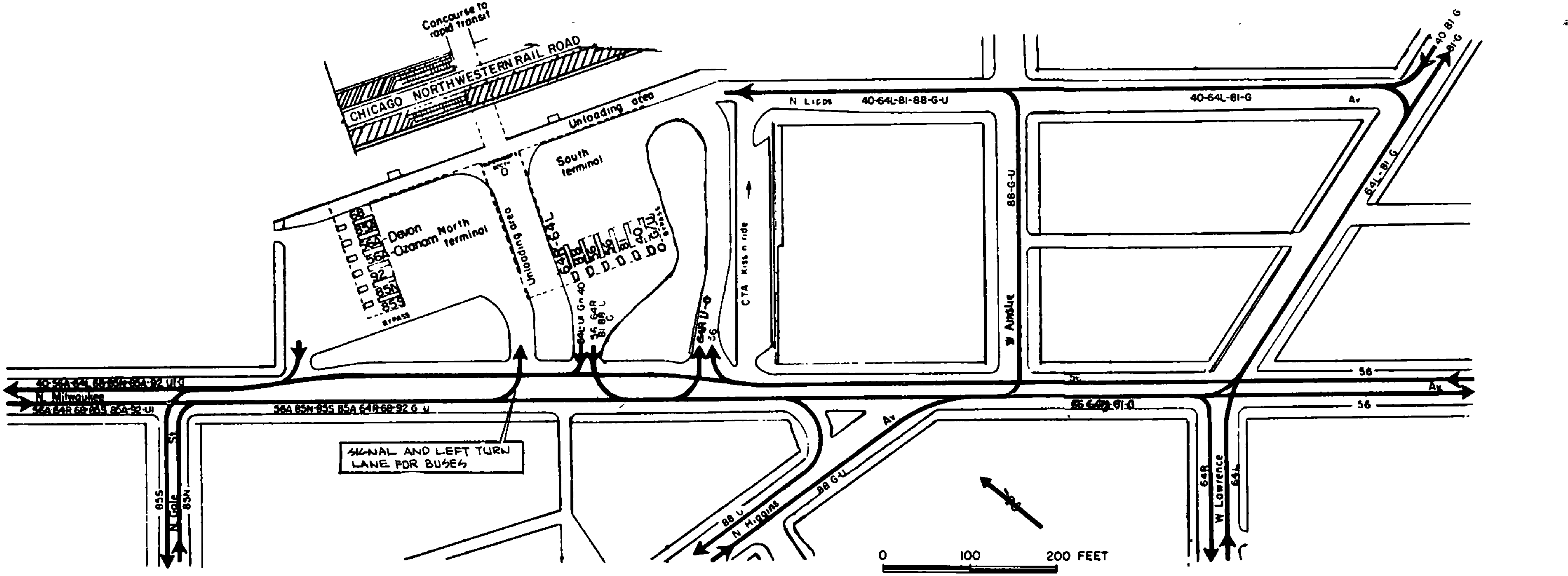


Figure D-6 Design concept, Jefferson Park bus terminal, Chicago, Ill



ROUTE		MAX. NO. OF BUSES IN TERMINAL SIMULTANEOUSLY	NO. OF BUSES IN MAX. HOUR A.M.	P.M.
56A	N. Milwaukee	2	10	10
56	Milwaukee	5	25	21
81	Lawrence	3	13	14
85	Central (NB)	1	14	16
85	Central (SB)	2	13	12
85A	N. Central	2	11	13
88	Higgins	2	10	10
64	Foster-Lawrence	3	20	21
92	Foster	2	9	11
68	Northwest Highway	2	8	9
40	O'Hare Express	1	2	2
G	Greyhound	2	varies	
U	United	1	2	2
		28	137	141

Figure D-7 Functional plan, Jefferson Park bus terminal, Chicago, Ill

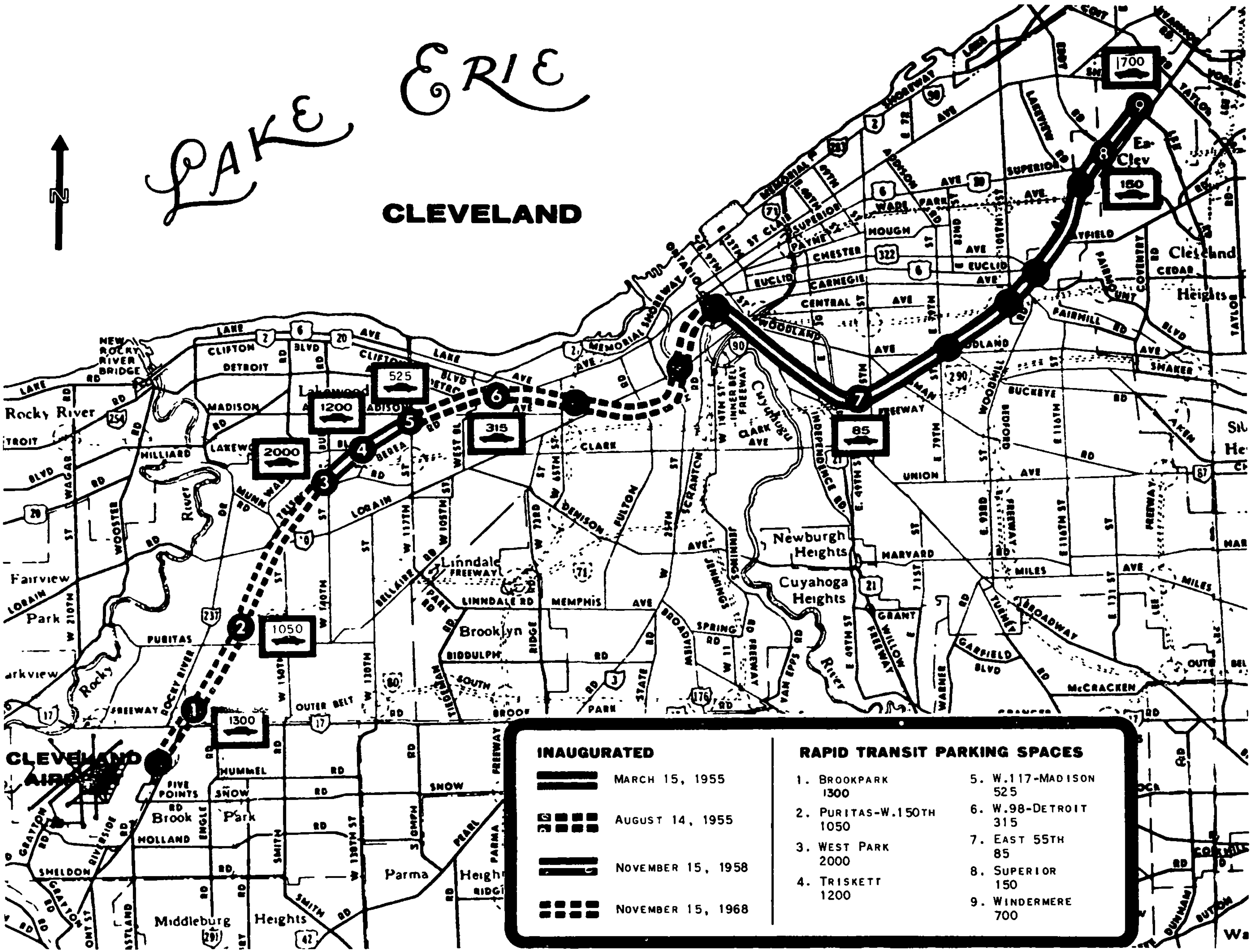


Figure D-8. Rapid transit station parking, Cleveland, Ohio

Figure D-9. Windermere bus loop and station, Cleveland, Ohio.

Figure D-10. West Park bus terminal and station, Cleveland, Ohio.

Buses awaiting space at the sawtooth loading platforms have ample space to lay over at the far end of the center island.

The most common change-of-mode arrangement at CTS rapid transit stations is typified by the 1968 airport extension The Brook Park bus-auto-rapid transit interchange is shown in Figure D-11. All bus passengers arrive and depart from the same position on the sawtooth loading platform The "kiss-and-ride" automobile roadway parallels the bus-only lane along the length of the station.

Planning Factors

In most cases, rapid transit stations must accommodate (1) bus lines rerouted and scheduled to feed the trains, (2) motorists who park, and (3) passengers who walk or are driven to the station The optimum size of park-and-ride lots seems to be about 1,000 auto spaces

The CTS determined that parking should be free whenever costs of developing the facilities were less than $500 per space Virtually all of the park-ride facilities were built at a cost of $300 per space Consequently, all fringe parking is free, except for some metered parking provided at the Windermere Station for shoppers

Travel Patterns

Modes of arrival at various Cleveland Transit System stations are summarized in Table D-8 Although the proportions of car-driver, walk-in, and bus passenger arrivals varied, approximately 15 percent of all passengers were dropped off at the rapid transit station by another driver This suggests that "kiss-and-ride" is an important part of the intermodal transfer process

3. MILWAUKEE FRINGE PARKING WITH EXPRESS BUS SERVICE

The Milwaukee (Wis.) Suburban Transport Company operated six "Freeway Flyer" routes on existing freeways in 1970 This represents a significant expansion of the bus rapid transit services initiated in 1964 Express bus service began in March 1964 from the Mayfair Shopping Center (on the west side of the city) to the downtown A similar service from the Bay Shore Shopping Center (on the north side) to downtown was then started. These and other shopping centers make available free parking. Patronage has grown from one route and 81,000 annual riders in 1964 to six routes and 605,000 riders in 1971, about 2,500 riders every weekday (A seventh route has since been added).

Summary Characteristics

System characteristics of six Freeway Flyer routes are summarized in Table D-9. Six shopping centers (Mayfair, Bayshore, Treasure Island North, Treasure Island South, County Fair, Spring Mall) provide a total of 800 spaces for all-day parking The parking capacities of these centers range from 2,500 to 8,000 cars (Bayshore and Mayfair, respectively) Thus, only a small portion of the total shopping center parking is actually used for all-day parking. The centers are located about 10 to 14 over-the-road miles from the downtown area.

TABLE D-8

TRAVEL MODES TO RAPID TRANSIT STATIONS, CLEVELAND, OHIO

MODE	DISTRIBUTION (%) [a]			
	1971		1964	
	PURI-TAS	BROOK-PARK	WEST PARK	TRIS-KET
Auto driver	31 1	51 9	25 9	40 8
Auto passenger parked at station	6 4	13 9	5 2	8 4
Auto passenger dropped off at rapid station	14 8	15 4	14.9	14 8
Suburban bus	0 3	0 6	N A	N A
CTS bus	32 2	16 8	52 8	25 5
Walked to rapid station	15 0	1 4	1 2	10 5
Other	0 2	—	—	—
All	100 0	100 0	100 0	100 0

Source Cleveland Transit System

[a] N A = not available

Bus service is provided during peak hours at headways ranging from 5 to 30 min Transit fares to the CBD average $0 50 to $0 55. Bus travel times to the CBD are comparable to those by car Buses operate non-stop on freeways until near downtown Milwaukee, then use surface streets. All parking facilities are lighted and provide bus shelters.

There are approximately three daily riders per automobile space provided at the shopping center. Occupancy of parking facilities varied from 30 percent for Treasure Island to 77 percent for Bayshore. There appears to be some correlation between bus service frequency and parking lot use, although the pattern is not clear (Mayfair, with 5-min headways, reported only one-half of its spaces utilized).

Mayfair and Bayshore Services

Detailed analyses of the use of both the Mayfair and Bayshore Shopping Centers were developed in 1968.

Bus Routing

The Mayfair Shopping Center is located two blocks from the Zoo Freeway in Milwaukee County and is about seven airline miles from downtown. The Zoo Freeway is linked by the East-West Freeway with the central business district. Buses operate nonstop from the shopping center to Wisconsin Avenue, the main downtown thoroughfare Local stops are made on Wisconsin Avenue at about every three blocks The round-trip distance from parking lot to downtown terminal and return is 20 4 miles.

The Bayshore Shopping Center is adjacent to the North-South Freeway, with entrance and exit ramps about two city blocks from it Buses operate on city streets after leaving the freeway and arriving downtown. The Bayshore Flyer also stops approximately every three blocks in the downtown area The round-trip distance from the shopping

Figure D-11. Brook Park bus terminal and station, Cleveland, Ohio.

TABLE D-9

PARK-AND-RIDE AND KISS-AND-RIDE FREEWAY FLYER ROUTES ORIGINATING AT REGIONAL SHOPPING CENTERS, MILWAUKEE, WIS , 1970

ROUTE	DATE SERVICE BEGAN	HOURS OF SERVICE	DAILY BUS TRIPS [a]	ANNUAL PASS TRIPS [b]	BUS FREQUENCY (MIN) PEAK	BUS FREQUENCY (MIN) OFF-PEAK	FARE TO CBD ($)	TIME TO CBD (MIN) TRANSIT	TIME TO CBD (MIN) AUTOS [c]	DISTANCE TO CBD (MIN) AIR-LINE	DISTANCE TO CBD (MIN) ROUTE	ALL-DAY PARKING [d] SPACES ALL	ALL-DAY PARKING [d] CARS PARKED [c]	ALL-DAY PARKING [d] PER-CENT USED	ALL-DAY PARKING [d] RI-DERS [a] / SP USED
41 Mayfair	3/30/64	6 20–8 25 AM 4 15–5.45 PM	12	210,000	5–10	None	0 50	21	21	7	10	300	150	50	2 7
42 Bayshore	11/29/65	6 45–9 00 AM 4 15–6 05 PM	15	154,000	10–15	None	0 50	10	10	6	7	150	115	77	2 6
44 Treasure Island South (West Allis)	11/6/67	6 15–8 20 AM 4 15–5 35 PM	9	104,000	20–30	None	0 50	20	20	8	10	100	50	50	4 0
45 Treasure Island North (Capitol Drive)	4/22/68	6 40–8 25 AM 4 00–5 30 PM	6	50,000	30	None	0 50	22	22	9	12	100	30	30	3 2
43 Country Fair (Hales Corners)	4/14/69	6 23–8 27 AM 4 15–5 30 PM	7	65,000	30	None	0 55	20	20	10	14	50	25	50	5 0
46 Spring Mall	7/6/70	6 25–8 25 AM 4 15–5 35 PM	7	22,000	30	None	0 55	15	15	7	10	100	30	30	1 4

Source Bureau of Traffic Engineering and Electrical Services, City of Milwaukee (Aug 1970), Southeast Wisconsin Regional Planning Commission

[a] Inbound [b] 1970–71 [c] Estimated average [d] No parking fee [e] Daily

center parking lot to the downtown terminals and return is 14 2 miles

Parking Facilities

The Mayfair Shopping Center provides parking spaces for more than 8,000 automobiles The shopping center management initially reserved an area for Freeway Flyer patrons equivalent to 450 automobiles A shelter was also furnished, this has since been replaced by a small fiberglass waiting station provided by the Company The lot is generally maintained by the shopping center, except that the transit company removes snow from the assigned area

The Bayshore Shopping Center provides about 2,500 parking spaces The shopping center initially set aside about 200 spaces for Freeway Flyer users and furnished a modest waiting station similar to the one at Mayfair All maintenance is done by the shopping center, and the parking space is provided with no charge to parkers or to the transit company.

Equipment

Standard "new look" transit buses are used The Mayfair route was originally scheduled to have buses operate at maximum speeds of 47 mph, but these were subsequently modified to about 53 mph Portions of the Mayfair Flyer route, however, have maximum speed limits of 60 mph Maximum speed limit on the North-South Freeway, on which the Bayshore Flyer operates, is 50 mph In both cases, the buses had no trouble in moving with traffic

The only modifications made on the buses were installation of (1) slightly larger fuel injectors (resulting in more power), and (2) a right-side view mirror to facilitate passing The buses are not used exclusively for flyer service, as most also provide school service.

Buses have 53 seats with a standard "urban" seating arrangement Standing is permitted, but passengers are reluctant to stand on the 7- to 10-mile trip.

Fares

Regular fares plus a $0 05 cash premium are charged. Any regular fare is accepted—cash, tickets, weekly pass, school pass, transfer—plus the premium The Mayfair Flyer operates from a zoned fare area Both Freeway Flyer routes were reported to be financially successful

Promotion

Both operations were started with house-to-house distribution of specially printed public bus schedules in the immediate area of the shopping center. Schedules, routing, fares, etc , were placed in the weekly suburban newspapers in communities that would be served There were also substantial amounts of free publicity—newspaper, radio, and television The company inaugurated each Flyer with a "continental" breakfast for the new riders and a free morning paper. This resulted in front-page news stories and pictures, and film clips on all TV stations The newspapers have since periodically reported the progress of the Flyers and any changes in service.

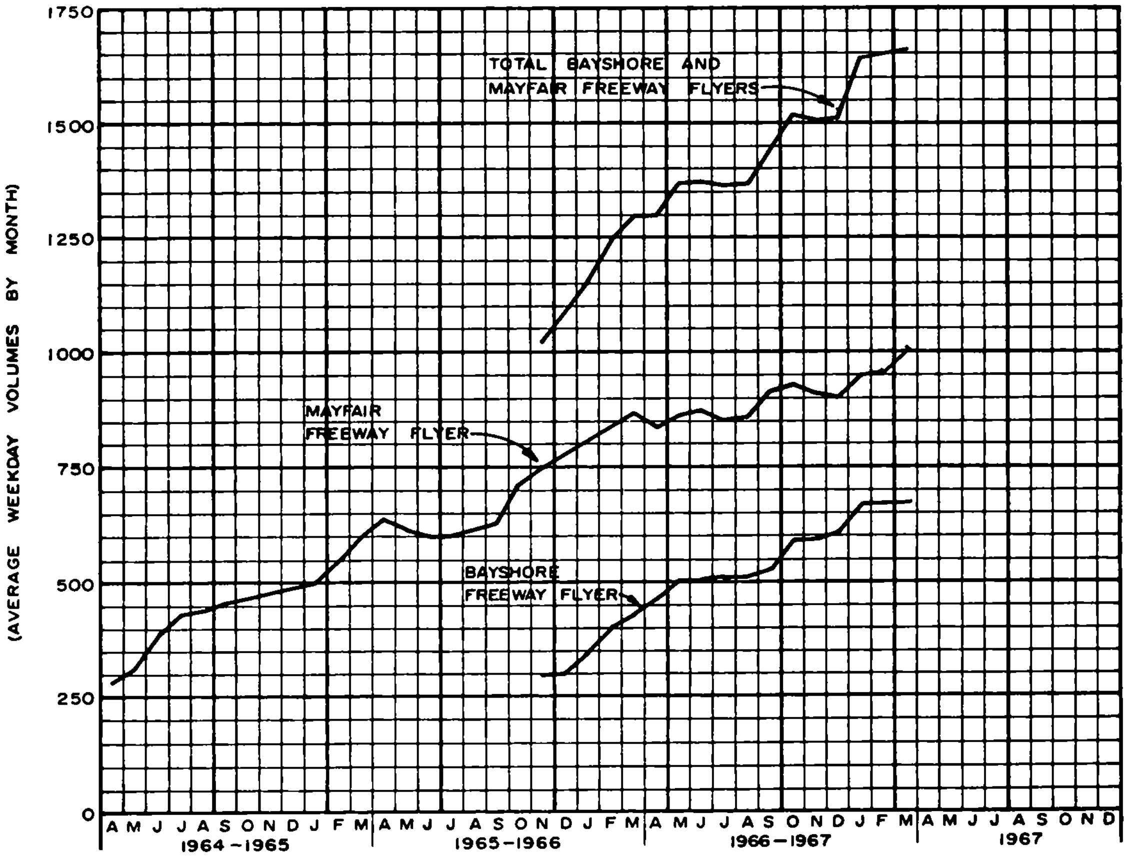


Figure D-12 Average weekday passenger volumes, Bayshore and Mayfair "Freeway Flyer" bus routes, Milwaukee, Wis

On the anniversary dates of the services, the company again offers a free "continental" breakfast for the morning riders, resulting in additional front-page publicity This publicity seems to encourage bus riding on both lines, even though it may pertain to only one There has been no paid advertising since inauguration of the service.

Patronage

The Mayfair Flyer started with 120 riders and in 1968 carried 1,000 one-way trips daily The Bayshore Flyer started with about 200 riders and in 1968 carried about 600 one-way trips daily The trends in riding on the two routes are shown in Figure D-12.

Surveys of the users of the two services are summarized in Table D-10 Two out of three drivers had one or more automobiles available for use Home-to-work and home-to-school and their return were the dominant trip purposes Of the users who formerly drove or rode the bus, more than 60 percent had been auto drivers The 333 inbound bus trips from Bayshore and 418 from Mayfair relate to 119 cars parked at Bayshore and 157 at Mayfair One-half of the riders indicated that they shopped at the center providing the parking

Significance

The study indicates that standard city buses can operate on an urban freeway safely and without hindering other traffic (This, of course, has been the experience of many transit companies) It shows that buses on freeways can provide speeds comparable to the automobile. When considering parking times in the CBD, buses may provide faster door-to-door service than the automobile Passengers appear receptive to using a bus in commuting downtown, they appear to be less willing to transfer from one bus to another Despite the express services, however, actual patronage on all of the lines is still small.

The Milwaukee shopping center experience shows how parking space that is not used during peak commuter parking hours can be used as part of a park-ride bus service Use of shopping centers as major express bus foci and park-and-ride terminals affords promise for many communities by possible increase in business at those shopping centers

4. NEW YORK METROPOLITAN AREA BUS TERMINALS

A wide variety of bus-to-car, bus-to-rail, and car-to-rail transfer stations is found in the New York Metropolitan Area These include parking at outlying subway and commuter rail stations (i e , the New Metropark Station), existing and proposed parking along express bus routes (i e , the 1,500-car parking facility along I-495), and the Port of New York Authority (now The Port Authority of New York and New Jersey) George Washington Bridge and Lincoln Tunnel bus terminals

Port Authority Midtown Bus Terminal

The Port of New York Authority Bus Terminal is an eight-story facility located in the entire block bounded by Eighth and Ninth Avenues and 40th and 41st Streets in Midtown Manhattan (Fig D-13) It principally serves passengers traveling between Manhattan and suburban New Jersey and upper New York State. However, it also serves intercity bus travelers Constructed in 1950, its development costs, including recent additions, have totaled $58,000,000 A plan of the terminal is shown in Figure D-14, pertinent characteristics are summarized in Table D-11.

Access Facilities

A system of roadway ramps connects the Lincoln Tunnel with each of the three bus terminal levels, as well as the parking levels Buses approaching from the west avoid Manhattan streets and enter the terminal without traffic interference The ramps are heated during the winter Direct pedestrian connections to the New York subway system facilitate convenient access to various parts of the city and to other transportation modes The terminal depends on the subway system for distribution of passengers to Midtown and Lower Manhattan

TABLE D-10

SUMMARY OF TRAVEL CHARACTERISTICS, FREEWAY FLYER RIDERS, MILWAUKEE, WIS, 1968

	MAYFAIR		BAYSHORE	
ITEM	NO	(%)	NO	(%)
Prior mode·				
Auto driver	182	33 0	141	37 6
Auto passenger	37	6 7	43	11.5
Bus	215	39 0	132	35 2
Train-taxi	8	1 5	2	0 5
No prior trip	109	19 8	57	15 2
Total	551	100 0	375	100 0
Auto availability				
Yes	343	63 2	228	61 8
No	200	36 8	141	38 2
Total	543	100 0	369	100 0
Mode of travel to bus stop [a]				
Auto driver, parking	157	39 2	119	38 4
Auto driver, kiss and ride	18	4 5	30	9 7
Auto passenger	139	34 8	88	28 4
Walk	66	16.5	51	16 4
Another bus	20	5 0	22	7 1
Total	400	100 0	310	100 0
Mode of travel from bus stop [b]				
Auto driver	2	0 5	1	0 3
Auto passenger	3	0.7	9	2 9
Walk	356	88 1	254	81 9
Another bus	43	10 7	46	14.9
Total	404	100 0	310	100 0
Trip purpose.				
Home-work	698	87 7	436	82 9
Other	98	12.3	90	17 1
Total	796	100 0	526	100 0
Median dist. of home-origin [c]	2.0 miles		1.7 miles	

Source Ref (*D-1*)

[a] At shopping center [b] CBD [c] From shopping center

Physical Characteristics

The Port Authority Bus Terminal is the largest of its type in the world It accommodates 12 short-haul carriers and 30 long-haul carriers at typical operating periods The bus loading and unloading facilities include an intercity (lower) level, a suburban bus level, and an upper bus level that mixes both of these (Fig D-14) There are 184 loading positions, 112 for long-haul buses, 72 for suburban services. Sawtooth loading docks are generally provided for long-haul vehicles, and linear platforms are used for suburban operations (Table D-12).

1 The lower bus level has 41 docks for long-distance buses on the perimeter of a central concourse An additional 12 loading positions are located along the platform on the south side of the terminal

2 The suburban bus level accommodates commuter buses at 16 island platforms with 72 docks. A common unloading platform is situated along the south side of the level

3 The upper bus level has 59 loading postions at both island platforms and a central concourse, together with a common unloading platform The central passenger concourse has 26 sawtooth docks for long-distance buses Thirty-three docks for commuter buses are located on the north side of the building

Patron service facilities housed within the terminal building include retail convenience stores and restaurant facilities, in addition to accommodations for drivers, maintenance personnel, and bus terminal and law enforcement operations Automobile parking facilities in three stories of the terminal accommodate about 1,100 vehicles.

TABLE D-11

GENERAL CHARACTERISTICS, PORT AUTHORITY MIDTOWN BUS TERMINAL, NEW YORK CITY

ITEM	DESCRIPTION
Date open	1950
Type of bus service	Commuter and intercity
Construction cost	$58,000,000
Approximate dimensions	800×200 ft
Number of bus levels	3
No of bus loading docks	184
No of parking spaces	1,080
Contiguous transp facil	Subways
Road access connections	Direct ramp connection with Lincoln Tunnel
Number of bus carriers	12 short haul; 30 long haul

Source Port Authority of New York and New Jersey

Figure D-13. Port Authority Midtown Bus Terminal, New York City.

Operating Characteristics

During an average weekday, approximately 105,000 passengers arrive and depart in some 3,300 buses. This results in an average bus occupancy of 27.4 persons, an average turnover of 18.2 buses per dock per day, and an average layover time of 1.32 hr per bus (Table D-13).

Peak-hour passengers represent approximately one-third of total daily passengers. The number of peak-hour buses is about 22 percent of the daily volume During a typical

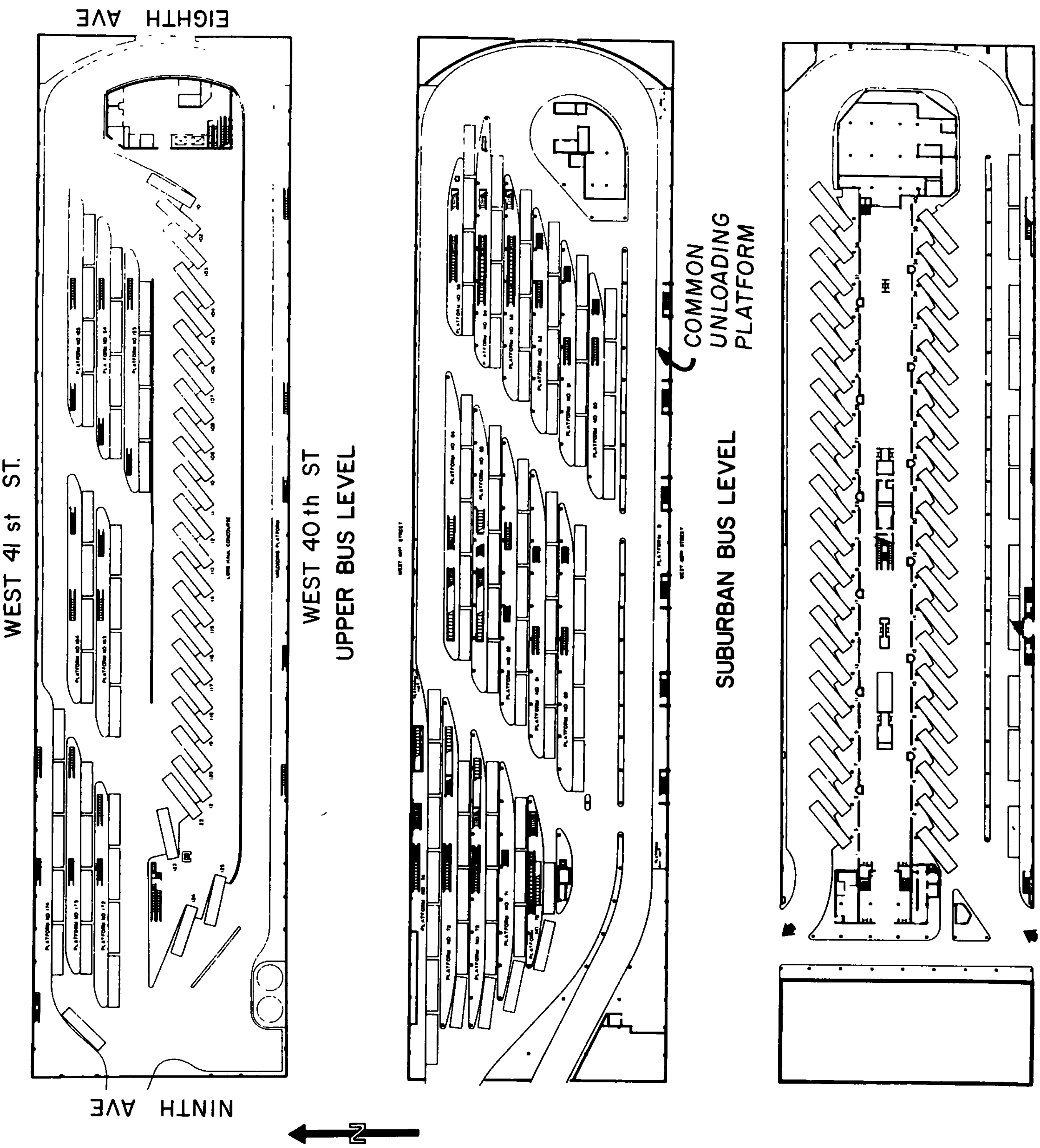


Figure D-14. Bus operating levels, Port Authority Midtown Bus Terminal, New York City

TABLE D-12

BUS LOADING CHARACTERISTICS, PORT AUTHORITY MIDTOWN BUS TERMINAL, NEW YORK CITY

	NO OF LOADING SPACES		
LOADING LOCATION	SAWTOOTH	PLATFORM	TOTAL
Lower level			
Long haul	41	12	53
Suburban	—	—	—
Suburban bus level			
Long haul	—	—	—
Suburban	—	72	72
Upper bus level			
Long haul	26	33	59
Suburban	—	—	—
Totals			
Long haul	67	45	112
Suburban	—	72	72
All categories	67	117	184
Percent	36 5	63 5	100 0

Source Port Authority of New York and New Jersey

weekday peak hour, approximately 30,000 to 35,000 passengers, one-way, are accommodated in 740 buses, resulting in an average bus occupancy of approximately 44.1 The average bus dock turnover is 4 0, and bus layover time averages 0 25 hr.

Expansion Plans

The Port Authority Bus Terminal is to be expanded to more than 1½ times its present size under an $80,000,000 project All eight levels of the present terminal will be extended over and under 41st Street north to 42nd Street, covering the entire area between Eighth Avenue and the McGraw-Hill Building Construction was expected to begin in 1972 and to take about 2½ years

The expansion is intended to increase peak-hour capacity by about 50 percent, significantly reduce traffic congestion, and include another direct connection from the terminal to the Lincoln Tunnel. Additonal bus loading and unloading zones will allow faster and more convenient travel for bus passengers. The air rights above the bus terminal extension are planned to be leased to a private developer, who would finance and construct a 45-story office tower at an estimated cost of $50,000,000. The expanded terminal and its air rights development will enhance the city's program for revitalization of the west side of Manhattan in the 42nd to 50th Streets area (*D-2*).

George Washington Bridge Bus Terminal

The George Washington Bridge Bus Terminal is located between 178th and 179th Streets at Fort Washington and Wadsworth Avenues in Upper Manhattan (Fig. D-15). It was built as an integral part of the lower-level expansion of the bridge in 1963 and is administered by the Port Authority of New York and New Jersey. Construction costs were about $15,300,000 (Table D-14).

TABLE D-13

BUS AND PASSENGER CHARACTERISTICS, PORT AUTHORITY MIDTOWN BUS TERMINAL, NEW YORK CITY

	ACTIVITY CHARACTERISTICS		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers [a]	105,500	32,561	30 8
Number of buses [a]	3,350	735	22 0
Passengers per bus	27 4	44 1	—
Number of berths	184	184	—
Avg bus turnover per berth	18 2	4 0	—
Avg bus layover time (hr)	1 32	0 25	—

Source Port Authority of New York and New Jersey
[a] One-way movements

The bus station serves approximately 45,000 passengers daily. Suburban buses serve communities in New Jersey as well as in Rockland County (New York) Long-distance bus service is provided from facilities located at the street level of the terminal. Patron services are also provided

Access Facilities

Access ramps lead directly to and from the George Washington Bridge from the west side of the terminal (Fig. D-16) Bus ramps are heated in winter to ensure year-round operation. The Cross Bronx Expressway operates under the terminal. (The terminal represents an important example of air rights development above an urban expressway.) There are direct connections with the Eighth Avenue subway

Physical Characteristics

The terminal dimensions approximate 400 by 185 ft. The

TABLE D-14

GENERAL CHARACTERISTICS, GEORGE WASHINGTON BRIDGE BUS TERMINAL, NEW YORK CITY

ITEM	DESCRIPTION
Date open	1963
Type of bus service	Commuter and inter-city
Construction costs	$15,300,000
Approximate dimensions	400 × 185 ft
Number of bus levels	2
No of bus loading docks	43
No. of parking spaces	—
Contiguous transp. facil	Subway
Road access connections	Direct connection to George Washington Bridge

Source Port Authority of New York and New Jersey

Figure D-15. George Washington Bridge Bus Terminal, New York City.

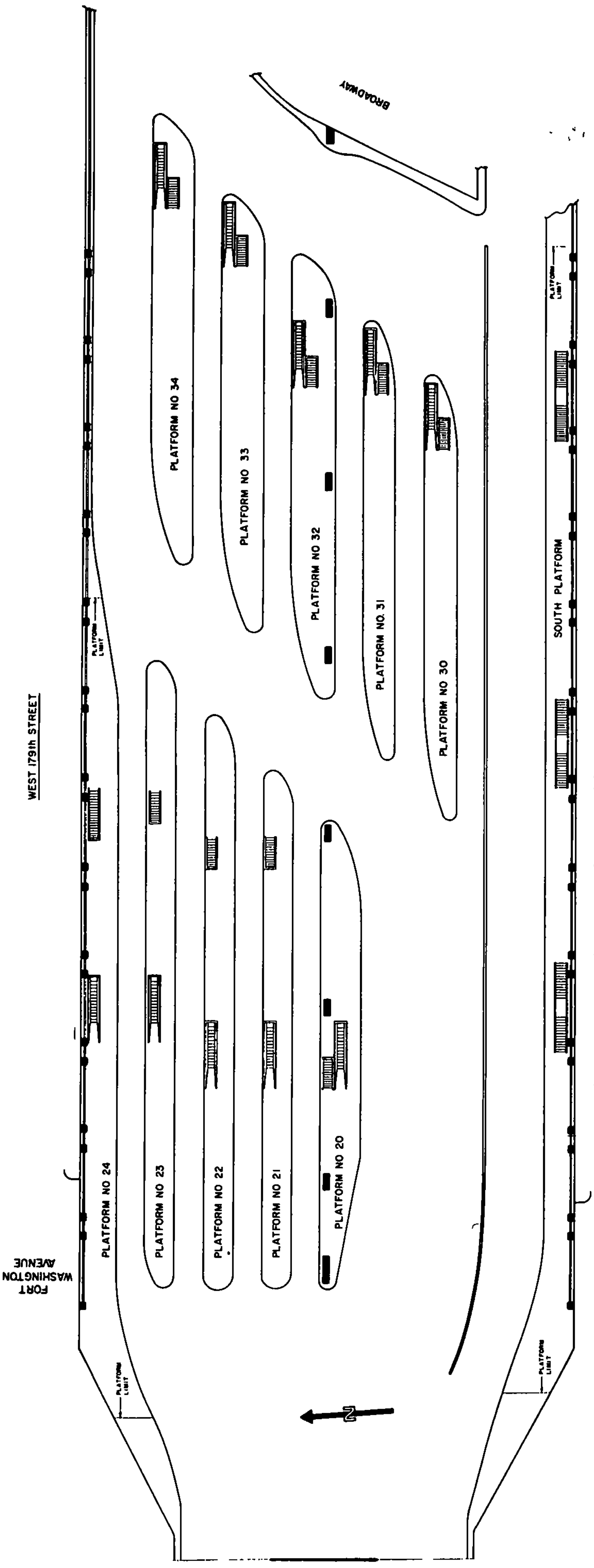


Figure D-16 Functional plan, George Washington Bridge Bus Terminal, New York City

three-story facility consists of (a) a lower level, accommodating seven long-distance bus docks; (b) a suburban concourse, containing ticketing offices and retail and other service functions; and (c) a suburban bus level with 36 bus docks in a platform configuration (Table D-15)

Operating and Use Characteristics

On a daily basis, approximately 20,000 one-way passenger trips are accommodated by the terminal in 850 buses This results in an average bus occupancy of 23.5 persons, an average bus turnover of 19.6 per dock per day, and an average bus layover time of 1 22 hr

During the peak hour approximately 4,200 persons use the facility in about 110 buses, resulting in an average bus occupancy of 39 persons. This indicates a bus turnover of approximately 2 5 per dock and an average bus layover time of 0.4 hr (Table D-16).

Lincoln Tunnel Parking Lot

The Port Authority of New York and New Jersey provides a highly successful park-ride facility at the west end of the I-495 contra-flow bus lane 2 5 miles from Manhattan This lot provides nearly 1,600 spaces, and it is used by nearly 1,800 parkers each day, of these more than 1,500 park before 9 00 AM

Bus service into Manhattan operates at 4-min intervals during the peak hours Auto-driver costs for parking and round-trip bus rides are $1 25; costs for each auto passenger are $0 60 one-way Thus, commuters have substantial cost savings into Manhattan as compared with driving. They also save time as a result of the morning peak-period contra-flow bus lane.

A profile of existing park-and-ride patrons is given in Table D-17 (1) car occupancy averages 1.2 persons per vehicle, (2) 88 percent of all trips are for work purposes; (3) 75 percent of all patrons have destinations in Midtown Manhattan; (4) nearly one-half of all patrons used bus, subway, or taxi to reach destinations in Manhattan; (5) more than one-half of all patrons made the trip each day, and (6) more than 40 percent had incomes of more than $20,000

5. PHILADELPHIA BUS TERMINALS

The Southeastern Pennsylvania Transportation Authority (SEPTA) operates nearly 200 change-of-mode parking lots serving the rail commuter system, lots range in capacity from 25 to more than 200 spaces Two mode-transfer points are especially important—the long-established 69th Street Terminal at West Chester Pike and the proposed Market Street East bus terminal in the central city

69th Street Terminal

The terminal is located north of 69th Street and the West Chester Pike, 5 miles west of the Philadelphia CBD in Upper Darby Township. It is opposite a well-established retail-commercial subcenter in the western suburbs.

The terminal is a key interchange facility for several transport modes These include the Frankford Rapid Transit Line, the Media-Sharon Hill and Norristown subur-

TABLE D-15

BUS LOADING CHARACTERISTICS, GEORGE WASHINGTON BRIDGE BUS TERMINAL, NEW YORK CITY

	NO OF LOADING SPACES		
LOADING LOCATION	SAWTOOTH	PLATFORM	TOTAL
Suburban bus level	—	36	36
Long-distance bus level	7	—	7
Total	7	36	43
Percent	16 2	83.8	100 0

Source Port Authority of New York and New Jersey

TABLE D-16

BUS AND PASSENGER CHARACTERISTICS, GEORGE WASHINGTON BRIDGE BUS TERMINAL, NEW YORK CITY

	ACTIVITY CHARACTERISTICS		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers [a]	20,000	4,240	20 1
Number of buses [a]	850	108	12 7
Average bus occupancy	23 5	39	—
Number of berths	43	43	—
Avg bus turnover per berth	19.6	2 5	12 7
Avg. bus layover time (hr)	1 22	0 4	32 8

Source Port Authority of New York and New Jersey
[a] One-way

TABLE D-17

SUMMARY CHARACTERISTICS, LINCOLN TUNNEL PARK-AND-RIDE FACILITY, NORTH BERGEN, N J, JUNE 1972

ITEM	DESCRIPTION
Total capacity	1,600 spaces
Distance from Manhattan	2.5 miles
Peak-hour bus frequency	4 min
Costs bus ride and parking	
Auto driver	$1.25 (round trip)
Auto passenger	$0 60 (one-way)
Total parkers per day	1,760
Max accum of parkers	1,580
Accumulative vehicle arrivals	
By 8 00 AM	42 percent
By 9·00 AM	81 percent
By 9 30 AM	87 percent
By 11 00 AM	100 percent
Vehicle occupancy [a]	
1 person	70 percent
2 persons	22 percent
3 or more persons	8 percent
Average	1 2 per vehicle
Trip purpose [b]	
Work	88 percent
Personal business	4 percent
Other	8 percent
New York City destination.	
Midtown	75 percent
Lower Manhattan	18 percent
Upper Manhattan	3 percent
Other	4 percent
Travel mode to New York destination	
Walked	53 percent
Subway	29 percent
Bus	14 percent
Taxi	4 percent
Frequency of use	
More than 4 times per week	54 percent
1 to 4 times per week	27 percent
Less than once per week	19 percent
Age group	
Under 21 years	5 percent
22 to 62 years	91 percent
Over 62 years	4 percent
Annual family income	
Under $12,000	15 percent
$12,000–$20,000	43 percent
Over $20,000	42 percent

Source Field Surveys, Wilbur Smith and Associates (June 1972)
[a] 1,760 vehicles [b] 1,950 persons

ban rail lines, and the Southeastern Pennsylvania Transportation Authority (SEPTA) bus routes.

The terminal consists of two buildings now connected together, but typical of the separation and competition in transit facilities at the turn of the century. One building serves the rapid rail and Morristown trains, the other serves the streetcars from Sharon Hill and Media, as well as buses

Operating Characteristics

The suburban cars and buses operate in a loop pattern (Fig D-17) In addition, buses load at the northern curb of West Chester Pike Although some stops are not located for convenient transfer, these are necessary because adequate space does not exist in any one area Both bus and suburban rail use has declined over the past few years

During the peak hour about 23 rail rapid transit trains, with 7,700 seats, depart for the Philadelphia CBD Train service is provided 24 hours a day

About 18,000 passengers bound for Philadelphia use this terminal daily Of these, 73 percent arrive at the terminal by either bus or suburban train The rest arrive by automobile and taxi (13 percent), or by walking (14 percent).

About 30 percent of the users arrive during the peak hour Although many of these use the fully grade-separated Norristown rail line, most arrive by bus or at-grade suburban cars The Media and Sharon Hill trains have reserved tracks in the border strip of Garrett Road, but must cross West Chester Pike at grade. All buses use surface streets to approach the terminal (however, the outer portion of Red Arrow Bus Route 103 traverses a 1.5-mile section of reserved busway in Haverford.) There is substantial interference between buses and interurbans entering the ter-

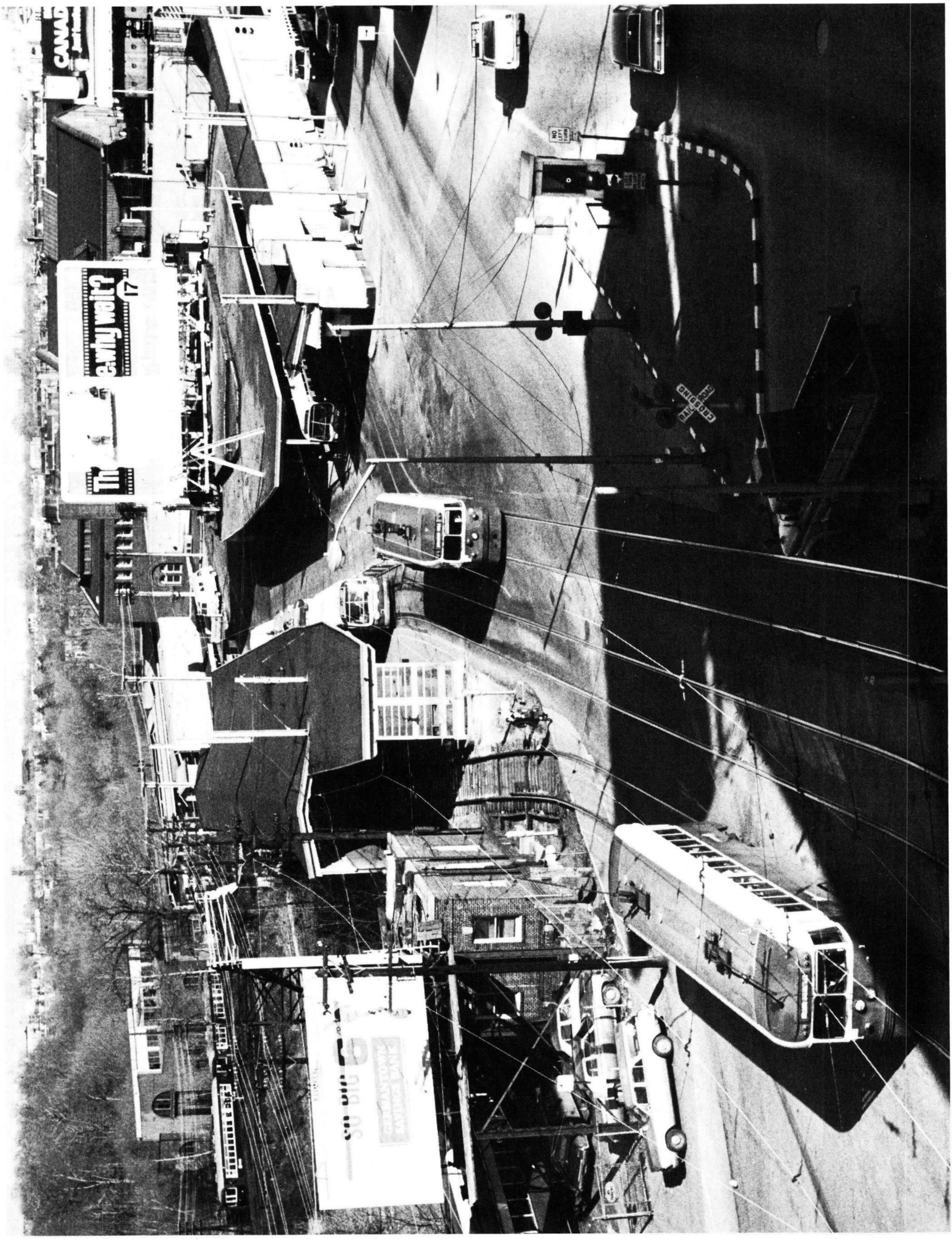


Figure D-17. 69th Street terminal, Philadelphia, Pa.

minal and traffic on West Chester Pike and Victory Avenue. A special bus ramp is being constructed to allow southbound buses on Victory Avenue direct access to the terminal (Fig. D-18) This exclusive two-lane (two-way) roadway will serve the northern sector of the terminal, providing passengers with more efficient service

Proposed Market Street East Bus Terminal

The proposed bus terminal within the Market Street East Project in Philadelphia will be a significant part of the over-all urban development project. Plans call for up to 9,000,000 sq ft of retail and commercial development, plus a major transportation center providing not only interchange between intercity, local, and commuter buses but also off-street parking structures, a new rail terminal, and improved subway stations The project has been discussed for more than a decade, and has been approved in basic concept by local public and private groups

Several design studies have been made for the project, and for its bus terminals in particular Certain elements have potential transferrability to other areas

1 Primary bus and automobile access will be to and from the proposed Vine Street Expressway. The expressway will replace an existing at-grade multi-lane facility

2. Two exclusive ramps from the terminal will link the project with the express road system This will make it possible for cars and buses to enter the project without using local downtown streets Separate ramps will be used by buses and cars

3 Provision will be made for several thousand short-term parking spaces Many of these represent replacement of open lot parking

4 Local bus services will be separated from intercity carriers This is further application of planning principles used in New York and Chicago

5. Various estimates show a need for 40 to 50 intercity bus berths, as a replacement and expansion of the existing Continental Trailways Terminal.

6. Peak-hour one-way commuter-bus person movements would approximate 120 to 150 buses and 6,000 people by 1980.

7. The commuter bus services, mainly for Transport of New Jersey (TNJ), will utilize a multiple-stop 1,600-ft-long linear loading pattern This is an off-street replacement of the existing city service pattern to accommodate the dispersed downtown destinations of New Jersey bus commuters In effect, the commuter bus facilities would represent an elevated busway through the heart of a commercial complex with a stub end at the terminal

8. Current plans call for a continuous loading platform to provide about 15 parallel bus loading spaces within the length of the project with adequate maneuvering space. It would provide for passenger platform space, parallel standing for bus loading, and two travel lanes

The linear bus terminal, with spur ramps from the Vine Street Expressway, is expected to shorten by 10 to 15 min the round-trip time between the terminal and Camden, via the Ben Franklin Bridge (It presently takes about 30 min for the round trip from the Camden bridgehead) This would save time for passengers and would also improve the efficiency (number of trips) of individual buses, it would reduce bus volumes and congestion on adjacent local streets (Fig D-19). It would minimize walking distances between transportation modes that interchange at the facility, improve bus accessibility to the center city, and reduce over-all trip time to major traffic generators

6. SAN FRANCISCO TRANSBAY BUS TERMINAL

The Transbay Bus Terminal in San Francisco, Calif., was constructed in January 1960 as a modernization of the Key-System Transbay Train Terminal The terminal now includes a building complex and an elevated exclusive bus loop that connects the terminal with the San Francisco-Oakland Bay Bridge The terminal obtained air rights over two streets for its operations, ramps connect the terminal to the Oakland-Bay Bridge

The Transbay Terminal is located on the southeasterly edge of San Francisco's high-density office and financial center It is currently served by streetcar lines; and it will be within a block of a BART station The terminal mainly serves Alameda-Contra Costa County Transit buses, as well as some Western Greyhound buses.

Physical Characteristics

General characteristics of the terminal are summarized in Table D-18 The terminal dimensions approximate 700 by 180 ft Three platforms with 37 docks are provided at the bus level. This loading and unloading level is connected to a lower street level, which has some retail convenience goods facilities, ticketing booths, and similar features (Fig. D-20).

The terminal is constructed in three sections (east unit, center unit, west unit) separated by Fremont and First Streets, over which the bus loading facilities are located.

Operating Characteristics

Approximately 44,000 persons enter or leave the facility daily in approximately 2,200 buses. This results in an average bus occupancy of 20.0 persons, an average bus turnover per dock of 59.5, and an average bus layover time of 0.4 hr. Bus storage takes place on the ramps leading to and from the terminal.

Approximately 13,000 one-way passengers in about 350 buses use the terminal in the peak hours, resulting in an average bus occupancy of 27.2 persons. Average bus turnover per dock is 9.5, resulting in an average layover time during peak hours of 0.16 hr (Table D-19).

7. TORONTO BUS TERMINALS

Toronto, Ont , has developed extensive bus-rail transfer facilities along its Bloor Street and Yonge Street subway lines Fringe parking is provided at the Islington and Warden terminals of the Bloor line.

Eglinton-Yonge Bus Terminal

The Eglinton Avenue terminal was constructed in 1954 as part of the Yonge Street subway. A plan of the terminal is

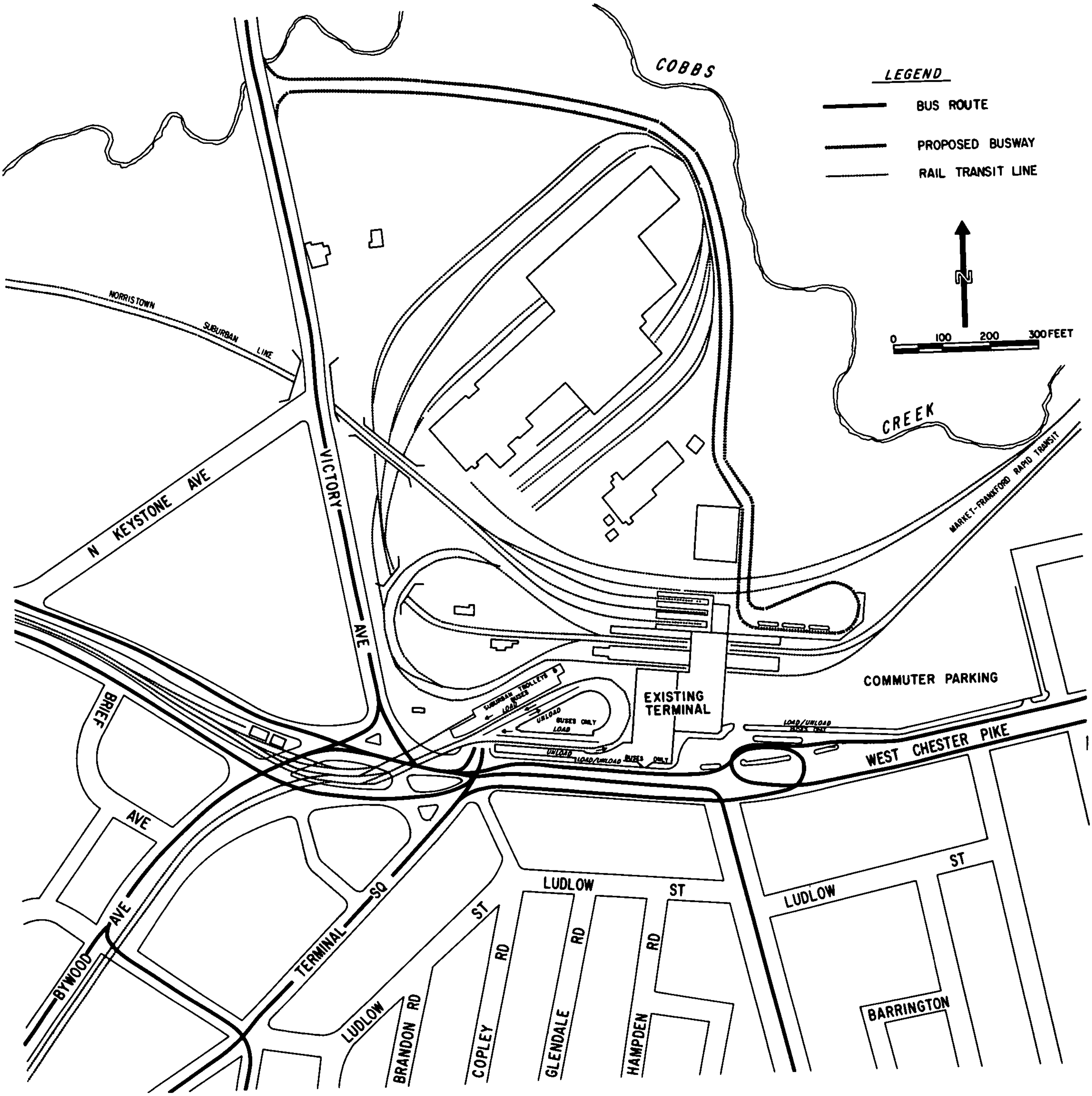
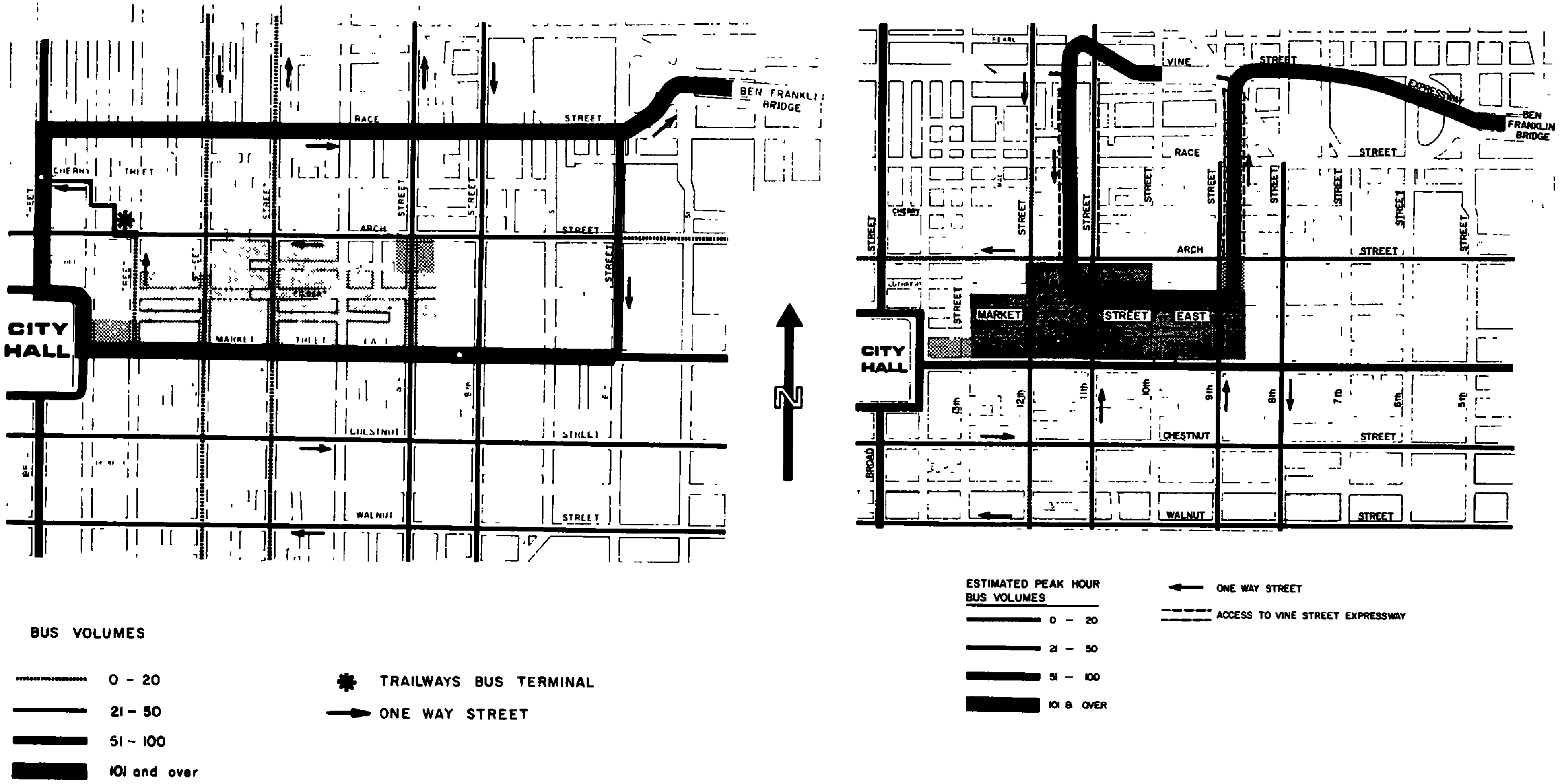


Figure D-18. Functional plan, 69th Street terminal, Philadelphia, Pa

shown in Figure D-21, pertinent characteristics are summarized in Table D-20

Physical Characteristics

The bus terminal area is approximately 200 ft long by 150 ft wide, located on the south side of Eglinton Avenue west of Yonge Street. Thirteen bus docks are provided for local bus services. Bus docks in the form of platforms at street level are used for loading and unloading passengers who proceed directly, via stairs and escalators, to underground passages leading to the subway trains. Below street level are located various convenience goods stores, ticketing facilities, janitorial, and other uses. Immediately adjacent to



TYPICAL WEEKDAY—1971
BEFORE DEVELOPMENT

1985
AFTER DEVELOPMENT

Figure D-19 Peak-hour bus volumes, Market Street East development, Philadelphia, Pa

TABLE D-18

GENERAL CHARACTERISTICS, TRANSBAY TRANSIT TERMINAL, SAN FRANCISCO, CALIF

ITEM	DESCRIPTION [a]
Date open/status	Converted from train operations, 1960
Type of bus service	Commuter
Construction costs	N A
Approximate dimensions	700 × 180 ft
Number of bus levels	1
No of bus loading docks	37
No of parking spaces	—
Contiguous transp facil	Streetcars
Road access connections	Direct connections to Bay Bridge (6,000-ft ramps)

Source California Division of Bay Toll Crossings
[a] N A = not available

TABLE D-19

BUS AND PASSENGER CHARACTERISTICS, TRANSBAY BUS TERMINAL, SAN FRANCISCO, CALIF

	ACTIVITY CHARACTERISTICS		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers	44,000	13,000	29
Number of buses	2,200	350	16
Average bus occupancy	20 0	37 2	185
Number of berths	37	37	—
Avg. bus turnover per berth	59 5	95	16
Avg bus layover time (hr)	0 40	0 16	40

Source California Division of Bay Toll Crossings

the bus terminal above the subway station is a high-rise office building, which in itself generates considerable bus and subway use. Another high-rise office building is currently under construction on the north side of Eglinton Avenue.

Operational and Use Characteristics

On a daily basis, approximately 55,000 passengers (one-way) in approximately 1,700 buses either enter or leave the facility, resulting in an average bus occupancy of 32.5 persons (Table D-21) This results in an average daily bus turnover per berth of 131 vehicles, and an average layover time of 0.18 hr During each peak hour, approximately 15,000 persons (one-way) enter or leave the facility on approximately 290 buses There is an average bus occupancy of 52 persons, an average bus turnover per dock of 22, and an average bus layover time of 0 05 hr. The extremely short turnover time results from passengers transferring directly, without fares or tickets, to and from the subway.

Significance

It is clear that a relatively small number of bus docks can accommodate large passenger volumes provided (1) bus layover time is kept to a minimum, (2) adequate pedestrian capacity is available, and (3) fare or transfer collection is not required The Eglinton station serves as many peak-hour passengers as San Francisco's Transbay Terminal, and 40 percent of the number served by the New York Port Authority's Midtown Terminal

Fringe Parking Facilities

In conjunction with the TTC, the Toronto Parking Authority developed fringe parking facilities at both the Islington and Warden stations at the outer ends of the Bloor subway Both terminals give priority to buses and "kiss-n-ride" (Figs D-22 and D-23) The Warden station also includes a direct trumpet interchange for buses

Studies of the Islington terminal indicate the following arrival modes: on a typical day, 1,100 people parked, 545 were dropped off, 2,715 came by bus, and 2,735 walked

The TTC has recognized the importance of "kiss-n-ride " Accordingly, it has adopted a policy of providing these facilities at all suburban subway terminals In this context, the new Finch terminal incorporates a radically new circular concept for "kiss-n-ride," which would be incorporated with the proposed commuter lot but remote from bus transfer facilities The circular island will be enclosed with glass walls to give persons waiting to be picked up a 360-deg view of approaching vehicles Vehicles entering the facility would use an "orbiting lane" until they could find a parking space facing the center island

8. WASHINGTON SOUTHWEST BUS TERMINAL

The Southwest Bus Terminal on D Street between 9th and 10th Streets in Washington, D.C , was opened on June 11, 1970, to serve the rapidly growing Southwest Employment Area, the focus of new federal offices as well as an increasing private employment It became clear that improved

TABLE D-20

GENERAL CHARACTERISTICS, EGLINTON-YONGE BUS TERMINAL, TORONTO, ONT [a]

ITEM	DESCRIPTION [b]
Date open	1954
Type of bus service	Local
Construction costs	$5,000,000
Approximate dimensions	200 × 150 ft
Number of bus levels	1
No of bus loading docks	13
No of parking spaces	N A
Contiguous transp facil	Yonge St Subway
Road access connections	Arterial
Number of bus carriers	1 (TTC)
Number of bus routes	12

Source Toronto Transit Commission
[a] Completely enclosed, and free transfer
[b] N A = not available

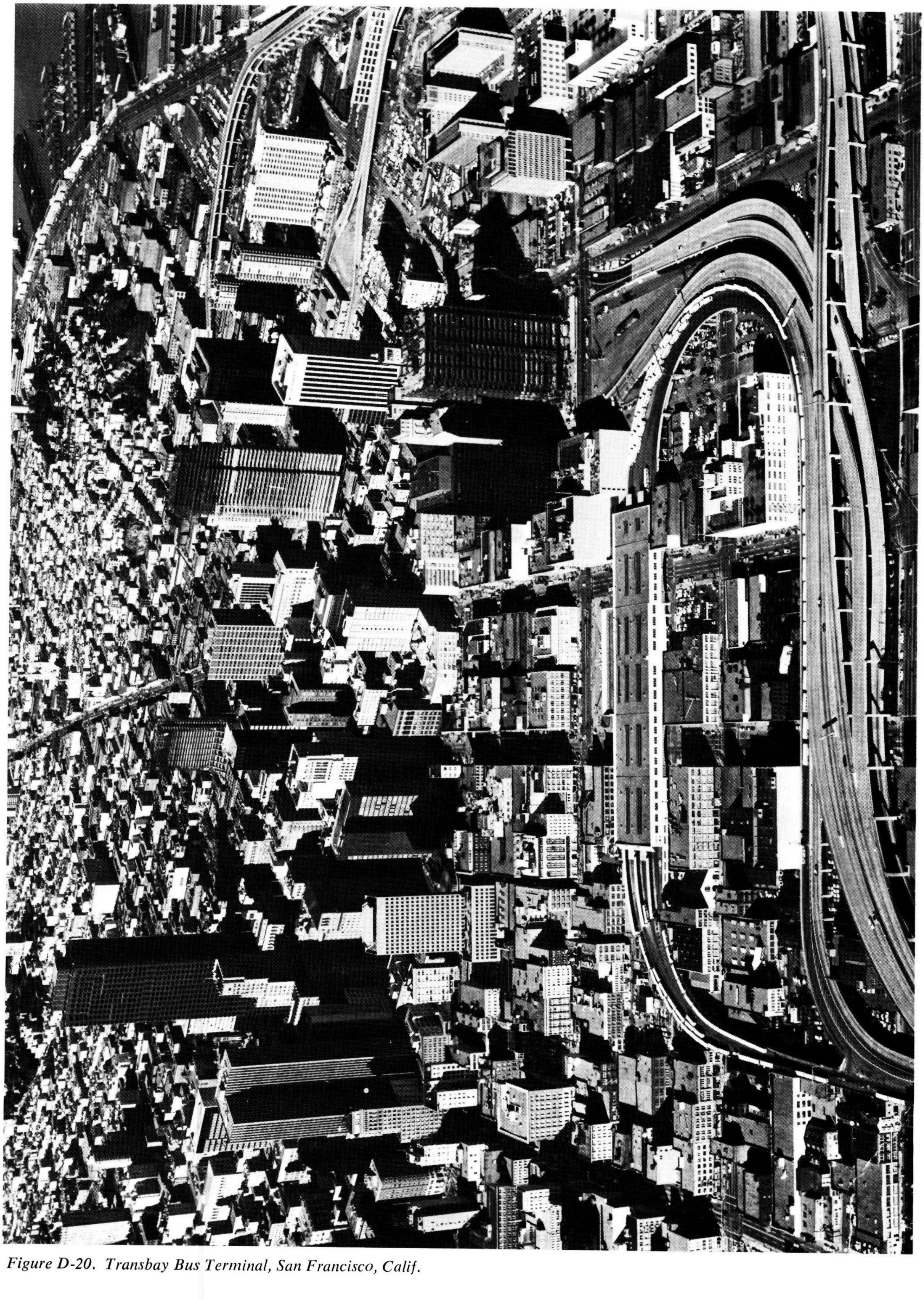


Figure D-20. Transbay Bus Terminal, San Francisco, Calif.

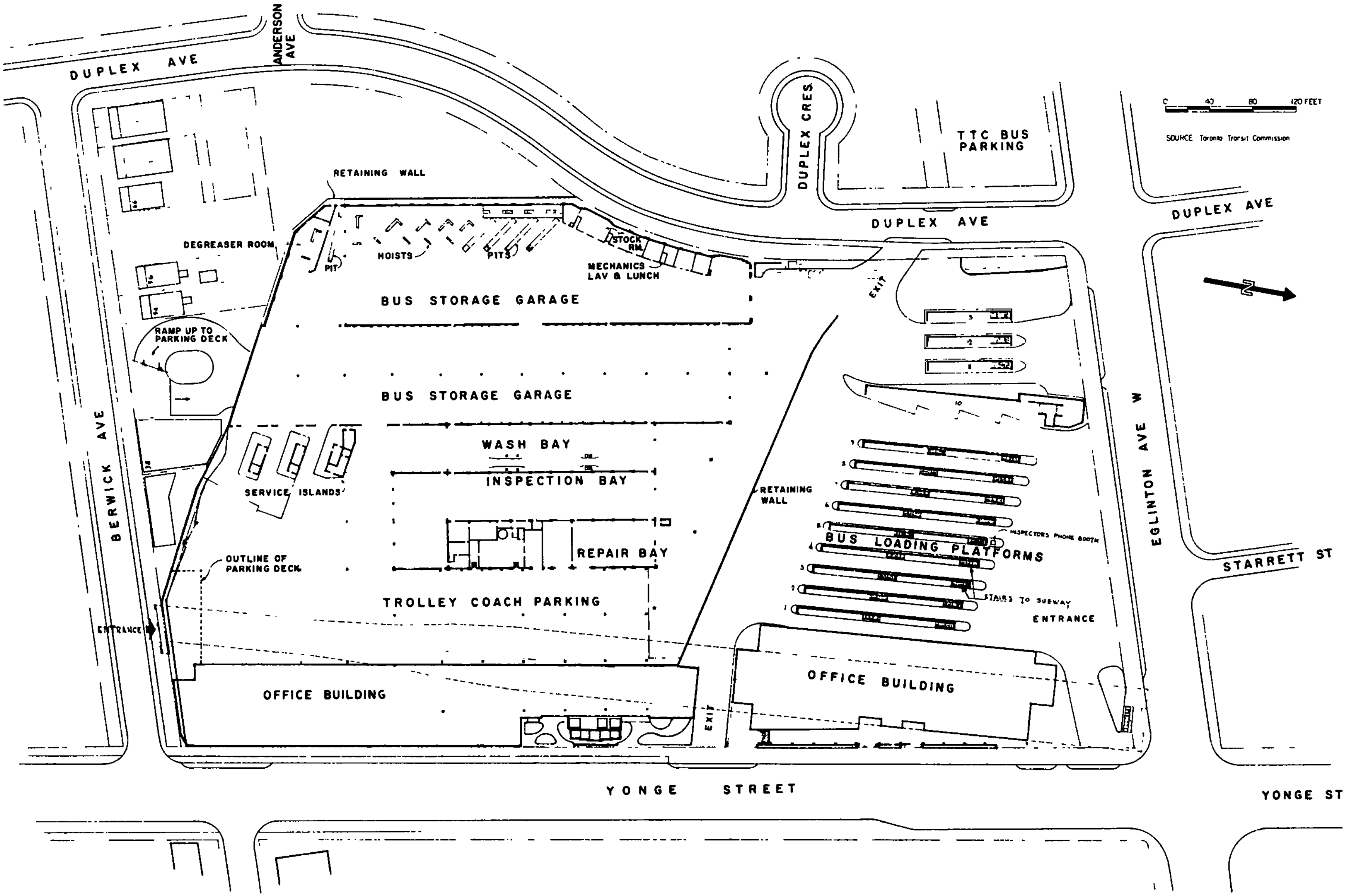


Figure D-21 Functional plan, Eglinton-Yonge bus terminal, Toronto, Ont

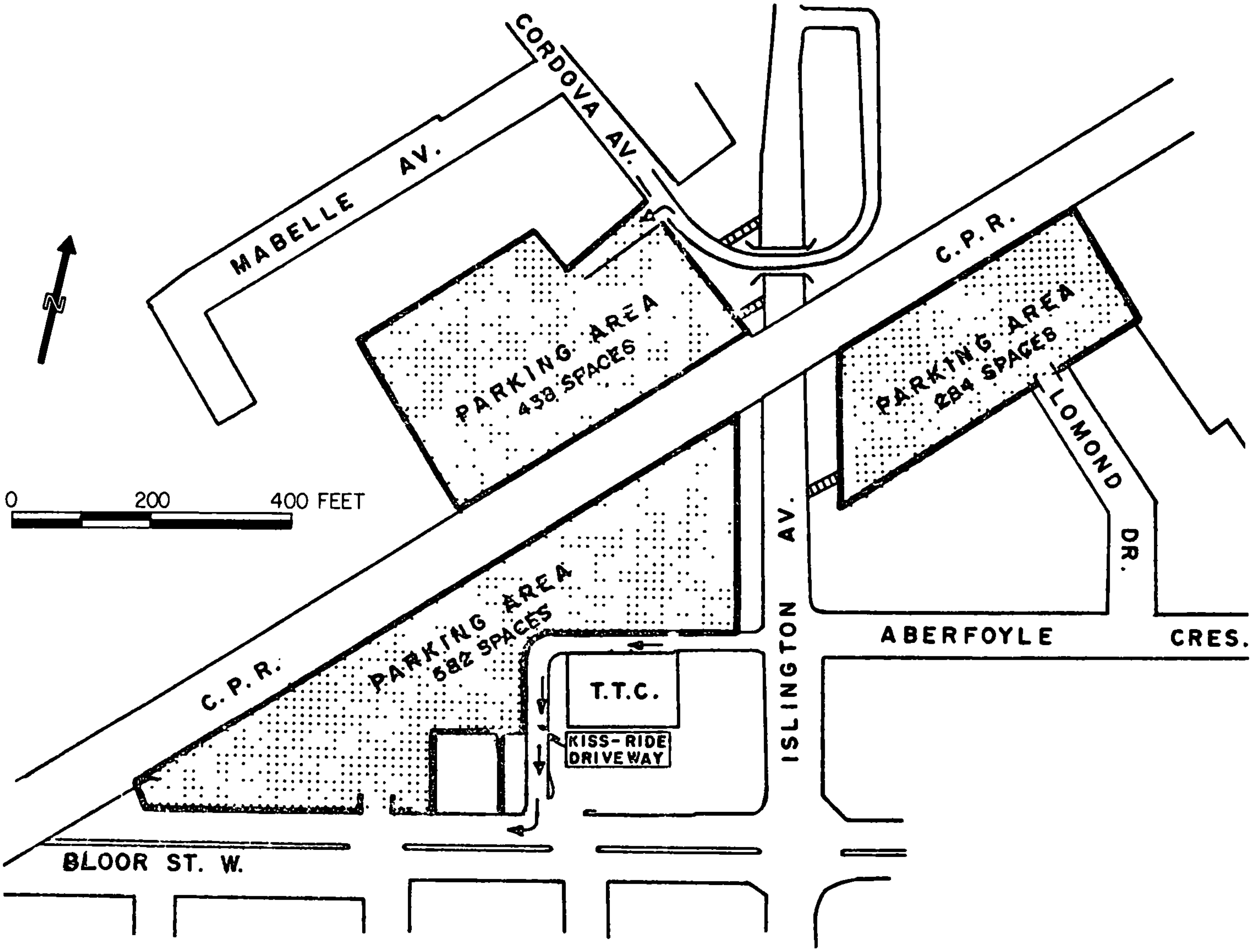


Figure D-22 Parking facilities, Islington terminal, Toronto, Ont

TABLE D-21

BUS AND PASSENGER CHARACTERISTICS, EGLINTON-YONGE BUS TERMINAL, TORONTO

	ACTIVITY CHARACTERISTICS		
ITEM	DAILY	PEAK HOUR	PEAK HOUR AS % OF DAILY TOTAL
Number of passengers (one-way, 1965–1969)	55,000[a]	15,000	27
Number of buses[b]	1,700[a]	290[a]	17
Average bus occupancy	32 5[a]	52	60
Number of bus docks	13[a]	13	—
Avg bus turnover per dock	131[a]	22	—
Avg bus layover time (hr)	0 18[a]	0 05	0 27

Source Toronto Transit Commission

[a] One-way movements

[b] Estimated, based on peak-hour volumes being approximately 15 percent of daily volumes

public transportation was essential to the sustained growth of the area, and that it would be impractical to provide sufficient parking space to accommodate the growing work force (about 50,000 in 1971 and 100,000 by 1990). The bus terminal is the initial response to the need for improved transit service

Costs and Development

The terminal was constructed by the D.C. Department of Highways and Traffic under a capital improvement grant provided by Urban Mass Transit Administration. The land was provided free by the D C Redevelopment Land Agency Costs approximated $232,000, of which L'Enfant Plaza Corporation contributed $25,000 toward the local share

Design Features

The bus terminal is located on the north side of D Street, directly opposite the entrance to L'Enfant Plaza It has three aisles with about three bays each for pick up and discharge of passengers (Fig D-24) The bays can accommodate a total of 10 buses at one time

Sawtooth "pullout" bays are provided in the first aisle, closest to D Street, the other two aisles are provided with traditional curbside loading and unloading spaces The sawtooth bay design is a prototype of the planned installation at Metro stations, and it is reported to be working well.

The terminal is served by four bus companies. AB&W and WV&M, serving Virginia, D.C Transit, serving the District and parts of suburban Maryland, and WMA, serving parts of suburban Maryland These companies are assigned to use particular aisles, based on their bus volume and frequency of service, as well as layover requirements front (sawtooth), WVM, middle, ABW and WMA, rear, D C Transit

Each passenger platform has a 7-ft-wide roof, sides are open and exposed to the weather. Canopies over the passenger platforms are translucent fiberglass, and fluorescent lighting is provided at night The street adjacent to the terminal is well lighted

Bus flow through the terminal area is counterclockwise Vehicles enter the terminal area by making either right or left turns off D Street. The approach road channelization is especially designed for bus movements—and has transferability to other situations A 200-ft left-turn lane is provided exclusively for buses

Bus Volumes and Patronage

Scheduled buses using the terminal in July 1970 are given in Table D-22 About 120 buses entered the terminal in the morning peak period and 80 in the evening peak An additional 20 to 35 buses used D Street.

Since opening of the terminal, the number of peak-period buses has increased. In March 1972 138 buses on 54 routes entered the terminal from 7 00 to 9 00 AM and 134 buses left from 4.00 to 6.00 PM (Table D-23).

Approximately one-fourth to one-third of the buses serving the terminal are reported to have one trip end there Only two D.C. Transit bus lines offer service to the terminal throughout the day

D C. Transit plans to use the terminal as a major loop point on its expanded and revised "minibus" service Some increases in commuter service to the area are anticipated as the Shirley Busway program expands and as present routes of other services are revised

Although the terminal lies within easy walking distance of more than 30,000 workers, initial patronage was low. an estimated 600 to 700 patrons a day, or an average of 3 to 2.5 per bus and 2 percent of the workers. Several important factors were responsible for this low initial volume, as follows:

1 The terminal functions, in large measure, as an off-street bus stop for through buses. Local stops are provided along D Street and other streets traversed by the buses throughout the Southwest Employment Area

2. Most federal agencies in the Southwest area stagger work hours This tends to discourage transit ridership and encourages auto use (especially car pools) by spreading the demand over a longer time period by reducing peaking.

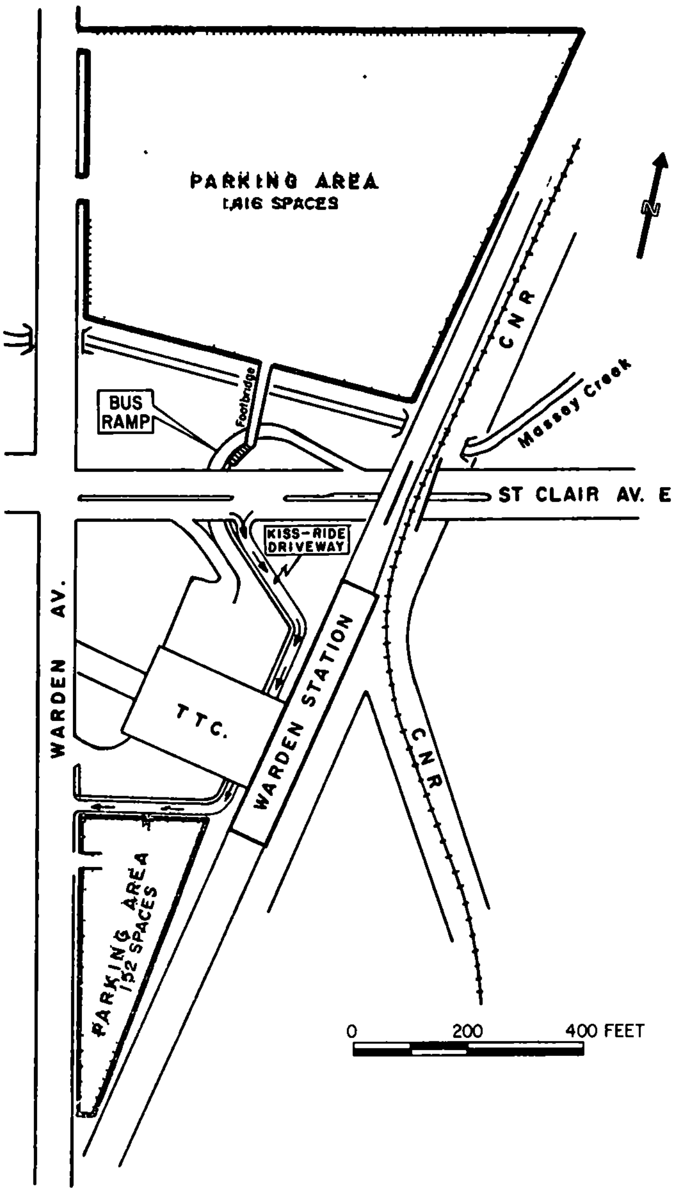


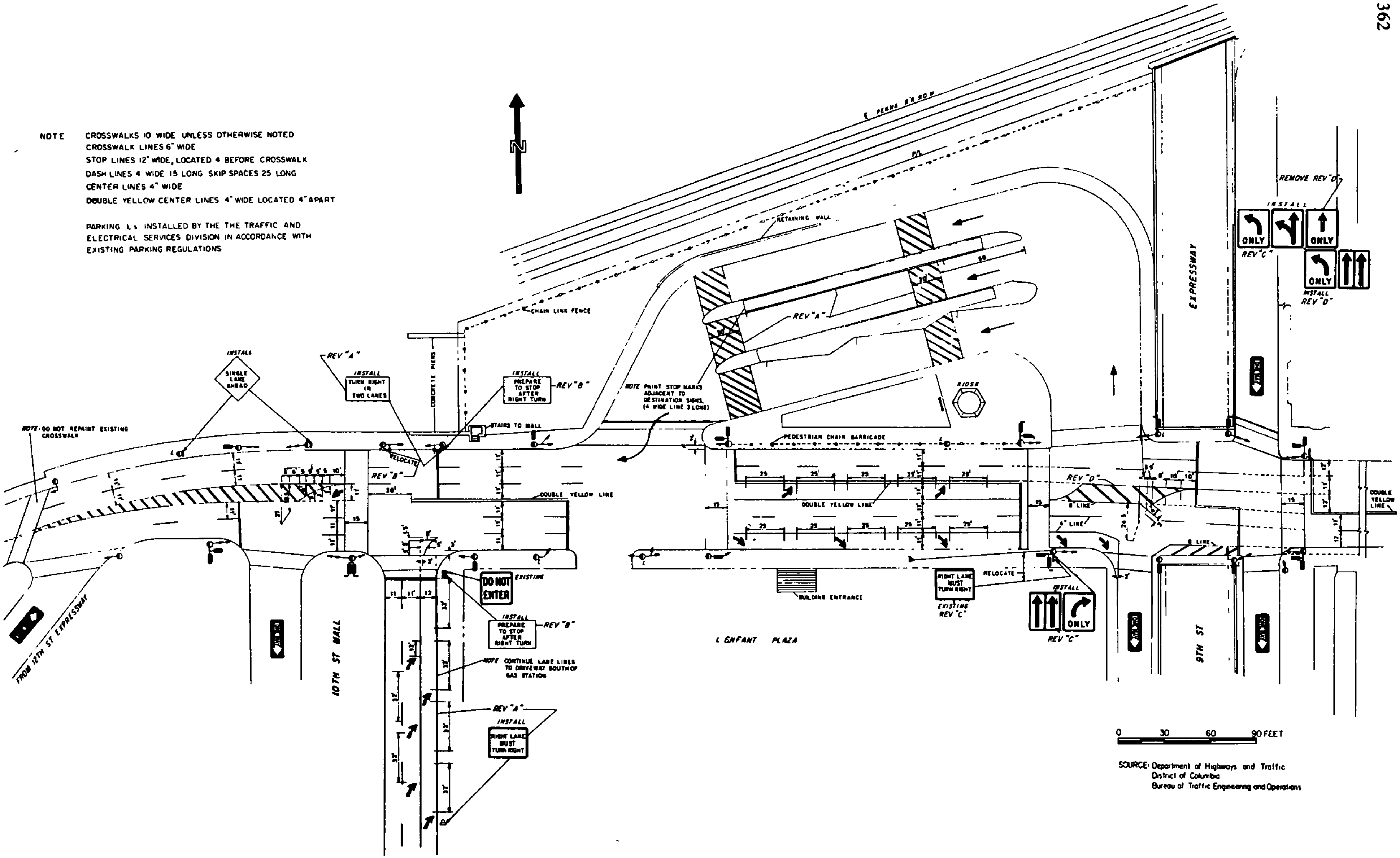
Figure D-23 Parking facilities, Warden terminal, Toronto, Ont

3 The Federal Government's program of subsidized parking for its employees discourages transit use. Monthly spaces are available to federal employees for $6 to $10, compared with commercial rates of $35 to $50. It is understood that this policy is presently under review.

9. TEL AVIV BUS TERMINAL

Tel Aviv, Israel, like many other major European and Asian cities, relies heavily on bus service. On a typical 1965 weekday, 1,121,000 bus trips were made in the Tel Aviv-Yafo metropolitan area, an average of 1 37 trips per resident.

The metropolitan population, which numbered 817,000 in 1965, approached 1,000,000 residents in 1972. Bus patronage is continuing to grow, although increasing use of



NOTE CROSSWALKS 10 WIDE UNLESS OTHERWISE NOTED
CROSSWALK LINES 6" WIDE
STOP LINES 12" WIDE, LOCATED 4 BEFORE CROSSWALK
DASH LINES 4 WIDE 15 LONG SKIP SPACES 25 LONG
CENTER LINES 4" WIDE
DOUBLE YELLOW CENTER LINES 4" WIDE LOCATED 4" APART

PARKING Ls INSTALLED BY THE THE TRAFFIC AND ELECTRICAL SERVICES DIVISION IN ACCORDANCE WITH EXISTING PARKING REGULATIONS

SOURCE: Department of Highways and Traffic
District of Columbia
Bureau of Traffic Engineering and Operations

Figure D-24 Bus terminal, Southwest Employment Area, Washington, D C

TABLE D-22

BUSES SCHEDULED TO SOUTHWEST BUS TERMINAL, WASHINGTON, D C , JULY 1970

	TERMINAL			ACROSS D STREET			
COMPANY	AM PEAK PE-RIOD	PM PEAK PE-RIOD	TOTAL	AM PEAK PE-RIOD	PM PEAK PE-RIOD	TOTAL	GRAND TOTAL
ABW	18	12	30	—	—	—	30
WVM	54	38	92	4	—	4	96
DCT	38	18	56	18	36	54	110
WMA	9	8	17	—	—	—	17
Total	119	76	195	22	36	58	253

Source D C Department of Highways and Traffic

private automobiles is reducing the rate of growth Bus use is expected to peak in the next few years

The Central Bus Terminal in the eastern section of Tel Aviv was the distribution center for about 400,000 daily bus trips in 1965—more than 35 percent of all bus passenger trips in the metropolitan area. These passenger flows were accommodated on 5,000 buses that enter and leave the station each day (i e , 5,000 inbound buses)

Because the Central Station is heavily overloaded, a new Transportation Center near the site of the old one has been under construction since 1968 and will be opened in 1973 (Fig. D-25) The new Transportation Center is designed to accommodate interurban and suburban bus lines in addition to local buses and provide parking space for motorists in a 3-floor, 850-space garage. Special facilities for commercial vehicles are also included The passenger concourse will contain retail convenience goods and service shops.

The new Tel Aviv Transportation Center (Fig. D-26) is located on the southern edge of the CBD. The Center will be served on its eastern side by an expressway with six lanes, plus two median lanes for buses. These lanes will extend for about 1.5 miles. Connections will be provided from the expressway by an elevated four-lane exclusive busway 0.2 miles long The busway will later be extended to a freeway just east of the expressway

TABLE D-23

BUSES SCHEDULED TO SOUTHWEST BUS TERMINAL, WASHINGTON, D.C , MARCH 1972

	ARRIVE 7 00–9:00 AM		DEPART 4 00–6 00 PM	
COMPANY	NO OF BUSES	NO OF BUS LINES	NO OF BUSES	NO OF BUS LINES
DCT	48[a]	12	49[b]	12
WMA	13[a]	11	12[d]	10
ABW	29[c]	10	28[f]	12
WVM	48[g]	21	45	20
All	138	54	134	54

Source Washington Metropolitan Area Transit Commission

[a] Five others arrive 9 00–9 25 AM

[b] Five others depart 3 40–4 00 PM and one 6 00–6 05 PM

[c] Three others arrive 6 40–7 00 AM

[d] Three others depart at 3 35 PM

[e] One other arrives at 9 21 AM

[f] One other departs at 6 05 PM

[g] Two others arrive at 9 09 AM

Altogether about 188 bus loading spaces will be dispersed over seven separate floors (Fig D-27), along with nearly 100 spaces for bus storage. Commercial and service areas include a variety of shops, two theaters, several banks, a post office, etc. Provision also has been made for a future office tower.

Bus underground areas are fully ventilated, while the upper levels are open to the air All pedestrian areas are air-conditioned

If bus volumes continue to grow according to past trends, the new Transportation Center will not be able to accommodate all of the bus traffic generated by Tel Aviv by 1985. Accordingly, an additional center is planned on a site in the northern section of the city (Fig. D-25)

REFERENCES

D-1. MAYER, H. P., "Change of Mode Commuter Transportation in Metropolitan Milwaukee." *Hwy Res. Circ. No. 93* (Oct 1968).

D-2. "Midtown Bus Terminal Extension Planned." *The Westsider* (N.Y City) (Fall 1971)

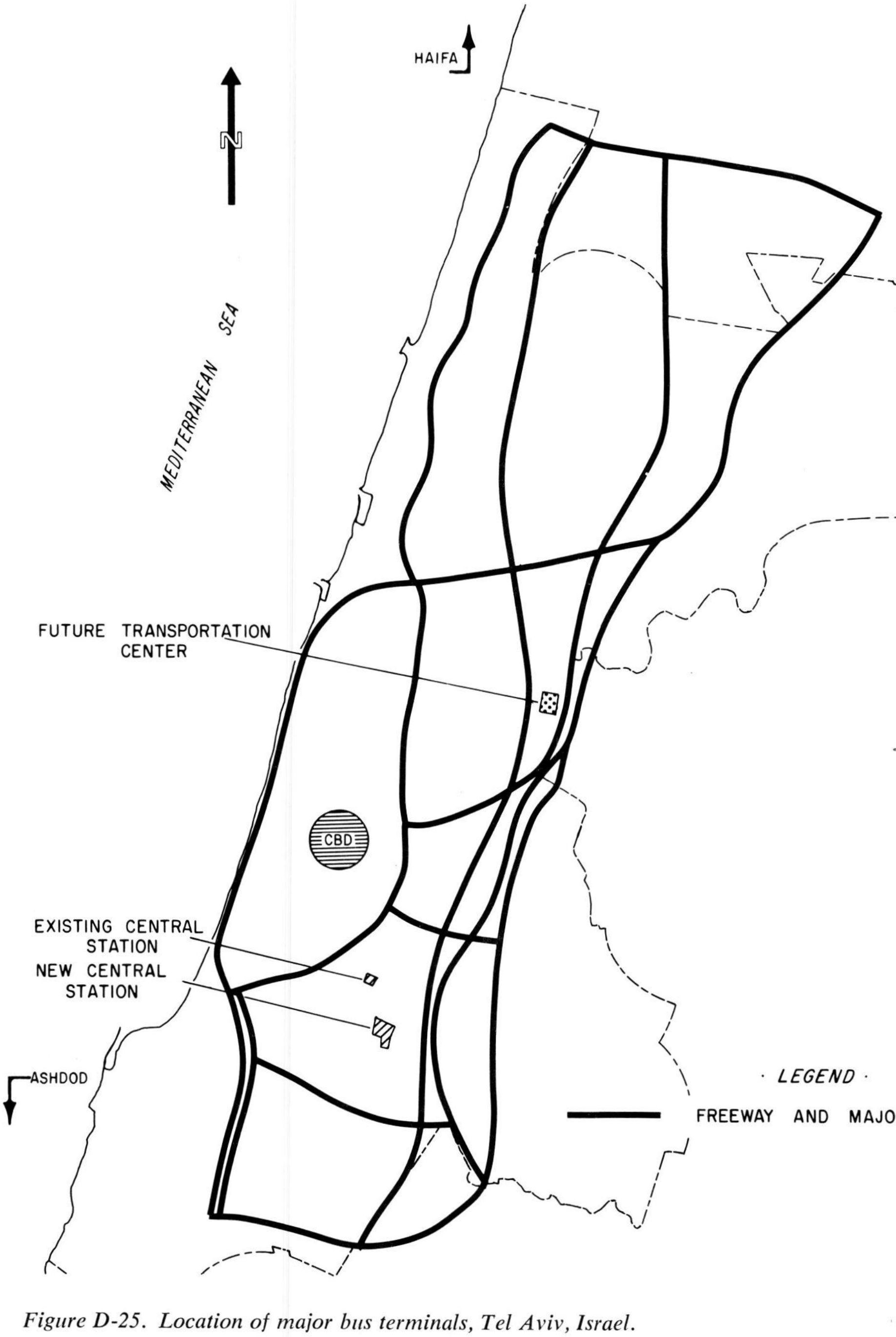


Figure D-25. Location of major bus terminals, Tel Aviv, Israel.

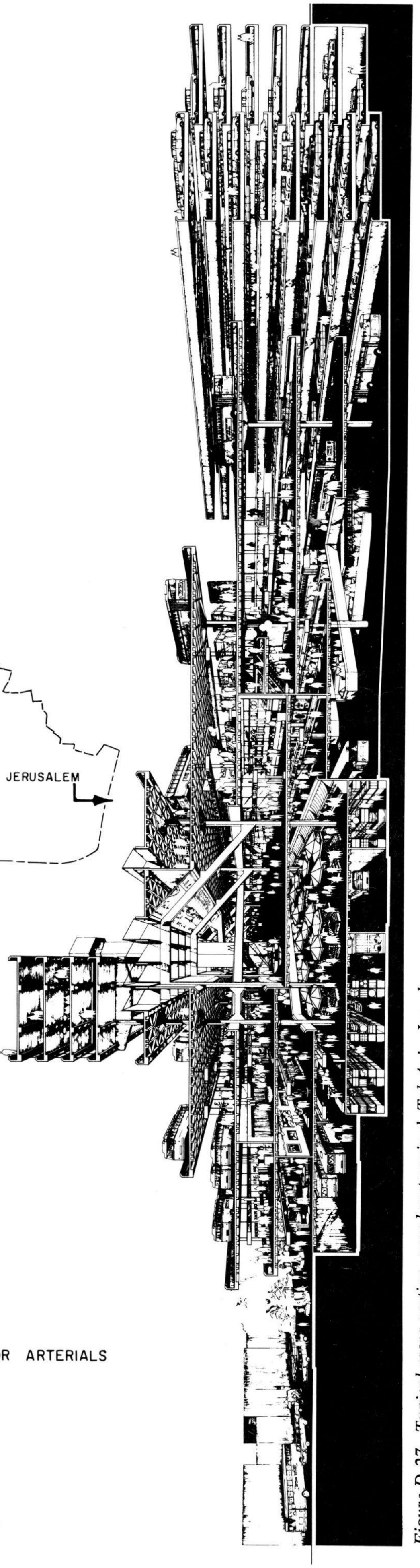


Figure D-27. Typical cross section, new bus terminal, Tel Aviv, Israel.

Figure D-26. New bus terminal, Tel Aviv, Israel.

APPENDIX E

SELECTED CHRONOLOGICAL BIBLIOGRAPHY ON BUS PRIORITY TREATMENTS

This bibliography summarizes the principal publications of the period 1937 to 1972 that relate to bus priority treatments Primary emphasis is on current materials.

1937

"A Comprehensive Local Transportation Plan for the City of Chicago" Harrington, Kelker, De Leuw (1937).

1945

Williams, L., "Planning Public Transportation on Urban Expressways." *Proc. HRB,* Vol. 25 (1945) pp. 363-375

1947

"Urban Freeways." Committee on Urban Transp., Amer Inst. of Planners, Amer. Transit Assn. (1947).

1949

"New York's New Union Terminal." *Arch. Rec* (Aug. 1949).

1951

"A Traffic-Transit Integration Plan for Providence." Smith, Dibble and Assoc. 1951.

1955

"A Plan for the Improvement of Traffic and Mass Transportation in St. Louis" St. Louis Public Service Co. (Sept. 1955).

1956

"Recommendation for Exclusive Transit Lane in Washington Street." Chicago Street Traffic Comm. (Mar 1, 1956).

Homburger, W. S, "A Study of Express Bus Operations on Freeways." *Res. Rep. No. 23,* ITTE, Univ. of California, Berkeley (Nov. 1956).

"Joint Report on Operations of United Transit Company." W C Gilman & Co., The Roberts Organization, and Wilbur Smith and Assoc. (1956).

A Policy on Arterial Highways in Urban Areas. American Association of State Highway Officials (1956).

"A Study of Traffic-Transit and Trade in Downtown Providence" Wilbur Smith and Assoc. (1956).

Schroeder, W W., "Metropolitan Transit Research Study." Chicago Transit Auth (1956).

1958

Homburger, W. S., and Kennedy, N., "The Utilization of Freeways by Urban Transit Buses· A Nationwide Survey." *Res. Rep. No. 28,* ITTE, Univ. of California, Berkeley (June 1958).

"Legal Basis for Reserved Transit Lane" Amer Transit Assn. (Dec. 17, 1958).

1959

"Mass Transportation Survey National Capital Region, Civil Engineering Report." De Leuw, Cather and Co., National Capital Regional Planning Comm., and National Capital Regional Planning Council (Jan. 1959).

Connor, E., and Robinson, B. F., "An Evaluation of Exclusive Bus Lanes in the City of Birmingham, Alabama." (Mar. 1959).

"Warrants for Exclusive Bus Lanes." *Traffic Eng.* (July 1959).

"St. Louis Metropolitan Area Transportation Study." W. C Gilman & Co. and Wilbur Smith and Assoc. (Aug. 1959).

"Freeways with Rapid Transit, A Study on Highway Planning: Part 2" Tech Committee for Metropolitan Planning, Vancouver, B.C. (Aug. 1959).

"Transit Faces the Future." Amer. Transit Assn. (Aug. 1959).

"We Owe it to Ourselves." D.C. Transit System (Sept. 1959).

1960

McConochie, W. R., "Public Transit on Freeways." *Amer. City* (May 1960) pp. 106-108.

"Rapid Atlanta." Atlanta Transit System (1960).

1961

Pratt, D., "Express Bus Service on the Schuylkill Expressway." *Metropol. Transp.* (June 1961) pp. 23-24.

Robinson, B. F., "Bus Lanes Are Better for Everyone." *Transport World* (London), No. 3840 (June 1961) pp. 17-18.

"Electronic Self-Guided Bus to Undergo Reserved-Lane Tests on Chicago Expressway." *Pass. Transp.* (Dec. 22, 1961).

Rainville, W. S., Jr., "Preliminary Progress Report of Transit Subcommittee on Highway Capacity." *Proc. HRB,* Vol. 40 (1961) pp. 523-540.

"Future Highways and Urban Growth." Wilbur Smith and Assoc for Automobile Manufacturers Assn., Detroit (1961).

1962

Frieling, G. H., "Transit Needs a Transit-Way" *Metropol. Transp.* (Feb. 1962) pp. 13-15.

"A Basic Concept for Rapid Transit Planning in the New Orleans Metropolitan Area." New Orleans Public Service (Aug. 1962).

Schell, J. W., and Foote, J. E., "Bus Operation in Single Lane Platoons and Their Ventilation Needs for Operation in Tunnels" *Res. Publ GMR-808,* G M Res Labs., Warren, Mich (Sept 1962).

Anderson, G W., "Rail and Bus Rapid Transit for Downtown Access" For symposium, "The Dynamics of Urban Transportation," Cobo Hall, Detroit (Oct. 23, 1962).

"'Leap-Frog' System of Bus Stops," also "Bus Lanes" Replies to inquiry sent Nov. 8, 1962, to 50 largest companies, 32 of them replying. Reported results by Amer Transit Assn (Dec 1962).

Webster, F V, "A Theoretical Estimate of the Effect of London Car Commuters Transferring to Bus Travel." TRRL, England (1962).

1963

De Leuw, C. D., and McConochie, W R, "Exclusive Lanes for Express Bus Operations." *Pass Transp* (Apr 22, 1963)

"A Study of Bus Rapid Transit Operations for the National Capital Region" Nat Capital Transp. Agency, Washington, D.C. (July 1963)

Rainville, W. S., "Expressway Bus Operations." Amer. Transit Assn (Aug. 1963) Also see "Use of Freeways by the Los Angeles Metropolitan Transit Authority" Office of Chief Engineer, LAMTA (Sept 1963)

"Number and Type of Special Bus Stop Facilities Along Freeways." Reported in 50 States, District of Columbia, and Puerto Rico, 1963 BPR survey (unpubl)

Bockemuhl, A., and Bandi, F., "Horizontal and Vertical Separation of Public and Private Transport to Improve the Fluidity of Urban Traffic" Internat. Traffic Committee, 35th Internat. Congress, UITP, Vienna (1963).

1964

Hodgkins, E A, "Effect of Buses on Freeway Capacity" *Hwy Res. Record No. 59* (1964) pp 66-82

Berry, D S, and Shuldiner, P. W, "Technological Aspects of Urban Transportation." *Jour Hwy. Div,* ASCE (Jan. 1964) pp 53-79.

"Old Colony Rapid Busway System between Boston and South Shore Communities" Simpson and Curtin (Feb. 1964).

"Busway Operations on Exclusive Lanes, or What is Safe Spacing?" *City and Suburban Travel* (May 1964) p. 10

Graham, E F, "Use of Freeway Bus Stops in California." *Traffic Bull No. 12,* California Dept. of Public Works (June 1964).

"Design of Traffic Signal Systems with Emphasis on the Needs of Surface Transit." (In German) *Kommunal wirtschaft* (Aug. 1964)

"Physical Feasibility of Utilizing Unused West Shore Railroad Right-of-Way for Exclusive Bus Operations." New Jersey State Highway Dept (Dec. 1964).

"Metro-Mode A New Approach to Rapid Transit" General Motors Corp (1964).

"A Survey to Determine Factors Which Influence the Public's Choice of Mode of Transportation." Joseph Napolitan Assoc for Massachusetts Mass Transportation Comm (1964)

Rothery, R, Silver R., and Herman R, "Analysis of Experiments on Single-Lane Bus Flow." G M Res Labs (1964).

1965

Neal, A F, "Bus and Car Comparison of Convenience, Comfort and Cost" *Modern Transp.* (May 29, 1965) pp. 11-12.

"Highway Capacity Manual, 1965" *HRB Spec Rep No 87* (1965)

1966

Zell, C. E, "San Francisco-Oakland Bay Bridge Trans-Bay Bus Riders Survey" *Hwy Res. Record No. 114* (1966) pp. 169-182

Holliday, J C, "Draft Plan for Runcorn New Town." *Traffic Eng and Control* (London), Vol. 7, No. 12 (Apr 1966).

"Express Bus Service Final Report." W. C. Gilman Co, Memorandum on MTD-8, Bi-State Development Agency (Missouri, Illinois, St. Louis Metropolitan Area) (1966)

"Introducing the Blue Streak Rapid Transit System" Seattle, Wash. (June 1966)

"Portland-Vancouver Mass Transit Use Study." Simpson and Curtin (July 1966).

"Bus Operation in Trains." *City and Suburban Travel* (Oct. 1966) pp. 4-5.

Wilson, H., Womersley, L, and Brown, M., "Redditch New Town. Report on Planning Proposals." (Dec 1966).

Deen, T. B, "A Study of Transit Fringe Parking Usage." *Hwy. Res. Record No. 130* (1966) pp 1-19.

"Transportation and Parking for Tomorrow's Cities." Wilbur Smith and Assoc for Automobile Manufacturers Assn., Detroit (1966).

Meyer, J, Kain, J., and Wohl, M., *The Urban Transportation Problem.* Harvard Univ. Press (1966).

"Exclusive Bus Lane Study on Interstate Route 495—Report on Second Phase of Field Tests in December, 1965" Port of New York Authority (1966).

"Summary Report of the D.C. Cordon Traffic Survey, 1966 and 1970." Dept. of Highways and Traffic, Dist of Columbia (1966, 1970).

"Transit for 1990 Memphis." Alan M. Voorhees and Assoc (1966).

1967

Drew, D. R, "Some Aspects of Reverse-Flow Freeway Design." *Hwy Res Record No. 172* (1967) pp 39-53.

"Reporting on Testing and Evaluating of the Transit Expressway." MPC Corp (Feb 1967)

"Bus-Only Expressway Revealed" *Passenger Transp.* (Apr 28, 1967).

"Reserved Bus Lanes Inquiry" American Transit Assn. (Apr. 1967)

Clines, C., "Clear the Tracks for Buses" *Commercial Car Jour* (May 1967)

"Reserved Bus Lanes Inquiry—Replies from Nine Cities" Amer Transit Assn. (May 1967)

Sommerville, R. L., "Rapid Busways Presentation" Atlanta Transit System (June 28, 1967)

"Rapid Busways." Atlanta Transit System (July 1967)

"Warrants for Bus Stops A Recommended Practice for Proper Location of Bus Stops" Approved by ITE Board of Directors (Aug 4, 1967)

"Manchester Rapid Transit Study." Vol 2 De Leuw, Cather and Co and Hennessey, Chadwick, Oheocha and Partners for City of Manchester and the Ministry of Transport and British Railways (Aug 1967).

"Statement of Position of the Federal Highway Administration on the Reservation of Freeway Lanes for Buses." FHWA (Aug 1967)

"Guided Bus System Studied in Britain" *Passenger Transp.,* Vol 25, No 21 (Sept. 1967).

"Rapid Busways" *Metropolitan* (Sept/Oct 1967)

"A Recommended Practice for Proper Location of Bus Stops" *Traffic Eng.* (Dec. 1967) pp. 30-34

"Preliminary Report on Long-Range Transit Plan for the Minneapolis-St. Paul Area" De Leuw, Cather and Company (1967)

Hille, S J, and Martin, T K, "Consumer Preferences in Transportation" *Hwy Res Record No 197* (1967) pp 36-43.

La Plante, J, "Exclusive Bus Lanes" *HRB Spec. Rep No 93* (1967) pp. 75-83

Ling, A, "Runcorn New Town" Runcorn Development Corp, England (1967).

May, A G, Newell, G. F., Oliver, R M., and Potts, R. B, "Q's and Q's" *Bull Oper Res Soc Amer,* Vol 15, Suppl. 3 (1967)

McDermott, J M., "Operational Effects of Automatic Ramp Control on Network Traffic" *Hwy Res Record No 202* (1967) pp 1-31

"Metro-Mode A New Approach to Rapid Transit" General Motors Corp., Detroit (1967)

"The Metro Flyer—A Suburban Bus Service to Downtown" Mass Demonstration Project MD-MTD-1, Metropolitan Transit Auth. of Maryland, Baltimore (1967).

"Proposed Exclusive Bus Lane on Interstate Route 495 from the New Jersey Turnpike to the Lincoln Tunnel" Port of New York Authority (1967)

Wynn, F H, and Levinson, H. S., "Some Considerations in Appraising Bus Transit Potentials." *Hwy. Res Record No 197* (1967) pp 1-24

1968

Henderson, A, and Cole, M., "Design Vehicle Criteria and Geometric Design" *Traffic Eng and Control* (London) (Jan. 1968).

"Joint Project Concept. Integrated Transportation Corridors." Barton-Aschman Assoc for U S. Dept. of Housing and Urban Development (Jan. 1968).

"Study of Evolutionary Urban Transportation" Westinghouse Air Brake Co., Wilbur Smith and Assoc., Melpar, Inst for Public Administration, for U.S. Dept of Housing and Urban Development (Feb. 1968).

"Concept of Rapid Transit" Howard, Needles, Tammen and Bergendoff for Kansas City Area Transportation Auth. (Mar 1968)

"Some Observations on the Circulation of Buses in Paris." A report by the Independent Transport District of Paris (Mar 1968)

"Survey of Transit Operations." Simpson and Curtin, for New Orleans Public Service (Mar 1968)

Design and Performance Criteria for Improved Nonrail Urban Mass Transit Vehicles and Related Urban Transportation Systems Nat. Academy of Engineering (1968)

"Étude des mesures ayant pour object de donner aux transports publics une priorté effective de circulation." 18th Tech. General Assembly, Marseilles, France (May 1968)

"Tomorrow's Transportation" U.S. Dept of Housing and Urban Development (May 1968)

"Final Report of Southern California Rapid Transit District—Examination of Alternate Modes of Rapid Transit (Los Angeles)" Simpson and Curtin (May 1968).

Brierly, J, "Exeter's Traffic Management Experiment" *Traffic Eng. and Control* (London) Vol 10, No 1 (May 1968).

Frebault, J., "Effect on the Community of Creating a Lane Reserved for Buses." Road Traffic Studies and Res Dept, France (July 1968)

"An Evaluation of Free Transit Service" Charles River Assoc, Cambridge, Mass (Aug 1968)

Eburah, J. W, and Yates, L. B, "Bus Lane Review, Vauxhall Bridge and Park Lane" Dept of Highways and Transp, Greater London Council (Aug 1968)

"Bus Rapid Transit on our Freeways." National Highway Users Conf. (Aug 1968) 12 pp (mimeo.)

"Report and Recommendations, Transit Expressway and PATways" Port Authority of Allegheny County, Pittsburgh, Pa. (Aug. 1968).

Cady, C, "Now, Take the Bus." *Highway User,* National Highway Users Conf (Sept 1968).

"Bus Rapid Transit Current Concepts and Proposals" *Info Rep No 12,* National Capital Region Transportation Planning Board (Oct. 1968).

"Urban Commutation Alternatives." Office of Planning and Program Review, FHWA (Oct 1968) pp 6-7

"General Criteria for Transitway Design" Barton-Aschman Assoc, Milwaukee County Mass Transit Tech Planning Study (Dec 1968)

Glennon, J. C, and Stover, V. G, "A System to Facilitate Bus Rapid Transit on Urban Freeways" *Res Rep. 524-1,* Texas Transportation Inst. (Dec. 1968)

"A Method for Estimating the Impact of Travel Time or Cost Changes on Diversion of Car Drivers to Transit Work Travel to Central Business Districts" Wilbur Smith and Assoc for FHWA (1968).

Met Washington COG, *Improving Express Bus Travel*

Times in Peak Hours Between Downtown Washington and Fringe Parking Sites. Vol I: "Use of Baltimore and Ohio's Georgetown Branch for Public Transportation " Metropolitan Washington Council of Governments (Oct 1968).

"Transportation Facts for the Boston Region." Transportation Planning Dept., Boston Redevelopment Auth. (1968).

1969

CONSTANTINE, T , and YOUNG, A. P., "Bus Priorities in Traffic Management Schemes " *Traffic Eng and Control* (London) (Jan. 1969).

CORRADINO, J. C , "Busways—Rapid Transit for an Intermediate-Sized Metropolitan Area " Soc. Automotive Eng (Jan 1969)

GLENNON, J. C., and STOVER, V G., "Bus Rapid Transit on Urban Freeways Using Traffic Surveillance and Control " *Res Rep 524-2,* Texas Transportation Inst (Jan 1969)

HARR, C M , "Tomorrow's Transportation—New Systems for the Urban Future." *Proc. SAE,* Vol 77 (Jan 1969) pp. 62-63

Improving Express Bus Travel Times in Peak Hours Between Downtown Washington and Fringe Parking Sites Vol. II "Traffic Improvements to Speed Express Bus Operations " Metropolitan Washington Council of Governments (Jan. 1969)

"Description of Project to Establish and Operate an Express Busway on Exclusive Lanes between Santa Anita-El Monte and the Los Angeles Civic Center." Southern California Rapid Transit Dist. (Jan. 20, 1969)

"Bus Lanes in Wiesbaden" (in German). *Der Stadtverkehr* (Feb 1969)

"Transit System Development Objectives, Principles and Standards." Barton-Aschman Assoc , Milwaukee County Mass Transit Tech Planning Study (Mar 1969)

BROUWER, P., "Separate Traffic Lanes for Buses—What Is the Present State of Affairs?" *UITP Revue,* Brussels (Mar. 1969)

STOVER, V G., and GLENNON, J C., "Effective Use of Bus Rapid Transit on Urban Freeways " *Texas Transp Researcher* (Apr 1969) pp. 3-5

"Summary Highlights, Recommended Transportation Program." Alan M. Voorhees and Assoc. for Technical and Policy Committees, Atlanta Area Transportation Study (Apr 10, 1969)

"An Evaluation of Alternative Transit Equipment Systems for Milwaukee County " Barton-Aschman Assoc , Milwaukee County Mass Transit Tech Planning Study (May 1969).

FOOTE, J E., and SCHEEL, J. W., "Comparison of Experimental Results with Estimated Single-Lane Bus Flow Through a Series of Stations Along a Private Busway." *Res. Publ. GMR-888,* G M. Research Lab (May 1969).

CONSTANTINE, T , and YOUNG, A P , "Existing and Proposed Bus Priority Schemes " *Traffic Eng and Control* (London) (May 1969).

NEWMAN, L , DUNNET, A , and MEIS, G. J , "Freeway Ramp Control—What It Can and Cannot Do " *Traffic Eng* (June 1969) pp. 14-21.

"Sensitivity Analysis of the Evaluation of a Bus Transit System in a Selected Urban Area." Federal Highway Admin (June 1969).

"City Traffic and Expressways." WITI-TV, Milwaukee, Wis (June 1, 1969).

"Evaluation of a Bus Transit System in a Selected Urban Area." Peat, Marwick, Livingston & Co for FHWA (June 1969).

"Feasibility of an Exclusive Lane for Buses on the San Francisco-Oakland Bay Bridge." Business and Transportation Agency, California Dept of Public Works (June 1969)

"Special Lanes for Buses " Research and Planning Report, Chicago Transit Authority (June 1969).

MAYNARD, W. P., "The Busway to Make Rapid Transit Work—Now " *Traffic Quart* (July 1969) pp. 353-363

"A Proposal for Interim Use of a Transportation Right-of-Way The Route 66 Busway." Metropolitan Washington Council of Governments (July 1969).

MORIN, D. A., and REAGAN, C. D., "Reserved Lanes for Buses and Car Pools." *Traffic Eng* (July 1969)

YATES, L B., "Vauxhall Bridge Bus Lane 12 Months After Study." Dept of Highways and Transportation, Greater London Council (July 1969)

FLURY, A., "Detectors at Signalized Intersections" (in German) *Bus and Tram* (Aug. 1969)

GALLAGHER, R , and NELSON, S. B., "Proposed Exclusive-Express Busway in and Along the San Bernardino Freeway Between Los Angeles and El Monte." Inst of Traffic Engineers, 39th Annual Meeting (Aug 1969)

"Transit Needs Study in Minneapolis-St. Paul " Twin Cities Area Metro Transit Comm , with HUD (Sept. 1969)

LACY, J. D , "TOPICS—Special Bus Lanes." Circ. Memo., U.S Dept of Transportation (Sept 18, 1969)

FREBAULT, J., "Assessment of the Effects of Introducing Reserved Bus Lanes—Application in Paris and Marseilles " Organization for Economic Cooperation and Development, Paris (Oct 1969)

MAIZONNET, M., "Practical Experience with the Use of Exclusive Bus Lanes in Paris " Organization for Economic Cooperation and Development, Paris (Oct 1969)

"A Systems Analysis of Transit Routes and Schedules " Alan Voorhees and Assoc , Mass Transportation Demonstration Project (Nov 1969)

BENNETT, J D., and LANGLEY, D., "The Application of a Bus Priority Control Strategy to a Traffic Light Controlled Intersection." *GLC RM 24,* Greater London Council (Nov. 1969).

"Shirley Highway Bus Rapid Transit Feasibility Study." Metropolitan Washington Council of Governments (Nov 6, 1969).

Russell, G. L, "Exclusive Bus Lanes" *Traffic Bull. No 18,* Traffic Dept., California Dept. of Public Works (Nov. 1969) 8 pp.

Vuchic, V. R, "Optimum Bus Stop Locations on a Street with Coordinated Signalization" Presented at ORSA, Miami (Nov. 1969).

Yates, L B, "Brixton Bus Lane Study Interim Report for All Vehicles Except Buses." Dept of Planning and Transportation, Greater London Council (Nov 1969).

Brown, S J., "Priority for Buses in Rugby." *Bus and Coach* (Dec. 1969).

Deen, T. B, and James, D H, "Relative Costs of Bus and Rail Transit Systems" *Hwy. Res. Record No. 293* (1969) pp 33-53.

Ellen, F R., "Ways of Helping Buses on Urban Areas" *UITP Revue,* Brussels, No 4 (1969) pp. 289-314.

Graver, C., Brennand, J. R., and Baumann, D., "Feasibility and Cost of Urban Transportation Systems." *Urban Eng and Transp.,* Urban Technology Committee, ASME Process Industries Div. (1969) pp. 43-55

"KCI Rapid Transitway." Howard, Needles, Tammen and Bergendoff, Engineering Design Report (1969)

Wilson, D. G., et al., "Quadramode Transport· A Class of Controlled Systems" *Urban Eng. and Transp,* Urban Technology Committee, ASME Process Industries Div (1969) pp. 88-100

"Allegheny County Rapid Transit" Port Auth. of Allegheny County, Pittsburgh, Pa. (1969).

1970

"Throughways Guided Bus—Best of Both Worlds." *Commercial Motor* (Jan 16, 1970) pp. 32-33.

Corradino, J. C, "Busways—Rapid Transit for an Intermediate-Sized Metropolitan Area" *UITP Revue,* Brussels, Vol. 19, No. 1 (Jan. 1970) pp 15-19.

Martin, D. B., "Feasibility of an Exclusive Lane for Buses on the San Francisco-Oakland Bay Bridge" *Hwy. Res Record No 303* (1970) pp. 17-29

"Bus Stops for Freeway Operations. Tentative ITE Recommended Practice." *Traffic Eng.* (Jan. 1970) pp. 14-22.

Yates, L. B, "Park Lane Bus Lane Study—Scheme 2." Dept. of Planning and Transportation, Greater London Council (Jan 1970)

"The Potential for Bus Rapid Transit." Wilbur Smith and Assoc. for Automobile Manufacturers Assn. (Feb. 1970).

Weiner, E, "Improving Bus Transit as a Mode of Transportation." *Urban Transportation Planning Course,* Public Transportation Branch, Urban Planning Div, FHWA (Feb. 17, 1970) 7 pp. (mimeo.).

"Capacity Analysis and Peak-Hour Loading for PATways" (Feb. 1970).

"Test Vehicle Monitoring System in New York" *Communications News* (Mar. 1970).

"Feasibility Study for Bus Rapid Transit on the Shirley Highway Corridor" Howard, Needles, Tammen and Bergendoff for Metropolitan Washington Council of Governments (Mar. 1970)

"Complementary Commuter Service Needs Penn-Central Railroad, New Haven Division" Wilbur Smith and Assoc for Connecticut Research Comm (Mar 1970). Ch. III, "Evaluation of Bus Transit Potential for Access to Stations," pp. 28-45.

"Reading Central Area, Comprehensive Traffic Management Scheme, Contra Bus Lane in King's Road" Traffic Advisory Unit, Reading, England (Apr. 1970)

"Analysis of Milwaukee's Transit Service." Barton-Aschman Assoc for Expressway and Transportation Comm (Apr 1970)

"Report to the Minister" Working Group on Bus Demonstration Projects, T L. Beagley, Chairman, Ministry of Transport, England (Apr 1970).

Goodman, J M, "Operation of a Freeway Priority System for Buses and Car Pools." *Traffic Eng.,* Vol 40, No. 7 (Apr. 1970) pp 30-33

"No Stop at Toll Gate for Transbay Buses." *Passenger Transp* (Apr 1970).

Taylor, J. G., "Reserved Lanes for Buses. The Shirley Highway Experiment." Inst. for Defense Analysis, Urban Mass Transportation Project, Arlington, Va (Apr. 1970).

"Sensitivity Analysis of a Bus Transit System in a Selected Urban Area." Peat, Marwick, Livingston & Co. for FHWA (May 1970).

Barnett, J., "Express Bus Mass Transit" *ASCE Proc, Transp. Eng. Jour.,* Vol. 96 (May 1970) Paper 7256

"Bus Only Lanes." Planning and Transportation Dept., Greater London Council (May 1970)

Herman, R, Lam, T, and Rothery, R., "Further Studies on Single-Lane Bus Flow Transient Characteristics" *Transp. Sci.,* Vol 4, No. 2 (May 1970) pp. 187-216

Howe, R T., "Plan for Financing Urban Mass Transit Systems" *ASCE Proc, Transp Eng Jour.,* Vol 96, No. TE2 (May 1970) Paper 7286, pp 219-227.

"Bus Priority in Theory and Practice." *Motor Transp,* London "Bus Coach" Supplement (May 1, 1970) p. 22.

"Buses-Only Transitway Moves People Faster on Minneapolis Nicollet Mall." *Passenger Transp* (May 1970)

"Urban Design Considerations in Transitway Development." Barton-Aschman Assoc., Milwaukee County Mass Transit Technical Planning Study (June 1970).

Echols, J. C., "The Shirley Highway Express Bus on Freeway Project." Metropolitan Washington Council of Government (June 1970).

"Highways and Public Transportation" *Metropolitan,* Vol 66, No 4 (July 1970) pp 21-24.

Marple, G E., "Transportation Planning for Exclusive Bus Facilities" *Instr Memo* FHWA (July 1970).

Marple, G. E., "Warrants for Exclusive Bus Facilities" *Instr. Memo* FHWA (July 1970)

Mayer, H M, "Milwaukee's Bus Rapid Transit" (June 26, 1970)

Sparks, G. A, and May, A D, "A Mathematical Model for Evaluating Priority Lane Operation on Freeways" FHWA (June 1970)

Turner, F. C., "Moving People on Urban Highways" *Traffic Quart* (July 1970) pp. 321-333.

"Reserved Lanes for Transit Buses on Urban Freeways" Directory of Research, Development and Demonstration Projects, UMTA (June 1970)

Williams, G. M, "Consideration of Exclusive Bus Facilities in Highway Project Development." *Circ Memo* FHWA (June 17, 1970).

Bendixson, T., "Results of Reading Bus Lane Experiment" *Traffic Eng. and Control* (London) Vol. 12, No. 4 (Aug 1970) pp 188-189

Carroll, J. D, "Urban Corridor Demonstration Project Manhattan—New Jersey." Tri-State Transportation Comm, N Y, N.J, Conn, with FHWA and UMTA (Aug. 1970).

Ferrari, M G, "Improving Urban Bus Operations." *ASCE Proc., Transp Eng Jour*, Vol. 96, No. TE3 (Aug 1970) Paper 7465, pp 319-331

"Balanced Transportation Through Efficient Use of Existing Facilities" *Traffic Eng* (Aug 1970)

Lave, C A, "The Demand for Urban Mass Transportation" *Review of Economics and Statistics,* Vol 52, No 3 (Aug 1970) pp. 320-323

Pignataro, L J, Falcocchio, J. C, and Roess, R. P, "Selected Bus Demonstration Projects" *ASCE Proc., Transp Eng. Jour*, Vol. 96, No TE3 (Aug 1970) Paper 7454, pp 251-268.

Prangley, R. E., "Commuter Transportation Problem, University of Maryland." Consortium of Universities, Washington, D C. (Aug. 1970)

"Blue Streak" Washington Department of Highways, Puget Sound Reg. Trans Study, and Seattle Traffic Engineer, with HUD (Aug 1970).

"Center City Transportation Project—City Reports on Atlanta, Dallas, Denver, Pittsburgh, and Seattle" Arthur D Little, Real Estate Research Corp., Skidmore, Owings and Merrill, and Wilbur Smith and Assoc (Sept. 1970).

"The Proposal for an Exclusive Bus Lane in the Interstate Route 495 Corridor from the New Jersey Turnpike to the Lincoln Tunnel." New Jersey Dept. of Transportation, New Jersey Turnpike Auth, and Port of New York Auth. (Sept 1970).

"Seattle's Blue Streak—Off and Running Sept. 9." *Passenger Transp* (Sept 1970)

"Urban Transportation Concepts—Center City Transportation Project." Wilbur Smith and Assoc. (Sept 1970)

Evans, H. K, and Skiles, G W, "Improving Public Transit Through Bus Preemption of Traffic Signals." *Traffic Quart.,* Vol 24, No. 4 (Oct. 1970) pp 531-543.

"Houston, Texas—A Future Mass Transportation Concept" Rapid Transit Comm. (Oct 1970).

"Existing Transit Operations, Downtown Vancouver" City of Vancouver Engineering Dept. and B C Hydro and Power Auth. (Oct. 1970).

Madrzak, R, "Successful Bus Lanes in Madison, Wisconsin—Illegal" FHWA (Nov 1970)

Henderson, A., Bobrowski, J., and Stovel, J. C., "Guided Bus Rapid Transit System." Arthur Henderson, Consultants, England (Nov. 1970).

"A Case for Bus Transit in Urban Areas" Peat, Marwick Mitchell & Co, Washington, D.C. (1970).

Vaughn-Birch, K, "Exclusive Transit Lane." Vancouver, B.C, Canada (Nov. 1970).

"Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Car Pools." Alan M Voorhees and Assoc. (Nov 1970)

"I-84 Environmental and Joint Use Study" Wilbur Smith and Assoc. for Connecticut Dept of Transportation (Nov 1970).

"Pittsburgh Multi-Modal Approach to Transit" *Railway Age,* Vol 169, No. 9 (Nov. 1970) pp 30-32.

"Highway Transportation" FHWA (Nov. 1970).

Morin, D A, and Fisher, R. J, "Bus Rapid Transit." *Amer. Road Builder* (Dec. 1970).

"Improvements Attainable Through Transit Operations." In *An Evaluation of Urban Transport Efficiency in Canada Technical Memorandum,* N. D. Lea and Assoc (Dec 1970) 49 pp

"Improvements Attainable Through Pricing." In *An Evaluation of Urban Transport Efficiency in Canada. Technical Memorandum,* N D. Lea and Assoc. (Dec. 1970) 49 pp.

Goodman, J C., MacDorman, L C, and Weiner, E., "Evaluation of a Bus Transit System in a Selected Urban Area." *Hwy. Res Record No. 314* (1970) pp. 114-122.

Newman, L., Dunnet, A H, and Meis, G, "An Evaluation of Ramp Control on the Harbor Freeway in Los Angeles." *Hwy. Res. Record No. 303* (1970) pp. 44-55

Sweek, J. E., and Horwood, E. M, "Evaluating the Central City Access Opportunity Provided by a Public Transportation System." Univ. of Washington (1970).

"Blue Streak Bus Rapid Transit Demonstration Project: Phase I Interim Report." Alan Voorhees and Assoc for Washington State Highway Comm. (1970)

1971

"Milwaukee Central Area Transit Distribution System" Barton-Aschman Assoc (Jan. 1971).

"Transit Improvement Program 1971-1975 for the St. Louis Missouri-Illinois Metropolitan Area" Bi-State Development Agency (Jan. 1971)

Capelle, D. G., "Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Car Pools." FHWA and UMTA (Jan. 1971).

"Busway Headway vs. Speed . . ." *City and Suburban Travel,* No. 118 (Jan. 1971) p. 9.

"Los Angeles Area Freeway Surveillance and Control Project, First Annual Report." Business and Transportation Agency, Dept of Public Works, to the State Legislature (Jan. 1971) 19 pp.

Gersten, M. C., "Bus Rapid Transit in the Shirley Highway Corridor." Presented at Metropolitan Section meeting, ASCE, New York City (Feb 9, 1971).

Goodman, L., "Bus Rapid Transit on Existing Highways." Presented at Metropolitan Section meeting, ASCE, New York City (Feb. 9, 1971).

Goodman, L , "The I-495 Exclusive Bus Lane." Presented at Metropolitan Section meeting, ASCE, New York City (Feb. 9, 1971).

Highway Planning Program Manual Vol 8, Ch 10, "Public Transportation," FHWA (Feb 26, 1971).

Sorrentino, M , "The Role of Public Transport in Traffic Policy " *UITP Revue,* Brussels, Vol 20, No 2 (1971)

"Bus Lane Opens." *Traffic Eng.* (Feb 1971)

Turner, F C , "The Case for Buses " Presented at Metropolitan Section meeting, ASCE, New York City (Feb 9, 1971).

"Transit Design on Freeway Corridors." Vol. 1, Functional Planning Office, Ontario Dept. of Highways (Mar 1971).

Marple, G E., "Preferential Treatment of Buses." FHWA Notice (Mar 29, 1971)

Mercer, J , "The Runcorn Plan for a Rapid Transit Bus Service " Univ of Newcastle-Upon-Tyne (Mar 1971).

"Exclusive Busway System in City Transport Report " *Truck & Bus,* Sydney (Mar. 1971) p 133.

"The Effect of Reserved Lanes for Public Transport on Skeppsbron and St Eriksgatan Streets, 1969-1970." *Rep. No. 24,* Stockholm Traffic Department (Apr. 1971)

"Feasibility Study on an Exclusive Lane for Buses and Car Pools on the San Francisco-Oakland Bay Bridge " California Dept of Public Works (Apr 1971).

Oelsner, L , "Yorkville-Wall St. Bus Express Makes Debut, and It's On Time " *New York Times* (Apr. 13, 1971)

"Runcorn Busway Concept " *Buses,* Shepperton, Great Britain, Vol. 21, No 193 (Apr 1971) pp. 141-142

Stock, Wm A , Wang, J. J , and May, A. D., "Priority Lane Operations on the San Francisco-Oakland Bay Bridge " ITTE, Univ. of California (Apr 1971)

Bastarache, G. M , "Here Come the Buses!" *Highway User Quart.* (May 1971).

Reed, M. F., Jr., "Bus Rapid Transit—A New Role " *Highway User Quart.* (May 1971)

"Milwaukee Area Transit Plan, A Mass Transit Technical Planning Study " Barton-Aschman Assoc. (June 1971).

"Buses Before Cars at Southampton." *Highways and Traffic Eng.* (June 1971).

Clarke, W , "Bus Lanes—A Threat to Traffic Flow?" *Commercial Motor,* London (June 18, 1971).

"North Yonge Subway Stations—A Review of Recommended Kiss-n-Ride Facilities." Metropolitan Toronto Transportation Technical Advisory Comm (June 1971).

"Exclusive Bus Lane: A Demonstration Project." City of San Juan, Puerto Rico (July 1971)

Krambles, G., "Expressway Rapid Transit " Presented at 1971 ASCE-ASME National Transportation Engineering Meeting, Seattle (July 26, 1971).

Suen, L , and Johnson, H., "Dial-A-Bus Implementation, Theory and Practice in Canada." Presented at 2nd Annual Demand Responsive Transportation Conf., MIT (July 1971).

"The Shirley Highway Express-Bus-On-Freeway Demonstration Project " National Bureau of Standards, U S. Dept of Commerce (Aug. 1971)

"Busways." ITE Committee 6RA, Final Report to ITE Dept. 6, Div. of Planning Applications (Aug. 20, 1971).

"Dial-A-Bus The Bay Ridges Experiment." Ontario Dept. of Transportation and Communications (Aug. 1971)

"Action Plan for Early Improvements in Transportation Systems in the Washington, D.C , Metropolitan Area " Final Report, U S. Dept of Transportation (Sept. 1971).

"Proposed 69th Street Transportation Center " Wilbur Smith and Assoc with Louis T Klauder and Assoc for Delaware Valley Regional Planning Comm (Sept 1971)

"Metropolitan Atlanta Rapid Transit Plan " Parsons Brinckerhoff-Tudor-Bechtel (Sept. 1971).

"I-35W Urban Corridor Demonstration Project Bus-Metered Freeway Final Report " Metropolitan Council Dept of Transportation Planning, Minneapolis, Minn (Sept 1971)

Ashman, F. T , "Nicollet Mall Civic Cooperation to Preserve Downtown Vitality." *Amer. Inst of Planners Notebook,* Vol. I, No 6 (Sept 1971)

"Rapid Transit for Metro Atlanta." Metropolitan Atlanta Rapid Transit Auth (Sept 1971).

"South Capitol Street Urban Corridor Study " Alan M. Voorhees and Assoc , Wilbur Smith and Assoc , and Frederick R. Harris Assoc. (Sept 1971)

"Reserved Lanes Shorten Commuting Time " *Metropolitan* (Sept -Oct. 1971) pp 25-28

Poston, J. P. H., et al , "Bus Simulation at Signals." *Symposium on Road Traffic Simulation,* Univ of Birmingham (Sept. 1971)

"East Side Demonstration Corridor Program." Ohio-Kentucky-Indiana Regional Planning Auth , Cincinnati (Sept. 1971)

"Urban Corridor Demonstration Program." Schimpeler-Schuette Assoc for Metropolitan Council of Governments, Ohio, and UMTA, Louisville, Ky. (Sept. 1971).

"Shirley Highway Express Bus Demonstration Statistics." *UMTA News Notice No 3,* U S Dept. of Transportation (Oct 1971).

"Chicago Crosstown Expressway " Crosstown Assoc., Preliminary Design, Crosstown Public Transportation System (Oct. 1971)

"Urban Corridor Demonstration Program." System Planning Report, Montgomery-Greene County Transportation and Development Planning Program, Dayton, Ohio (Oct. 1971).

"Buses Increase Highway Capacity." *Passenger Transp.* (Oct 29, 1971).

"Use and Delineation of Exclusive Ways for Public Transport" (in French). *Azienda Transporti Municipali,* Milan (Nov 1971)

"Special Lanes for Buses " Planning and Research Report, Chicago Transit Authority (Nov 1971).

"Buses in Camden. A Study of Bus Segregation in the

Central Area of London." Dept. of Planning and Communications, Borough of Camden, London (Nov 1971).

"Kungsgattan—Bus Street." *Rep No. 21,* City of Stockholm Street Dept. (Nov. 1971).

"The Capital Flyer Bus Service Between the District of Columbia and Maryland and Virginia Counties in the Washington Metropolitan Area " Demonstration Project in center city and suurban employee transportation facilitation Prepared by Metropolitan Washington Council of Governments for UMTA (Nov. 1971).

"Transportation Facilities Planning for Market Street East " Wilbur Smith and Assoc (Nov 1971).

"Express Buses Speed New Yorkers' Trips " *Passenger Transp* (Nov 19, 1971)

"NVTC Gets Funds to Purchase More New Shirley Buses." *Passenger Transp* (Nov 26, 1971).

"Bibliography, Bus Lanes " *UITP Revue,* Brussels (Nov 1971)

"Urban Corridor Demonstration Program Manhattan CBD-North Jersey Corridor " Final Report, Tri-State Planning Comm. (Nov. 1971)

"South Capitol Street Urban Corridor Demonstration Project " Alan M. Voorhees, Wilbur Smith and Assoc , and Frederick R. Harris, Inc , for Metropolitan Washington Council of Governments (Nov 1971).

Smith, W. S , "Bussed or Bust?" *The APWA Reporter* (Nov. 1971) pp 16-21

"Philadelphia Bus Service Area Planning for Market Street East " Wilbur Smith and Assoc for Bower and Bradley, Architects, Philadelphia (Nov 1971).

Young, A P , "Bus Priorities and Lanes in Great Britain." *Traffic Eng* (Nov 1971).

"Freeway Lanes for High Occupancy Vehicles " First Annual Progress Report, California Business and Transportation Agency, Dept of Public Works, to the State Legislature (Dec. 1971)

Parkinson, T E., "Passenger Transport in Canadian Urban Areas " Canadian Transport Comm (Dec 1971)

"Urban Corridor Demonstration Program " City of Dallas Traffic Control Dept , Dallas Transit System , Texas Transportation Inst., and Wilbur Smith and Assoc (Dec 3, 1971)

Fausch, P A , "A Transit Station Simulation." *Traffic Eng* (Dec 1971) pp. 18-25

"Santa Anna Freeway Corridor Study " Prepared by LARTS for SCAG and FHWA (Dec 1971)

"Busway Opens Into Louisville " *Passenger Transp* (Dec 3, 1971)

"MARTA Begins Construction on 50-Mile Rapid Rail System " *Passenger Transp* (Dec 10, 1971)

"Runcorn's New Busway Opened, the First of Its Kind in Europe " *Coaching Jour* , London (Dec 1971)

Wohl, M , "Current Mass-Transit Proposals Answer to Our Commuter Problem?" *Civil Eng.* (Dec 1971) pp 68-70

"Leicester Bus Priority at Traffic Control Signals " Bus Demonstration Project No. 2, Dept of the Environment, England (1971)

"Route 10—Canal Line Urban Corridor Demonstration Project " Frederick R. Harris Assoc. (1971)

"Parking Principles." *HRB Spec Rep. 125* (1971) 217 pp

Pontier, W. E , Miller, P. W., and Kraft, W. H., "Optimizing Flow on Existing Street Networks " *NCHRP Rep 113* (1971) 414 pp.

"Demand-Actuated Transportation Systems " *HRB Spec. Rep. 124* (1971) 121 pp.

Pradillo, P J , and Ortega, R , "Study on Preferential Treatment of Surface Transit in Madrid." Madrid (Spain) Dept. of Traffic (1971).

"Bus Priority System Study." *Directory of Research, Development and Demonstration Projects,* UMTA (1971)

"Freeway Traffic Control System for Improving Bus Rapid Transit " *Directory of Research, Development and Demonstration Projects,* UMTA (1971).

"Examples of Reserved Bus Lane Operation " Toronto Transit Comm (1971)

"Exclusive Lane for Both Bus and Car Pooling." *Directory of Research, Development and Demonstration Projects,* UMTA (1971).

"Blue Streak Phase I Report." Alan M. Voorhees and Assoc. for Washington State Highway Comm and Seattle Transit System (1971).

Manual on Uniform Traffic Control Devices for Streets and Highways FHWA (1971).

"Midtown Bus Terminal Extension Planned " *The Westsider,* New York City (Fall 1971)

"Report of the Exclusive Bus Lane Demonstration on the Southeast Expressway." Bur of Traffic Operations, Massachusetts Dept of Public Works (1971)

State of Texas Public Transportation Development Manual Wilbur Smith and Assoc for Texas Mass Transportation Comm., Austin (1971)

"Transportation in Dublin " Dublin Transportation Study (1971)

"A Bus Priority System for Traffic Signals " Joint project between Kent State University Campus Bus Service, Center for Urban Regionalism, and City of Kent, Ohio, prepared for UMTA (Project Ohio MTD-4) (Summer 1971)

1972

"Bus Lanes " *Res Bibl No. 31,* Dept. of Planning and Transportation, Greater London Council (Jan 1972) 5 pp

Morin, P A , Lindsey, L C , and Riemer, R , "A Report on the Reston Bus Passenger Survey." FHWA (Jan 1972).

"Groundbreaking Opens L A Busway, First in California " *Passenger Transp* (Jan 23, 1972)

Walker, E L , Jr , and Cummings, J J., "Forecasting Impacts of Transit Improvements and Fringe Parking Developments on Downtown Parking Needs." *Hwy. Res Record No 395* (1972) pp 37-46

Webster, F V , "Priority to Buses as Part of Traffic Management " *Symposium on Road Traffic Problems in Ireland,* TRRL, Dublin (Jan 1972)

Rae, B J , "The Mythology of Urban Transportation " *Traffic Quart* , Vol. 26, No 1 (Jan 1972) pp 85-98

SMITH, W S., "Impact of Buses on Traffic Congestion." Prepared for Transport Assn of America (Jan. 1972)

"Dallas Bus Operational Study, Dallas, Texas." Vol. II, "A Report on Immediate Action Transit Improvements." Wilbur Smith and Assoc, Dallas Transit System, City of Dallas, and UMTA (Jan. 1972)

COBURN, T. H., "Bus Priority Experiment on Test Track." *Bus Priority Symposium,* TRRL, England (Feb 1972).

COSTE, J. F, "Bus Lane Experiments in Marseilles" *Bus Priority Symposium,* TRRL, England (Feb 1972)

EARP, J. H, "Bitterne Traffic Scheme" *Bus Priority Symposium,* TRRL, England (Feb 1972).

FRUIN, J. J, "Environmental Factors in Passenger Terminal Design." *Transp. Eng Jour.,* ASCE (Feb 1972) pp. 89-101.

GAHAN, E, "A Bus Lane Experiment on a Major Artery in Dublin." *Bus Priority Symposium,* TRRL, England (Feb. 1972)

HUDDART, K W., "Giving Buses Priority at Signalled Junctions." *Bus Priority Symposium,* TRRL, England (Feb 1972)

KRAFT, W H., and BOARDMAN, T. J., "Location of Bus Stops." *Transp. Eng Jour,* ASCE (Feb 1972) pp. 103-116

"Shirley Highway Express Bus-On-Freeway Project, Project Status Report." Northern Virginia Transportation Comm (Feb. 12, 1972).

MACNICHOLAS, M J., "A Model for the Evaluation of Bus Lanes in a Radial Catchment" *Bus Priority Symposium,* TRRL, London, England (Feb. 1972).

"Exclusive Lanes Approved for Portland Buses." *Passenger Transp.* (Feb. 4, 1972)

"An Evaluation of Free Transit Service" Charles River Assoc, Cambridge, Mass. (Feb 1972).

VINCENT, R A, "Junction Priority for Public Transport." *Bus Priority Symposium,* TRRL, England (Feb. 1972).

YOUNG, A P, "A General Review of Bus Priorities in Great Britain." *Bus Priority Symposium,* TRRL (Feb 1972)

MORIN, D, "Status Report on Highway-Related Public Transportation Projects in the United States" *Transp,* Vol 1, No. 1 (May 1972) pp. 69-78

AVERY, G. A., and ECHOLS, J C., "The Shirley Highway Project. Achieving Effective Intergovernmental Cooperation" *Traffic Quart* (July 1972) pp. 373-390

PETERSON, S. G, and BRASWALL, R H., "Planning and Design Guidelines for Mode Transfer Facilities." *Traffic Quart* (July 1972) pp. 405-423.

BLY, P H, "Bus Lane Simulation" TRRL (1972).

CAPELLE, D G, WAGNER, F A, and HENSING, D J., "Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Car Pools." *Hwy Res Record No 388* (1972) pp. 32-44

WEBSTER, F C., and OLDFIELD, R. H, "A Theoretical Study of Bus and Car Travel in Central London" TRRL, England (1972).

APPENDIX F

SELECTED ANNOTATED BIBLIOGRAPHY

This appendix lists and describes the more important periodicals, books, and other references that deal with planning and design guidelines for efficient bus use of highway facilities The appendix is separated into 10 sections bus lanes, bus priority treatments, bus rapid transit, bus stations, bus stops, bus-vehicle design, busways, express bus service, modal split, and transit systems.

1. BUS LANES

SCHROEDER, W. W, "Metropolitan Transit Research Study." Chicago Transit Auth. (1956).

In considering more effective use of streets, Schroeder suggests the following "*Transit Lanes.* Establish lanes for through movement of transit vehicles and taxicabs. . . At some locations use of this special lane perhaps should be continuous throughout the business day six days per week, while at other locations the *transit* lane would operate only during rush periods five or six days per week."

Although Schroeder recognized the need for better traffic organization and controls to keep streets open and free-running in downtown areas, he does not seem to have recognized the place of the busway as a possible alternative to rail rapid transit in conditions where passenger volumes are too light to be effectively (economically) handled by rail service extensions

RAINVILLE, W S, JR, HOMBURGER, W S., and STRICKLAND, R I, "Preliminary Progress Report of Transit Subcommittee, Committee on Highway Capacity." *Proc HRB,* Vol 40 (1961) pp 523-540

Reserved transit lanes are described and discussed, with examples from five cities showing the improvement achieved in speeds by use of reserved lanes. Also discussed are bus stops on freeways and freeway bus stop capacity

Most buses (at the date of this study) operated non-stop on the portion of route on the freeway network.

The discussion of the paper makes some adverse criticism about the efficacy of exclusive bus lanes where they are not heavily used but reduce the amount of street space available to other traffic. Other recent reports have provided evidence that this is so, and fewer people can actually use a street with a reserved lane for buses, if demand in the other lanes exceeds their capacities and the bus lane is not fully used by bus traffic

De Leuw, C E, and McConochie, W. R., "Exclusive Lanes for Express Bus Operation." Prepared for American Transit Assn Western Regional Conf, San Francisco (Apr. 22, 1963)

This excellent paper, like many "early analyses," gets right to the heart of the problem, defining the conditions under which express buses might prove attractive to patrons, the limitations necessary on road congestion, transit stops, etc., to make the system work so that express riders save substantial time over other transit riders It enumerates some of the real dimensions of urban travel that have to be considered if the service is to work Attention is given to the location of terminal areas, in practical terms of what may be possible, and to the realities of downtown person distribution

Brierly, J, "Exeter's Traffic Management Experiment." *Traffic Eng. and Control* (London), Vol. 10, No. 1 (May 1968).

Describes emergency measures taken during Christmas holidays to increase traffic capacity in the center of Exeter by routing all traffic except buses and emergency vehicles one-way along one of the principal arterials, buses and emergency vehicles were permitted to travel against traffic in a special reserved lane. Results were so encouraging that a modified scheme, incorporating the reverse-flow feature, was instituted on a permanent basis Buses could maintain scheduled performance, whereas before they sometimes lost up to 15 additional minutes on a 30-min run because of traffic congestion. Length of the critical route section appears to be about four blocks

"Traffic Improvements to Speed Express Bus Operations" Metropolitan Washington Council of Governments (Jan. 1969)

Preferential treatment of buses on city streets can effectively reduce bus travel times between downtown Washington, D.C, and suburban shopping center parking areas Treatment includes parkway routes, exclusive use of parkway sections now unused, use of "wrong side" lanes, bus-driver-actuated traffic signals, and signal progression Time savings can be as high as 20 min, or 50 percent of total trip time, for some routes

Brouwer, P, "Separate Traffic Lanes for Buses· What is the Present State of Affairs?" *UITP Revue* (Brussels) Vol. 18, No 3 (1969).

Between 1959 and 1969, use of reserved bus lanes on public streets grew from a handful of experimental applications in the U S to a widely practiced art in nearly a dozen countries The names of 68 transit companies that operate one or more exclusive bus lanes in 11 countries are listed in an appendix. Others doubtless exist Several of the larger cities have considerable mileage of exclusive bus lanes in a number of separate projects, some of which may be 2 miles or more in length The principal advantage to transit riders is the ability of buses to maintain on-time schedules throughout hours of heavy traffic and congestion In many cases, the special lanes are routed along tram tracks and are used by both buses and trams. Frequently, the exclusive bus lane is located on wide streets, leaving several lanes for other traffic. In a few instances, however, the buses have been allowed to preempt one lane of two-lane streets, with great advantage to bus passengers Maximum peak-hour demands on many of the special preserves are for no more than 40 vehicles per hour, in some heavy-demand situations, the level of use may go as high as 112 trams and buses in the peak hour (Brussels). A summary makes three points:

> 1 Public transport should basically be kept outside traffic congestion This can be done, for instance, by arranging special bus lanes
> 2 There is a marked increase in the number of separate lanes for buses
> 3 There is a large number of examples of special bus lanes in various countries, giving a clear indication that they form an efficient and practical method

Lacy, J. D, "TOPICS—Special Bus Lanes" *Circ Memo*, U S. Dept. of Transportation (Sept 18, 1969)

Transmits a Research and Planning Report by the Chicago Transit Authority that describes use of special bus lanes in Chicago to speed bus operations, serve large concentrations of passengers, aid in terminal operations, and maintain service during special events

Report reviews reserved bus lanes in Washington St. from Wacker Drive to Michigan Ave., Canal St. from Randolph to Washington and from Adams to Jackson; River Drive from Adams to Jackson; reserved U-turn lane on Cermak Road at 47th Ave.; special bus lanes on State St (downtown) for use during parades; special lanes for buses handling 21,000 daily transfer passengers at Logan Square rail transit station; "bus only" lanes in 63rd and Halsted Shopping Center, and special bus bridges over Dan Ryan Expressway at 69th and 95th St. stations for passenger transfers to and from rapid transit lines.

"Bus Only Lanes." Planning and Transportation Dept., Greater London Council (May 1970).

A number of "bus only" lanes, in which buses have priority over other traffic at prescribed times of day, are examined The number of lanes installed will be between 7 and 20 Some will permit buses to overtake queues of traffic at congested junctions; some will permit buses to travel against the traffic flow in one-way streets, and some will provide for use of special sections of road and movements (such as turns) that are banned to other traffic. Lanes are examined before and after for traffic capacity and the diversion of traffic to surrounding streets.

VAUGHN-BIRCH, K , "Exclusive Transit Lane " Vancouver, B C. (Nov 1970)

With commuter volumes continuing to increase across Vancouver's Lions Gate Bridge, officials are looking for measures to reduce rush-hour congestion An exclusive lane for transit vehicles was recently installed along Georgia St , the major artery leading onto the bridge The exclusive bus lane extends for six blocks out of the CBD, through an area where accumulation due to turning movements, pedestrians, and passenger pick-ups previously caused heavy congestion in the curb lane The average bus travel time over the distance covered by the regulation was reduced from 6 4 to 4 5 min (30 percent), while patronage increased by 12 percent in the four months following installation of the new system.

CLARKE, W , "Bus Lanes—A Threat to Traffic Flow?" *Commercial Motor,* London (June 18, 1971)

Considers the negative aspects of reserved bus lanes In general, urges that such lanes not be established until study has verified that they will not cause more person-delay to motorists than the time savings achieved by bus riders, discusses the hazards implicit in permitting contra-flow buses on one-way streets Mentions other possible problems. Notes that the use of very short street sections for exclusive bus use does not usually create these problems Inasmuch as all but two of 35 contra-flow operations surveyed by Constantine and Young ("Existing and Proposed Bus Priority Schemes," *Traffic Eng and Control,* May 1969) were less than 500 ft in length, it appears that most of these situations have created few of the problems that concern the author.

"Urban Corridor Demonstration Program " Schimpeler-Schuette Assoc for Metropolitan Council of Governments, Ohio, and UMTA, Louisville, Ky (Sept 1971)

In the absence of a freeway in the corridor selected for study in Louisville, transit service improvements take the form of conventional measures, applied in imaginative ways, to improve transit riding in the corridor Perhaps the most important improvement in this regard would be the designation of a pair of one-way streets, each with four lanes, with a reserved bus lane provided on each street at peak hours only These would be "wrong-way" lanes, with buses moving against traffic. Buses would use the inbound street during afternoon peak hours for outbound buses, thereby adding a bus lane to the four lanes used by car traffic on the adjacent street. The situation would be reversed in morning peaks, with buses using the outbound street to carry transit passengers into the CBD. It is anticipated that buses would have at least a 25 percent time advantage over cars using the parallel streets during the hour of peak congestion

Other measures would include preemption of traffic signals by bus drivers through use of special radio frequencies, enabling the bus to avoid some traffic signal delay.

Special express transit routes would also be developed in the one-way corridor to take advantage of the new street operation Other control improvements would consist of special provisions for left turns at locations where such turns are prohibited to other traffic, and experimental use of two-way radio between buses and a helicopter to see if advantage can be gained by permitting buses to evade bottlenecks and traffic tie-ups when they are spotted from the air

"Buses in Camden A Study of Bus Segregation in the Central Area of London " Dept of Planning and Communications, Borough of Camden, London (Nov 1971)

An engineering study to appraise the feasibility of improved bus service in central London a theoretical application

The bus segregation schemes considered demonstrate that it is technically feasible to provide separate bus facilities on all the main roads throughout the study area That is not to say that there are no problems, but rather that with some traffic engineering ingenuity they can be overcome Certain details need to be considered, including traffic signal arrangements and how these can be incorporated in the proposed Area Traffic Control Scheme Other details need consideration jointly with the Greater London Council, London Transport, and Metropolitan Police in a manner similar to that adopted for other traffic management schemes.

Probably the most important result of the study is that it should be possible to increase bus operating speeds by between 40 and 50 percent and reduce over-all bus journey times by about one-third

Losses to non-bus traffic are likely to be substantial, but considerably less than the benefits to bus passengers and the bus operator.

YOUNG, A P., "Bus Priorities and Lanes in Great Britain " *Traffic Eng* (Nov 1971)

Discusses various bus-only lanes and contra-flow operations, usually applicable to very short sections of route in several towns in England Much of the information seems to be drawn from the survey of special bus lanes conducted in 1968 (See Constantine and Young, "Existing and Proposed Bus Priority Schemes," *Traffic Eng and Control,* May 1969).

BLY, P H , "Bus Lane Simulation " TRRL, England (1972).

Based on the test track experiment with bus lanes, the TRRL is developing a computer model simulating traffic flow in a with-flow bus lane The following points were made. (1) Simulation is for a single approach to a signalized intersection. (2) Input to the model includes approach volume, proportion of trucks, cars, and buses, and left-turning, right-turning and straight vehicles, the position of vehicles in the simulation model is randomly distributed, volume of opposing traffic hindering right turns crossing intersection (the model simulates the British left-hand traffic rules), distance from intersection where bus lane is terminated (3) The model is being developed for an ICL 470 computer (4) Five hours of real travel are simulated in 1 min on the computer (5) The model is being developed and is not yet fully operational

"Bus Lanes." *Res Bibl No 31,* Dept of Planning and Transportation, Greater London Council (Jan. 1972) 5 pp

Contains information on the sources for data concerning reserved lanes, busways, bus priority schemes, etc, under four major headings London, other United Kingdom areas, overseas, theoretical aspects

Young, A P., "A General Review of Bus Priorities in Great Britain" *Bus Priority Symposium,* TRRL, England (Feb 1972).

> The first and most obvious reason for affording preferential treatment to the bus is that it plays a crucial part in the balance between public and private transport, and as such potentially holds the key to the problem of peak congestion The success or failure of public transport will influence the quality of urban life and the form of urban structure for the future
>
> A second, but equally important, reason for giving priority to the bus rather than to any other road vehicle is that the bus is the only road vehicle which is an interrelated part of a time-dependent system A delay to a private car, or even a commercial vehicle, is experienced as time lost to that vehicle only A delay to a bus creates a disturbance in time which is propogated throughout a route or network, ultimately affecting all the buses in the system A result is the familiar phenomenon of bunching Furthermore, the unreliability thus created decreases the demand for the service. The bus, therefore, cannot fulfill its function unless delays are kept to a minimum, and predictable, level
>
> There is a third reason for giving special consideration to public transport services, and this is the need to maintain user convenience For services to remain attractive, access times must be kept to a minimum
>
> It would be misleading to suggest that the provision of adequate bus priority measures will alone ensure reliable standards of service But it can be argued that without these measures, bus operation in congested urban areas will not be able to meet the demands made of public transport in the future
>
> A recent circular from the Public Road Transport Association lists 45 towns and cities where bus priorities are currently in operation, and over 30 of these towns have schemes which have been introduced since 1968
>
> The use of bus priority measures appears to be focusing on three problem areas They are the central area, the main radials, and specific local problems

Comprehensive traffic management approaches have been attempted for the central areas of three towns of about 100,000 population each—Reading, Derby, and Stockton-on-Tees These have been fairly successful. There has been less success on schemes to improve conditions on main radial routes, although experiments are under way in Southampton, Dublin, and Manchester

> The majority of bus priority schemes introduced to date are in the third category, namely, those designed to overcome specific local problems They may be a part of a larger traffic management scheme, but do not form part of a comprehensive approach to the problems of public transport operations in a given area These schemes may often appear insignificant, but a simple priority or exemption can be of great benefit in reducing delay or maintaining passenger convenience
>
> There will always be a need for the small local priority measure to fulfill a specific function It may be needed to reduce delay at a particular point, or to minimize the adverse effects on bus operation of traffic management schemes A short length of bus lane, or a turning exemption can, if strategically placed, bring considerable benefits for a relatively small investment
>
> Recent experience suggests that in medium-sized towns it will be feasible to design traffic management schemes which incorporate sufficient bus priority measures to enable buses to operate satisfactorily in central areas It remains to be seen whether or not these principles can be applied to a large city
>
> The situation on main radial routes is less encouraging There is a fundamental reason for this concern The philosophy currently applied in urban redevelopment and highway construction is based upon the principles of a hierarchical highway network and the segregation of pedestrian and vehicle movements These objectives are in themselves sound, but they unfortunately conflict with the essential characteristics of an efficient public transport service There is a growing number of examples of urban renewal schemes where bus routes have become fragmented and tortuous because they are forced to conform to a highway network designed primarily for private transport. Resolution of this conflict can only be sought in the earliest design stages

"Exclusive Lanes Approved for Portland Buses" *Passenger Transp.* (Feb 4, 1972).

Two major downtown streets (5th Ave and 6th Ave) in Portland, Ore, are now operated as a one-way pair. It is proposed that the two right lanes on each street be reserved exclusively for buses over a 10-block stretch in the CBD, the remaining two lanes on each street are for cars and trucks One of the reserved lanes on each street would be for bus loading, the other would permit buses to "leapfrog" around stopped buses for alternate-stop service, express operation, etc.

2. BUS PRIORITY TREATMENTS

Constantine, T, and Young, A P, "Existing and Proposed Bus Priority Schemes" *Traffic Eng and Control* (May 1969)

Bus priorities are suggested as an alternative to expensive rapid transit projects, or as a simple and effective measure to improve the attractiveness of public transport. A survey of existing and proposed schemes is described and some conclusions are drawn from the results The survey reported on 35 instances where reserved bus lanes had been instituted or were in the development stage, in addition, reports were obtained on 15 bus-only streets (only five current, the others being developed) Most reserved bus lanes represent bus-flow opposing traffic in one-way streets, and most reserved sections were less than 500 ft in length, with some up to 2,000 ft long, indicating that these are primarily "spot" controls to overcome specific bottleneck situations Volume of buses did not seem to be a significant criterion All examples are identified, and information is supplied on type of bus lane, its length, width, bus volume (peak and off-peak or all-day), hours of operation All examples are in England or Scotland

Newman, L, Dunnet, A, and Meis, G. J, "Freeway Ramp Control—What It Can and Cannot Do" *Traffic Eng* (June 1969) pp 14-21

The California Division of Highways began ramp metering experiments in 1969 at three locations—two in Los

Angeles and one in the San Diego area. Objective of the study was to reduce over-all travel time to the total traffic stream—freeway and local street traffic. By controlling the number of vehicles allowed to enter a freeway ramp at a critical location on the freeway when freeway volumes approach breakdown levels, such breakdown would be avoided and delays on the freeway would be avoided or reduced.

EVANS, H. K, and SKILES, G. W., "Improving Public Transit Through Bus Preemption of Traffic Signals." *Traffic Quart.*, Vol 24, No 4 (Oct 1970) pp. 531-543.

One means suggested for relief of traffic congestion is automatic extension of traffic signal green time to permit passage of buses. A manual system was tested in Los Angeles to determine whether there was an improvement in over-all traffic flow at two intersections in the CBD. A detailed analysis is presented of this study, which concluded that extension of the experiment to other intersections would result in a 5 to 7 percent reduction in portal-to-portal time and in a 15 to 20 percent reduction of riding time in Los Angeles. The bus occupancy level at which preemption is justified is chiefly a function of side-street auto volumes and bus volumes on the main street.

"Los Angeles Area Freeway Surveillance and Control Project" First Annual Report, Business and Transportation Agency, Dept. of Public Works, to the State Legislature (Jan. 1971) 19 pp.

For many years, the need for better communication between the user of the California highway system and the system itself has been recognized. The 42-mile surveillance and control project in the Los Angeles area is considered to be a major step toward fulfilling that need.

The project is an experimental effort to test and evaluate a freeway surveillance and control system that could eventually become a standard installation on most urban freeways. The project will include four basic phases· (1) an electronic surveillance system with traffic-responsive ramp control, (2) early detection and rapid removal of unusual "incidents", (3) "real time" warning and information, and (4) service for stranded motorists In addition, a major air monitoring experiment is being coordinated with the project This experiment will determine the amount and distribution of automobile emissions on and adjacent to the freeway It will then attempt to relate the level of emissions to freeway geometrics and operating conditions.

"A Bus Priority System for Traffic Signals" Joint project between Kent State University Campus Bus Service, the Center for Urban Regionalism, and the City of Kent, Ohio Prepared for UMTA (Project Ohio MTD-4) (Summer 1971).

Bus travel times and delays can be reduced through improved traffic control equipment and proper signal timing, and through modification of existing traffic controllers by which special consideration is given to vehicles carrying large numbers of people

WEBSTER, F V., "Priority to Buses as Part of Traffic Management." *Symposium on Road Traffic Problems in Ireland,* TRRL, Dublin (Jan 1972).

TRRL has used three different methods of assessing the suitability of bus lane schemes Analysis of this work is continuing, but the following tentative conclusions are made·

Track Experiment

1 A position for the end of the bus lane relative to the stop-line could be found such that the loss of saturation flow for non-bus traffic was almost negligible, while the saving of delay to buses was practically the maximum possible

2. This position depended on the length of the green time, in the experiment with the particular values of the variables this position was 60 m from the stop-line and the estimated saving to bus passengers for an equilibrium queue length at the junction of 100 m was nearly 40 bus passenger-hours per hour.

3 Bus bays sited at the stop-line were found to have advantages over bus bays sited some distance from the stop-line, the capacity of the intersection was increased due to occasional use by non-bus traffic, and the buses found it easier to leave the bus bay when sited at the stop-line.

Theoretical Work

1. A bus lane at an isolated signalled junction could be represented by a simple theoretical simulation, which could effectively extend the track experimental results to unsaturated conditions and to other cases where different signal settings and different bus flows, etc , were used.

2. A simple representation of a network link showed that under certain circumstances non-bus traffic along the link could apparently be speeded up when a bus lane is installed, even though this would not be true for longer journeys on the network This illustrates the dangers of considering too small an area for assessing the effects of a bus-lane scheme

3 The more sophisticated model of a homogenous urban area as applied to central London suggested that a comprehensive bus-lane network over the whole area operating all day would produce a net loss in over-all travel speeds. If operating for the peak periods only, an over-all gain could be achieved with speeds rising to 18 km per hour This analysis assumed that the bus lane ended at such a distance from the stop-line that 0.45 of the pcu's used that portion of the nearside lane between the end of the bus lane and the stop-line.

Study of Actual Bus Lanes

1 With most of the ten bus-lane schemes studied, bus journey times decreased, usually by about 2 min.

2 Non-bus traffic journey times were less consistent sometimes there was a saving, at other times there was no change, or even a loss. In most cases, a fall-off in non-bus flow on the roads resulted

3 Where there was a gain to both buses and other traffic it was generally because capacity of the road system had been increased at the time of implementation; e.g , through banning parked vehicles or creating an extra lane.

4 The main difficulties associated with bus-lane schemes were with loading and unloading of commercial vehicles, turning traffic, and enforcement problems.

VINCENT, R A, "Junction Priority for Public Transport." *Bus Priority Symposium*, TRRL, England (Feb. 1972).

> Clearly, if public transport vehicles are to be given priority at interchanges, it must be accepted that this will, in many cases, be to the detriment of other road users It should be remembered, however, that the timing of traffic signals and indeed their installation in the first place has been inherently biased against public transport by the assumption that a bus can be simply treated as a few pcu's. Giving priority to public transport can be considered as merely trying to correct this earlier fundamental error, thereby removing the unwarranted advantage given to private transport. . . .
>
> It must be emphasized here that wherever the buses travel unsegregated from private traffic the improvements achieved for buses by any priority method which increases the capacity of the bus phase of the signals must necessarily be shortlived The extra capacity will be rapidly used up by private traffic Ideally, therefore, such methods should be used in conjunction with bus lanes leading close enough to the stop-line for buses to cross on the first green after arrival. This gives permanently increased capacity to buses and has the added advantage that the retiming of signals to give less bus delay can be more effective due to the practical elimination of random delay . .

Conditions other than isolated signals also are dealt with, including

1. Re-ordering of phases at intersections with more than two phases to provide two short green phases for buses, alternating with the other phases in a single cycle
2 Special phases called only by driver-operated signal from the bus, for left-turning phases not allowed other vehicles, or for early start through the intersection after the bus has loaded at a stop prior to entering the intersection.
3 Extension or recall of a normal phase by bus detection, so that the bus can avoid waiting through an entire red phase.

A variety of examples in England and Switzerland are given The paper concludes

> It is clear that methods for giving public transport priority are available even though not fully developed. What is mostly lacking is the will to use them because of pressure from other road users It is particuarly the job of town planners and traffic planners—to whom the inevitability of some form of preference for public transport in towns is clearer than to many—to make the case politically acceptable, especially at a local level.

COBURN, T. H., "Bus Priority Experiment on Test Track." *Bus Priority Symposium*, TRRL, England (Feb. 1972).

Describes an elaborate 4-day experiment using 160 cars and 40 buses. A great variety of conditions were explored with regard to saturated traffic flow under different conditions of cycle length, number (%) of buses in traffic, proportions of right and left turns, etc. From these tests it was found that positioning of the bus stop is important—the closer the stop is to the intersection, the more efficient it is in minimizing time losses

HUDDART, K W., "Giving Buses Priority at Signalled Junctions" *Bus Priority Symposium*, TRRL, England (Feb 1972)

> Equipment exists or could readily be designed to detect buses and to give them priority at traffic signals Complications in the traffic engineering demand care in selecting sites at which a net benefit to travelers can be obtained, so that the likely extent of this application is limited Some advantage is already given to buses by linked signal systems and Area Traffic Control, and this advantage can be increased by taking account of the economic importance of the bus in calculating the signal plans

3. BUS RAPID TRANSIT

WILLIAMS, L, "Planning Public Transportation on Urban Expressways" *Proc HRB*, Vol. 25 (1945) pp. 363-375.

Sets forth the broad public interests that would be served and the types of public transportation service that could be rendered by operating public transportation vehicles—motor buses, trolley coaches, and electric cars—on urban expressways.

Indicates the facilities necessary to permit public transportation to provide an adequate and safe service and advocates the incorporation of turnouts, off the traveled roadways, for free-wheel rubber-tired transit vehicles and rails and transfer stations in the central malls where traffic volume warrants. Suggests that these improvements be financed, as are highways, through taxation because such provisions are essential features of the highway, built for the convenience and safety of the public; and persons using public transportation, presumably, pay their fair share of the taxes used for highway improvements.

Points out that by combining expressway design features, including turnouts and transfer stations, a highway is produced, which, on a passenger-mile basis, is safer and generates more capacity per construction dollar spent.

HOMBURGER, W. S, "A Study of Express Bus Operations on Freeways." *Res. Rep. No. 23*, ITTE, Univ. of California, Berkeley (Nov. 1956)

A review of three express bus operations inaugurated in January 1956 by San Francisco Municipal Railway, using the Bayshore Freeway. On two routes, most passengers were diverted from other transit lines. On one route, 24 percent of passengers formerly drove cars Because local transit fares are a flat sum, the new operations ran deficits because of longer distances traveled. Because transit labor costs vary with time rather than mileage, the deficit was kept relatively low because of higher speeds. It was concluded that freeways are a feasible means of serving passengers between outer sections of a city and its downtown area, with time savings being the principal attraction.

"A Policy on Arterial Highways in Urban Areas." Excerpts on Public Transit, Amer. Assn. of State Highway Officials (1956).

Tentative standards are identified for provision of public transport on streets and highways. These include turning radius, length of bus stops, bus stop designs on freeways.

Bus Stops at Intersections Both near-side and far-side locations are used. Far-side stops are advantageous where: (1) other buses turn in either direction, (2) turning movements from the major street are heavy, particularly right turns, (3) cross-traffic is heavy and parking lane is needed for storage, and (4) several streets meet at the intersection. Midblock bus stops generally are advantageous only on streets without parking.

Lengths of bus stops on major streets should be 80 (preferably 100) ft at intersections, and 120 ft at midblock locations For two buses, the dimensions should be increased by 40 ft Where borders are wide enough to provide separate bus turnouts, their length, including reverse-curve widening, should be 100 to 130 ft at far-side and 150 to 200 ft in midblock locations.

HOMBURGER, W S, and KENNEDY, N, "The Utilization of Freeways by Urban Transit Buses A Nationwide Survey" *Res Rep. No. 28*, ITTE, Univ of California, Berkeley (June 1958)

Intraurban freeway express buses are operated in one-half of the 40 major metropolitan areas of the U.S Service is predominantly non-stop between downtown and outer terminals, which are generally in residential areas Routes range from 6 to 40 miles. Some cities provide service throughout the day, but many routes operate only during weekday peak periods. Speeds range from 16 to 45 mph A truly "rapid" service is doubtful in mixed traffic

"A Study of Bus Rapid Transit Operations for the National Capital Region." Prepared by NCTA, with supplementary studies by Operations Research, Inc, Kaiser Engineers, Wilbur Smith and Assoc. (July 8, 1963).

Discusses the advantages of bus rapid transit in comparison to rail, and the advantages that rail has over bus in certain circumstances. Makes the following observation

> Analysis of the advantages and disadvantages inherent in both transit modes indicates clearly that buses are more economical and more adaptable to service requirements in low traffic density use (i.e, in feeder and local services and along low-density radial corridors), while rail transit (inherently faster, safer and more comfortable) is required in the downtown area and along high-density routes.

"Volume Capacity Implications for Bus Transportation in CBD, Washington, D C" App. IV. Prepared for NCTA by Wilbur Smith and Assoc (July 1963).

Considered the variety of special conditions that might be put into effect to maximize bus transit use and efficiency of operations to achieve prescribed performance levels in the Washington, D.C, CBD. An all-bus rapid transit system was developed to distribute traffic within the "Zero Sector," assuming levels of demand by 1980 which had been developed in considering rail rapid transit To accommodate increases projected, special provisions for buses were described Two special bus subways were suggested for part of the downtown distribution because of the added capacity afforded and the freedom from interference and street sharing by other vehicles and pedestrians.

RAINVILLE, W. S., JR, "Expressway Bus Operations, 1963." American Transit Assn. (Aug. 31, 1963).

Results of a survey of 24 urban transit companies regarding experience with transit bus operations on expressways in urban metropolitan areas up to July or August 1963 Among the companies represented were Alameda-Contra Costa (Bay Area in Calif), Los Angeles MTA, Atlanta Transit System; Philadelphia Transp. Co., Niagara Frontier Transit (Buffalo), Cincinnati Transit Co, Dept of Street Railways, Detroit, San Francisco Municipal RR, San Diego Transit, A B &W. (Washington, D.C); Pittsburgh Railways Co., Chicago Transit Authority, Cleveland Transit System; Chicago and Calumet District Transit, Cincinnati, Newport & Covington Transp. Co., Metropolitan Dade County Transit Authority, United Motor Coach Co. (Des Plaines, Ill), Baltimore Transit Co, Virginia Transit Co (Richmond), Sacramento Transit Authority; and Metropolitan Corp of Greater Winnipeg. Additional data were obtained from St Louis, Dallas, and San Antonio

All 24 reporting cities have one or more express routes using freeways Six report that they make stops on the freeway (only one of these has no special bus stop facility in the freeway). Alameda-Contra Costa, Los Angeles, and Atlanta reported 25 or more routes that operate over portions of freeways Alameda and Los Angeles reported more than 240 peak-hour bus operations on expressways each day Express use of the freeways is reported to have slowed the loss of patronage in those systems that make extensive use of such service and often has shown growth on the routes that use the freeways. Average speeds were improved on routes diverted to freeways, with savings in travel time of 35 to 40 percent in some cases.

No city reported reserved lanes exclusive to buses, except for a "priority" afforded buses using the San Francisco-Oakland Bay Bridge while the lower deck was being resurfaced. However, at the peak hour of operation on the bridge, 175 buses carried 7,200 passengers vs 1,981 passenger cars with 3,314 occupants—better than two to one in favor of transit and a "clear cut case" for a reserved all-bus lane according to BPR criteria.

"Use of Freeways by the Los Angeles Metropolitan Transit Authority." Office of Chief Engineer, LAMTA (Sept 1963).

Reviews use by the Transit Authority of 12 of the 18 area freeways for 26 bus line revenue operations, plus use of all 18 freeways when nonrevenue equipment movements are considered. Discusses three types of freeway bus stops one involving special pull-out lanes for passenger stops; another involving on-off freeway movements at ramps or interchange roads; a third type being stops on the freeway shoulder near intersections of local streets The third type proved unsatisfactory because of lack of acceleration-deceleration lanes, but was continued in operation on one freeway because of demand

Operating speeds ranged from 12.6 to 26 1 mph, with all routes showing considerable time savings over surface-street routes Traffic accidents per 1,000,000 bus miles were 28 03 on freeway lines and 87 16 on surface lines. Accidents per 1,000,000 passengers carried were 1.15 for freeway lines, 9.51 for surface lines All freeway lines showed a profit. Although no special fares are charged, minimum fares have been set that act as premium fares for the small number of passengers who alight at intermediate points along particular lines.

BOCKEMUHL, A., and BANDI, F., "Horizontal and Vertical Separation of Public and Private Transport to Improve the Fluidity of Urban Traffic." *Proc. 35th Internat Congress,* UITP, Vienna (1963).

This exhaustive study of public transport in major cities of the world places emphasis on means to separate transit vehicles from other forms of traffic in the interest of speeding the performance and improving the competitive stance of public transit. Most of the report is devoted to examination of means in use for separating trains, trams, and buses from conflicts with other modes of travel. Typically trains and trams on steel rails occupy rights-of-way that have some degree of physical separation from other vehicle types, where they operate on the same level or plane In addition, rail vehicles are often separated from street traffic by a vertical change, placing them in subways or on elevated facilities, thereby eliminating intersection conflicts with other forms of travel

Buses, being part of the normal street traffic and using the same pavements provided for cars and trucks, are less frequently provided with exclusive facilities than are other public transport modes In recent years there has been a proliferation of special reserved lanes for buses, and the report takes the position that such lanes are justified, where they are physically feasible, if the peak-hour volume of buses amounts to 75 or more vehicles, or the daily volume amounts to 500 or more

Includes an extensive description of the reserved bus lane developed in Chicago on Washington St. A center lane in the one-way street was reserved for buses, which numbered about 90 per hour during peak periods (pp. 45-49)

Most of the study relates to railways and trams.

HODGKINS, E A, "Effect of Buses on Freeway Capacity" *Hwy Res Record No 59* (1964) pp. 66-82

The auto equivalency factor for a bus on a reasonably level freeway is 1 6 An exclusive bus lane can carry 1,300 buses per hr in the right-shoulder lane or middle lane at 25 mph, but up to 1,450 buses per hr at 35 mph in the far left lane.

An exclusive bus lane is judged as not practical unless the freeway is operating beyond its normal capacity to a point of congestion, and at least 200 buses per hr would use the lane in peak periods

ZELL, C F, "San Francisco-Oakland Bay Bridge Trans-Bay Bus Riders Survey." *Hwy Res. Record No 114* (1966) pp 169-182

A survey was made to determine if an exclusive bus lane provided in 1961 on the Bay Bridge caused a significant number of people to change from auto to bus travel. The study indicated that patronage increased 6 percent from 1961 to 1962, coinciding with the inauguration of the exclusive lane, but also increased 6 percent from 1960 to 1961, before the exclusive lane was established. There is no evidence that the exclusive bue lane caused a major increase in bus patronage or a significant reduction in auto traffic on the Bridge Three percent of the bus passengers interviewed had switched from auto travel during the exclusive lane period. Of these, 38 percent said they switched to bus travel because it was more convenient, and 23 percent because the bus was faster. Only one out of 239 former auto users said specifically he switched because of the exclusive bus lane. Changes in place of employment or residence caused large shifts in bus patronage.

"Transportation and Parking for Tomorrow's Cities." Prepared by Wilbur Smith and Assoc for Automobile Manufacturers Assn., Detroit (1966).

As part of this comprehensive study, bus rapid transit is considered in concept and considerable detail in one of the first published discussions of the potentials and likely manner of operation for a bus rapid transit system Basic configurations of bus rapid transit services are set forth for a variety of hypothetical situations to illustrate the flexibility inherent in this type of system.

DREW, D. R, "Some Aspects of Reverse-Flow Freeway Design" *Hwy Res. Record No. 172* (1967) pp. 39-53

Discusses the reverse-flow freeway and its use in accommodating projected traffic demands, and suggests interchange designs that enable ingress and egress directly to and from the at-grade street system rather than the outside freeway roadways Explains a step-by-step procedure for using this type of reverse-flow facility.

MAY, A. G., NEWELL, G. F, OLIVER, R M., and POTTS, R. B, "Q's and Q's" *Bull. Oper. Res. Soc. of Amer.,* Vol. 15, Suppl. 3 (1967)

If a highway system is to be used for both public (buses) and private (cars) transportation, it is often advantageous to give some type of priority service to buses. Because severe congestion is usually confined to only a few critical sections of a highway or to some critical bottlenecks, a priority scheme for service of these bottlenecks could have a significant effect on the total passenger delay in the entire highway system Two related types of strategies are considered. First, suppose that on a finite section of a multilane expressway there is a total flow *Q* and no queue at the entrance or exit If buses are given one or more lanes for exclusive use, it is possible to achieve a higher velocity for buses but a lower velocity for cars than would exist under mixed operation at the same total flow The higher velocity for buses, each carrying many passengers, will in many cases offset the increased delay to car passengers Second, if a queue does exist at a bottleneck, there are various queue disciplines that might be applied to keep the queue of buses as low as possible, at the expense of the cars Strategies of first come, first served, priority service, and separate service for buses are compared under the condition of a heavy rush-hour demand

"Joint Project Concept. Integrated Transportation Corridors." Prepared by Barton-Aschman Assoc for U S Dept of Housing and Urban Development (Jan. 1968)

Reviews a wide variety of joint development projects to show how they can serve as effective means for integrating major urban transportation facilities with the surrounding urban environment. The influence of joint project opportunities should be felt in the actual process of route location, as one factor in evaluating alternatives.

The major conclusion is that no unusual or especially significant problems stand in the way of much wider use of the joint development concept. Transit and parking facilities related to urban freeways are reviewed, along with other joint development programs. Extensively illustrated, with a few examples of bus priorities.

FREBAULT, J., "Effect on the Community of Creating a Lane Reserved for Buses." Road Traffic Studies and Res. Dept., France (July 1968).

The first stage of the research consists of determining theoretically the time saved and time lost by users after the creation of the lane, as functions of the characteristics of the road and traffic conditions It assumes that there will be no transfer of users between private cars and buses, nor any change of route Measurements are then made that enable a relation to be established between journey time and the flow of buses on the reserved lane Criteria are formulated to enable the creation of a special lane for buses to be justified

DEEN, T. B, and JAMES, D. H., "Relative Costs of Bus and Rail Transit Systems." (Aug. 1968).

Cost figures were developed for a busway system and then related to historical cost data for rail transit services and equipment. This required setting up standards for all aspects of bus service and peripheral facilities as well as the busways.

Hypothetical bus and rail systems were developed that provided identical services for the two modes. Relative costs for providing the service vary, depending on line length, proportion of the line requiring subways, and passenger loadings. Sensitivity of costs to rising wage rates and variable interest rates was examined

Rail systems can demonstrate cost superiority where peak-hour passenger volumes exceeding 12,000 per hour must be carried and/or where more than 20 percent of the system requires subways At volumes of 4,000 peak-hour passengers, and where no subways are required, buses show cost superiority.

"Bus Rapid Transit on Our Freeways." Res Dept., National Highway Users Conference, Washington, D.C. (Aug 1968) 12 pp. (mimeo.)

Reviews existing urban transit bus operations on freeways in Chicago, Kansas City, Los Angeles, Miami, Milwaukee, Minneapolis, Oakland-Berkeley, Richmond, San Diego, San Francisco, Seattle, St. Louis, and St. Paul. Discusses future plans for similar operations in Baltimore, Detroit, Houston, Minneapolis, Pittsburgh, Atlanta, Washington, D.C., and Milwaukee County, Wis

"Urban Commutation 'Alternatives" FHWA, Office of Planning and Program Review (Oct. 1968) pp. 6-7

Comparisons are made between cost to develop additional freeway capacity to accommodate peak-hour auto traffic in a corridor and cost to develop a single reversible lane exclusively for buses, or to develop a two-lane busway, or otherwise provide for an exclusive bus roadway. Bus service is costed on the assumption of front-door jitney pickup on scheduled demand, transfer to waiting bus (operating on not more than 5-min headways) and express (non-stop) run to CBD, with transfer to a delivery vehicle making only two or three stops in CBD; door-to-door time not more than 5 min greater than by private car (possibly less than by car). It is far cheaper to provide transit express service than additional cars at peak hours—in some cases the cost to the community is only one-fifth or one-sixth as much.

GLENNON, J. C., and STOVER, V. G, "A System to Facilitate Bus Rapid Transit on Urban Freeways." Texas Transp. Inst. for UMTA (Dec. 1968) 95 pp.

Discusses the technical feasibility of providing priority operation for buses on urban freeways by employing freeway surveillance and control. Under this system (Bus-Freeway System) buses would be provided priority access to the freeway via exclusive bus ramps; automobiles would be metered into the system so as to use the excess capacity, but short of the volume that would jeopardize the desired level of transit service.

In evaluating the technical feasibility of the Bus-Freeway System, preliminary designs and cost estimates were prepared for four existing freeways: (1) John C Lodge Freeway in Detroit, (2) Gulf Freeway in Houston, (3) I-35W in Minneapolis, and (4) Penn-Lincoln Parkway (east) in Pittsburgh.

The preliminary designs present the plan and profile of the existing freeway and show the necessary modifications for the Bus-Freeway System, including. (1) location and type of each surveillance and control element, (2) location and design of bus ramps, and (3) approximate location of bus terminals.

The estimated costs of modifying the four study freeways for operation of a Bus-Freeway System are considered to be representative of the costs that might be encountered in converting other existing freeways or in constructing a Bus-Freeway System on new location. These cost estimates include (1) bus ramp construction costs, (2) bus terminal construction and right-of-way costs, and (3) capital costs of the surveillance and control system. Cost estimates for all surveillance and control elements are for current (1967) prices based on the cost of equipment and installation of the John C. Lodge and Gulf Freeway facilities operated by the Texas Transportation Institute

The capital costs to modify the four study freeways to a Bus-Freeway System operation were found to range from $519,000 to $785,000. Annual operation costs vary between $226,000 and $288,000

CORRADINO, J. C, "Busways—Rapid Transit for an Intermediate-Sized Metropolitan Area." Simpson and Curtin for Society of Automotive Engineers (Jan. 1969).

Reviews busway proposals for Atlanta, Boston, Memphis, and Portland-Vancouver. Contains detailed information on costs, travel speeds, projected patronage, and cost-earnings estimates.

A rapid system for intermediate-sized areas (those containing one to two million people by 1980) is a possibility, and although a fixed-rail system may not be attainable, rapid bus transportation, commonly known as busways, might be The busway is a relatively new innovation in the field of mass transportation Essentially, buses circulate through residential communities, then speed over exclusively reserved trunk lines to the CBD.

"Sensitivity Analysis of the Evaluation of a Bus Transit System in a Selected Urban Area " FHWA (June 1969)

A followup to a previous study that found bus transit a viable alternative to the construction of more urban highways. These elements are considered (1) the effect on transit patronage of various policy modifications, such as changes in bus fares and parking rates; (2) how different components of transit service and design contribute to the attractiveness of bus transit, (3) the different effects of congested and uncongested roadway facilities on transit patronage, and (4) the effectiveness of providing public transportation service to an entire metropolitan area through a fine-grained, ubiquitous bus transit network, including exclusive busways, a downtown terminal, and a pedestrian distribution system.

MORIN, D A , and REAGAN, C. D , "Reserved Lanes for Buses and Car Pools " *Traffic Eng.*, Vol 39 (July 1969) pp. 24-28.

Analyzes the delay inflicted on low-occupancy automobiles when various combinations of buses and "car-pool autos" are granted exclusive use of one lane on a freeway. The analysis is applied to demands of 10,000 and 20,000 persons/hour (one-way) for the four conditions of (1) mixed flow on all lanes, (2) one lane reserved for buses only, (3) lane reserved for all vehicles with two or more occupants, and (4) lane reserved for all vehicles with three or more occupants.

With four freeway lanes for one-way flow, and a demand for 20,000 person-trips pèr hour, reserving one lane for buses only, or for buses and cars with two or more occupants, would mean greater total delays than under mixed traffic flow. The least delay would occur if one lane was reserved for all vehicles containing three or more persons

RUSSELL, G. L , "Exclusive Bus Lanes " *Traffic Bull. No. 18,* Traffic Dept , California Dept of Public Works (Nov 1969) 8 pp.

Relates to legislation favoring buses on freeways. The Carrell Act (California Senate Bill No. 43 approved by the Governor August 7, 1969) "intends to authorize and encourage the Department of Public Works to study and experiment with various methods of freeway use to discover the manner in which the freeway system in urban areas can be most effectively utilized " The Carrell Act further states under § 149 of the Streets and Highways Code.

> In addition to all other existing or future authority relating to the joint use or occupancy of highways, the department may, by regulation or cooperative agreements with public or private agencies furnishing mass public transportation, authorize or permit exclusive or preferential use of freeway lanes for such mass public transportation
>
> Such exclusive or preferential use of freeway lanes shall be based upon competent traffic engineering and surveys and estimates developed or supported by the continuing comprehensive transportation planning processes of the urbanized areas involved

A model for computing the vehicle capacity and person capacity of freeways, with and without exclusive bus lanes, was developed to determine when an exclusive lane would permit more people to use the highway than could use it if all traffic were mixed It shows that under most "normal" conditions the proportion of buses in traffic would not warrant an exclusive lane—the lane would be under-used, while cars in the remaining lanes would experience increased delay

MARTIN, D B , "Feasibility of an Exclusive Lane for Buses on the San Francisco-Oakland Bay Bridge " *Hwy Res Record No 303* (Jan. 1970) pp. 17-29.

Study initiated by a request from BPR for an evaluation of the potential for reserving one or more exclusive bus lanes on the San Francisco-Oakland Bay Bridge. This section of highway has the greatest peak-hour bus concentration in California, and delay occurs because demand exceeds capacity during peak periods. The existing traffic conditions were surveyed for both morning and evening peak periods. The data obtained included capacity of bridge, number of persons using each mode, volumes (automobiles and buses), travel times, and demand This information was used to determine the present person-delay being suffered These data were then used in a simulation of conditions with an exclusive bus lane in effect The assumption was made that the lane used exclusively for buses was previously a lane used for mixed traffic in the same direction. A graph was developed that showed person-delay with and without an exclusive bus lane as a function of modal split Concludes that an exclusive bus lane on the Bay Bridge is not feasible because the increased delay to automobile users would far exceed the savings to the bus passengers At the present demand there is no modal split that would make an exclusive bus lane feasible The conclusions were based principally on recurrent congestion If nonrecurrent congestion (such as that caused from breakdowns and accidents) had been included in the delay, the exclusive bus lane alternative would have been even more detrimental.

"The Potential for Bus Rapid Transit " Prepared by Wilbur Smith and Assoc. for Automobile Manufacturers Assn. (Feb 1970)

Focuses on those elements in urban transportation planning that have particular reference to the potential role of motor bus systems The concept of metering express buses into freeway lanes, and restricting the volume of traffic on the freeway to numbers that will permit free flow at all times, leads directly to the larger concept of urban "transportation corridor" planning. Under this approach, a wide right-of-way is acquired and used initially as an arterial street, with special turnouts for bus stops The second step is conversion to a freeway, with preferential metering of buses into the freeway when peak volumes approach freeway capacities. Exclusive bus lanes, special busways, and other improvements would be introduced when transit volumes require them. The initiation of bus rapid-transit service would come at a time when customer demand was well below the level needed to sustain a rail service Although bus rapid-transit systems involve relatively little cost for capital facilities, bus operating costs increase more rapidly than rail system operating costs as patronage grows. Busways can be converted to rail transit as the corridor transit demands reach a level where the economies of rail systems for handling large passenger volumes justify the change in mode

"Exclusive Bus Lane Port of N Y Authority Alternate Proposal for N.J. I-495 " Planning and Development Dept, Port of New York Authority (Mar. 1970).

The Port Authority proposed, in January 1967, an exclusive bus lane operation eastbound, in the normally westbound median lane of I-495 from the New Jersey Turnpike to the Lincoln Tunnel connecting with New York City in the morning peak period The alternative plan reported here called for using the normal eastbound median lane instead (The "wrong way" lane operation was subsequently adopted.) The alternate proposal was found to involve a 10-min saving to 25,000 bus passengers. Based on a Stanford Research Institute finding that commuting time has a value of $2 82/hr/person, the annual saving to bus commuters was estimated at $2 8 million, equivalent to annual debt service, at 8 percent over 30 years, for a capital investment of $29 million The capital cost of the exclusive bus lane was estimated at less than 10 percent of this investment.

GOODMAN, J M, "Operation of a Freeway Priority System for Buses and Car Pools." *Traffic Eng*, Vol. 40, No. 7 (Apr. 1970) pp. 30-37.

The practice of reserving lanes in freeways for use by buses during peak traffic periods has been examined in several recent papers. The consensus is that such a priority system achieves more efficient use of the freeway than does the conventional uncontrolled or mixed traffic system One study has even recommended that urban freeways be constructed primarily to provide for off-peak demand and that buses be used to provide for peak demand. Eleven operational techniques that can be used to implement the system are described in detail. Selection of the particular technique to be used should be based on an examination of the site where a freeway priority system for buses and car pools is being considered for implementation.

MAY, A. D., and SPARKS, G A., "A Mathematical Model for Evaluating Priority Lane Operations on Freeways" FHWA (June 1970).

Explains a computer model that evaluates the operation of priority lanes on freeways. The model is capable of (1) handling linear and nonlinear speed-flow relationships, (2) handling trapezoidal or triangular demand curves, (3) varying the number of reserved lanes, (4) varying the vehicles permitted to use the reserved lane based on vehicle occupancy, and (5) varying distribution of vehicle occupancies.

The model was applied to an existing facility and a procedure was presented by which the more promising strategies were selected from all possible strategies. A detailed investigation was carried out with regard to shifts in occupancy distribution and changes in demand level and/or modal split factor. Conclusion· priority lanes on freeways is a promising concept that should be investigated further.

MARPLE, G. E, "Transportation Planning for Exclusive Bus Facilities." *Instr. Memo. 21-13-67(1)*, FHWA (July 17, 1970).

An interim policy and procedure memorandum regarding explicit consideration of exclusive or preferential bus lanes in the urban transportation planning process as set forth in § 9, Federal-Aid Highway Act of 1962. Calls for consideration of exclusive bus facilities and preferential bus treatment in the total urban transportation plan, with particular reference to home to work and return travel oriented toward downtown areas and other large employment centers.

MARPLE, G. E., "Warrants for Exclusive Bus Facilities." *Instr Memo. 21-13-67(2)*, FHWA (July 17, 1970).

Supersedes Instructional Memorandum 21-13-67, "Statement of Position of the Federal Highway Administration on the Reservation of Freeway Lanes for Buses," and considers all types of highways in addition to freeways, as well as enlarging busway definition to include exclusive and car pool highways.

The general warrant for an exclusive bus lane is whether such a lane will accommodate more people than when used by general traffic. For an exclusive bus highway (as against a lane reservation for peak-period use), the analysis should consider not only the peak period but also the off-peak period. Additional analyses should examine the alternative of exclusive bus use in the peak period, and mixed use in other hours.

For preferential treatment of buses, the warrant should be applied when the number of persons served would be insufficient to consider exclusive bus use

WILLIAMS, G. M., "Consideration of Exclusive Bus Facilities in Highway Project Development." *Circ. Memo*, FHWA (July 17, 1970).

In future studies that determine the number of lanes to be provided on high-volume radial highways, including freeways, States should give special consideration to exclusive bus lanes or preferential bus treatment in preliminary planning. One consideration of such analyses should be whether or not additional lanes above those needed to handle off-peak vehicular travel are more cost-effective than alternate highway operating plans that provide for exclusive or preferential bus use. Included here would be outer bus terminals or loops, special parking areas and bus loading facilities, and inner-city bus terminals or loops that would provide attractive service. The State should take the initiative in contacting the local transit authority or operator and in jointly developing project plans for increased bus service on the basis that the transit agency will undertake the associated service improvements.

TURNER, F C., "Moving People on Urban Highways." *Traffic Quart.* (July 1970).

The Federal Highway Administrator reviews current joint efforts of FHWA and UMTA to encourage expanded bus transit operations in the Washington, D C., area, Milwaukee, Pittsburgh, Los Angeles, and under the Urban Corridor Demonstration Program

"Highways and Public Transportation." *Metropolitan,* Vol 66, No. 4 (July 1970) pp. 21-24

Public transportation, in all but a few of the largest cities, is being provided exclusively by buses on highways. Buses account for about three-fourths of the nation's urban mass transportation, on a person-trip basis, thus, most public transportation is totally dependent on the contribution made by an improved highway network The role of buses is described in urban highway transportation. The BPR believes that, effectively handled, buses on freeways can offer the type of rapid transit needed to lure motorists away from their cars during their peak-load commuting hours. The Federal-Aid Program for traffic operations improvements in the urban cities includes such things as separate bus lane controls and lanes for loading transit passengers, including platforms and shelters. To achieve the objective of increased urban mobility, the FHWA is assisting in construction of highway facilities for preferential treatment of buses.

A quick review is made of such specific projects as the Shirley Highway Bus lanes, the Seattle Blue Streak, and the Los Angeles-San Bernardino Freeway busway.

CARROLL, J D., "Urban Corridor Demonstration Project Manhattan-New Jersey." Tri-State Transp. Comm , N Y , N J , Conn., with U.S. DOT, FHWA, UMTA (Aug. 1970).

Bus commuting is being improved from northern New Jersey to midtown Manhattan, considering exclusive bus lanes, park-ride lots, electronic bus identification, expressway surveillance and control with preferential bus access, and pedestrian distribution facilities.

"I-84 Environmental and Joint Use Study." Wilbur Smith and Assoc. for Connecticut Dept of Transportation (Nov. 1970). See Ch. 14, "Improving Freeway Efficiency and Acceptability· Improved Public Transportation, the Fundamentals of Freeway Bus Operation," p 130

Considers the potential for an express bus service to bring workers to the central area of Hartford, Conn , in a heavily traveled freeway corridor. The principal competitive relationships to be resolved in establishing an effective bus service are described and quantified in general terms These include competitive door-to-door speeds by motorists parking in fringe lots and transferring to bus; bus frequency, passenger distribution and pick-up in CBD; size of parking lots, and optimum operation to achieve efficient bus use. Bus fares (not investigated) would have to be low-cost or free of charge.

"Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Car Pools." Prepared for U.S. DOT by Alan M. Voorhees and Assoc., in association with Northwestern University Traffic Institute and Daniel J. Edelman, Inc. (Nov. 1970).

An analysis of the potential value of reserving one lane of the eight-lane I-90 Memorial Shoreway (extending 12 miles east from Cleveland's Inner Belt Freeway) for inbound buses and car pools in the morning peak weekday commuting period, and one outbound lane in the evening peak period.

Conclusions: The concept is basically sound Its objective should be to induce significant numbers of commuters to shift from low-occupancy cars into higher-occupancy buses and car pools. Feasibility depends on unique characteristics of each specific freeway The left lane on each side of roadway is recommended for reservation on I-90, because it will minimize lane-changing to and from entrance and exit ramps.

Police and judges in the three affected cities believe that enforcement of the reserved-lane ordinance will be extremely difficult.

Note The reserved-lane proposal was subsequently rejected by the municipalities involved, on grounds that enforcement problems cannot be overcome

MORIN, D A , and FISHER, R. J , "Bus Rapid Transit." *American Road Builder* (Dec 1970).

Reviews the development and operations of the Shirley Highway (I-95) reserved bus lanes between Washington, D C , and northern Virginia suburbs At the end of 1970, the route carried 8,650 passengers, in 190 buses, during the four hours of combined morning and evening peak commuting hours. Another 5,000 daily passengers were expected when a temporary busway extension was completed. Problems anticipated at several locations where buses are allowed to cross normal street traffic lanes were handled by use of special YIELD TO BUSES signs, pavement markings, and roadway barricades

"Highway Transportation " FHWA (1970).

Reviews DOT policy positions regarding coordinated development of freeways and urban transit facilities, funding details, and bus rapid transit studies and proposals under way in 1970.

GOODMAN, L , "Bus Rapid Transit on Existing Highways." ASCE Metropolitan Section Meeting, New York City (Feb 9, 1971)

Describes the I-495 Exclusive Bus Lane developed to expedite bus movements over the connection between the New Jersey Turnpike and the Lincoln Tunnel in the New York metropolitan area The facility was opened Dec. 18, 1970, and carries about 33,000 passengers into New York during the morning peak hours (21,000 passengers in 460 buses in the single hour, 8-9 AM) The buses preempt a westbound lane of I-495 and travel in the reverse (eastbound) direction, making use of excess capacity in the westbound lanes without penalizing eastbound traffic by preempting a lane in the direction of heavy flow. Time savings realized by the bus riders who use the route has been computed at $5.5 million annually. Benefits are about 6 5 times the cost of the innovation.

MARPLE, G. E., "Preferential Treatment of Buses." *FHWA Notice*, U.S. DOT (Mar 29, 1971).

Advises that emphasis on movement of people rather than vehicles has resulted in DOT sponsoring experiments and demonstrations in the preferential treatment of buses and car pools in selected locations where there appeared to be a potential net gain in numbers of people moved and net saving in over-all travel time of all persons in traffic. Examples include the Shirley Highway scheme; I-495 "wrong-way" lane to the N J. portal of the Lincoln Tunnel; the San Francisco-Oakland Bay Bridge toll plaza experiment (exclusive bus lane, deferred toll collection); Seattle's Blue Streak; and several pending projects such as the San Bernardino Busway; Pittsburgh PATways; Milwaukee bus highway, bus signal priority system in Washington, D.C ; Chicago busways in freeway medians; and related research.

"Transit Design on Freeway Corridors." Vol 1, Functional Planning Office, Ontario Dept of Highways (Mar 1971).

An initial attempt to formulate guidelines for transit in freeway corridors

> For some time now it has been felt that in functional planning work on freeways, provision should be made to utilize the freeway corridor for transit systems as well Consequently, consideration such as provision of wider medians and flexible types of structures has been given in some of our recent freeway projects; but no design criteria has been seen formulated to deal with the various transit modes, etc
>
> This first part of the study deals with the conceptual aspects of transit using the freeway corridor. . For trunkline operation the location of passenger transfer stations is of prime importance and several schemes for these have been developed and evaluated . . particular attention was given to (1) flexibility, (2) safety, (3) economy, and (4) shortest walking distance for pedestrians.
>
> The next step deals with the layout of passenger transfer stations This includes the vertical movement of pedestrians between two road levels by means of stairs and escalators . Integral to the transfer stations is the provision of adequate parking facilities Several parking schemes for transfer stations, within and outside the freeway right-of-way, have been suggested and briefly characterized For better comprehension of the planning approach, cross sections of road structures and transfer stations, and perspective drawings of transfer stations have been prepared.
>
> Finally, to help establish some suitable design criteria for transit on freeway corridors, a review of the various operational modes of transit and preliminary dimensions for system design requirements was carried out

STOCK, W. A , WANG, J. J., and MAY, A D , "Priority Lane Operations on the San Francisco-Oakland Bay Bridge." ITTE, Univ of California, Berkeley (Apr. 1971)

A theoretical analysis of alternative methods for assigning freeway (bridge) lanes to buses and high-occupancy cars on the five-lane, one-way bridge, based on a computer model developed for this purpose Similar to the idea of an exclusive bus lane, the priority operation is expected to reduce passenger travel time on the freeway section.

The model was applied to westbound and eastbound traffic separately. In testing all reasonable configurations for priority lane(s) and priority vehicles, the most effective condition was defined and recommended for experimental testing in the field (demonstration). Traffic operations variables were the main decision criteria, especially important was the total passenger-hours expended in the study section during the morning peak period (westbound traffic flow). Queuing patterns were also investigated. Four alternative westbound plans were studied under various occupancy shifts and numbers of toll booths assigned to reserved lanes. Only one plan offered benefits over normal operations without the occurrence of an occupancy shift.

Ten alternative plans were analyzed for the eastbound direction of traffic flow. Under the condition of no occupancy shift, none of these alternatives showed a potential benefit.

"Feasibility Study on an Exclusive Lane for Buses and Car Pools on the San Francisco-Oakland Bay Bridge." California Dept. of Public Works (Apr. 1971).

> This study was designed to review the feasibility of an exclusive lane for buses and car pools on the San Francisco-Oakland Bay Bridge. Senate Resolution 216-Sherman 1970 Regular Session suggests that the Bridge capacity, in terms of person trips, could be increased and travel delay decreased if high-occupancy vehicles were provided with a special lane to speed their trip during commute hours, and that this result would be accomplished in part by inducing some auto travelers to switch to buses This study has attempted to analyze alternative strategies for such an exclusive lane to identify alternatives offering the greatest possibility of success.
>
> Theoretical analysis indicates possibility of success for a plan providing an exclusive lane for westbound buses and autos containing three or more people approaching the toll booths and an exclusive lane from the toll booths onto the bridge This plan will be successful only if there is a significant increase in the number of people using car pools and buses.
>
> The analysis proved that it is not feasible or beneficial to establish an exclusive lane for buses and car pools across the bridge in the eastbound direction, and that carrying an exclusive lane all the way across the bridge in the westbound direction would result in serious operational problems

"Milwaukee Area Transit Plan, A Mass Transit Technical Planning Study." Barton-Aschman Assoc. (June 1971).

This report and the accompanying technical reports describe an all-bus 1990 rapid transit system for Milwaukee. Bus operations on freeways would provide express transit service. Where freeways will be overloaded by 1990, special transitways will be developed. A proposed 8-mile east-west transitway between 13th St and I-84 is an integral part of the system. Downtown distribution would be on bus-priority streets A former railroad right-of-way, now owned by the County, is recommended for later development as a north-south busway

KRAMBLES, G, "Expressway Rapid Transit" Prepared for 1971 ASCE-ASME National Transp Eng. Meeting, Seattle (July 26, 1971)

A historical sketch of transit development in Chicago (including rails and subways), followed by discussion of the Expressway Transit Concept leading into examination of the Congress Street Rapid Transit facility, the Dan Ryan, and the Kennedy Expressway routes. Attention is given to special bus transit operations in the Stevenson (I-55) Expressway and Lake Shore Drive, with speculation about development of bus rapid transit in the Crosstown Freeway being planned.

"Reserved Lanes Shorten Commuting Time." *Metropolitan* (Sept.-Oct 1971) pp 25-28.

A review of the principal reserved-lane projects in the U S., including· (1) Shirley Highway; (2) I-495 New York-New Jersey (Lincoln Tunnel approach in N J.), (3) Seattle Blue Streak, (4) San Francisco-Oakland Bay Bridge, (5) Golden Gate Bridge (planned exclusive bus lane on lower level); (6) Los Angeles, San Bernardino Freeway-busway; and (7) Pittsburgh PATways

"Express Buses Speed New Yorkers' Trips" *Passenger Transp.* (Nov. 19, 1971).

A "wrong-way" lane on the Long Island Expressway has been set aside for westbound traffic on the last 2 miles of the expressway before it enters the Queens-Midtown Tunnel; the lane will be used for buses from 7 to 10 AM on weekdays.

Buses on the new lane, with about 6,500 passengers during the typical morning hours of use, average about 3.5 min to traverse the 2-mile section of route. Cars in the parallel lanes average about 18 min to cover the same 2 miles.

"Santa Ana Freeway Corridor Study." Prepared by LARTS for SCAG and FHWA (Dec. 1971).

> Congestion, delay, and the rush-hour headache—all are virtually synonymous with the Santa Ana Freeway to many thousands of daily commuters along that route
>
> The Santa Ana Freeway Corridor is an urban radial corridor to the CBD of the City of Los Angeles, generally served by the Santa Ana Freeway (I-5) and taken to be a strip approximately 35 miles long and six miles wide from the L A CBD to the Newport Freeway (Rt 55) in Orange County The objective of the study was to decrease corridor travel times during rush hours through recommending a program of projects relieving traffic congestion in the corridor and in the L A. CBD in the near term.
>
> Because of the diagonal orientation of the Santa Ana Freeway, few surface routes serve as effective freeway alternatives . A total of 71 individual projects were identified by the study team and proposed for implementation . . Of these, ten are on freeways. The intended concept is to increase freeway capacity by widening, restriping and implementing ramp controls, thus improving the level of service. It is anticipated that such improvements will reduce typical morning inbound and evening outbound peak-hour travel time between the San Gabriel River Freeway (I-605) and the L A. CBD from 45 to 20 minutes.
>
> With the anticipated improvement in freeway travel times, enhancing the desirability of public transit is planned by allowing preferential treatment for buses at metered freeway access ramps In addition, three projects related directly to bus service are proposed Two involve fringe parking and new freeway bus stops For the third, SCRTD anticipates that freeway improvements will provide an opportunity for improved and expanded bus services and new peak-hour commuter service is being recommended for the 1972-73 fiscal year from Buena Park/Norwalk to the L A CBD

"Freeway Lanes for High-Occupancy Vehicles" *First Annual Progress Report,* California Business and Transp Agency, Dept of Public Works, to the State Legislature (Dec 1971) 27 pp

Reviews the projects that the California Department of Public Works has designed to encourage greater public use of high-occupancy vehicles. These include· (1) preferential freeway on-ramp lanes for buses in conjunction with ramp metering projects in Los Angeles and San Diego; (2) a preferential bus lane through the congested toll plaza area of the San Francisco-Oakland Bay Bridge from April 20, 1970, to December 7, 1971; (3) replacement of the bus lane at the Bridge by longer ones for buses and car pools on December 8, 1971, (4) construction of an 11-mile busway on the San Bernardino Freeway at a cost of approximately $39 million, (5) studies (under way) for preferential bus treatment in Marin County; (6) a study (under way) of the Santa Ana Freeway corridor, (7) a research contract for methods to increase vehicle occupancy on the Hollywood Freeway; (8) construction projects and bus studies along the Golden State Freeway; (9) preferential bus treatment studies (under way) on the Hollywood Freeway.

"Freeway Traffic Control System for Improving Bus Rapid Transit." *Directory of Research, Development & Demonstration Projects,* Proj. TRD-14, UMTA (1971)

The objective was to investigate the technological feasibility of the development, installation, and operation of a freeway traffic surveillance and control system that would provide for any desired level of service for bus rapid transit vehicles.

The Bus-Freeway System, as studied, was a rapid transit system where buses operated in mixed traffic on an urban freeway under strict means of traffic surveillance and control.

In highly controlled circumstances, the system operated as a rapid transit in medium-density urban areas, with private vehicles filling the unused freeway capacity between buses.

Exclusive ramps provided quick freeway access for buses; automobiles were permitted access to the freeway only in regulated numbers according to the desired level of service. Because private vehicles were delayed at entrance ramps while buses were traveling at reduced terminal-to-terminal times, transit patronage greatly increased. For example, travel through a 6-mile control section on the Gulf Freeway was reduced from 20 to 12 min, while service volume on the freeway increased by 12 percent.

The study indicated such a bus-freeway system could be implemented with only a modest capital investment as an interim solution in areas not yet sufficiently populated to support rail rapid transit.

4. BUS STATIONS

FRUIN, J. J, "Bus Terminals." Sec. 3, draft report on Public Transportation (no date)

A textbook discussion of bus transit, its capacities and limitations, with examples of existing and proposed treatment of buses for high-volume service in CBD's and heavily traveled corridors It considers the design layout of bus terminals for a variety of conditions, with extensive discussion of the PONYA terminal in New York City; discusses preliminary feasibility studies for terminal design, based on tentative forecasts of future transit patronage; deals then with basic factors and details of terminal organization and design, and includes many illustrations of terminal layout, with attention to the geometric limitations. It discusses passenger-handling capacities of various loading facilities, people-mover systems and stairways.

"Site Planning and New Stations." Ch. 10, *Manual of Guidelines and Standards*, prepared by Cambridge Seven Assoc., for Massachusetts Bay Transportation Authority (no date).

An architectural treatment of the development of transit stations. Covers (1) site selection; (2) site analysis and design; (3) design criteria (for pedestrians, bus facilities, parking, kiss-and-ride patrons, etc.); and (4) station design (for various conditions of bus, train, car access).

Prepared in form of summary statements and guidelines. Contains numerous sketches to illustrate arrangement of component parts of stations, lighting, materials used, etc.

"New York's New Union Terminal." *Arch. Record* (Aug. 1949).

A nontechnical description of the bus terminal, with illustrations of layout at various levels and mention of principal or unique architectural features.

"Complementary Commuter Service Needs· Penn-Central Railroad, New Haven Division " Report to Connecticut Research Comm. by Wilbur Smith and Assoc. (Mar. 1970). Ch. III, "Evaluation of Bus Transit Potential for Access to Stations," pp. 28-45.

Considers some problems of providing highly individualized commuter access to trains for persons riding into New York City from Westport, Conn. Capital, maintenance, and operating costs computed for four different modes (annual basis); performance computed for assumed routes, based on O-D data compiled on passengers who now use the train. The following conditions were examined: (1) conventional buses, 40- to 50-passenger capacity; assumed headways of 15 to 20 min; assumed fares of $0.25 each way, plus zone surcharge; (2) mini-buses, 20- to 25-passenger capacity; assumed headways of 15 to 20 min; assumed fares of $0.25 each way, plus zone surcharge; (3) limousine-type vehicle, 8- to 10-passenger capacity, frequent headways (on-call basis); assumed fare of $0 30 to $0 40 each way, plus zone surcharge; (4) modified taxicab vehicle, 3- to 4-passenger capacity; on-call basis only, assumed zone fare system, $0 40 to $0 50 each way (minimum)

"Proposed 69th Street Transportation Center" Prepared by Wilbur Smith and Assoc with Louis T. Klauder and Assoc. for Delaware Valley Regional Planning Comm. (Sept. 1971). (Urban Corridor Study)

The terminal is located north of 69th St. and the West Chester Pike, west of the Philadelphia city limits in Upper Darby (Pa.) Township It is opposite a well-established retail-commercial subcenter in the western suburbs The center is an interchange facility between buses, trams, and the Market Street-Frankford Rapid Transit Line About 50,000 persons pass through the terminal daily. More than 80 percent of these arrive at the terminal via public transportation. About 30 percent of the daily passenger load passes through the terminal during morning peak hour, with the same proportion returning in the evening peak hour (commuters).

About 1,200 passengers drive to the terminal to take the train; another 570 drive to a tram or bus stop and arrive at the terminal on tram or bus.

A variety of improvements are recommended in the report, to improve the terminal's efficiency and attractiveness. A short busway is proposed to allow buses to bypass congested areas.

FAUSCH, P. A, "A Transit Station Simulation." *Traffic Eng* (Dec. 1971) pp. 18-25

> The Milwaukee County Expressway and Transportation Commission is currently planning a bus rapid transit system which, when fully implemented, will feature a system of exclusive right-of-way transitways and 38 rapid transit stations. One of the critical requirements for the successful operation of this system is a convenient, comfortable, and efficient station facility which can help induce the automobile driver to change modes
>
> The purpose of this paper is to describe a transit station simulation technique which was developed and used in the Milwaukee Transit Study to assist in the development of prototype transit stations for the Milwaukee System. This transit station simulation technique is a tool which the traffic engineer can use for developing design data for various station situations.

Six specific objectives were listed for study and simulation:

1. Determine basic floor and platform area requirements in and around the station based on a given level of service.
2. Determine congestion in pedestrian flow area created by normal fluctuation in demand at locations where pedestrian flows are restrained; i.e., doors, fare collection gates, stairs, and platform loading areas.
3. Determine the number of transit vehicle loading bays required.
4. Determine the effect of capacity restraints (i e., gates) on space requirements.
5. Determine the effect on area requirements of varying the capacity or average service time of capacity restraints.
6. Develop a simulation tool that will be flexible enough to handle varying conditions; i.e, different types of vehicular and pedestrian loadings and station configurations.

Walker, E. L., Jr., and **Cummings, J. J**, "Forecasting Impacts of Transit Improvements and Fringe Parking Developments on Downtown Parking Needs." *Hwy Res Record No. 395* (1972) pp. 37-46.

The changing economic role of most downtown areas, with office employment becoming the major growth factor, has resulted in a rapid rise in peak-period auto trips and all-day parking demands, and a lower growth rate for short-term (under 3 hours) parking. Few CBD core areas can accommodate all current parking demands, or the expected higher demands of the next decade

Reviews techniques used in a recent Baltimore study to forecast the number of long-term CBD work-trip parkers who can be diverted to a planned new rapid transit system, and to CBD fringe and outlying parking locations, linked to the CBD by improved transit and other people-mover systems. Without these developments, a core-area deficiency of 15,700 spaces is estimated for 1985—double the 1969 deficiency.

Recommended programs to divert some long-term work-trip parking to fringe and outlying locations can reduce the core-area deficit to 10,900 spaces If the rapid transit system also is operational in 1985, most CBD sectors will have surplus parking space. The core area will need only 4,500 more spaces. These needs can be met by recommended 1975-1985 CBD parking programs The paper explains the parking demand forecasting model and suggests methods for future refinement of the model.

Fruin, J J., "Environmental Factors in Passenger Terminal Design." *Transp. Eng. Jour.*, ASCE (Feb. 1972) pp. 89-101

Summary and conclusions· (1) Application of the term "environment" to passenger terminals represents an increasing awareness of the human qualities of design and the impact of a terminal on the community, rather than a revolutionary design approach. (2) A passenger terminal may be categorized as a building system that has an external (community) environment and an internal (passenger interface) environment. The external environment includes its land use, access system, and aesthetics; also, socioeconomic, health, tranquility, and ecological impacts Factors affecting the passenger environment include its design, service standards, traffic characteristics, visual design, patron services, comfort, convenience, and maintainability. (3) Terminals contribute to the community environment if their land use is controlled, they have adequate and efficient access, have attractive aesthetic design, promote employment and cultural opportunities, limit sources of pollution, and enhance natural ecological systems. (4) The quality of the internal terminal environment depend on the application of adequate service standards, a thorough understanding of traffic patterns and demand forecasts, coherent physical design, communicative directional signing, provision of proper patron services, and security. It also includes comfort and conveniences, particularly for the handicapped passenger, and the selection of equipment and building materials that facilitate building maintenance and cleaning.

5. BUS STOPS

"'Leap-Frog' System of Bus Stops," also "Bus Lanes," replies to inquiry sent Nov. 8, 1962, to 50 largest companies, 32 of them replying. Reported results by American Transit Assn (Dec. 1962).

Of the transit companies questioned, 14 indicated that they used the "leapfrog" technique, or variants of it, to achieve more efficient bus operation in CBD. Five companies were using small sections of exclusive bus lanes at critical points in their systems.

The leapfrog technique is used to reduce the number of routes stopping at a single point, to segregate interurban from intraurban routes, and as "skip-stops" to speed up travel time on all routes. Most companies with leapfrog operations do not believe that exclusive bus lanes would help them because their buses must encroach on a second lane when making the "leap." Some companies noted that when bus traffic is very heavy, it preempts the curb lane anyway.

"Number and Type of Special Bus Stop Facilities Along Freeways." Reported in 50 States, the District of Columbia, and Puerto Rico, 1963 BPR Survey (unpub).

A tabulation of bus stops, with layout sketches Column headings include. city and state, route, cross street; type of interchange; cross street level (down or up), location of stop, facilities required (bus ramps, wider shoulder, sidewalks, stairs, etc.), date constructed; type of F.A. (local funds; state funds; no F.A , etc.); current use (number of buses, daily and peak hours); remarks; and sketches of interchange layout, bus stop arrangement, etc.

"Warrants for Bus Stops: A Recommended Practice for Proper Location of Bus Stops." Approved by ITE Board of Directors (Aug. 4, 1967)

Provides guidance and criteria for placement of bus stops in city streets.

"A Recommended Practice for Proper Location of Bus Stops." *Traffic Eng* (Dec. 1967) pp 30-34.

Discusses bus-stop locations for efficient traffic management Updates earlier "Recommended Practice" published in *Traffic Engineering* (Dec 1965).

Vuchic, V R., "Optimum Bus Stop Locations on a Street with Coordinated Signalization " Presented at ORSA, Miami, Fla (Nov. 1969).

Indicates that in many practical situations bus travel times can be reduced significantly by proper choice of stop locations. It is shown that the alternate stop pattern (near-side, far-side, near-side, far-side, etc) is, in most cases, superior to the all-near-side or all-far-side patterns. The possible disadvantage of the change is some confusion of passengers due to lack of consistency of locations along the bus route; this problem should be easily solved with appropriate signing.

"Warrants for Freeway Bus Stops· Bus Stops for Freeway Operations· Tentative ITE Recommended Practice." *Traffic Eng* (Jan 1970) pp. 14-22.

The many and varied configurations used for bus stop facilities indicate that development of standard geometrics applicable to all situations is not feasible However. certain elements of design and desirable appurtenances to bus stop facilities in general can be enumerated

1 Any freeway bus stop must be conceived as a part of a total transportation system and must be compatible with that system.

2. Individual locations of bus stops should be determined by estimating patronage, based on types of traffic generators within walking distance (or, if parking is provided, within driving distance), which will be better served by the freeway bus service than other transit routes; and by forecasting future use as indicated by growth of the served area

3 Typical geometric arrangements of bus stops are illustrated.

4. The alignment of turnouts should permit bus movements into and out of loading areas without adverse effect on traffic flow and safety on the freeway and without discomfort to the passengers

5 In urban areas, bus stop facilities at the cross-street level are preferred because of the safety and convenience to the entering and leaving passengers, but cause delays to through passengers At rural-area flag stops, freeway-level locations are generally considered the more suitable.

6. Bus stops at freeway level should be isolated from the through freeway lanes Where a bus stop location on a freeway is not within an interchange area, deceleration and acceleration lanes adequate for bus capabilities should be provided. Where bus stops are located at an interchange, access should usually be via ramps or collector roads, not directly to and from through lanes

7 Freeway-level bus stops should be designed as a separate roadway at least 20 ft wide to permit buses to pass a standing or stalled bus

8. Street-level bus stops on diamond-type ramps may consist of a widened shoulder area adjacent to the ramp roadway or they may be on a separate roadway. Generally, bus stops adjacent to on-ramps are preferred Street-level bus stops can also be provided at cloverleaf-type interchanges.

9 Street-level bus stops may be appropriate as a first stage toward ultimate construction of more elaborate facilities at freeway level, which can be provided for in the initial design and built if and when warranted by actual demand

10. Loading platforms should be not less than 6 ft wide, and preferably 8 ft Platform lengths must be adequate for the anticipated number of buses loading and unloading simultaneously.

11 Where warranted by location and use, a parking area near the bus stop should be provided for "park and ride" and "kiss and ride" patrons

12 A shelter with benches visible from the roadway should be provided In cold climates, a full enclosure with heating is desirable if policing problems can be solved The area should be illuminated for protection and safety from harassment In certain locations, telephone facilities should be installed

13 Provision should be made to keep pedestrians off the freeway lanes by fencing or other suitable means Where pedestrians are required to cross a ramp at grade, a crosswalk should be painted and illumination provided

KRAFT, W H, and BOARDMAN, T. J, "Location of Bus Stops." *Transp. Eng. Jour.*, ASCE (Feb. 1972) pp. 103-116.

Reports on some of the background research conducted in developing ITE's 1967 report, "A Recommended Practice for Proper Location of Bus Stops."

6. BUS VEHICLE DESIGN

"Guided Bus System Studied in Britain." *Passenger Transp*, Vol. 25, No. 21, Amer. Transit Assn. (Sept. 1967).

A guided bus system is under study. An ordinary bus runs under normal driver control until it reaches the congested center of the city, then moves on specially reserved track on the surface or overhead. An electrical cable underneath the road surface or similar devices keep the middle of the bus within a foot or two of the middle of the lane, and the driver is instructed when to accelerate or slow down. In this way, lane widths can be narrower than in streets carrying mixed traffic and bus speeds averaging 30 mph may be feasible. Bus design and operation, economic potential, control gear, signaling system, and the track are being investigated. Methods are being sought for controlling the distances between vehicles in mixed traffic and to warn of pedestrians or animals straying into the road.

HENDERSON, A., and COLE, M., "Design Vehicle Criteria and Geometric Design." *Traffic Eng. and Control*, England (Jan. 1968).

Turning radius and other controlling dimensions for use in geometric layout of roads and terminals For use in England, based on common vehicle types there

HENDERSON, A., BOBROWSKI, J., and STOVEL, J. C., "Guided Bus Rapid Transit System." Arthur Henderson, Consultants, England (Nov. 1970).

Many public transport systems that use buses are finding that modern traffic conditions restrict services so much that new forms of transport are being actively examined, and so is the possibility of providing separate facilities for buses, such as special bus lanes The principle of the guided bus contains the advantages of both tracked systems and the flexibility of normal motor traffic, and studies of various physical ways of guiding buses are in progress.

"Dial-A-Bus. The Bay Ridges Experiment." Ontario Dept of Transportation and Communications (Aug 1971)

During the summer of 1970, the Ontario Department of Highways initiated a many-to-many dial-a-bus service experiment feeding the Pickering Station of the Go Commuter Railroad Service, serving the Toronto Metropolitan Area. The service uses four buses during peak hours and a central manual dispatching office. In February 1971, the project began a limited many-to-many service during the off-peak periods of the day. Patronage has grown to 500 passengers a day; the former fixed-schedule service had failed for lack of patronage. Weekday revenues meet about 44 percent of weekday costs.

7. BUSWAYS

"St. Louis Metropolitan Area Transportation Study. A Comprehensive Transit Survey and Study of the Metropolitan Area of St. Louis and St. Louis County, Mo." W C. Gilman & Co., with Wilbur Smith and Assoc and Marketers Research Service, Inc., for

Citizens' Metropolitan Transit Committee of St. Louis and St. Louis County (Aug 1959).

Recommendations relating to special transit services include the following

A bus rapid transit system consisting of· A grade-separated 60-ft-wide bus roadway distribution loop on or adjacent to 6th, Chestnut, 11th, and Lucas in downtown St. Louis; seven radial routes connecting this downtown loop with the outer sections of the city and adjacent sections of St. Louis County and a north and south crosstown connecting route; a total of 86 net route-miles of rapid transit service, of which 41 8 route-miles will be on grade-separated exclusive bus roadways and 44 2 route-miles on the outer sections of present or proposed expressways, local and express rapid transit bus services on the rapid transit bus roadways and expressways with the same buses providing local feeder service as needed on surface streets, requiring no change of vehicle by rapid transit passengers

Surface distribution of parkers in CBD fringe facilities was recommended To make the program feasible, the report recommends establishment of an areawide political agency or authority with specific powers which include Complete supervisory authority over the general planning, construction, and operation of all transportation facilities, the right to construct rapid transit facilities and lease them to be operated by a private operator with the present transit systems as a coordinated system, the right to construct rapid transit facilities and purchase the present transit system for operation by it as a consolidated system, the right to construct and lease, or construct or purchase and operate parking facilities, complete autonomy as to transit fares and parking rates, complete freedom of its property and operations, if any, from all taxes, and the power to levy taxes, to provide funds for constructing or assisting in financing the construction of highway, parking, and transit facilities over which it has jurisdiction.

"Metro-Mode· A New Approach to Rapid Transit." General Motors Corp., Detroit (1967).

G.M C Truck & Coach Division's proposal for a 7-mile busway linking Milwaukee's CBD with western suburbs, based on a joint study by G.M. and the Southeastern Wisconsin Regional Planning Commission. Buses would use neighborhood streets and outlying uncongested freeways to collect inbound passengers, then enter the busway for the CBD trip, returning to downtown streets for CBD distribution. This is the basic alignment for the 1971 transitway.

"Rapid Busways." Atlanta Transit System (July 1967).

The rapid busways service proposed in Atlanta is outlined and discussed Rapid busways mean a series of exclusive corridors through which buses, not having to fight other traffic, can bring people to and from the heart of Atlanta, from home to work in a single vehicle, at speeds and with comfort comparable to the auto or rail rapid transit. The system could serve an important role in preparing the way for rail rapid transit by beginning to shape travel desires and corridors of high density development along the major rail routes, while relieving traffic congestion and providing commuter transportation As traffic volumes develop to sufficient levels to warrant rail service, conversion could take place through stage development.

Capital cost of rapid busways was estimated at $52 million, or one-tenth rail rapid transit system cost, because of no track requirements, no major electrification or stations, lower unit cost per vehicle, and lower system mileage requirement. The system could be in operation in much shorter time, or even part of one line could operate before the entire line is completed

"Use of B&O Georgetown Branch for Public Transportation" Metropolitan Washington Council of Governments (Oct 1968).

Reviews the feasibility of using the Baltimore and Ohio Georgetown Branch railroad tracks for bus operations between downtown Washington, D.C , and Connecticut Ave., in Chevy Chase, Md. A rail-bus operation is rejected because the existing rail tracks would need complete rebuilding The recommended solution is to build a paved roadway for buses, while still retaining railroad tracks for joint use by express buses and freight trains A three-phase program of busway construction is recommended for further study. The first phase provides 11-min travel time reductions between three suburban fringe parking areas and downtown Washington by permitting exclusive bus use of an existing but incomplete parkway and a short temporary road, constructed for this purpose at a cost of approximately $40,000. The second phase is construction of a 3-mile busway on that portion of the B&O Georgetown Branch that is within the District of Columbia, further reducing travel times by 5 min for these three parking areas. The third phase is extension of the busway along the rail line into Montgomery County to serve Westwood, Bethesda, and Chevy Chase Lake.

FOOTE, J E., and SCHEEL, J. W , "Comparison of Experimental Results with Estimated Single-Lane Bus Flow Through a Series of Stations Along a Private Busway." *Res Publ GMR-888,* G.M. Research Lab (May 1969).

Experimental results are compared with the estimated behavior and performance of single-lane bus flow through a series of stations along a private right-of-way. Six buses were driven as a convoy through a series of simulated passenger stations, stopping at each station to simulate the dwell time associated with stopping for passenger pickup and discharge. In every case, the capacities in vehicles per hour observed during these experiments exceeded those predicted by the computer program written to study bus motion through such a system. Using buses in groups of six, at a cruise speed of 30 mph between stations 0.3 mile apart, and using a 30-sec dwell time, capacities ranged from 350 to 400 buses per hour and system speeds ranged from 13 to 15 mph.

Additional experiments are needed to gain an understanding of the effects of variations in vehicle performance, roadway grades and curves, and passenger loading and off-loading procedures on these predicted performance levels.

MAYNARD, W. P , "The Busway to Make Rapid Transit Work—Now " *Traffic Quart.* (July 1969) pp 353-363 [A follow-up on "Rapid Busways," Atlanta Transit System (July 1967)]

Further discussion and argument on the desirable features that an exclusive bus lane on a freeway, or private busway, would introduce to make bus use more attractive than it now is, and perhaps enable buses to compete with the motor car on its own terms (equal door-to-door trip time to CBD)

GALLAGHER, R., "Proposed Exclusive-Express Busway in and Along the San Bernardino Freeway Between Los Angeles and El Monte " 39th Ann Meeting, Inst. of Traffic Engineers (Aug. 1969).

The Southern California Rapid Transit District (SCRTD) operates some 1,500 buses in four counties of this metropolitan area The Los Angeles metropolitan area may look forward to having the world's first exclusive-express busway It is proposed that this express busway be approximately 12 4 miles in length between Santa Anita Ave in El Monte and the Los Angeles Civic Center The trip will take approximately 18 min (including station stops), which will yield an average speed of approximately 41 mph Maximum bus speed will be just under 60 mph. These buses will stop only at certain express stop locations This project would initiate high-speed rapid transit service within the SCRTD at the earliest possible date Peak-hour passenger volumes in the peak direction at the peak load point on the busway were approximately 4,000 persons per hour. This exclusive-express busway would be the equivalent of adding two additional lanes to each side of the San Bernardino Freeway between El Monte and the Civic Center.

Initial one-direction patronage estimated at 4,000 per hour in the peak period. Estimated construction cost, $35 million. Completion date two years after all financing is available.

CORRADINO, J. C., "Busways—Rapid Transit for an Intermediate-Sized Metropolitan Area " *UITP Revue,* Vol. 19, No. 1 (1970) pp. 15-19

A rapid transit system for intermediate-sized areas (those containing one to two million people by 1980) is a possibility, and, although a rail system may not be attainable, bus rapid transportation, commonly known as busways, might be The busway is relatively new in the field of public transportation. Essentially, it consists of a network of buses that circulate through residential communities, particularly through the low-population-density suburban areas, and then speed over exclusively reserved trunk lines to the local point of the community, which in most instances is the CBD of the area. Includes a brief description of busway studies made for Atlanta, Boston, Memphis, and Portland, Ore.

"Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor." Howard, Needles, Tammen and Bergendoff for Metropolitan Washington Council of Governments (Mar. 1970).

A pilot study of busway development in the Shirley Highway corridor of the Washington metropolitan area Develops the patronage forecasts, economic implications, and basic design options for busway development Indicates that a full-bus-only roadway would cost about $5 4 million to build as compared with $1 4 million for a partially reserved roadway. The full-bus roadway, however, would present an annual return of 51 percent over the partial busway alternative.

Thoroughly documented with traffic, transit, and patronage statistics Documents the increase in bus patronage experienced with interim bus operations

HERMAN, R., LAM, T., and ROTHERY, R., "Further Studies on Single-Lane Bus Flow Transient Characteristics " *Transp. Sci.,* Vol 4, No 2 (May 1970) pp. 187-216

Reports the results of a series of experiments carried out to determine the transient characteristics of a platoon of buses starting and stopping along an exclusive right-of-way By using a six-bus platoon on a 2½-mile test facility, the effects of such factors as platform spacing, station spacing, speed, and delay on platoon dynamics were investigated The results indicate that the dynamics of a cyclic operation of starting at one position and stopping at another is highly predictable The motion of the platoon through such a cycle can be described in terms of a starting transient, steady state, and a stopping transient Furthermore, the "smoothness" of the acceleration of a platoon to a steady state is strongly dependent on starting delay, vehicle performance, and intervehicle spacing at the starting position. The experimental observations were compared with the theoretical results obtained from numerical solutions of the linear car-following model of single-lane traffic flow.

"Blue Streak." Washington Dept of Highways, Puget Sound Reg. Trans. Study, Seattle, Seattle Traffic Engineer, with HUD (Aug. 1970).

The effects of providing express bus traffic with preference over the individual automobile will be tested by the Seattle Transit Commission. The two-year test, called Blue Streak, involves use of a reserved ramp for transit buses on urban freeways Buses will operate around a small collector loop on city streets within the CBD, enter and leave the freeway (I-5) via an exclusive "reversible" bus ramp, operate non-stop for distances up to 8 miles on reversible lanes of the freeway, and then operate as local service on the outermost ends of presently operated routes In addition to redesigning the outer ends of eight existing routes, which serve Seattle's north end, a 550-car park-and-ride lot will be established near the north end of the reversible freeway lanes and served by the Blue Streak. Blue Streak is expected to test the theory that if bus traffic is given preference over the automobile, commuters will find transit service more attractive and some will be induced to switch to the bus If successful, the bus rapid transit concept will be proved as a method of handling large volumes of commuter traffic and will increase urban freeway use by moving more people in fewer vehicles.

"Pittsburgh: Multi-Modal Approach to Transit." *Railway Age,* Vol. 169, No 9 (Nov. 1970) pp. 30-32.

About $228 million in federal and local funding has been assured Allegheny County, Pa., for rehabilitation of trolley routes, construction of exclusive bus lanes, construction of an 11-mile graded transit expressway (formerly "Skybus"), and study of rail commuter services Particular attention is given to the political, financial, and technical difficulties faced by the Transit Expressway.

Highway Transportation FHWA (Nov. 1970).

Contains brief articles on several aspects of bus priority planning for highways in cities. Among them

"Highways to Be Used More Efficiently" (pp 4-5). FHWA's Division Engineers have been instructed to explore the following methods of providing special treatment for buses on highway facilities:

> *Exclusive Bus Highway*—an entire highway facility reserved at all times solely for the use of buses (This category could be expanded to include other vehicles, such as car pools)
>
> *Exclusive Bus Lanes*—one or more lanes of a highway facility reserved solely for the use of buses, usually during peak periods (This might be expanded to include car pools)
>
> *Preferential Bus Treatment*—making special allowance for bus movement within the general stream of mixed highway traffic, usually during peak periods (e g , metering vehicle access to freeways with bypasses for buses, bus-actuated traffic signals, etc)

"Attack on Traffic Congestion" (pp 11-14). Briefly describes demonstration programs designed to make highways more efficient carriers of buses Demonstrations are going on in Atlanta, Cincinnati, Dallas, Dayton, Los Angeles, Louisville, Minneapolis-St Paul, New Haven, New York, Philadelphia, and Washington, D.C.

"Bus Lane to Speed Travel to Lincoln Tunnel" (p. 15).

"Exclusive Bus Lane Extended on Shirley Highway" (pp 18-19).

"Blue Streak Phase I Report" Alan M. Voorhees and Assoc , for Washington State Highway Comm., and Seattle Transit System (1971).

Service consists of special Blue Streak buses using the Seattle Freeway (I-5) reversible roadway in the peak flow direction and the Columbia-Cherry St on-off ramp in the southern part of the Seattle CBD. Direct Blue Streak service is provided to and from a park-ride lot 8 miles north of downtown. Other Blue Streak buses serve seven existing routes and enter or leave the reversible roadway at appropriate ramps in the north-end service area.

Buses have been granted exclusive use of the Columbia-Cherry ramp by the State Highway Commission, with approval of the FHWA

In the study corridor, I-5 is a six- and eight-lane freeway with an additional two- to four-lane reversible roadway with separate entrance and exit ramps Daily volume on the freeway averages about 150,000 vehicles. Buses use the reversible roadway into the CBD in the morning, returning via the outer roadway of I-5; the pattern is shifted at noon each weekday so that buses out of the CBD use the reversible lanes northbound in the afternoon

Users of the Blue Streak found that they could save up to 15 min in trip time from the end of the route (parking lot) to the CBD, based on data collected at the time the experiment began. The 475-car parking lot filled quickly, with 500 or more vehicles regularly using it (some in aisles and other unmarked spots). Partly because of this, the ridership seems to have stabilized at a little under 12,000 riders per day, as of May 1971.

Phase I was intended to report only on the preexisting conditions that apply to the Blue Streak experiment. Phase II report will be prepared on the results of the first full year of operation. Phase III will report on the two-year period of experiment (the last year is to permit cars to use the Columbia-Cherry St. ramp together with the buses).

GERSTEN, M. C., "Bus Rapid Transit in the Shirley Highway Corridor," ASCE Metropolitan Section Meeting, New York City (Feb 9, 1971).

The busway consists of a two-lane, reversible roadway located between (in the median) two three-lane, one-way roadways. The two center lanes were reserved for buses during the demonstration phase of the experiment An initial 5-mile section of the busway was opened in the fall of 1969 and immediately provided a time saving for passengers of more than 90 buses routed over it during the morning peak hours. Eventually, an 11-mile stretch of the Shirley Highway will include the busway feature and will reduce one-way, peak-hour trip times by about 30 min, as compared to trip times on the parallel highway lanes. The improvements have included purchase of 90 new, fully equipped buses for use on the busway.

TURNER, F. C., "The Case for Buses." ASCE Metropolitan Section Meeting, New York City (Feb. 9, 1971)

States that bus rapid transit is a logical and feasible means to improve bus transit in most urban areas that do not generate sufficiently heavy corridor volumes of demand to justify rail. Use of exclusive lanes and busways in freeway rights-of-way is feasible under some conditions. Several studies in progress demonstrate these possibilities, including· Shirley Highway (I-95) in Virginia suburbs of Washington, D.C.; the reverse-direction lane inbound to the Lincoln Tunnel on I-495, connecting the N.J. Turnpike; the Seattle Blue Streak; the San Bernardino Freeway (I-10) plans for an 11-mile busway, the Milwaukee plans and study for busways; Pittsburgh's busway plans, and other studies planned or under way in Cleveland and Oakland-San Francisco.

ASCE Technical Council on Urban Transportation, "Transportation News Notes." (no date; probably 1971).

Lists news on financing of special busways and amounts allotted DOT approval of $51 5 million project to construct an 11-mile busway in Los Angeles, partially within and partially adjacent to the San Bernardino Freeway, Boston's new "wrong way" exclusive bus lane extends for 8 miles along the Southwest Expressway; I-495 exclusive bus lane to Lincoln Tunnel in N.Y City; Washington's Shirley Highway (I-95) busway, first automatic vehicle identification system for buses using Lincoln Tunnel.

ITE Committee 6RA, "Busways." Final Report to ITE Dept. 6, Div. of Planning Applications (Aug. 20, 1971).

Objective was to prepare an informational report that will include guidelines to determine the need for, operation of, and feasibility of separate busways as part of an over-all transportation system.

Concludes that busways are a relatively inexpensive method of obtaining a satisfactory principal corridor movement of commuter traffic moved on rapid routes from the suburbs to the CBD and return.

Lists advantages and disadvantages of busways (special facilities used exclusively by buses and not easily violated by cars); reserved lanes on throughways and local streets; priority of access to freeway ramps where traffic is metered into freeway to preserve uncongested rates of flow on freeway; etc. Sets forth preliminary roadway design criteria and standards for busway construction, stations, stops, terminals, furniture, etc.

"Philadelphia. Bus Service Area Planning for Market Street East." Wilbur Smith and Assoc. for Bowcr and Fradley, Architects, Philadelphia (Nov 1971)

The proposed bus facilities will offer opportunities to reduce traffic congestion on adjacent local streets; reduce walking distances between transportation modes that interface at the facility; improve bus accessibility to the center city; reduce over-all trip time to major generators; strengthen the center city's transport and land-use functions; and provide better service to all city residents and visitors.

A separate linear bus facility, one level above the surface street and adjacent to the intercity terminal, is proposed for local and commuter buses.

A continuous parallel loading platform about 1,500 ft long would be used by local and commuting bus passengers, providing about 15 parallel bus loading spaces within the length of the project, with adequate maneuvering space Width of the linear facility would provide for passenger platform space, parallel standing for bus loading, and two travel lanes. Estimated peak-hour bus volumes are expected to range between 100 and 125 vehicles Vehicles using the busway to and from a multilevel intercity bus terminal with its own loading area and berthing bays could increase peak-hour volume to as many as 186 vehicles, having a seating capacity in excess of 9,000 persons. The linear bus terminal, with spur roadways from the Vine St Expressway, would be expected to cut 10 to 15 min from the 30-min round-trip time between the terminal and Camden, via the Ben Franklin bridge.

"Dallas, Texas· Urban Corridor Demonstration Program" Prepared by City of Dallas Traffic Control Dept., Dallas Transit System, Texas Transportation Inst., and Wilbur Smith and Assoc (Dec 3, 1971).

Analysis of operational alternatives indicated that construction of a special roadway, for exclusive use by transit buses offers the greatest opportunity for obtaining a major improvement in transit service in the North Central Corridor. Recommends an 11-mile busway, which 1,000 bus trips would use daily.

The recommended busway would be entirely elevated except for possible short sections that might be on surface or underground, depending on detailed engineering design studies. Most of the route would use air rights over the Southern Pacific right-of-way, or over portions of the frontage roads of the North Central Expressway. The busway, about 30 ft wide, would be designed to allow for future fixed-guideway transit.

"MARTA Begins Construction on 50-Mile Rapid Rail System" *Passenger Transp.* (Dec. 10, 1971).

The MARTA program consists of approximately 1,500 miles of surface bus operations, 64 miles of rail rapid transit and bus rapid transit lines in a network of ten legs with a total of 41 stations coordinated with the feeder bus routes that will be operating in Fulton and De Kalb Counties. The MARTA system consists of 50 miles of rapid rail lines served by 37 stations, with parking provided at 27 stations for more than 26,300 cars. The rapid busway system will be constructed in three separate corridors and will include 14 miles of busways. The three busways will be served by four stations with parking for more than 3,200 cars, more than 36 surface bus routes will be coordinated with the busways. Specific plans call for purchase of up to 490 new, air-conditioned buses to allow MARTA to expand and improve service on more than 30 routes now operated by ATS; for more than 100 passenger waiting shelters; and for implementation of seven new radial routes into areas not now served.

"Groundbreaking Opens L.A. Busway. First in California" *Passenger Transp.* (Jan. 28, 1972).

Reports the groundbreaking for an 11-mile El Monte-Los Angeles Busway, to be built mostly within the right-of-way of the Southern Pacific Railroad. About 8 miles of route are scheduled for opening by Fall 1972. When the entire project is complete, buses using the lanes will make the trip on the busway in approximately 18 min, as compared with the 35 to 45 min presently required by motorists using parallel freeways under peak-hour conditions of congestion.

8. EXPRESS BUS SERVICE

Barnett, J., "Express Bus Mass Transit." ASCE Proc. Paper 7256, *Transp. Eng. J*, Vol. 96 (May 1970).

Outlines a seven-point program for an express bus mass transit system Fringe parking, transfer areas, terminals, a new bus type, separate ways for express buses, underground operation through dense urban areas, and lower fares. Life in cities can be improved by reducing traffic congestion; this requires attack on a broad front, including planning to reduce needed vehicle-miles of travel, a freeway system, improvement of arterial streets, and a mass transit system that will result in drivers leaving their cars at home. Separate ways for express buses are discussed, particularly separate highways

"Houston, Texas—A Future Mass Transportation Concept." Rapid Transit Lines, Inc (Oct. 1970).

Proposes 14 arterial street express bus lines, each with two or three park-and-ride terminals These terminals would be at either drive-in theater lots, or at city parks with ample parking facilities. Buses would run express between the terminals and the CBD Bus priority lanes would be designated in selected locations

OELSNER, L., "Yorkville-Wall St Bus Express Makes Debut, and It's On Time" *New York Times* (Apr. 13, 1971)

An express bus service between York Ave. and 91st St on the Upper East Side of Manhattan to Water St. and John St in the financial district, via the F.D. Roosevelt Drive (East Side Highway). The run is scheduled for 30 min and departs Yorkville at 15-min intervals from 7 15 to 9 00 AM, stopping at York Ave. and 91st, 86th, and 79th, and at 79th and East End Ave. before entering FDR Drive. It operates between 4.00 and 5 45 PM in the reverse direction. The express bus cuts 15 to 20 min off alternative transit modes, costs $1.00 each way, which is competitive with a number of private limousine services in the area During its early days, the buses managed to maintain their schedules and attract passengers

"Chicago Crosstown Expressway. Preliminary Design." Crosstown Public Transportation System (Oct. 1971)

Concerned with the design of a Crosstown express busway, to be included in the expressway median or alongside the northbound roadway in those sections where the expressway is of a split design.

> A consideration of public transportation needs in the Crosstown corridor and in the Chicago region leads to two conclusions about the role of a Crosstown busway facility.
>
> 1 Traffic analysis indicates that public transportation in an exclusive right-of-way is essential to the proper functioning of the Crosstown Expressway To accommodate anticipated peak-hour public transportation ridership in automobiles on the expressway itself would require addition of at least two more expressway traffic lanes
>
> 2 Public transportation in the regional interim plan will continue to be heavily oriented towards downtown Chicago As the only service which connects the radials of the regional system beyond the downtown area, the Crosstown busway will have a unique regional transportation role.
>
> The basic criteria for a public transportation system for the Crosstown Expressway are to:
>
> 1. Provide space for an initial system, as well as possible future systems
> 2 Provide express service in a separate ROW for the length of the expressway.
> 3. Provide a means of transferring passengers from the local arterial system to the express bus system
> 4 Provide flexibility so that a parallel local system can be included in the corridor.
>
> The public transportation system for the Crosstown Expressway is proposed as an express bus system traveling in a reverse flow pattern at the expressway level in a relatively constant 43-ft right-of-way . The reverse flow pattern permits use of a single common platform serving standard CTA buses . the system has the added advantage of relatively simple conversion to rail operation if future conditions should warrant It also requires minimum right-of-way and is, thus, the minimum cost system

"The Capital Flyer Bus Service Between the District of Columbia and Maryland and Virginia Counties in the Washington Metropolitan Area" Demonstration project in center city and suburban employee transportation facilitation, prepared by Metropolitan Washington Council of Governments for UMTA (Nov. 1971).

Final report on operation of a two-way express bus project linking the Washington, D C., center city with suburbs in neighboring Prince Georges and Montgomery Counties in Maryland and Fairfax County in Virginia. Its purpose was to demonstrate approaches to two chronic urban problems First, by offering suburban commuters free fringe parking facilities and modern express transit service to their jobs downtown, the system may uncover factors that will assist in stemming the rising tide of rush-hour highway congestion by single-occupancy automobiles Second, by providing preferentially reduced-fare direct bus service to inner-city residents working or qualified to work in suburban areas where their skills are in demand, the system may open new employment horizons for youthful trainees, the unemployed, and the chronically under-employed, as well as already employed persons who formerly had only inconvenient and expensive bus service to the suburbs.

9. MODAL SPLIT

"A Method for Estimating the Impact of Travel Time or Cost Changes on Diversion of Car Drivers to Transit Work Travel to Central Business Districts." Wilbur Smith and Assoc for FHWA (1968).

Evaluates "modal split" and develops criteria for measuring the effectivenes of fare reduction and/or improvement in transit performance levels. It was found that in very large urbanized areas (Philadelphia and Boston), rail rapid transit provides a level of service that successfully competes with the car on the basis of time and cost; the result is use of transit service in proportions consistent with relative level of performance; that is, if transit costs and door-to-door times are equal to those of the car, half of the persons with cars (and therefore capable of choosing between car or transit modes) will elect to use transit (the train) to CBD; if trip time and/or trip costs turn out to be less, over-all, than by car, then proportionately more people will elect to use transit than use their cars for the trip to CBD.

"Test Vehicle Monitoring System in New York." *Communications News* (Mar. 1970).

An automatic vehicle monitoring system that can facilitate prompt police response to crime and accident calls and improve schedule adherence in transportation systems has been demonstrated in New York City by Hazeltine Corp The system, which electronically identifies and locates any vehicle in a fleet, regardless of course or speed, is said to be the first of its kind demonstrated in the U.S. The new AVM system is said to reduce radio voice channel congestion through use of digitally coded "canned messages " Each vehicle equipped with a Hazeltine transponder automatically replies to an electronic roll call. The reply provides a location fix, the identity of the vehicle, a call for help, if needed, and other digitally coded information, such as operational status and passenger count The roll call can be accomplished in as little as 1 sec for each 1,000 vehicles

PRANGLEY, R. E., "Commuter Transportation Problem, University of Maryland." Consortium of Universities, Wash., D C (Aug. 1970).

Suggests that economic pressures can be applied by providing free bus service and increasing parking fees for travel on a college campus The same approach could be used to encourage use of transit from peripheral car-parks to centers of high demand (CBD's, employment centers, sports arenas, etc) The following summarizes the findings

> In considering the peripheral auto-bus system, it can be concluded from the results of the market survey that any bus system must be of no charge per ride and financed by fees incorporated in the tuition charge. The parking fees should never be incorporated in the tuition fees as they lose their regulatory impact when doing so Probably the clearest conclusion of all is the dire need for better scheduling of classes

10. TRANSIT SYSTEMS (BUS LANES, BUS RAPID TRANSIT)

"A Plan for the Improvement of Traffic and Mass Transportation in St. Louis." St Louis Public Service Co. (Sept. 1955).

A far-sighted proposal, whose salient features have been widely applied in recent years throughout the U.S The proposal called for (1) use of two reversible center lanes on six-lane arteries for inbound morning and outbound evening traffic flow; (2) exclusive use by buses and right-turning cars of a curb lane in the flow direction during morning and evening peak hours on three major transit routes, (3) closing of certain "feed in" streets during rush hours, on the flow side only, and (4) at certain signal-controlled intersections, 10-ft curb setbacks for a distance of 150 ft ahead of intersections, to provide "reservoirs" for right-turning vehicles, eliminating use of the reserved transit lane for right turns.

ANDERSON, G. W., "Rail and Bus Rapid Transit for Downtown Access." For Symposium, "The Dynamics of Urban Transportation," Cobo Hall, Detroit (Oct 23, 1962).

An attempt to be realistic regarding the place of car and transit in urban transport. Points out the advantage to be gained by transit vehicles if they can be routed over uncrowded freeways on express portions of their runs between CBD and outlying suburbs, and quotes from a report on the Mark Twain Expressway in St. Louis.

"The Autoline." General Motors Styling Staff (1962).

The Autoline system conceives of operating standard vehicles (cars and buses) in groups on special lanes in express highways. To increase highway capacity, vehicle drivers would give control to an electronic guidance system as they enter the freeway. Cars (or buses) would then enter the traffic stream when the system sensed a gap coming up, and the new vehicle would be added to the rear end of a group. The driver would signal when he wished to leave the freeway, and the system would automatically eject him at an appropriate off-ramp, where he would resume manual control of his vehicle. By this means, the number of vehicles that might be accommodated at 60 to 70 mph in a single lane could be tripled or quadrupled, thereby obviating the need to build new freeways in congested corridors.

"A Survey to Determine Factors Which Influence the Public's Choice of Mode of Transportation " Joseph Napolitan Assoc for Mass Transportation Comm., Commonwealth of Massachusetts, Boston (1964)

Information for this report came from 1,379 in-depth interviews with five types of travelers. Except for the private car, the management of each mode of transportation reported on took part in operational and policy experiments carried out in 1963 under direction of the Mass Transportation Commission. The public transportation modes included Train—both Boston and Maine and New Haven RR (713 interviews), MTA buses (91 interviews), MTA rapid transit (parking-lot users—252 interviews), and private bus riders (157 interviews). Some 252 interviews were conducted with private automobile users

Findings showed that most users of a particular mode for work travel were strongly oriented to the mode Bus users, for example, were typically from apartment buildings, had relatively few cars, included many households without a worker (retired people). Train users were middle- to upper-income people on one-family lots in suburban towns with one or more cars; they usually drove to the train station and parked there, or were driven by another household member.

Most motorists were fully aware of the transit alternative available to them, chose the car for convenience (or lack of good transit alternative) because they thought it cost less. Most bus users used bus because a car was not available, or was needed by others in household, or was not available to them. Time saving was a more important consideration to most workers than cost.

HOLLIDAY, J. C, "Draft Plan for Runcorn New Town " *Traffic Eng. and Control* (London), Vol. 7, No 12 (Apr. 1966).

A critical article on the Draft Plan for redevelopment of Runcorn, to accommodate at least 90,000 people (it now has 27,000) with rapid bus transit to accommodate one-half of all trips in the town Notes that 85 percent of dwellings will have cars, and population densities will average about 75 persons per acre; parking will be in areas somewhat removed from residential structures. Every dwelling will be within 500 yd (or 5-min walking distance) of a bus stop. Doubts that one-half of the trips by residents will be made by transit.

LING, A., "Runcorn New Town." Prepared for Runcorn Development Corp , England (1967)

Contains an extensive Appendix E (pp 126-134) on the application of trip generation and modal-split theory to prediction of bus and rapid transit travel demands in Runcorn at the time it reaches maturity (100,000 residents). Design assumption is that 85 percent of peak-hour demand will be for private cars on highways (plus buses and trucks to match this condition). "Probable" peak-hour traffic demand will be a 50:50 split between car and transit, and this assumption is used to calculate transit vehicle and scheduling requirements.

Appendix D describes pedestrian walking speeds and distances; it assumes that no essential walk within the New Town should take more than 5 min for an average walker.

Transport plan for Runcorn includes a figure-eight busway.

> The solution adopted provides the buses with a separate track so that they are not subject to the delays of traffic congestion and at the same time provides other vehicles with a road system that is free of the delays occasioned by buses which stop and start at frequent intervals
>
> A conventional form of public transport, such as buses using the normal roads, for the level of car ownership ultimately envisaged, would result, for a town of 100,000 population, in high fares, a poor frequency of service or a public subsidy. To provide an acceptable economic level of service for the non-car owners and to make a significant saving in parking provisions, a "modal split" between the use of private cars and public transport of 50:50 for work journeys has been taken as an objective This means that a proportion of workers having the use of a car must be attracted to public transport and to achieve this the service must be cheap, fast and frequent, giving as near "door-to-door" service as possible. A separate rapid transit track has therefore been provided linking the communities, the town centre and the industrial areas, with walking distances kept to a minimum, so as to keep door-to-door journey times by public transport favorably competitive with those by private car. The separate tracks will enable the buses to maintain higher average speeds than normal as they will be free from delays caused by traffic congestion The directness of the routes will also ensure that operating costs will be at a minimum In comparing journey costs, the parking charges at the town centre and at the industrial estates as well as the cost of petrol must be taken into account The level at which parking charges are fixed will affect the cost of the journey by car They can be adjusted so that the journey by rapid transit will be cheaper than the journey by car. . If there is no parking charge, the cost swings more in favor of the car journey, which emphasises the need for a policy on parking charges consistent with the objectives of the rapid transit system

(In other words, all drivers should be charged for parking at a sufficiently high rate as to make the transit trip markedly less expensive.)

Hille, S. J., and Martin, T. K., "Consumer Preferences in Transportation." *Hwy. Res. Record No. 197* (1967) pp. 36-43.

The objective of the study was to identify the characteristics of an ideal transportation system as conceived by the consumer. Results were based on a sample survey (550 individual interviews) in the Baltimore Metropolitan Area and selected adjacent rural areas

Based on the findings, the main attributes of an idealized transportation system, from most important to comparatively unimportant, are: (1) Reliability of destination achievement (probably reflecting both safety and time considerations). This factor was most important among lower-income, non-white, full-time workers without cars; this implies that higher-income persons with cars are not as likely to give high ranking to the item because they seldom experience failure to arrive on time (their cars are newer and more dependable). (2) Convenience and comfort (with emphasis on flexibility and ease of departure). (3) Travel time (but considerable difference depending on trip purpose—most significant for work trips, most important to non-car owners. (4) Cost. (5) Independence of control (reflecting autonomy of individual in determining speed, routes, diversions, etc., during trip). This becomes increasingly important as income levels rise—the more affluent are able to purchase the luxury of convenience, represented by their cars. (6) Traffic and congestion (probably reflecting annoyance and perhaps safety). Inference is made that annoyance is not sufficient to keep people from continuing to seek suburban living and use of their cars for travel to work, etc. (7) Social (reflecting concern about who is being or capable of being traveled with). The bus is not a good place to court your girl. (8) Age of vehicle (perhaps indicative of a status dimension). Also a factor in dependability. (9) Diversions (with some understatement of the importance of the scenery attribute). Important only to trips made to view scenery.

Wynn, F. H., and Levinson, H. S., "Some Considerations in Appraising Bus Transit Potentials." *Hwy. Res. Record No. 197* (1966) pp. 1-24.

The purpose of this study was to identify the potentials for bus transportation in medium-sized U S. cities (under 1,000,000 population). The following implications arise: 1. In the lower range of middle-sized cities (less than 250,000) increases in transit use on approaches to the CBD would have relatively small effects on reducing peak-hour highway lane requirements 2. In cities near the upper limit of the size range (750,000 to 1,000,000) street and highway improvements might be substantially reduced by retaining and increasing bus transit patronage. Corridors of travel are typically near vehicle saturation levels at peak hours on the CBD approaches and relatively small increments of vehicular traffic can make the difference between congestion and free flow 3. Improvements in income or mobility levels tend to increase trip-making within the urbanized area. If this mobility increase could be achieved through improvements in public transport operations, it might afford a substantial new market for transit. 4. Some of the benefits that might result from improved transit would be increased mobility for underprivileged or deprived strata of the population A revitalized bus transit service might also relieve drivers of trips that are primarily motivated to accommodate nondrivers (up to one-quarter of all driver trips are made to "serve passengers" and about one-half of the serve-passenger trips are made solely to accommodate the passengers). 5 Most transit riding in small- and in medium-sized cities is by people who are essentially "captive" to the mode. Conventional transit media have difficulty competing with the car when travel by bus requires substantially more time. 6. In larger cities, where transit seems to have potential for substantial peak-hour relief, further attention might be given to improved line-haul and downtown distribution facilities (reserved freeway bus lanes or private busways to improve the transit/car travel-time ratio).

Design and Performance Criteria for Improved Non-Rail Urban Mass Transit Vehicles and Related Urban Transportation Systems National Academy of Engineering (May 1968) 109 pp

Six service types are defined.

> 1 Arterial Trunk Line—the most common type of transit service in today's urban areas.
>
> 2. Freeway Trunk Line—over freeway or exclusive busway, generally with local service at one or both ends of the line.
>
> 3. Single Activity Feeder-Distributor—for cases where most passengers embark or disembark at a single point.
>
> 4. Diffuse Origin and Destination Service—for transportation between many scattered points, perhaps through dynamic scheduling and routing on a door-to-door basis.
>
> 5. Downtown Circulation Service—for low-speed, short trips in the central business district, by relatively small vehicles.
>
> 6 New Town Circulation Service—to satisfy transportation needs in newly developed self-sufficient communities

Classifies the people of concern into seven sets· actual and potential passengers, vehicle drivers, vehicle maintainers, transit operators, labor and other community groups, vehicle manufacturers, and the general public. The first set is further divided into three types. users who must and do use buses, those who prefer to use buses but cannot because of physical handicaps, economic handicaps, or lack of bus service; and those who now prefer other modes but who would change to nonrail transit if vehicles and/or services were different.

> Freeway trunk line service is relatively new and is found in less than ten cities at present (1968) It is, or could be, a growing service type with further expansion tied to extensions and additions to the present urban freeway systems, to attractiveness of the service offered, and to the numbers of persons who might be attracted to the service Basically this type of service operates at least a portion of its route over a high-speed freeway facility or exclusive busway It may or may not have local service areas at one or both ends of the line Its major advantage and attraction is a total travel time, including transfers and walking, that approaches that of the private automobile
>
> The most promising use of this type of service is where long stretches of freeway running are possible and where a relatively high fare per mile may be charged to mitigate lack of passenger turnover A necessary condition is presence of a large group of potential passengers with essentially the same origins and destinations within a time frame that makes provision of such service both economical and attractive
>
> There are many special features involved in freeway service These include the provision of stops along the freeway to increase turnover and the use of restricted busways, special ramps, and certain preferential CBD distribution systems designed to reduce conflict with automobile traffic Special considerations are essential, particularly near the CBD where freeways tend to become congested.
>
> Speed of travel is an essential consideration in that door-to-door travel time is a major factor in the choice of travel mode. Speed considerations include route speed, headway, routing, location of stops, and the fact that time spent in waiting and transferring generally seems longer than it actually is.
>
> Increased speed can be accomplished in a number of ways. Today's vehicles have the capability of attaining top legal speeds quite rapidly Similarly, rates of deceleration are such that they can exceed the limits of comfort and safety Yet the only area where the vehicle itself can provide increased speed is in its acceleration. However, the effects of improvements in acceleration must be negligible compared to effects that might be obtained through improvements in extra-vehicular factors such as routing, frequency of service, and techniques for picking up and discharging passengers.
>
> . Improved convenience of nonrail transit will result from shorter waiting intervals between buses and shorter walking distances. It is important, however, that in one respect transit riders enjoy a convenience denied to the auto driver—freedom to relax, to read, to view the scenery, and to perform other activities while moving
>
> Perhaps the most important extra-vehicular comfort characteristics are those associated with terminals and stops; e g , protection from weather while waiting
>
> Reliability is clearly an important service characteristic. In certain situations unreliable service may lead to severe losses in patronage. Transit schedule unreliability is usually related to extra-vehicular factors such as variable traffic density and unexpected heavy passenger loads Of course, the vehicle itself can be the cause of unreliability if it is poorly maintained, or of such an age that it is unreliable in itself. . . A source of reliability, of course, is good transit management—concern for schedules, and understanding of predictable variations in demand.

Also discusses cost, comfort, safety, and the provision of adequate information about bus routes and services. Aimed primarily at identifying and proposing tests for improvements to bus hardware, mostly the buses

"An Evaluation of Free Transit Service." Charles River Assoc., Cambridge, Mass. (Aug. 1968).

An intelligent and thoughtful analysis of the factors that affect the relative use of transit and car and the significance attached to cost savings and time savings to users of transportation services. Shows that the effects of cost savings (fare reductions) on transit use are relatively unimportant. Similarly, time savings due to improved line-haul service are not nearly as important as time savings that reduce access and waiting time Concludes that line-haul time savings due to use of busways or exclusive bus lanes on freeways will have less effect in creating new ridership than will incremental time reductions due to shorter headways (less waiting time), shorter walks (proliferation of routes), and avoidance of vehicle transfers (transfer time). Considers each of these aspects in detail and is an important reference for understanding the complexity of the modal-split relationship.

CADY, C., "Now, Take the Bus " *Highway User,* National Highway Users Conf (Sept 1968)

Although buses carry approximately 75 percent of all transit passengers, the bus is seldom thought of as rapid transit It has the advantage of being flexible, economical, and adaptable New styles of buses are being used, both in cities on short runs and for interurban transit Experiments are being made with buses-only lanes, reserved lanes on freeways, and bus-train interchange combinations By means of electronic routing and control, schedules are being speeded up and refined to serve the users more efficiently.

HARR, C. M., "Tomorrow's Transportation—New Systems for the Urban Future." *Proc SAE,* Vol. 77 (Jan. 1969) pp. 62-63.

Most of today's ground transportation technology was developed 50 years ago for the then-existing way of life Further benefits can be obtained from that hardware by applying known techniques in communication, command, and control. For example, bus service can be improved by exclusive bus lanes, traffic flow control, bus priorities in traffic, automated scheduling, and modified concepts such as the dial-a-bus (a cross between a bus and a taxi). Trains can be improved by automating the controls; there are applications for both partial and full automation. Automatic computer control of traffic signals in urban areas can improve the flow of traffic on both regular streets and freeways. Use of two-way radio in subways and buses can improve service and provide better security. This report is a summary of studies undertaken to outline a program of research and development in urban transportation.

"Tomorrow's Transportation." U.S. Dept. of Housing and Urban Development (May 1968)

An overview of the decline in urban transit patronage and increase in auto use between 1950 and 1966, and a series of findings and recommendations, centered on increased national government funding of research and development programs for advanced technology in urban transportation.

Major emphasis is on increased use of bus transit, through recommendations for exclusive bus lanes on streets and freeways, freeway metering to prevent overloads in peak hours, traffic-signal preemption by buses, and dual-mode and articulated buses.

"Transit Needs Study in Minneapolis-St. Paul." Twin Cities Area Metro Transit Comm , with HUD (Sept. 1969).

A mass transportation study will prepare a plan for a complete, integrated transit system for the Minneapolis-St Paul metropolitan area. Immediate needs for improving the existing bus transit system are analyzed The study will consider express bus operation on freeways and separate bus roadways, special traffic controls to expedite transit operations, and other new techniques. In long-range transportation development, emphasis is placed on the importance of transportation in planning and in long-range area development.

WEINER, E., "Improving Bus Transit as a Mode of Transportation." Urban Transportation Planning Course, Public Transportation Branch, Urban Planning Div., FHWA (Feb. 17, 1970) 7 pp (mimeo.)

This paper (prepared August 1968) outlines the many elements that enter into bus transit operations and planning and suggests the specific areas susceptible of improvement for immediate action improvements; intermediate-term improvements; and futuristic proposals. Section headings under each of these categories are:

Immediate Action Improvements

1. Improved bus flow on congested streets.
2. Improved bus flow on freeways.
3. Provide fringe parking facilities
4 Improved passenger comfort.
5 Premium express bus service.
6. Improve fare collection.
7. Use of small buses.
8. Provide better information on service.
9. Improve routing and scheduling of buses.

Intermediate-Term Improvements

1. Separate buses from other traffic.
2. Improve coordination of modes
3. Bus trains.
4. Optimal bus system design.

Futuristic Proposals

1. Demand scheduling of buses.
2. Complete redesign of the transit bus.
3. "Quick-change" buses.
4. Electronic bus guidance systems.
5. "Modular" buses.
6. "Ground effects" buses
7. Computerized fare collection.

EVANS, R , "Sick Transit " *Humble Way,* Vol. 9, No. 1 (First Quarter 1970) pp. 20-23.

Evans, professor of psychology at the University of Houston, suggests that, if plans for mass transit systems are to succeed, planners must take certain human factors into consideration. Individuals are willing to endure a certain amount of inconvenience and inefficiency in exchange for control over their own locomotion. The need to control one's locomotion probably has a biological basis, the need can be modified or sublimated, but not eliminated. A mass transit system that would take psychological needs into consideration would have to be a system with more concern for flexibility than for efficiency. For the immediate future, planners should consider using modified procedures of transportation rather than attempt totality. They should strive for a system that affords maximum opportunity for the individual to retain control of the system. Wherever mass transit has worked at all, it has been through better use of a modified system with many options.

"Report to the Minister." Working Group on Bus Demonstration Projects, T. L. Beagley, Chairman, Ministry of Transport, England (Apr. 1970).

Summary (from the report)·

- It is primarily the lack of reliability of bus services that induces people to prefer private transport, and it is the extent of traffic congestion and degree of enforcement of traffic regulations that principally determine bus reliability

- There needs to be greater readiness to experiment with bus priority schemes
- The number of passengers carried per lane per road in peak hours is generally more important than the number of vehicles
- Bus operators need to take the lead in putting forward new ideas
- The Ministry should be more critical of local authorities who are not tackling with sufficient vigor bus problems in their area.
- The effects of introducing bus priority schemes need to be evaluated on a systematic basis and the Ministry should help in this
- It is important to make adequate provision for good accessibility by bus in the plans for pedestrian precincts and long-term town centre renewal
- Authorities should consider introduction of closed-circuit television and radio-telephone equipment in those towns with suitable road layout.
- There would be considerable value in trying out various unconventional types of bus service to induce people to travel by bus rather than by private car
- The closest possible cooperation is needed between the local authority's highway engineer and bus operators whenever a road reconstruction or new one-way scheme is proposed
- Every sizeable local authority should institute a thorough review of bus routes to see what experimental bus priority schemes are feasible.
- Imposition of parking and waiting restrictions and their effective enforcement on main bus routes are critical to successful bus operation
- The Ministry should give full publicity to the proposed new procedures and the signs to be used for safeguarding bus stops against indiscriminate parking
- The Ministry should discuss this report with the police to convince them of the need for experiments with bus priorities
- Bus operators should ensure that full publicity is given to the reasons for present shortcomings in their services
- A list of 11 specific demonstration projects is recommended; and special attention should also be paid to the results of four other schemes· (see attached list)
- The Ministry should cooperate with local authorities and bus operators to get these demonstration projects started and should meet the cost of the studies required to assess their effects
- A booklet should be prepared for publication giving an account of the Group's work and a widespread publicity campaign should be mounted; further publications should be issued from time to time recording the results of the demonstration projects

Traffic Management Schemes With Bus Priority·

Project 1, Derby Comprehensive traffic management scheme in town center.

Project 2, Leicester. Experiment with selective vehicle detectors giving priority to buses at traffic signal installations in Charles Street

Project 3, London (North) Contra-flow bus lane in Tottenham High Road, and possibly in Seven Sisters Road.

Project 4, London (West). Application of traffic management measures designed to minimize delays to buses on E3 route with rigorous enforcement of traffic regulations

Project 5, Manchester. New one-way traffic system in Piccadilly and London Road, but permitting buses only to continue to use these streets in a northbound direction as well as southbound

Project 6, Reading Comprehensive traffic management scheme in the town center.

Project 7, Southampton Linking of traffic signals on Bitterne Road and Bursledon Road, with special provision for priority access by buses to the route.

Project 8, Bristol Installation of computerized bus fleet control system, including radio-telephone link between control center and buses

Project 9, London Variant of Bristol project with alternative means of bus location.

Project 10, Leeds Operation of small buses circulating through the city center and penetrating pedestrian precincts

Project 11, Liverpool Introduction of a new bus feeder service to the existing railway station at Formby, with provision for through booking on bus and train to central Liverpool

Ferrari, M. G, "Improving Urban Bus Operations." ASCE Proc. Paper 7465, *Transp Eng. J.*, Vol. 96, No TE3 (Aug. 1970) pp. 319-331.

To lower costs and increase routing flexibility, most operations now favor long-lived diesel-powered buses over electric trolleys. The few vehicle innovations otherwise attempted, such as size variations, anti-air pollution devices, containment of production monopolies, and rider amenities, are limited in meeting the principal financial stress of increasing cost of labor coupled with declining revenue Fare changes have predictable limits. upward to $0 25 revenue gains offset passenger losses; higher rates create both revenue and riding losses; free transit service is deemed unproductive of revenue and ridership benefits. Convenience of service, increased speed, elimination of need to transfer, and enhancement of passenger comfort remain the most likely and largely untried areas of urban operations improvements. Possibilities include installation of bus shelters, operation of express buses, and preferential treatment of bus transportation such as transit streets, exclusive bus lanes, preferential signal timing, bus-actuated traffic signals, and rapid busways.

Presents a wide range of innovative vehicle designs and other measures intended to improve vehicle performance or system operation Makes the important point that the great majority of such improvements are not recognized as factors in service improvement, so far as the riders are aware As always, time and cost turn out to be the principal considerations, with comfort and convenience running a poor third, so far as work riders are concerned

Pignataro, L J, Falcocchio, J. C, and Roess, R P, "Selected Bus Demonstration Projects." ASCE Proc Paper 7454, *Transp. Eng. J.*, Vol. 96, No. TE3 (Aug 1970) pp. 251-268.

Results from selected demonstration projects dealing with bus service to low-income communities and express bus service to suburban communities are evaluated. Results from six projects are compared and analyzed. Criteria for evaluation are considered. Principal conclusions from the study include. (1) it is desirable to establish a method for the evaluation of poverty area bus services that considers not only financial factors but also social factors, (2) it is doubtful that normal bus services can provide adequate mobility for poverty-area residents; (3) express bus services have the potential to be self-supporting; (4) reported cost data of operating bus services are insufficient for proper analysis; (5) lack of uniformity in structuring and reporting of results from demonstration projects makes it difficult to correlate various studies and to generate more widespread application of results; (6) prior to the award of a demonstration grant it is highly desirable that socioeconomic and travel characteristics data be available.

The comparative study related to the following: Maryland Metro-Flyer, suburban express bus service to downtown, Radial Express and Suburban Crosstown Bus Rider, St Louis metropolitan area; Chesapeake Mass Transportation Demonstration Project, Chesapeake, Va., Premium Special Bus Service, University of Illinois, Peoria, and Decatur.

These studies showed that higher-income people with cars could be induced to use public buses when the service was operated on a "premium" basis, and would pay its own way under some circumstances. Underlines the importance of the "comfort and convenience" angle, as well as time savings, even at additional cost—Peoria, especially.

LAVE, C A., "The Demand for Urban Mass Transportation" *Rev of Econ and Stat.*, Vol. 52, No 3 (Aug. 1970) pp. 320-323.

Explores some of the factors that influence the commuter's choice of mode. Attempts to provide quantitative estimates of the degree of transit improvement that will be necessary to attract commuters. A behaviorally oriented model or modal choice is developed and estimated. The two main results were an estimate of the value of travel time to commuters, which was 42 percent of the commuter's wage rate, and an estimate of the time and cost elasticities of choice between modes, which turned out to be relatively small Unless comfort becomes a much more important factor than either time or cost, the possibility for any substantial diversion of automobile users onto the proposed rapid transit systems does not appear to be very good.

"Urban Transportation Concepts—Center City Transportation Project." Wilbur Smith and Assoc. for UMTA (Sept. 1970).

The central theme of this study is that the center city is worth preserving. By preservation is meant the maintenance of an alert business community and a viable, efficient center for commerce and trade; preservation also implies continued growth, inasmuch as experience shows that cities that cease to grow at the center soon lose their attractiveness for maintaining an economically sound community center—they deteriorate.

If these criteria are accepted, it is important that all possible means be taken to assure the continued primacy of the center city. This means keeping the area accessible and striving to make it even more so, so that center city functions can compete successfully with other developing centers and thereby maintain and increase the tax base, which is the source of public funds with which to administer the community. The center city transportation study is an analysis of alternative ways to maintain and improve this accessibility. Based on the assumptions that the central focus of activities is good and that accessibility must be improved to the limits of practical technologies currently available, the following goals underlie the study· (1) travel time to the center city should be minimized, (2) travel within the center city should be minimized through better land-use planning, (3) the multiple use of downtown land should be encouraged; (4) movement corridors should be preserved through advance acquisition of rights-of-way and careful coordination of urban renewal and transportation planning; (5) urban renewal should be more extensively applied in the center city.

There is strong interdependence between public transport and the center city. Public transport makes possible high land-use and employment concentrations; simultaneously, existence of these concentrations makes capital investments in public transport feasible. Continued office building developments will increase employment densities and increase peak-hour travel demands that can best be met by improved public transit. Consistent with the over-all development pattern urged by this point of view is the priority and encouragement given to public transit:

- Public transit deserves and should be given priority over other modes.
- Interception or diversion of automobiles on the approaches to the center city or at outlying line-haul express transit stations should be encouraged.
- The intercept strategy should complement, not compete with, line-haul transit services.
- The extent to which public transport use should be encouraged through inhibiting or constraining auto travel depends on downtown employment density and reliance on public transport.

An adequate lead time is essential to put new technologies into operation. Consequently, during the near future, it is essential to rely on innovative use of existing, available technologies.

Pedestrianways and microsystems are possible means of improving internal mobility and serving to distribute people from line-haul transit. The application of microsystems (people movers) should be selective. The best potentials for microsystems in the center city exist in urban redevelopment projects, where pedestrian transport facilities can be incorporated integrally into the over-all development plans.

The field of innovational center city technologies is replete with concepts, yet there is a deficiency of microsystems in actual revenue services. Additional research and development is essential to progress. The Federal Government should encourage and support research and experimentation with new transportation technologies

Effective downtown distribution facilities are an essential complement to regional bus rapid transit services. Effective downtown distribution can be achieved by: (1) special busways in tunnels, (2) on-street distribution using special streets or lanes, or (3) bus terminals.

Special bus streets have the advantage of reducing capital cost requirements in conjunction with through-routing opportunities. Ideally, these streets should penetrate the core area, and not be part of the major arterial street system.

The location, type, and intensity of present and future downtown developments, the expected interaction among major activity concentrations, and the community's desire to minimize fractionated parking developments will influence development prospects. The high capital cost of most microsystems suggests the need to serve heavy pedestrian concentrations, and/or to offset the investment as part of redevelopment or renewal projects.

Factors favorable to microsystem development include (1) extensive core area congestion (both street and sidewalk); (2) limited parking in core areas; (3) major movement barriers within the center city; (4) anticipated rapid center city growth; and (5) extensive urban renewal prospects. Movement distances of 700 to 1,000 ft or more are required for microsystems to significantly reduce trip times over walking. These distances are longer than most pedestrian trips within the center city today.

An effective microsystem must consider the following factors.

- Personal convenience and time appear more important than out-of-pocket parking and travel costs to most CBD employees and shoppers. This is reflected by their willingness to pay higher rates in core-area parking facilities.
- The free market demand for microsystem riding to peripheral parking facilities would come from the downtown employees and visitors who are now walking long distances to avoid high parking costs. These represent only a limited portion of all parkers
- Moving the large group of parkers now walking only short distances to parking in the CBD periphery would probably have to be accomplished by limiting the available parking in the core of the CBD.
- Most internal CBD building-to-building trips are less than 1,000 ft Such trips could be effectively served by a microsystem in time competition with walking only if the people mover is continuous.

"An Evaluation of Urban Transport Efficiency in Canada. Improvements Attainable Through Transit Operations." N. D. Lea & Assoc. (Dec 1970) 49 pp.

Canadian transit services are similar to those in the U.S. in virtually every respect. This is a study of transit service improvements that are now attainable through thoughtful application of known technology and straightforward operational planning efficiencies. Among the items discussed are a number of well-accepted changes that should be pushed further for improving both social and economic efficiency. These include:

- Bus rapid transit.
- Freeway bus operations
- Express bus services.
- Exclusive transit streets.
- Exclusive bus lanes.
- Bus stop bays.
- Diversification of services.
- Improvements in bus design.
- Improved maintenance techniques.
- Improved surface bus planning.
- Convenience facilities.
- Improved communications.
- Dynamic demand routing.
- Contract management.
- Pricing policies.

Results of these analyses are expressed in a national framework in monetary terms and in terms of some measure of the quality or level of living. Improved transit operations are intended to include all economic efficiency and social efficiency improvements that are attainable through changes in present operations using already developed technology. Financing is not considered to be a constraint, provided a proposed improvement is demonstrably a social and/or a economic improvement.

"An Evaluation of Urban Transport Efficiency in Canada. Improvements Attainable Through Pricing." N. D Lea & Assoc. (Dec. 1970).

The optimum combination of pricing policies is likely to include: parking charges reflecting full cost, special motor vehicle licenses required to use designated routes in the rush hour, license fees varied by vehicle type to reflect long-run marginal costs, toll charges at very expensive crossings, and transit fares adjusted to be lower off-peak and to reflect marginal cost differences between modes.

Implementation of such measures in Canada would be expected to bring economic benefits of about $100 million per year by 2001, plus some social benefits.

The benefits would be concentrated in the CBD and in routes leading to it where congestion could be somewhat relieved through pricing. There would also be some benefits to transit users, particularly off-peak users.

The social benefits would be modest but broad, including some reduction in unpaid travel time, some improvements in accessibility, some accident reduction, and some environmental improvement.

GOODMAN, J. C, MACDORMAN, L. C., and WEINER, E, "Evaluation of a Bus Transit System in a Selected Urban Area." *Hwy. Res. Record No. 314* (1970) pp 114-122.

The objective of this study was investigation and evaluation of a bus transit system as a reasonably acceptable and economical alternative to the construction of additional highways in medium- to large-sized urban areas. In a selected urban area (Baltimore), the location and magnitude of the forecast year peak-hour vehicular overloads on the existing and committed highway systems were determined. Two alternative transportation systems were designed to reduce or eliminate the forecast year overloads—one automobile-oriented, the other bus transit-oriented. Through use of a modal split model developed as part of the study, the ability of each system to relieve the vehicular overloads on the highway system was evaluated Costs of each system were estimated. It was concluded that bus transit was capable of alleviating peak-hour overloads on urban freeways. Based on the findings of the study, bus transit systems were considered a viable alternative to increased urban freeway construction.

SWEEK, J. E , and HORWOOD, E M., "Evaluating the Central City Access Opportunity Provided by a Public Transportation System " Univ of Washington, Seattle, for HUD (1970).

Objectives of the study were.

1. Develop an "access opportunity" measurement for any urban resident seeking to reach a destination via the public transportation system.

2 Develop a more precise identification of the variables affecting transit travel cost than presently exists.

3. Develop a query-type system to be used by anyone interested in assessing his particular public transit convenience.

Study was limited to residents of the Model Cities Area and examined access between ten bus stops in the Model Cities Area and three principal destinations—CBD, the University of Washington, and the Boeing plant. Existing bus routes and a system of feeder buses and proposed rail rapid transit were compared. The system employed is shown capable of producing the kind of information needed to establish relative accessibilities via the different route configurations (objective 1), and to distinguish the amount of time consumed in each of the separate "legs" of the trip (objective 2); the system, if extended to cover the entire metropolitan area, could be used to provide the type of information needed to provide answers to inquiries about specific routes, travel times, and fares (objective 3)

"A Case for Bus Transit in Urban Areas." Peat, Marwick, Mitchell & Co., Washington, D C. (1970).

Research was conducted to see if improved bus transit systems should be seriously considered as an alternative to the construction of additional facilities to alleviate highway overloads. Recent transportation studies have indicated that bus transit is capable of alleviating peak-hour overloads on urban freeways. Use of exclusive rights-of-way offers distinct advantages for bus travel in maintaining a competitive position. The costs of the bus transit- and the automobile-oriented systems are nearly equal in terms of direct, quantifiable monetary considerations However, the bus transit system can provide accessibility to more people, promote more heterogeneous social contacts, and be less disruptive of community values. It is believed that the development and implementation of an efficient, competitive, and viable public transportation system that can effectively cope with urban transportation problems will require (1) aggressive leadership interested in the planned and orderly development of the metropolitan area through comprehensive transportation programs that reflect the economic, social, and environmental goals of the community; (2) rational analyses of the public and private transportation system, fully coordinated with a comprehensive urban planning process, and (3) financial assistance in the form of grant-in-aid programs of the Urban Mass Transportation Act, the funds of the Federal-Aid Highway Act, and various aid progiams of the Housing and Urban Development Act.

Highway Planning Program Manual Vol. 8, Ch 10, "Urban Transportation Planning Public Transportation," FHWA (Feb 26, 1971).

Presents an outline for the transit study needed in every urban area to meet FHWA study requirements. Sets forth objectives, scope of study, and general range of procedures called for in making the transit study. Discusses analysis of existing systems, alternative future systems, including busways and exclusive bus lanes on freeways and streets, with means of evaluating the several different kinds of facilities Includes a short bibliography

SUEN, L , and JOHNSON, H , "Dial-A-Bus Implementation, Theory and Practice in Canada." 2nd Annual Demand-Responsive Transportation Conf , MIT (July 1971).

Dial-a-bus shows promise in helping to solve some urban transportation problems However, ubiquitous application of the system on a city-wide basis would not likely solve the public transportation crisis A realistic level of demand-responsive service plus a combination of existing and new transit technologies would offer the best solution. This is evidenced in the Regina Telebus Study, which shows that an hourly transit demand of from 50 to 100 trips per square mile in a medium-density area (10,000 persons per square mile) provides an optimum situation for a 20-seat dial-a-bus service. Above that level, it becomes more economical to operate the regular-size 43-seat buses on a fixed route schedule.

Winter appears to be ideal time for dial-a-bus implementation in Canada. Due to long and severe winters in many parts of the country, transit patronage tends to be the highest in this season, especially during snowstorms. Dial-a-bus definitely fulfills a need in cutting down the discomfort of waiting when the weather is — 20°F.

Among the diversified uses that have been suggested for dial-a-bus (e.g., parcel delivery service) thought should be given to catering to the travel demands of handicapped persons. If the bus design is geared toward this end, a special service for this group can be implemented. The special service for the handicapped could be 'nstituted to take advantage of the excess capacity during off-peak hours to increase system use.

The paper reports on a theoretical analysis of dial-a-bus potentials. It was expected that the actual experiment would get under way in September 1971, and would run for about a year, with an interim report in February 1972.

"Rapid Transit for Metro Atlanta." Metropolitan Atlanta Rapid Transit Authority (MARTA) (Sept. 1971).

MARTA proposes:

- Building 56 miles of rail rapid transit and 14 miles of rapid transit busways and adding almost immediately 450 miles of new surface bus service in the four counties.
- Having first sections of the rapid transit system in use by early 1977, and the complete 70-mile rapid transit system in service by 1980.
- Acquiring assets of and operating the Atlanta Transit System.

- Establishing $0.15 bus and rapid transit fares for seven years, with free transfers throughout the system
- Buying 490 new air-conditioned buses to replace obsolete equipment to serve new bus routes and to provide additional buses on most of the present routes
- Providing some 100 passenger shelters at heavily used bus stops and transfer points to protect riders from rain, heat, and cold.
- Establishing eight new bus routes radiating from downtown and eight new crosstown routes that will intercept radial routes outside the downtown area These will provide direct access to crosstown destinations without having to come downtown.
- Starting at once a series of major route extensions to take bus service to new residential areas and centers of employment.
- Upgrading service on existing routes by adding buses, extending service periods, and modifying present routings
- Creating new rush-hour express and limited-stop services on six bus routes
- Providing a series of special bus services to help residents of three heavily populated neighborhoods get to jobs and to shopping centers.
- Providing express bus service into the city from outlying parking facilities as an interim park-and-ride service to lighten the automobile load on present expressways
- Concentrating on bus improvements while rapid transit is under construction and then coordinating the two systems into a single high-speed transportation system serving all built-up areas in the four counties.
- Obtaining two-thirds of capital outlays from the Federal Government and one-third from local sources
- Saving $150 million in interest charges by financing largely on a pay-as-you-go basis, with short-term bond financing (5 to 10 years) required only in the last half of the construction period.

> Totaling some 14 miles, these rapid busways will serve the residential areas and other destinations in the quadrants between the rail rapid transit routes. Two are proposed in the median strips of future highways now being planned by the Georgia State Highway Department A third, serving the Tucker-North DeKalb residential area, will be built by MARTA along a railroad right-of-way Thirty-eight bus routes will use the rapid busways
>
> Inbound buses will circulate through neighborhoods over residential surface street routes, picking up passengers at regular bus stops Upon completion of its neighborhood route, the bus will get to its own private road—the busway—and speed to a junction with the rail rapid transit line Outbound, the reverse procedure will be followed

"Dayton, Ohio, System Planning Report." Prepared by Montgomery-Greene County Transportation and Development Planning Program for the FHWA Urban Corridor Demonstration Program (Oct 1971).

The Dayton study is one of eleven urban corridor demonstration programs being carried out in the U.S. The major objective has been to outline for implementation a CBD-oriented corridor plan that can be used to demonstrate methods for moving persons and vehicles efficiently. Significant goals of the study were to minimize disruption of existing residential, commercial, and public areas; reduce congestion in the region's most rapidly urbanizing corridor, and provide higher speeds, lower costs, and shorter travel times than can be obtained with the present public transit system.

The recommended system consists of three parts·

- A neighborhood collection and distribution service for 15 neighborhoods, each with three subareas for a demand-actuated system on flexible routes.
- A line-haul component operating between the suburban terminals and the CBD on main arterials and a busway constructed within Penn-Central ROW's
- A CBD shuttle component operating on two routes (a—clockwise, b—counterclockwise) to provide access to all major activity centers in the core area.

The demand-actuated pick-up service would operate with fixed schedules from suburban terminals throughout the neighborhood areas, picking up patrons and terminating the run at the suburban terminal

The initial system use of the railroad ROW would be for buses only. After the service has been tested for a period of time, car pools would be permitted to use the facility during peak periods If the mixed-mode operation does not adversely affect transit service, it would be continued Only cars with three or more riders would be permitted on the busway, and the route would be constantly monitored to ensure compliance.

"South Capital Street Urban Corridor Demonstration Project." Alan M. Voorhees and Assoc , Wilbur Smith and Assoc., and Frederick R. Harris, Inc., for Metropolitan Washington Council of Governments (Nov. 1971).

The study sought to develop a plan for reducing congestion through provision of:

- A transit terminal in Anacostia that would serve as an interface between local service and express bus service to the CBD.
- Fringe parking lots for the use of both bus riders and car-poolers.
- Express bus service to the CBD from the transfer terminal and the fringe lots.
- Imbalanced lane operations on the Douglass Bridge during peak periods.
- Exclusive bus lanes and signal preferences for buses.
- Traffic operations improvements to improve traffic flow in corridor.
- Alternative modes of travel between home and transfer terminal.
- A timely public awareness program regarding new bus service and traffic flow operations.

The most novel proposal to come out of the study is to provide free jitney pick-up service between the homes of persons in the area served and a new transit terminal building where express buses would operate at high frequency to CBD destinations. Express bus service would be amplified further by providing fringe parking lots with frequent buses into the terminal, where quick transfer could be made to any of the other buses using the terminal, if the buses serving parking lots were not destined to the passenger's desired destination.

The study recommends the foregoing measures for a demonstration program to test their validity.

Smith, W. S, "Bussed or Bust?" *The APWA Reporter* (Nov. 1971) pp. 16-21.

A state-of-the-art review of current practice in bus use and preferential street use by buses in U.S. cities. Principal conclusions.

> If peak-hour traffic volumes are to be held at manageable levels, effective measures must be taken to increase the proportion of peak-hour person-trips made by public transit. The most promising measures appear to be special bus roadways or reserved freeway lanes, so buses can bypass traffic delays. Demonstration projects have shown that when buses improve on the trip time of automobiles during peak travel hours, increasing bus patronage results
>
> Some of the approaches to reducing traffic congestion by use of buses will require that certain city streets be limited to bus use in peak travel hours, and that other types of preferential treatment be accorded bus transit
>
> Public support—particularly by the automobile user—will be necessary for adoption and strict enforcement of preferential treatment of buses

Wohl, M, "Current Mass-Transit Proposals: Answer to Our Commuter Problem?" *Civil Eng* (Dec. 1971) pp 68-70.

Asks if rail rapid transit is the answer to CBD congestion, as an aid to the poor, minority races, and those without cars, aged, or otherwise in need of transport from some public source. Rail rapid transit to connect CBD with outlying suburbs is not the answer—80 percent of households without cars and 80 percent of the nonwhite population live in the central city, not the suburbs. About 60 percent of all poor families live in the central city, with only 40 percent in the suburbs. Three-quarters of all central city workers originate in central city, the number rising to nearly 80 percent in the CBD.

An alternative might be to improve taxi services, which can provide the kind of ride most people need In New York City, nearly a million taxi rides per day are provided, compared to about 4 5 million subway riders and 400,000 rail commuters. A large effort to increase the number of cabs, reduce fares, encourage "pooling" or rides, etc, would result in a better service to the ill, crippled, elderly, children, and others who are not work-oriented in their travels, and would supply the direct connection between origin and destination that even good transit such as NYC's does not provide.

"State of Texas Public Transportation Development Manual." Wilbur Smith and Assoc. for Texas Mass Transportation Comm., Austin (1971).

A compilation of information on bus transit operations in the 19 Texas cities with transit service; on current DOT and HUD programs for transit development, on state and local legislative provisions relative to transit operations, on criteria and standards for city bus service, and methods in current use for increasing bus operating speeds on streets and through development of exclusive lanes or roadways, and a review of new urban transit technology now in research and development stages.

Sorrentino, M., "The Role of Public Transport in Traffic Policy," *UITP Revue* (Brussels), Vol. 20, No. 2 (1971)

Makes a strong plea to improve the public transport system in large cities by separating transit from private cars. The main argument is to develop rail transit systems in cities that are large enough to need it and to expedite bus transit (in advance of rail, which takes a long time to build, or as the principal mode in cities too small for rail) by providing bus lanes on freeways, bus streets, or other private ROW's. Also makes a strong case for removing parked cars from streets in order to recover streets for moving traffic, by providing off-street parking facilities, preferably on the periphery of urbanization so that most people would enter downtown via transit.

Several Italian cities presently provide considerable mileage of bus lanes:

1. Turin has 4,895 m of bus lane, 3,320 m of bus road, and 11,200 m of busway planned; a total of 20,000 m (12+ miles) built or planned
2. Genoa has 17,550 m of of bus lane, and 4,040 m of bus road; a total of 21,590 m (13+ miles)

Rae, B J, "The Mythology of Urban Transportation." *Traffic Quart.*, Vol. 26, No. 1 (Jan. 1972) pp. 85-98.

Discusses some of the common misconceptions about bus transportation and potentials for increased use through application of popular panaceas. For example, higher speed capabilities are seen as a necessary element when it can quickly be shown that vehicles with top-speed capabilities of 100 mph have no advantage over vehicles with 55-mph ability if station stops are less than 5 miles apart. There is also widespread belief that rail rapid transit has diverted large numbers of motorists to trains wherever new systems have been tried, whereas the Toronto and Montreal experience has shown that 90 percent of the subway riders formerly were bus patrons. The public also has been told that use of buses or trains by motorists would reduce air pollution by important amounts when, in fact, even the most successful rapid transit operations have not resulted in substantial relief of street traffic and, in any case, generation of electricity or substitution of diesel buses for gasoline-powered cars has changed the kind of air pollution rather than eliminating it. The notion that greater use of transit would reduce central-city congestion is unfounded, based on all historical precedent; where large numbers of people come together, there is bound to be congestion—even large numbers of people on foot. Finally, the claim that congestion and the use of cars for much work travel would be changed by adoption of another form of urban development more closely tailored to the modern transportation forms has not been borne out by experience; central-city focal points (with a somewhat different set of land uses) continue to develop as in the past, while suburbs for residential purposes continue to proliferate and generate strong radial traffic demands

"Dallas Bus Operational Study, Dallas, Texas." Vol. II, "Report on Immediate Action Transit Improvements" Prepared by Wilbur Smith and Assoc. for Dallas Transit System, City of Dallas, and UMTA (Jan. 1972).

Concerned mainly with improvement of existing transit services by conventional means. However, contains recommendations for a park-and-ride express-bus service, and for development of additional downtown bus lanes on some streets at peak hours Recommends that buses contain preemption devices to enable drivers to expedite bus movement through traffic signals where signal delay is encountered.

MACNICHOLAS, M. J., "A Model for the Evaluation of Bus Lanes in a Radial Catchment." *Bus Priority Symposium,* TRRL, England (Feb. 1972)

It is important to recognize that bus lanes do not rectify the weaknesses of public transport. Instead they simply adjust the relative attraction of bus and car in favor of the bus, at the expense of the car Depending on the circumstances, bus lanes may or may not give real transportation benefits. If bus lanes are to be considered a success, the benefits to bus users must outweigh any increased costs to existing and former car users

A model was formulated for the work trip to a city center from a radial catchment. It was assumed that the elasticity of demand for work trips is zero, and that a radial is a typical element of the total transportation system Even if this is not strictly accurate, one can be fairly sure that if bus lanes are not successful for concentrated work-trip destinations it is unlikely that they would be successful for more dispersed destinations

All computer runs made to date show that although bus lanes do reduce net user cost and bus captive costs at the expense of car captive costs and user costs, these improvements are relatively modest (less than 10 percent). Because the synthetic data used are considered to be realistic, there would not seem to be any evidence to justify the belief that bus lanes will solve the urban transportation problem. However, the search for conditions where bus lanes might give better results is continuing.

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