August 1975

The Evaluation of the Shirley Highway Express - Bus - on - Freeway Demonstration Project/

Final Report

Urban Mass Transportation Administration
U.S. Department of Transportation
Washington, D.C. 20591

Report DOT/UMTA 7

EVALUATION OF THE SHIRLEY HIGHWAY EXPRESS-BUS-ON FREEWAY DEMONSTRATION PROJECT - FINAL REPORT

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August 1975

Prepared for
URBAN MASS TRANSPORTATION ADMINISTRATION
Department of Transportation
Washington, D.C. 20591

PREFACE

This final report is the culmination of series of documents comprising an evaluation of the Shirley Highway Express-Bus-on-Freeway Demonstration Project. The evaluation effort undertaken for the Urban Mass Transportation Adminstration (UMTA), U. S. Department of Transportation, by the Technical Analysis Division, National Bureau of Standards, U. S. Department of Commerce, extended over four years - beginning in early 1971 and ending in 1975.

The program began with the development of a research plan which conformed to generally accepted experimental design practice and at the same time was feasible to implement in the field and fell within prescribed budgetary constraints. The development of this plan was coordinated by Ralph E. Schofer of the National Bureau of Standards (NBS), with the participation of Ronald Fisher (UMTA), Dr. Alan Goldman (NBS), James M. McLynn and Robert Watkins (DTM Inc., Bethesda Md.), Dr. Peter Sherrill, (Consultant, San Francisco, California), Dr. Martin Wachs, (University of California, Los Angeles); Stanley Price (UMTA) and John Crain (Consultant, Menlo Park, California).

When the research design was being conceived, the planners could scarcely have anticipated an economic recession with consequent decline of employment; the 1973-74 oil oil embargo and the accompanying fuel shortages and price increases/general inflation; and the resulting increase in importance of public transport and car pooling. These external events caused some rearrangement of priorities, and (along with the discernment of clearly improved ways of accomplishing some objectives) resulted in plan modification during the implementing of the evaluation. Despite these unanticipated discontinuities, the original research plan was generally adhered to throughout the evaluation program. It was reappraised and modified, as necessary, annually. Drs. Wachs and Goldman served as consultants to the project team in periodic reassessment efforts to improve both methodology and reporting procedures.

Abolition of the Technical Analysis Division in June of 1975 somewhat curtailed original expectations for this final report. Once it became clear in the autumn of 1974 that project personnel would be departing prior to June 1975, the report's scope had to be reduced to permit finishing its supporting research and analysis early in the calendar year 1975.

It is likely that the evaluation team members,although dispersed in new positions, will in the near future produce several technical papers related to the Shirley Highway Evaluation. In addition, mode choice research supportive of the transferrability of the bus-on-freeway technology will be published separately late in 1975.

Gerald K. Miller served as project leader for the evaluation during its first two years. He was succeeded by James T. McQueen, who directed the work through to its conclusion in this final report.

ACKNOWLEDGEMENTS

Throughout this evaluation of the Shirley Highway Express Bus-on-Freeway Demonstration Project, many individuals have contributed both their ideas and their time. Space will not permit the recognition of all of them; however, we want to acknowledge major contributions by the following persons:

Ronald Fisher and James Bautz of the Urban Mass Transportation Administration for direction and assistance;

Perrie Nutwell and Mike Bresnahan of the Washington Metropolitan Area Transit Authority and David Erion of the Northern Virginia Transportation Commission for their cooperation in obtaining information important to the evaluation;

Ken Brown, Merrie Fraser, Faith VanderClute and others of the Metropolitan Washington Council of Governments for their diligent efforts in the collection and processing of the data used in the evaluation; and

Colleagues at the National Bureau of Standards for their support. Significant among them are: Keith Goodman, Richard Yates, Theodore Saks and Carol Harrison who worked on earlier phases of the evaluation; Ralph Schofer, George Suzuki and Alan Goldman who provided technical direction and analytical assistance; Dorothy Wood and Ruth Ciufolo who prepared the draft; Elaine Bunten who assisted in the development of our commuter surveys; and Sally Peavy who provided computer programming assistance.

ABSTRACT

The Shirley Highway Express Bus-on-Freeway Project began in June 1971 and ended December 31, 1974. The principal goal of the project was to demonstrate that express bus-on-freeway operations can improve the quality of bus service and lead to an increase in the people moving capability of peak period transportation facilities for an entire urban corridor. Secondary project goals were to demonstrate the effectiveness of this technology as a means of reducing auto pollutant emissions and gasoline consumption, improving the mobility of the transportation disadvantaged and the economic condition of the transit operator.

This report summarizes project performance with respect to the attainment of the above goals. An analysis of bus operations is presented which shows that the project effected an improvement in the quality of the Shirley Highway Corridor bus service as evidenced by the reduction in travel times by bus, and the increase in both the reliability and the coverage of the bus system. Trends in peak period traffic volumes are presented which show that the subsequent increase in bus patronage and bus' share of Corridor commuters led to an increase in the peak period people moving capability of the Corridor. Corridor people moving capability was also increased by project stimulated growth in carpooling.

Data from surveys of Corridor commuters were used in identifying factors important in commuters' decisions to use bus or to carpool. Bus users who formerly had commuted by auto reported that the most important factors in their decisions to switch from auto were the expense and discomfort of commuting by auto, and the express features of project bus service. Factors reported as most important in decisions to join or form a carpool were reduction in commuting costs, special parking privileges for carpools, and availability of the express busway to carpools.

The report concludes with an analysis of project performance with respect to the secondary goals. The project resulted in significant reductions in peak period auto usage, auto pollutant emissions and gasoline consumption. The utilization of project bus service by transportation disadvantaged persons is discussed and project costs and revenues are analyzed.

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1.0 SUMMARY OF EVALUATION

A major goal of the Urban Mass Transportation Administration (UMTA) of the Department of Transportation (DOT) is to foster transportation innovations which are likely to lead to more efficient transportation operations and to an improved urban environment. The Shirley Highway Express-Bus-on-Freeway Demonstration Project -- the largest bus-transit and highway project ever sponsored by DOT -- represented a major effort in the promotion of innovation in urban transportation. The project, which began April 1971 and ended December 1974, had three major elements: 1) an eleven-mile, two-lane reversible busway in the median of the Shirley Highway (I-95) which was used by buses and later by carpools with four or more members, 2) buses with new interior features, and 3) fringe parking lots coordinated with the express bus service.

The primary goal of this project was to demonstrate to state and local transportation authorities that express bus-on-freeway operations can improve the quality of bus service and lead to an increase in the people moving capability of peak period transportation facilities for an entire urban corridor. Related project objectives were:

(1) Increase reliability of bus service.

(2) Reduce travel time for transit and auto commuters.

(3) Increase coverage by bus routes.

(4) Increase bus passenger convenience and comfort.

(5) Increase bus patronage.

(6) Increase bus's share of corridor commuters.

A secondary project goal was to demonstrate that this technology can have a favorable impact on the transportation-related environmental and social conditions within a corridor and on the economic condition of the transit operator. Related project objectives were:

(1) Reduce peak period auto pollutant emissions.

(2) Reduce peak period gasoline consumption.

(3) Increase mobility of the transportation disadvantaged.

(4) Increase productivity of the bus operator.

This document reports an investigation of project performance with respect to the previously stated goals. The present section summarizes the findings of the evaluation and their more important implications.

1.1 Attainment of Project Objectives

The project demonstrated that a comprehensive bus-on-freeway operation can be integrated with corridor bus service and that the resultant express bus service can be operated as a high quality transit system. It also demonstrated that high quality express bus service can attract commuting motorists (primarily those who drive alone) and increase the peak period people moving capability of corridor transportation facilities. Such shifting of motorists to the express bus service effected reductions in auto usage, auto pollutant emissions and gasoline consumption. Although special project services resulted in increased mobility for a few of the transportation disadvantaged, the project did not demonstrate that express bus-on-freeway operations lead to substantial increases in mobility for the disadvantaged group.

Corridor Bus Service Was Improved. The evaluation shows that this bus-on-freeway operation improved aspects of bus service which have been found to be important to commuters: 1) service reliability, 2) travel time, 3) service convenience, and 4) trip comfort. Prior to the project, only about 33 percent of the buses arrived at their first stop in Washington, D.C. within six minutes of the scheduled time. Immediately after the project was implemented, this figure rose to 92 percent. The improved performance was maintained over the life of the project. Average speeds of express buses (buses using the busway) were consistently higher than those of non-busway buses. Also, reported door-to-door travel times of passengers on the express buses were lower than those of non-busway passengers for similar trips. The express bus service fitted corridor commuter travel patterns better than the non-busway service, as service was more direct, and walk and wait times lower.

These lower access and waiting times also reflect the large expansion in the coverage of the bus service. In 1971, the project consisted of 60 route miles of express bus service during each peak period. In September 1974, this figure had risen to 138 route miles. During the same period the number of express bus trips operated during each peak period rose from 156 to 299. The expansion in express bus service allowed the system to provide reasonably comfortable service in spite of continued increases in patronage. Even though daily A.M. peak period patronage on the express buses rose from about 4,200 riders in June 1969 to about 16,100 riders in November 1974, seat availability remained high, with about 80 percent of the passengers reporting that they "usually get a seat."

Peak Period People Moving Capability Was Increased. The project resulted in a substantial increase in the people moving capability of the Shirley Highway Corridor (the influence area of the express bus-on-freeway service). Much of this increase was due to the increase in Corridor bus patronage. During the life of the project, daily peak period corridor-wide bus ridership (one-way) increased by 11,000; from 14,000 (June 1969) to 25,000 passengers (November 1974). This increase was due to the project, as daily peak period patronage (one-way) on the new express bus service increased by almost 12,000; from 4,200 to 16,100 passengers (including passengers carried by private companies).

This growth in bus ridership led to an improvement in the effectiveness of people movement through the Shirley Highway Corridor as evidenced by changes in bus market-share (the percentage of potential bus person trips that are made by bus). Prior to the beginning of the project, bus market-share was about 27 percent. In November 1974, this figure had risen to 41 percent.

The increases in bus patronage and bus market-share were, in large part, the result of motorists switching to the new express bus service. These former auto commuters reported that express features of the bus operation together with the high cost and discomforts of commuting by auto were the major reasons for their decisions to switch to bus. In contrast to the motorists who switched to bus, many of the commuters who drove alone to work had formerly used bus. These motorists, most of whom had used non-busway bus service, reported that excessive waiting and travel times and poor service reliability were their principal reasons for no longer using bus.

An increase in carpooling during 1974 also contributed to the increase in Corridor people moving capability, as auto occupancy (both Corridor-wide and on the Shirley Highway), which had been declining since the beginning of the project, began to rise. In October 1974, near the end of the project, both Corridor-wide and Shirley Highway auto occupancy rates were higher than at any time previously during the project. Most of the increase in carpooling and auto occupancy can be attributed to motorists; however, former bus users comprised about 25 percent of the surveyed carpoolers. This was especially true for commuters diverted to carpool by the availability of the busway to that mode; about one-third formerly commuted by bus, the large majority of whom resided in the service area of busway bus routes. Both former auto and former bus users reported that reductions in commuting costs and preferential treatment -- use of the busway and provision of special parking privileges -- were the principal factors in their decision to carpool. Carpool locator services were not a significant factor. Commuters who drove alone identified loss of flexibility as the greatest obstacle to carpooling.

Another measure used to indicate the effectiveness of people movement is "person movement per lane during the peak hour." In November 1974, the Shirley Highway carried nearly 36,800 persons on the main roadway and the reversible lanes (i.e., busway) during the A.M. peak period (6:30-9:00 A.M.); 16,100 bus riders and 20,700 auto commuters, (including 4630 carpoolers on the reversible lanes). During the peak hour (7:00-8:00 A.M.), averages of persons per lane on the main roadway (three lanes) and on the reversible roadway (two lanes) were 2310 and 6080 respectively. Thus, the peak hour throughput per lane of the reversible roadway was more than 2 1/2 times that of the main roadway.

Peak Period Auto Usage, Auto Pollutant Emissions and Gasoline Consumption Were Reduced. As a result of the project, approximately 7600 autos were diverted from daily peak period traffic on Corridor roadways (as of October 1974), an 18 percent reduction from what auto usage would have been without the project. About 7280 were attributable to the express bus service and about 320 to the policy allowing carpools with four or more members to use the reversible lanes. However, it appears that the opening of portions of the reconstructed Shirley Highway was more responsible for reducing congestion and auto travel times than was the diversion of automobiles. Nonetheless, had these large numbers of express bus riders not been diverted from auto travel, the highway system would have been even more congested and all auto users would have been subjected to additional delays and longer travel times.

Other consequences of this removal of autos from Corridor roadways were a 21 percent reduction in auto pollutant emissions and a 23 percent reduction in gasoline usage. Between June 1971 and December 1974, the estimated reductions in auto emissions were as follows: about 5,500 tons of carbon monoxide, 700 tons of hydrocarbons, and 400 tons of nitrogen oxides. During the same period, approximately seven million gallons of gasoline were saved. (Gasoline usage and pollutant emissions attributable to the additional bus service were negligible.)

The Impact On the Bus Operator Was Favorable. The busway has had a generally positive impact on the bus operator. Utilization of vehicles and labor improved on routes that use the busway. Time savings on these routes allowed the same number of buses and drivers to make more trips than would have been possible otherwise. Increased utilization, however, was not enough to accomodate growth in patronage, and additional buses were put into service. To maintain November 1974 bus headways if the busway did not exist would have required approximately 20 additional buses and would cost the operator an estimated additional $30,000 per month.

Peak period service was expanded substantially during the life of the project. In addition, wages and the cost of fuel and other resources increased considerably. Still, the revenue from project riders (without an increase in fare after 1970) was nearly sufficient to cover total operating costs. Project revenues totaled $6,556,000. Project operating expenditures totaled $6,699,000, and operating costs averaged $.84 per mile (about $1.00 per mile for peak period service alone). Project revenues averaged $.83, bringing about a deficit of about $143,000 (slightly over $.01 per bus-mile).

1.2 Implications of Findings for Transportation Planning

The findings of the evaluation are significant in that they provide an example of the potential impacts of bus-on-freeway operations. The following discussion of the findings will focus on their implications for similar bus projects as they affect: 1) patronage potential, 2) incentives for increasing carpooling, 3) impact of preferential treatment for carpools on express bus operations, and 4) benefits and costs.

With regards to the implications of the evaluation for planning similar projects, the findings suggest the following:

Many Motorists Will Use Express Bus Service.

Auto commuters, even those from upper-middle income, multiple-auto households, switched to the high quality bus service because commuting by auto was expensive and difficult. Faced with expensive parking and frustrating commuting on congested roadways, many motorists switched to the express bus operation which provided: 1) travel times shorter than pre-project travel times by bus, 2) improvements in the reliability of bus service, and 3) expansion in the coverage and frequency of that service.

These findings suggest that plans for increasing bus' share of a corridor's commuters are best directed towards improving operating performance (as opposed to interior features), more specifically reducing travel times and increasing reliability. The plans might also include modifications to schedules which would reduce waiting times and increase commuters' arrival and departure time options.

Priority Treatment on Highway Facilities and in the Assignment of Special Parking Privileges Can Stimulate Substantial Increases in Carpooling.

These two incentives along with the gasoline shortages of the Winter of 1973-74 were found to be the principal reasons for the increase in Corridor carpooling. The greatest increase in carpooling was attributed to the availability of the reversible lanes, which reduced travel times and increased the reliability of expected auto arrival and departure times. Also significant to the increase in carpooling were the special parking privileges which made convenient parking available to carpools, often at reduced rates. Carpool locator services and concern for air pollution problems were not found to be important.

Most of the increase in carpooling was attributable to former auto commuters. However, at least one-fourth of the carpoolers using the busway had formerly commuted by bus. Most of these former bus users resided in the service area of busway bus routes, suggesting that the availability of a busway to carpools can have a significant impact on the patronage of express bus service.

With respect to conflicts with the express bus operations, neither bus operating speed nor bus schedule adherence suffered because of carpools on the reversible lanes. During 1974 there were only three accidents between the buses and carpools, and none of these involved injuries.

Substantial Benefits Are Possible With Bus-on-Freeway Service Involving Exclusive Highway Facilities.

The project resulted in a substantial increase in the people moving capability of the Shirley Highway, due primarily to large increases in patronage on busway bus routes. Also attributable to the project were an 18 percent reduction in auto usage, a 21 percent reduction in auto pollutant emissions and a 23 percent reduction in gasoline consumption (compared with estimates of what they would have been without the project). Expenditures for the Project were primarily for the construction of the reversible lanes, the acquisition of buses, and the operation of the express bus service. Construction costs averaged $4.1 million per mile (1972 costs). Bus costs averaged $45,000 per vehicle. Combined, peak period and mid-day bus operating costs averaged $.84 per bus-mile. An average cost of about $1.00 per bus-mile was ascribed to peak period service alone. Combined, peak and mid-day passenger revenues averaged $.83 per bus-mile, with about $1.10 attributed to peak period service alone.

Many of the elements of this project have been implemented in the past with varying results.[1] This demonstration project is different in the simultaneous implementation of project elements, the aggressive expansion of bus service (as opposed to the reduction of service as with most transit operations), and the continued provision of timely and highly

[1] "Bus Use of Highways: State of the Art," National Cooperative Research Program Report 143, Transportation Research Board, Washington, D. C., 1972, Ch. 2.

reliable bus service. While there is certainly much more to be learned about bus-on-freeway operations, the impressive results achieved here are an affirmation of the potential of well designed and carefully implemented bus service.

2.0 DESCRIPTION OF PROJECT AND EVALUATION PROGRAM

2.1 Purpose of Report

This report presents the principal results of a comprehensive evaluation of the four year Shirley Highway Express-Bus-on-Freeway Demonstration Project by the Technical Analysis Division of the National Bureau of Standards. Although directed towards transportation professionals, it should also be of interest to Federal and local administrators, and to transportation planners. Measures of performance with respect to specified goals of the project are presented, and results of an investigation into commuters' mode choice decisions are discussed. The report also presents an analysis of carpooling within the Shirley Highway Corridor.

It is not a purpose of this report to present detailed descriptions of the data and analytical procedures used in the evaluation, and only brief summaries appear. For more complete discussions, the reader is referred to our interim reports. References to these reports are included in the next subsection.

The remainder of Section 2 lists other publications on the demonstration project; describes the demonstration project and Corridor operating environment; and discusses the project evaluation program. Sections 3 through 6 present the major findings of the evaluation.

2.2 Related Reports

While this final report of the evaluation of the Shirley project covers all aspects of the multi-year project, related publications may also be of interest. Such publications include those which cover the feasibility investigation conducted prior to the project, the interim results of the Technical Analysis Division monitoring program and discussions of the project by others.

Since 1969, several publications have described elements or interim results of this multi-year project. One of the earliest, the "Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor,"[1] predicted the benefits and costs of alternative express bus operations within the Corridor area. The study concluded that express-bus-on-freeway operations were feasible, and the design of one of the alternatives considered became the basis for the development of the Shirley Highway Express-Bus-on-Freeway Demonstration Project. Two subsequent reports, prepared in 1971, recommended implementation plans, and monitoring and evaluation programs for the project.[2] Many of these recommendations were adopted as elements of the demonstration project and evaluation program.

Since the evaluation of the project began in 1971, six interim reports have been published by the Technical Analysis Division: Interim Report 1 presents a detailed description of the project, including the background and location and the major elements of the project.[3] Interim Report 2 presents results from the monitoring of project performance since

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[1] The "Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor" by Howard, Needles, Tamen, and Bergendoff, prepared for the Metropolitan Washington Council of Governments, March 1970.

[2] One, "The Implementation Plan for the Shirley Highway Express-Bus-on-Freeway Project," was prepared for the Federal Highway Administration and the Urban Mass Transportation Administration by the Metropolitan Washington Council of Governments, March 1971. Another, "Plans for the Operation of New Express Bus Services Using the Shirley Highway Exclusive Lane," was prepared for the Northern Virginia Transportation Commission by Alan M. Voorhees and Associates, February 1971.

[3] "The Shirley Highway Express-Bus-on-Freeway Demonstration Project - Project Description, Interim Report 1" (Report DOT/UMTA 1), August 1971. Available from National Technical Information Service (NTIS), Springfield, Virginia, PB 218-983.

its beginning in April 1971 through July 1972. It contains detailed discussions of the analytical procedures and data used to estimate project performance measures. Also included are profiles of bus and auto commuters developed from a 1971 survey.[4] Interim Report 3 presents results of a survey of users' reactions to the innovative interior features of project buses.[5] Interim Report 4 parallels the second report and presents results from the monitoring of project objectives through July 1973, with primary emphasis on the period between July 1972 and July 1973.[6] Interim Report 5 examines the reverse commute service provided by project buses, describes the users of the service, estimates benefits to the users, and recommends guidelines for the development of future reverse commute operations.[7] Interim Report 6 examines park-and-ride services which have been developed in conjunction with the express bus-on-freeway operation, and describes the demographic and travel characteristics of the users of the service from the lots. The report also discusses the reasons why auto users switched to bus service at the park-and-ride lots, as obtained from a special bus user survey.[8]

A report by a consultant to the Technical Analysis Division describes a mode choice modeling analysis performed using the 1971 survey data.[9] This report presents statistical analyses of the 1971 survey data and a set of mode choice models calibrated on these data.

The Shirley Highway project is the subject of three Transportation Research Board publications. One describes the project and interim results.[10] Two others compare the project with other transportation projects. One, "Bus Use of Highways - State-of-the-Art," describes and presents performance statistics (patronage, cost, etc.) for the Shirley Highway and other existing or planned bus-on-freeway projects in the United States and Europe.[11] The second, a recent research paper, compares the Shirley project with the Lindenwold rail line which provides rail rapid transit service to and from Philadelphia, Pennsylvania.[12]

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[4] "The Shirley Highway Express-Bus-on-Freeway Demonstration Project/First Year Results, Interim Report 2" (Report DOT/UMTA 2), November 1972. Available from NTIS, Springfield, Virginia, PB 214333.

[5] "The Shirley Highway Express-Bus-on-Freeway Demonstration Project--Users' Reactions to Innovative Features, Interim Report 3," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, June 1973. Available from NTIS, Springfield, Virginia, COM 73-11453.

[6] "The Shirley Highway Express-Bus-on-Freeway Demonstration Project/Second Year Results, Interim Report 4," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, November 1973. Available from NTIS, Springfield, Virginia, COM 74-10785.

[7] "The Shirley Highway Express-Bus-on-Freeway Demonstration Project/A Study of Reverse Commute Service, Interim Report 5," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, December 1974. Available from NTIS, Springfield, Virginia, COM 75-100412.

[8] "The Shirley Highway Express-Bus-on-Freeway Demonstration Project/A Study of Park-and-Riding, Interim Report 6," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, April 1975. To be published Spring, 1975.

[9] J.M. McLynn, et al., "Mode Choice and the Shirley Highway Experiment," prepared for the Technical Analysis Division, National Bureau of Standards, November 1973. Available from NTIS, Springfield, Virginia, PB 231-893.

[10] Ronald J. Fisher, "Shirley Highway Express Bus-on-Freeway Demonstration Project," Highway Research Record 415, Transportation Research Board, Washington, D.C., 1972.

[11] "Bus Use of Highways: State-of-the-Art," National Cooperative Highway Research Program Report 143, Transportation Research Board, Washington, D.C., 1973.

[12] V.R. Vuchic and R.M. Stanger, "Lindenwold Rail Line and Shirley Busway: A Comparison," Highway Research Record 454, Transportation Research Board, Washington, D.C., 1973.

2.3 Description and Background of Project

In 1969 a section of the reversible lanes in the median of the Shirley Highway opened exclusively to buses. This "busway," the first in the United States, became part of the Shirley Highway Express-Bus-on-Freeway Project which began in April 1971 and ended December 31, 1974. (Currently the Washington Metropolitan Area Transit Authority (WMATA) operates the project bus service.) During that period it demonstrated the coordinated development of a major, comprehensive transit service improvement for an entire urban corridor. The demonstration project involved the operation of express buses and carpools on an exclusive right-of-way within the median of the Shirley Highway (I-95) from the Northern Virginia suburbs into Washington, D.C. Over 90 new buses on many new and extended express routes dramatically improved the coverage area and quality of bus service for many commuters. Fringe parking lots were coordinated with the new bus service to provide park-and-ride facilities, and bus passenger shelters were built at many bus stops to protect waiting users from inclement weather.

The project showed that bus service could be significantly improved, that a major shift of auto commuters to bus could be attained, and that people moving capability could be increased substantially by such a bus-on-freeway operation. The four year experiment was sponsored jointly by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration, both in the Department of Transportation. Administered by the Northern Virginia Transportation Commission (NVTC) and the Virginia Department of Highways and Transportation, the project also demonstrated the cooperation among state, regional, and local organizations that is required to implement and operate a joint highway and mass transit system.[13]

Such a large system of integrated elements was not implemented all at once, but was developed in stages based upon an initial comprehensive plan.[14] As the project evolved, a steering committee was established to guide the development and coordinate the implementation of its various elements.

In this section, the major elements--the priority lanes, the bus transit operations, and the fringe parking lots--will be described and their evolution will be summarized. The salient geographical, socio-economic, and transportation characteristics of the project corridor will be presented. Finally, changes which have occured in the project environment and in the transportation system will be highlighted.

2.3.1 Major Project Elements

Three major elements comprised the project: 1) the reversible priority lanes for buses and carpools on the Shirley Highway and the bus priority lanes in downtown Washington, D.C.; 2) a bus transit operation involving additional buses (with special features) on new routes and with new schedules; and 3) residential fringe parking facilities for bus riders. The relative locations of the elements are shown in Figure 1.

The first project element provides exclusive or priority lanes for buses from the time they enter the Shirley Highway until they reach their terminal points in downtown Washington or the Pentagon. Figure 2 depicts the Shirley Highway, showing the completed 9 mile permanent eight lane section (two three-lane directional roadways separated by a two-lane reversible express roadway) and the 2 mile portion still under construction with the single-lane temporary busway.[15] Also shown are the bus and carpool access points. When completed

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[13]Other participating agencies included the Metropolitan Washington Council of Governments, the Washington Metropolitan Area Transit Authority, and the District of Columbia Department of Highways and Traffic.

[14]For the early history of the project planning and implementation, see Section 1 in Interim Report 1 - "Project Description."

[15]The permanent reversible lanes are 24 feet wide with 10 foot shoulders. The temporary busway is 18 feet wide, but may narrow in some locations to 11 feet; of course, I-95 is built to interstate standards.

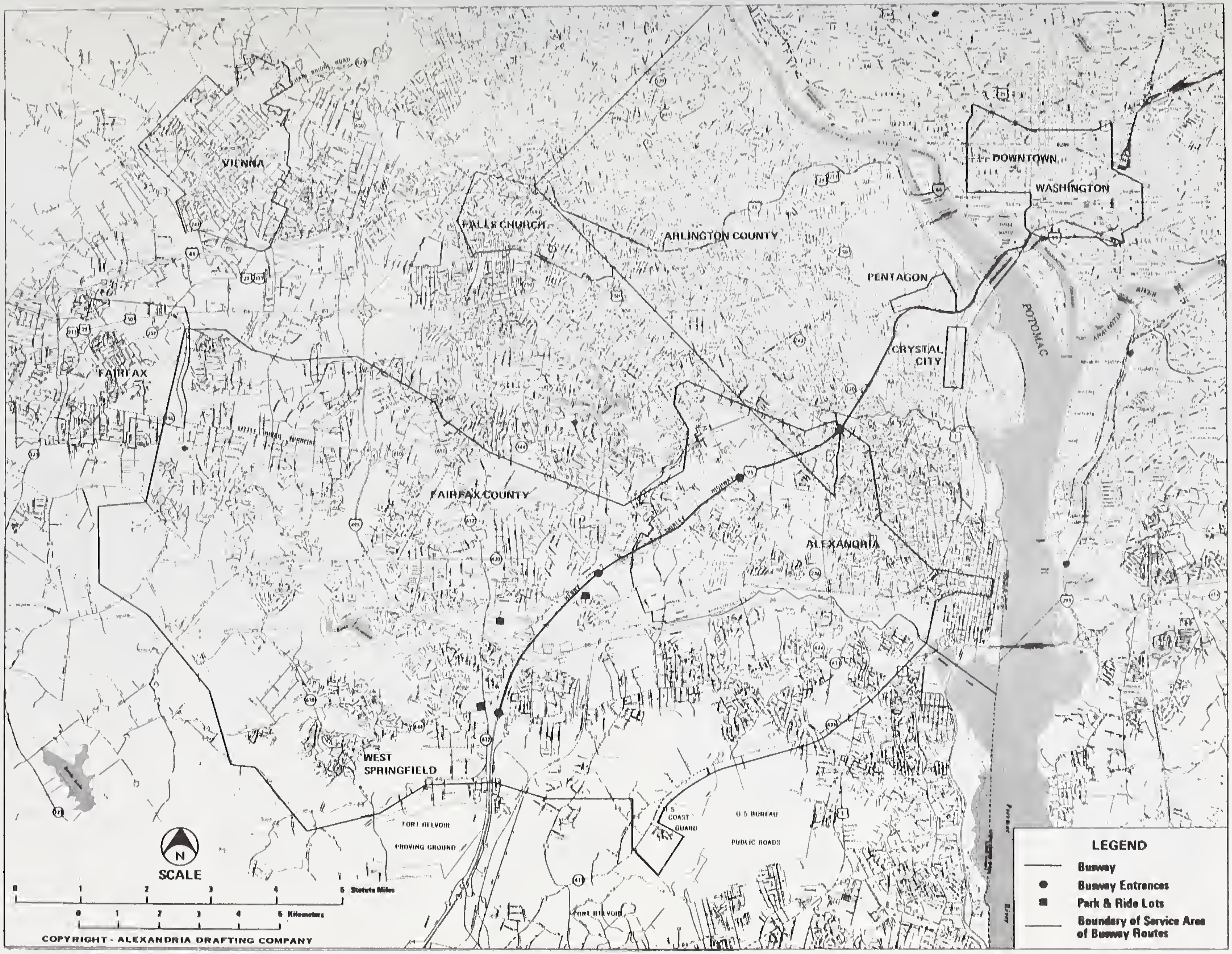

Figure 1. Elements of the Shirley Highway Express-Bus-on-Freeway Project

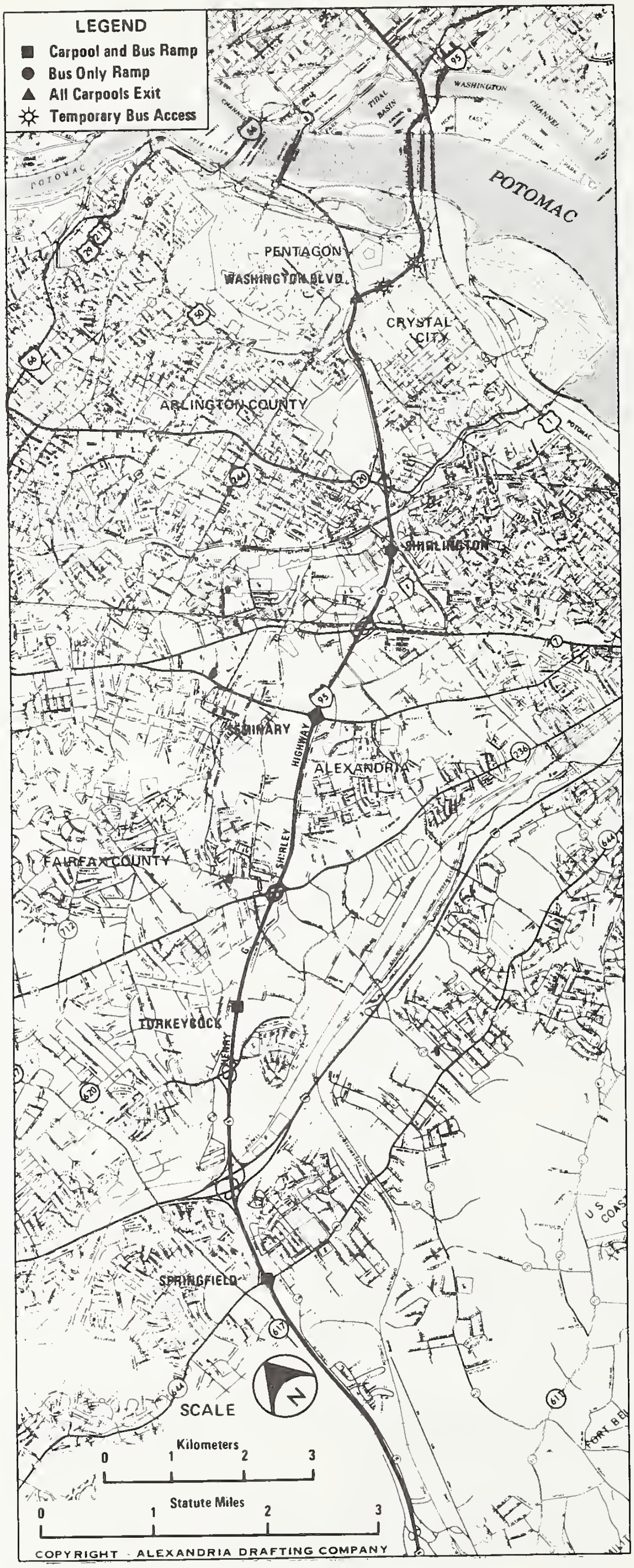

Figure 2. Shirley Highway and Entrances to the Reversible Lanes

in Fall 1975, the reversible priority lanes will be approximately 11 miles long and will end at the southern end of the 14th Street Bridge over the Potomac River.

After travelling through the Corridor on the busway, inbound buses crossed the Potomac on the 14th Street Center Span Bridge. (The reversible lanes were only used during the peak periods--inbound from 6:30 to 9:00 AM and outbound from 4:00 to 6:30 PM.) The buses then merged with regular District of Columbia traffic. Within the District, peak period bus lanes and special turn advantages gave the buses some priority over autos. Figure 3 shows the locations of priority bus lanes and special turn advantages as of December 1972. This plan was modified during the project as construction of the local subway (Metro) progressed.

In December 1973, the 9 mile completed section of the reversible priority lanes that had been previously used exclusively for buses was opened to carpools with 4 or more occupants. As indicated in Figure 2, the carpools entered the reversible lanes at the two southern-most points and exited at Washington Boulevard (just before the temporary buslane began). Carpools and buses will share the entire length of the facility when the I-95 reconstruction project is completed in 1975 (current policy of the busway operator, the Virginia Department of Highways and Transportation).

Project bus operations (the second project element) consisted of peak period Shirley Highway bus service operated by the AB&W bus company prior to the project,[16] the new demonstration service which was administered by the Northern Virginia Transportation Commission (NVTC), and new service initiated by the Washington Metropolitan Area Transit Authority (WMATA) to accomodate expanded patronage.[17] WMATA (formerly AB&W) served the pre-project bus routes; however, the project service was provided by 90 new special feature buses purchased by NVTC using UMTA demonstration grant funding.[18] UMTA funding was also used to install bus passenger shelters along these routes; 20 were installed, six by the NVTC and the rest by WMATA.

Figure 4 depicts the A.M. peak period service as of April 1971. Figure 5 depicts the A.M. peak period service as of December 1974. The complexity of the routes (a single route number may subsume many variations in routing and starting and ending points) is omitted to preserve the clarity of the figures. The new project routes had more direct routing in suburban and downtown collection and distribution to complement the express lanes, and thus provided fast and reliable peak-period bus service. (Section 3 presents further information on the peak period bus service improvements.) In addition, project buses were also used to provide new base day and reverse commute routes.

The new buses had special features (relative to typical urban transit buses) which increased passenger comfort and service reliability. Features designed to increase passenger comfort included: air conditioning, wider seats and aisles, smooth line interiors (no advertising racks) with colorful plastic wall coverings, and carpeting or a new vinyl mat-type floor covering that was color coordinated with the walls and seats. Two-way radios were provided to enable dispatchers to communicate with drivers in the event of break-downs or accidents, and to direct route changes when warranted by traffic conditions. In addition to the above features, all of the buses were equipped with anti-pollution devices to reduce exhaust emissions, and some were powered by eight-cylinder engines (typical urban transit buses have six-cylinder engines).

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[16] WMATA acquired the AB&W Transit Company, a private firm, on February 4, 1973, as part of the regional bus system. It now operates the former AB&W buses as well as the NVTC service.

[17] Although not part of the project, private companies such as Colonial Transit, Greyhound, and Trailways also operated commuter buses on the reversible lanes.

[18] At the completion of the demonstration project WMATA acquired the NVTC buses and continues to operate the project service.

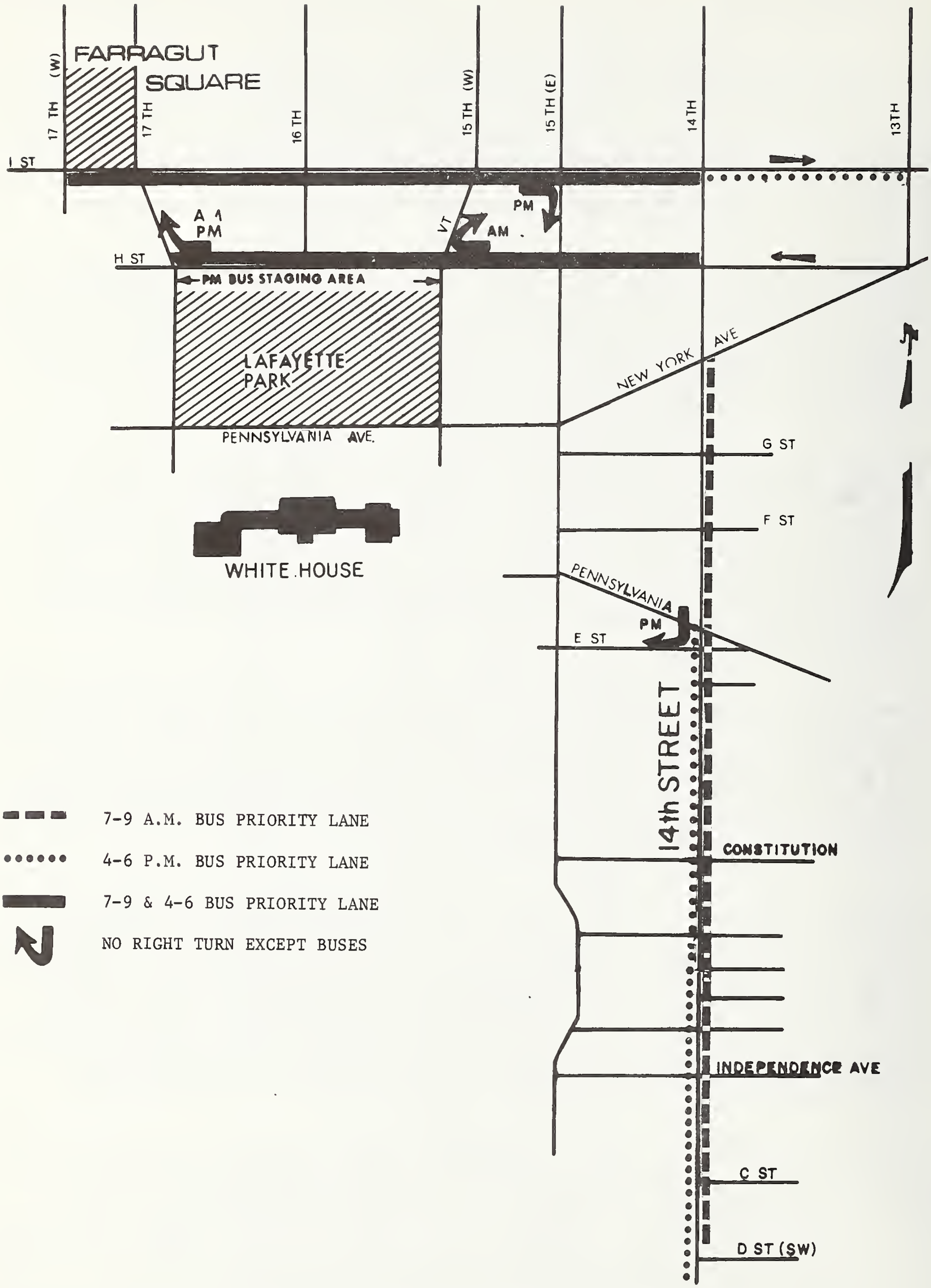

Figure 3. Peak Period Bus Priority Lanes in Downtown Washington

Figure 4. Peak Period Bus Service in June 1971

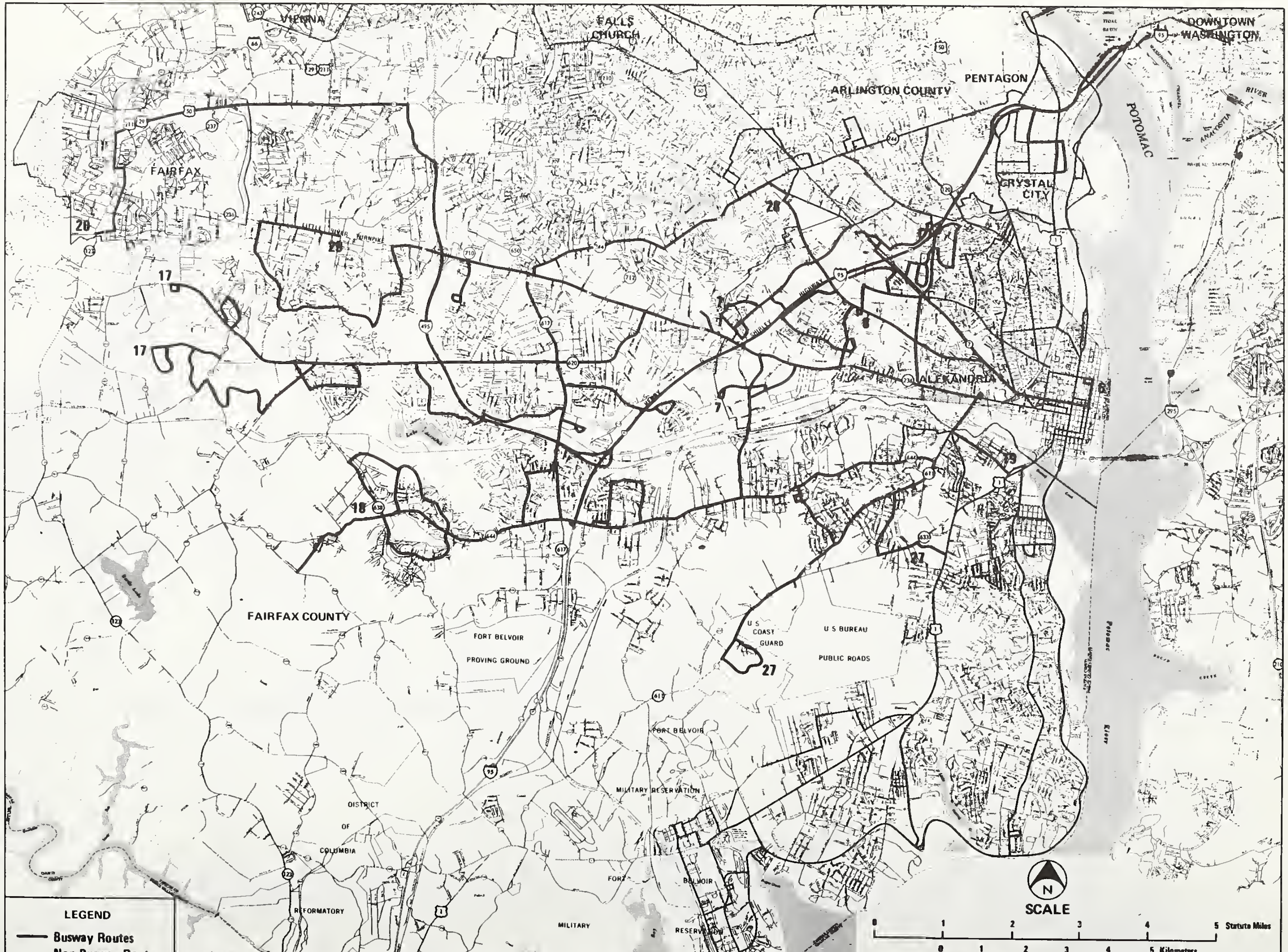

Figure 5. Peak Period Bus Service in December 1974

Residential fringe parking facilities (third project element) were coordinated with the new bus service to serve park-and-ride patrons. Figure 1 indicates the locations of the three official lots. The lot at Backlick Road near the Capital Beltway (I-495) is a permanent park-and-ride facility on the site of a future Metro station which NVTC leased during the project. The five acre, lighted lot has 400 parking spaces, an area for passenger boarding and alighting, and a kiss-and-ride staging zone as well as a bike rack and passenger shelters. The NVTC also obtained permission from two shopping centers (Springfield Plaza and Shirley Plaza) to designate portions of their lots for all-day free parking for bus users. Other shopping centers were also used for parking by daily riders, but were not officially part of the project.

2.3.2 The Development of the Project

The major project elements have evolved into a coordinated system over a 6 year period (1969 to 1974). This section will highlight that evolution.

The reversible priority lanes were opened in stages as the reconstruction of the Shirley Highway (I-95) progressed northward to Washington. Beginning in 1964, the Shirley Highway has been improved from a four-lane controlled access highway to an eight-lane interstate facility with two three-lane directional roadways and a two-lane reversible express roadway. In September 1969, the completed portion of I-95 reversible roadway was opened during the morning peak period to buses exclusively. This 4.8 mile section between Edsall Road and Shirlington (see Figure 2 for locations of interchanges) provided buses a savings of 12 to 18 minutes (over travel on the main roadway).

In September 1970 the first portion of a single lane temporary busway was opened through the area under construction from Shirlington to north of Glebe Road. An estimated 5 to 8 minutes were saved by the buses on this 1.6 mile section, and about 50 additional bus trips were routed onto the busway at Shirlington.

The final section of the temporary busway, extending to the new Center Span Bridge, was opened on April 5, 1971, and provided a total savings of about 25 minutes (compared with autos) over the entire length. At the same time, the new bridge was opened to buses and a system of peak period priority bus lanes on downtown Washington streets was implemented.

As the reconstruction progressed, the temporary single buslane was replaced by the two-lane reversible roadway. By May 1973, the nine-mile section of the reversible roadway from Springfield to the Pentagon was completed. The Shirley Highway, including the reversible lanes, is still under construction from there to the Potomac River, with a temporary busway through this section.

Bus service was developed as the busway was opened in sections, and the 90 demonstration project buses were purchased in increments. Although the opening of the initial busway sections in 1969 and 1970 stimulated increased ridership, the private bus company was unable to expand the peak period bus service significantly until the demonstration project began in 1971. After the opening of the entire busway into Washington and the beginning of the demonstration project, 30 new-feature project buses and eight new peak period routes were introduced in June 1971. Twenty more buses were added in February 1972, 10 more in June, and 16 were placed into service in September. The final 14 began operating in February 1973. Mid-day bus service began in 1972. This service consisted of two radial routes between the southern part of the Corridor and Washington, D.C. and two which circulated in opposite directions within the Corridor.

The fringe parking lots also were not introduced simultaneously. Parking at designated portions of the two shopping centers began in June 1971, while the permanent facility at Backlick Road was opened in October 1972. Bus passenger shelters were installed during 1973 and 1974.

2.3.3 Characteristics of the Shirley Highway Corridor

The demonstration project provides Northern Virginia commuters with fast and reliable peak-period bus service to the major employment areas in downtown Washington, D.C., the

Pentagon, and Crystal City, Virginia. The project influenced travel by bus and auto within a broad wedge-shaped section of Northern Virginia that extends south from the Nation's Capital and includes portions of Arlington, Fairfax and Prince William counties and the cities of Alexandria, Falls Church and Fairfax. The shaded portion of Figure 6 indicates the position of this influence area (referred to in this report as the Shirley Highway Corridor) within the National Capital Region.

The Corridor was defined according to the expected influence of the project on radially oriented commuter travel from the Northern Virginia suburbs. If it was plausible that a significant number of travelers from a particular area might use the project buses, the area was included as part of the Corridor. After analysis of the 1971 commuter survey, data, the Corridor area indicated in Figure 7 was defined.

At the northeast of the Corridor are the major employment centers, including the Pentagon, the Crystal City Complex, and downtown Washington, D.C. The northern boundary is U.S. Route 50 (Arlington Boulevard), with the Potomac River on the east. The southern perimeter extends to Woodbridge (almost 20 miles from Washington) and includes the suburban areas of Fairfax and Prince William counties. Route 123 defines the western boundary. The total area is over 150 square miles.

2.3.3.1 Demographic Characteristics

Approximately 500,000 people lived within the Corridor in 1970 (about 20 percent of the total population in the Washington, D.C.-Maryland-Virginia SMSA). It is one of the most affluent areas in the Nation. In 1970 the median family income was about $15,000 per year, about 28 percent more than the national median for suburban areas and about 15 percent more than the median income of the Washington, D.C. SMSA. (The SMSA median family income of $12,993 was the third highest in the Nation.[19])

Highlights of other 1970 census demographic statistics include the following (also see Table 1):

(a) Seven percent of the Corridor population were Black compared to 25 percent for the entire SMSA.

(b) The mobility of the Corridor residents is quite high, with 47 percent of the people moving into their homes within a 27 month period (January 1968 to March 1970) compared to only 41 percent of the SMSA residents and 37 percent of the District residents having moved during this same period.

(c) About 44 percent of the Corridor workers are government employees (37 percent Federal) compared to 39 and 42 percent for the SMSA and the District, respectively.

(d) Auto ownership is high, with an average of 1.34 cars per family and 41 percent having two or more cars. For the SMSA, the average number of autos per family is only 1.23, and 36 percent have two or more cars. The District average is 1.13, with only 19 percent having two or more cars available.

2.3.2.2 Transportation System Characteristics

Peak period traffic congestion is commonplace throughout the entire Northern Virginia highway network.[20] Corridor motorists commuting into the project destination areas

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[19] U.S. Department of Commerce, Bureau of Census, U.S. Statistical Abstract, 1972.

[20] The "Feasibility Study" concluded that each of the arterials operated at congestion during peak periods.

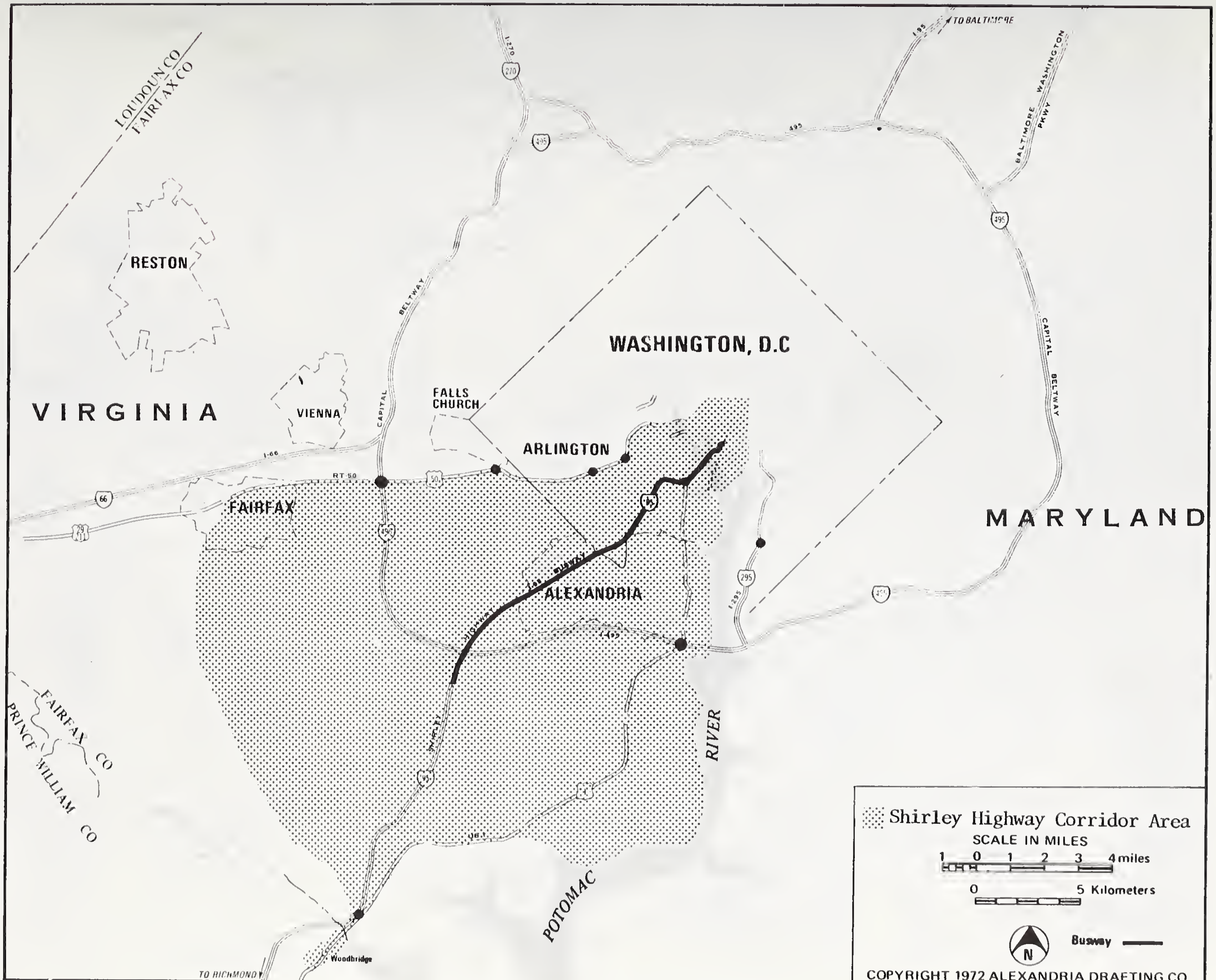

Figure 6. Washington, D.C. Metropolitan Area

Figure 7. Shirley Highway Corridor

Table 1

Selected Demographic Characteristics of
Shirley Highway Corridor and Washington, D.C. - Md. - VA. SMSA

1970 DEMOGRAPHIC CHARACTERISTICS	TOTAL CORRIDOR		TOTAL SMSA		WASHINGTON, D.C.	
	TOTAL	PERCENT	TOTAL	PERCENT	TOTAL	PERCENT
POPULATION						
Total	496,470		2,861,123		756,510	
Negro	32,379	7	763,445	25	537,712	71
Number Families	167,564		898,496		162,656	
AREA						
Square Miles	152.6		2,399		61	
Population Density per sq. mile	3,253		1,193		12,390	
YEAR MOVED INTO HOUSING						
1968-1970 (March)	73,871	47	367,995	41	96,118	37
1965-1967	35,147	22	206,136		59,743	23
1960-1964	24,117	15	139,366	15	40,229	15
1950-1959	17,922	11	128,366	14	41,226	15
1949 or earlier	5,764	4	62,059	7	25,222	10
1970 FAMILY INCOME[1]						
Median	$15,000		$12,993		$9,583	
CLASS OF WORKER						
Private	110,666	52	665,596	57	179,830	54
Government	95,080	44	460,779	39	141,163	42
Self-employed	6,788	3	50,419	4	13,510	4
Total	212,534		1,176,794		334,503	
AUTOS AVAILABLE						
1	74,497	44	405,179	45	113,671	70
2	60,004	36	277,330	31	28,380	17
3 or more	9,680	5	49,713	5	4,379	2
Total (Autos)	223,545		1,108,978		183,568	
Average (Autos/family)	1.34		1.23		1.13	
None	25,179	15	166,274	19	16,226	10
MEANS TRANSPORTATION TO WORK						
Driver	147,958	69	748,801	60	125,415	37
Passenger	30,186	14	163,922	13	39,246	12
Total	178,144	83	912,723	73	164,661	49
Bus	21,906	10	190,187	15	119,021	36
Walked to Work	7,965	4	78,504	6	33,745	10
Worked at Home	3,352	2	24,019	2	6,880	2
Other	4,107	2	33,022	3	11,039	3
WORK PLACE						
D.C. Central Business District	20,095	9	128,453	12	48,467	18
D.C. Remainder	38,259	18	363,813	33	171,925	63
Arlington	40,114	19	103,655	10	11,590	4
Virginia	88,847	41	183,811	17	7,181	3
Other	28,241	13	308,948	28	34,298	12

[1]The Corridor median annual family income of $15,000 is an approximation based on the mean of the median family incomes of the jurisdictions within the Corridor. (75 percent of the Corridor commuters live in Fairfax County where the median annual family income was $15,700 in 1969.)

Source: U.S. Department of Commerce, Bureau of the Census, Census of Population and Housing: 1970 Census Tracts PHC (1)-226, Wahington, D.C.-Md.-Va. SMSA, May 1972.

traveled on the Shirley Highway and six radial arterials: 1) Arlington Boulevard (Rt. 50), 2) Columbia Pike (Rt. 244), 3) Army-Navy Drive, 4) Arlington Ridge Road, 5) Jefferson Davis Highway (Rt. 1), and 6) George Washington Memorial Parkway. (See Figure 24, page 99 .) These arterials vary from four-lane undivided roads to a four-lane parkway. Trends in auto volumes are discussed in Section 4.

An extensive peak period bus system operated throughout the Corridor. In addition to the eight routes with over 300 bus trips on the priority lanes,[21] more than 240 bus trips operated on the other Corridor radial arterials. During the project development, there were no significant changes to the bus service on these non-Shirley routes. (In December 1974, a bus lane was opened on Arlington Boulevard.) Trends in transit ridership on the priority lanes as well as the other arterials are discussed in Section 4.

By 1980, the Metro regional subway system will be in operation and will intercept the buses in Virginia, hopefully alleviating traffic problems in Washington. For a discussion of the bus operations after Metro opens as well as more details on the transportation system characteristics prior to the project, see "The Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor."[22]

2.3.4 Changes in the Corridor Environment

Previous paragraphs have described the introduction of the major elements in this new experiment in mass transit technology, and presented the general demographic and transportation system characteristics of the area. The description of the project would not be complete without, however, a discussion of the major changes which occurred in its environment.

A stable environment cannot be expected to persist throughout a large scale transportation demonstration project. Suburban areas grow, and employment at major centers changes or shifts locations. Events such as the "energy crisis" as well as longer term influences like major transportation system construction can occur and affect the project. The following text will highlight those events within the Corridor and the metropolitan region that may have significantly affected the project outcome.

2.3.4.1 Population Growth Within the Corridor

During the 1960-1970 decade the rate of population growth in the Northern Virginia suburbs was among the highest in the Nation. During this period, population in the area increased about 50 percent, from 523,700 to 783,000 persons. For the same period, population in the Washington, D.C. SMSA and in the Nation's suburban areas increased about 38 and 39 percent respectively.[23]

Since 1970, the rate of population growth in the entire Northern Virginia suburbs declined substantially, but Fairfax County and Prince William experienced large increases in population between 1970 and 1973. In Fairfax County, where three out of every five Corridor residents live, population increased about 19 percent between 1970 and 1973, from 455,070 to 541,000 persons. In Prince William County, the population increased almost 30 percent between 1970 and 1973, from 111,100 to 145,000 persons.[24]

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[21] There are an additional 60 bus trips operated by the private companies serving the far southern sections of the Corridor.

[22] "The Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor," pp. 4-11, pp. 50-53.

[23] U.S. Department of Commerce, Bureau of Census, 1970 Census of Population and Housing, PHC(1)-226, Washington, D.C.-Md.-Va. SMSA, May 1972.

[24] 1973 Population estimates prepared by Northern Virginia Planning District Commission, October 1974.

These large population gains occurred primarily in the suburban developments far removed from central Washington. (The population of Arlington County, inside the Beltway and at the northern edge of the Corridor boundary, actually declined from 1970 to 1973.) The project bus service expansion took place in the distant suburban areas, many of which were developed during the last five years. Thus, the service was often introduced to commuters who had not lived in their communities very long. This high residential mobility may have influenced commuters' reactions to the new bus service (see Section 5).

2.3.4.2 Changes in Economic Conditions in Northern Virginia

Washington, D.C. has traditionally been a major employment center for the Northern Virginia Region. One-third of the labor force is employed in Washington, primarily as government and service workers. However, recent employment trends (1970-1974) indicate that for the first time combined employment in the service and retail trade sectors comprised a larger portion of total employment than the government sector,[25] suggesting reduced dependence upon Washington, D.C. as a source of employment.

The same data indicate that total employment in Northern Virginia rose at an annual rate of over 7 1/2 percent during the period 1970-1974 and that the annual population growth rate was 5 percent.[26] During that period, the unemployment rate was (as is usually the case) below the national average. In October 1974 the percent unemployed in the Northern Virginia region was only 3.5 as compared with the national rate of 5.5. The annual regional unemployment rates were less than 3 percent for 1970-1972 and only 3.5 in 1973.

2.3.4.3 Employment Changes at Corridor Destinations

Daily peak period Corridor travel is predominantly oriented toward downtown Washington, D.C. Major centers of employment in the downtown area are shown in Figure 8 with their 1969 and 1975 estimated levels of employment.[27] Project bus routes served these areas with an estimated 296,000 jobs in 1969 and over 399,000 forecasted for 1975. The Southwest area is expected to experience the greatest growth in employment, with the Downtown West and Connecticut Avenue areas following. Project bus routes also served the Crystal City Complex where employment was 30,000 in 1967 and is forecasted to be over 40,000 in 1975.

While employment in most areas increased during the project period, employment in two major centers with previous high transit ridership declined. The Pentagon employed over 27,000 in 1969 (with almost 20 percent of the Corridor's transit trips[28]); by 1974 Pentagon employment had declined to less than 21,000. Department of Navy buildings on the Mall in downtown Washington were closed in 1970, and over 5,000 employees were moved to Crystal City and other areas of Arlington, Virginia.

2.3.4.4 Changes in the Transportation System

Throughout the duration of the project, many changes occurred which directly affected the Corridor transportation system. Construction underway during the project on the Shirley Highway and the downtown portion of Metro disrupted traffic. The national energy crisis and subsequent gasoline shortages and price increases accelerated the

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[25]"Labor Market Trends 1970" - September 1974, Virginia Employment Commission.

[26]Ibid.

[27]These estimates from the "Feasibility Study" (p. 15) are used because more recent data are not available.

[28]"Project Description," p. 17.

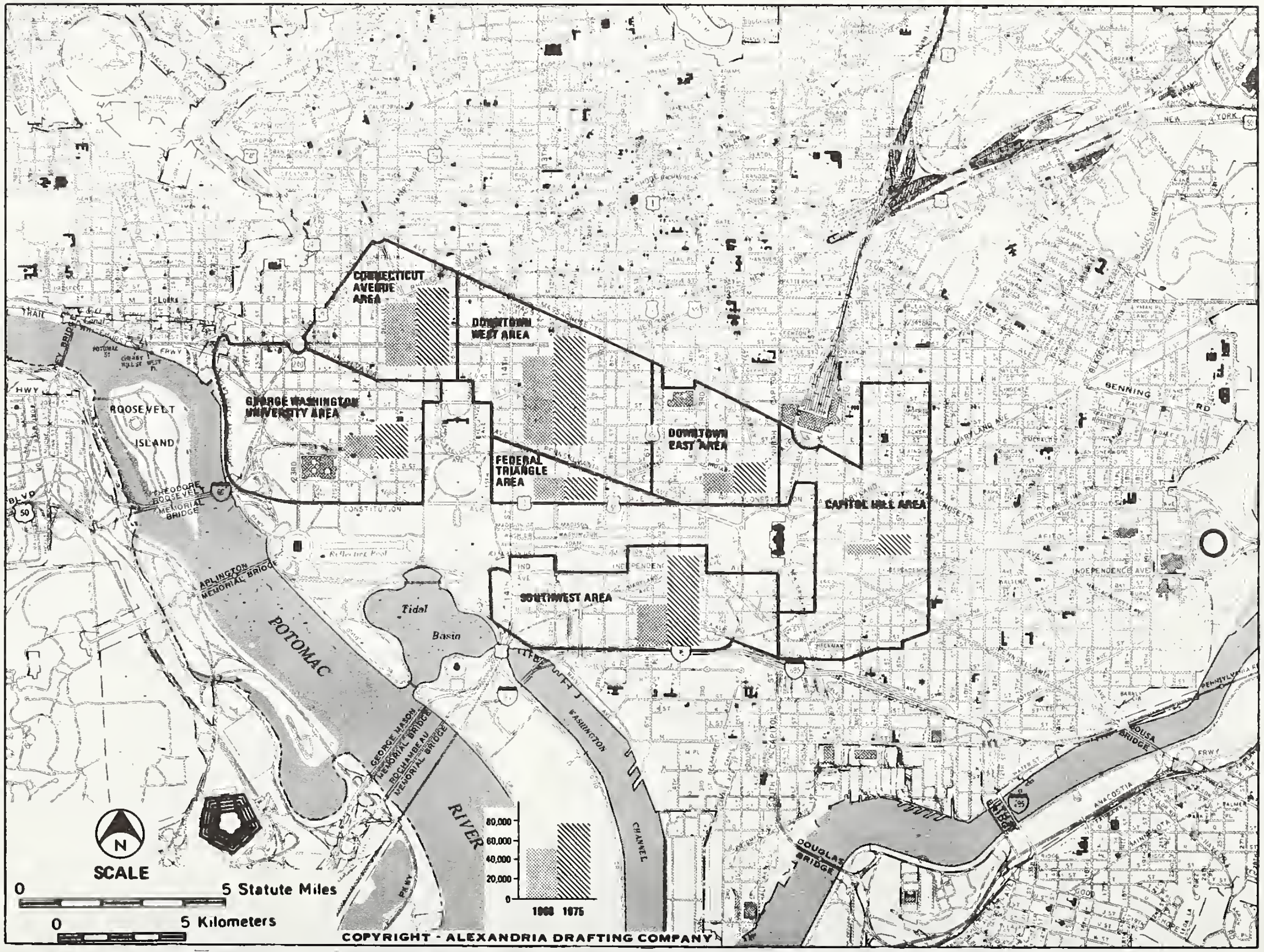

Figure 8. Forecasts of Employment Growth in Downtown Washington, D.C.

formation of carpools. The four bus companies operating in the Washington area were consolidated into an integrated regional bus system. (However, this had no perceptible effect on the project.)

For ten years the Shirley Highway has been under reconstruction. As the construction moved North from the Capital Beltway toward the 14th Street Bridge, peak period traffic was disrupted daily on some sections and increased the stress and frustration as well as travel time of the auto commuters in the Corridor. With routine traffic flow conditions disrupted by the construction, even slightly inclement weather, a minor accident, or a disabled vehicle was enough to cause even the normally uncongested sections of the highway to become clogged, and usually caused the congested sections near the Pentagon and over the 14th Street Bridges to break down completely. On these occasions the drive to work or home became an ordeal.

Construction on Metro has been underway in downtown Washington since 1970. During that time entire city streets were closed, or excavated and covered with timber while the subway construction proceeded. Auto and taxi traffic was extensively disrupted in various areas, and on-street parking spaces reduced. The impact on the downtown bus circulation and new priority lanes was severe, as buses moved slowly through the detours and congestion.

2.4 Project Goals and Description of the Evaluation Program

From the beginning, the development, operation, and evaluation of the Shirley Highway Express-Bus-on-Freeway Project were based upon a set of explicit goals. As a demonstration with national significance relating to the future construction and operation of highways and bus systems in many urban areas, its objectives were specified by UMTA and FHWA. Additional input into the formulation of project goals was provided by Corridor jurisdictions and the evaluation team. This section will present project goals and briefly describe the program designed to evaluate its performance.

2.4.1 Project Goals

The primary goal of the this project was to demonstrate to state and local transportation authorities that express bus-on-freeway operations can improve the quality of bus service and lead to an increase in the people moving capability of peak period transportation facilities for an entire urban corridor. Related project objectives were:

(1) Increase reliability of bus service.

(2) Reduce travel time for transit and auto commuters.

(3) Increase coverage by bus routes.

(4) Increase bus passenger convenience and comfort.

(5) Increase bus patronage.

(6) Increase bus system's share of corridor commuters.

(7) Increase peak capacity of the corridor transportation system.

A secondary project goal was to demonstrate that this technology can have a favorable impact on the transportation related environmental and social conditions within a corridor, and on the economic condition of the transit operator. Related project objectives were:

(1) Reduce peak period auto pollutant emissions.

(2) Reduce peak period gasoline usage.

(3) Increase the mobility of the transportation disadvantaged.

(4) Increase the productivity of the bus operator.

An additional goal which is involved in all Department of Transportation demonstration projects is to provide information useful in the planning and implementation of similar systems.

2.4.2 The Evaluation Program

UMTA's evaluation program for the project had two general objectives:

(1) Determine the extent to which the goals of the project were achieved.

(2) Relate the results to the planning and implementation of future bus-on-freeway operations.

In order to assess the degree to which the projects' objectives were attained, the evaluation program established measures of effectiveness for each goal. To determine if Corridor bus service was improved, changes in the following were measured for that service: 1) operating speeds, 2) door-to-door travel times of bus riders, 3) reliability of service, 4) area coverage by bus routes, and 5) passenger comfort and convenience features such as seat availability and fewer bus transfers. (Section 3 presents the evaluation results for this goal.)

The increase in people moving capability is measured in terms of 1) the increase in bus patronage and the rise in bus's market-share (the percentage of person-trips which are potentially bus trips and which are in fact made by bus) as well as increases in carpooling and reductions in single occupant autos, and 2) the growth in person volumes (bus and auto) per lane on the Shirley Highway as well as the resultant changes in the quality of service encountered by both bus and auto commuters. (These results are found in Section 4.)

Section 5 examines the reasons for the increase in Corridor people movement. Factors important in decisions to commute by bus or carpool are identified and the implications of these factors for mode choice modeling are discussed.

The secondary project goal concerns its economic, environmental, and social impacts. The evaluation program measured the economic impact on the bus operator in terms of project operating costs and capital expenditures, and savings from increased productivity. Environmental consequences were measured in terms of reductions in Corridor gasoline consumption and auto pollutant emissions. The social impact was measured in terms of the utilization of the bus service by persons from transit dependent households. (These results are presented in Section 6.)

The information from the evaluation should be useful from both national and regional perspectives. In the national interest, UMTA seeks to stimulate innovation within the transit industry by demonstrating the successful implementation of new techniques such as this express bus-on-freeway project. UMTA seeks also to provide to transit operators and transporation planners forecasting techniques and the planning information developed in conjunction with the Shirley Project. Such information includes the contribution of various features to increases in bus patronage, bus operator productivity, and efficiency of freeway lane utilization. This knowledge will aid in making decisions about future bus-on-freeway operations in other urban areas.

The regional perspective concerns the impact of the express bus operation on the Shirley Highway Corridor. Estimates of benefits and costs attributable to the project provide regional agencies with an indication of its impact upon the area it serves. These estimates will also provide planners in other areas with examples of the benefits and costs which they may experience.

2.4.3 Data Collection and Analytical Activities

The objectives of the evaluation program required the collection of various types of traffic and commuter data and the development of analytical procedures to estimate measures of project performance. The monitoring program and the series of commuter surveys are described in detail in the interim reports. The following highlights the kinds of information collected:

Periodic counts were made of peak period vehicular volumes and person trips (both bus and auto) crossing an eight-station screenline which intercepts the main radial arterials emanating from Washington, D.C. into the Corridor. (The counting program is discussed in Appendix A, and count data are summarized in Section 4.) Bus and auto travel times and bus schedule adherence data were collected periodically. The bus operator made monthly counts of all bus passengers using the busway and also provided aggregate system costs, revenues, and operating statistics.

Both general and special purpose commuter survey data were collected. In-depth, mail-back surveys of Corridor auto and bus commuters were conducted during October 1971, and October and November 1974. These surveys were used to determine demographic characteristics and travel patterns, and to determine reactions to the new service. The survey responses have also been used to develop and calibrate a mode choice model.[29] Copies of the 1974 survey questionnaires are presented in Appendix G. (Copies of the 1971 survey forms are found in the "First Year Results" referenced earlier.) Users of the two major Corridor park-and-ride lots were surveyed on-board buses during February and March 1973 to determine factors important in their decision to park-and-ride.[30] In June 1972, passengers were surveyed to determine their reactions to the special interior features (wide seats, carpeting, etc.).[31]

A number of analytical procedures, employing plausible assumptions when direct data were lacking, were utilized to estimate project impacts and measures of effectiveness. Many of these procedures are described in earlier reports and so are only mentioned in this document. These procedures were applied to estimate: 1) bus market share, 2) commuter travel time savings due to the priority lanes for buses and carpools, 3) reductions in automobile volumes, gasoline consumption and air pollutant emissions, and 4) bus operating costs.

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[29] See "Mode Choice and the Shirley Highway Experiment."

[30] See "A Study of Park-and-Riding -- Interim Report 6."

[31] See "Users' Reaction to Innovative Bus Features-Interim Report 3."

3.0 IMPROVEMENT IN THE QUALITY OF BUS SERVICE ATTRIBUTABLE TO THE DEMONSTRATION PROJECT

A primary goal of the project was to demonstrate that express bus operations improve the quality of Corridor bus service. "Quality of service" is an elusive characteristic of a bus transit system because it is a subjective concept, dependent upon user's perceptions. Subjective perceptions vary widely and are also difficult to quantify. However, previous studies have shown that commuters consistently rate the following measurable system performance characteristics as very important in mode choice decisions involving transit:[1] 1) schedule reliability, 2) travel time, 3) convenience of the service, and 4) comfort of the trip.

Based upon these findings, four characteristics were chosen as primary indicators of the quality of bus service, and the goal, "improve the quality of bus service," was then interpreted as 1) improve bus schedule reliability, 2) reduce bus travel time, 3) improve passenger convenience, and 4) improve passenger comfort. This section examines project performance to determine whether or not the quality of Corridor bus service was improved. Quality of service is assessed using both passengers' perceptions and direct measurement of changes in the four characteristics as defined below:

1. Schedule reliability - refers to the ability of buses to consistently arrive at their origins and destinations at the scheduled times.

2. Travel time - refers to the interval from the time a commuter leaves his home until he reaches his place of work. Travel time includes access time, the time spent traveling from home to the bus stop; waiting time, the time spent waiting for a bus to arrive; in-vehicle time, the time spent traveling in a bus; and egress time, the time spent traveling from bus stop to place of work.

3. Convenience - refers to the quality of the bus ride and includes the proximity of bus stops to both passenger origins and destinations, the frequency of bus service, and the directness of routing between origin and destination.

4. Comfort - refers to such amenities as air conditioning, sound proofing, and seating. Most of these characteristics are covered in the report, "Users' Reactions to Innovative Features," and will not be reiterated here. Another aspect of bus comfort, which was identified in bus passenger surveys, was freedom from the discomfort and stress associated with commuting by auto to work.

3.1 Improvements in Bus Schedule Reliability

Bus schedule reliability has two dimensions. One, "schedule adherence," is measured by the difference of the actual (observed) and scheduled (published) arrival times. The other involves commuters' perceptions as determined through responses to survey questions on the reliability of the bus service.

Bus schedule adherence was examined to determine the effect of the project priority elements--the reversible lanes on Shirley Highway and the bus priority lanes in downtown Washington--on the reliability of the bus service. To determine the effects of the busway upon schedule reliability, schedule adherence was examined for buses arriving at their first stop upon leaving the busway. Table 2 presents trends in the on-time distribution of buses arriving at 14th & C Streets, S.W. in downtown Washington, the first stop upon exiting the busway. The Spring 1971 observations were recorded prior to the opening of the entire busway in April 1971. As indicated by subsequent observations, there was an immediate improvement in schedule reliability after the busway opened.

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[1] Alan N. Nash and Stanley J. Hille, "Public Attitudes Toward Transport Modes: A Summary of Two Pilot Studies," Highway Research Record 233 (1968), 33-46; Thomas F. Golob, et al., "An Analysis of Consumer Preferences for a Public Transportation System" (Warren, Mich: General Motors Corporation, 1970), 17-23; Christopher H. Lovelock, "Consumer Oriented Approaches to Marketing Urban Transit," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, March 1973, available from NTIS, Springfield, Virginia, PB-220 781.

Generally, buses were within 6 minutes of scheduled arrival times at this first stop in downtown Washington. It should be noted that heavy patronage increases on busway routes (from about 3,800 in 1969 to 13,700 peak period passengers in October 1974)[2] and longer suburban collection route segments increased delays during the collection portion of the bus trip, thus preventing an even greater improvement in schedule adherence. Such delays could be recovered only partially through the higher operating speeds possible during the line haul segment on the reversible lanes.

Table 2

Schedule Adherence for A.M. Peak Period Busway
Buses at First Stop in D.C. (14 & C Streets, SW)

WHEN OBSERVED	NUMBER OF OBSERVATIONS	PERCENT OF OBSERVED BUS TRIPS				
		EARLY	ON TIME	MINUTES LATE		
				1-6	7-15	OVER 15
Spring 71[a]	32	15	0	18	67	0
Fall 71	226	36	8	35	16	5
Spring 72	91	42	13	14	3	0
Fall 72	296	40	12	42	6	0
Spring 73	169	51	12	31	6	0
Fall 73	124	44	10[b]	51	4	0
Spring 74	128	45	11[b]	37	4	2
Fall 74	177	41	8[b]	42	8	0

[a]Before the entire busway opened

[b]Includes up to one minute late

To measure the effect of the downtown priority lanes on schedule reliability during the distribution portion of the bus routes, schedule adherence checks were also performed at the last bus stop in the District. The results, shown in Table 3, reflect only the performance of the buses as they travel over the system of bus priority lanes between the first and last stops within the District. This is achieved by disregarding whether a bus was early or late at the first stop and computing its on-time performance at the last stop solely on the basis of the travel time between the two stops.

The effects of the priority lanes on schedule reliability were not as impressive as those of the busway. (See the "percent 7-15 minutes late.") This was due largely to the disruptive effects of subway construction in the downtown area. However, it should be noted that without the priority lanes, subway construction would have had a much more damaging effect on bus schedule adherence within downtown Washington.

[2]Unless otherwise noted, all references to patronage and bus trips refer to WMATA routes only.

Table 3

Schedule Adherence for A.M. Peak Period Busway Buses at Last Stop in D.C. (20 & Eye Streets, NW)

WHEN OBSERVED	NUMBER OF OBSERVATIONS	PERCENT OF OBSERVED BUS TRIPS				
		EARLY	ON TIME	MINUTES LATE		
				1-6	7-15	OVER 15
Fall 71	226	19	9	64	8	0
Spring 72	91	4	6	65	25	0
Fall 72	296	5	6	74	15	1
Spring 73	169	9	9	50	25	7
Fall 73	120	3	3	74	20	0
Spring 74	128	7	19	56	19	0
Fall 74	174	5	4	65	26	0

The on-board bus survey taken in November 1974 contained two questions designed to elicit information concerning passengers' perceptions of bus schedule reliability at both the origin and destination of the bus trip. The responses to these questions were categorized by 1) passengers on routes which utilized the reversible lanes and by 2) those which utilized other Corridor arterials (hereafter referred to as non-busway routes). As indicated by the results summarized in Table 4, no statistical difference was found between the two distributions (based on a Chi-square test at the 5 percent level). Approximately 70 percent of both populations indicated that their buses seldom arrive at their destinations later than the scheduled times. (It should be noted that patronage had declined on non-busway routes and expanded dramatically on busway routes.)

Table 4

Passengers' Responses to Bus Reliability Questions[a]

RESPONSE	BUSWAY Percent	NON-BUSWAY Percent
Q: Does this bus arrive at your boarding bus stop later than scheduled time?		
Never	10	8
Seldom	70	70
Usually	18	19
Always	2	3
Q: Does this bus arrive at your destination bus stop later than the scheduled time?		
Never	5	5
Seldom	66	64
Usually	25	27
Always	4	4

[a] From the November 1974 Bus Survey

3.2 Comparison of Busway and Non-Busway Bus Travel Times

Travel time by bus is influenced by the reversible lanes which affect speed, and by the expansion of service which affects both the frequency and routing of buses. Each of these project elements affects the different components of travel time in different ways. These effects were directly measured by observing bus travel times and speeds, and indirectly measured through an investigation of passengers' perceptions of travel time.

3.2.1 Measured Travel Time

The reversible lanes were expected to provide higher bus line haul speeds and hence shorter in-vehicle times. To investigate this, a comparison was made between trips on routes using the busway and those using other Corridor arterials. It would be expected that for a similar trip,[3] the operating speed for a busway route would be higher than for a route not traveling on the busway. Table 5 gives scheduled travel time, mileage, average passengers per bus and computed average speed for selected groups of busway and non-busway routes. These bus routes are shown in Figure 5 on page 14. For all groups examined, the scheduled bus operating speeds are faster for busway routes, with the difference ranging from 1.5 mph to 9.7 mph. These statistics reflect the fact that the busway allows buses to maintain a high average speed on the line haul portion of the route without interference from other vehicular traffic.

Table 5

Comparison of Scheduled Operating Speeds of Busway and Non-Busway Routes [a]

BUS ROUTE	LINE HAUL ROADWAY	AVERAGE PASSENGERS/BUS	TOTAL ROUTE LENGTH (miles)	SCHEDULED TRIP TIME (minutes)	SCHEDULED OPERATING SPEED (mph)
11A[b]	G.W. Parkway	42	21.3[c]	73	17.5
11T EX	G.W. Parkway	49	21.3[c]	66	19.7
18D	Shirley Busway	40	20.7[c]	56	22.2
11Y EX	G.W. Parkway	52	19.5[c]	61	19.2
18K	Shirley Busway	45	19.5[c]	53	22.1
16A EX	Columbia Pike	35	9.9[d]	44	13.5
29G	Shirley Busway	56	10.8[d]	28	22.3

[a]Based upon information available in Metrobus Timetables, September 1, 1974, published by the Washington Metropolitan Area Transit Authority.

[b]See Figure 5, page 14, for location of routes.

[c]Distance from origin of route to terminus at 20th & Eye Streets, N.W.

[d]Distance to Virginia end of 14th Street Bridge.

The line haul speeds attainable on the busway are highlighted by bus speed checks taken on the reversible lanes between the Turkeycock entrance ramp and the Washington Boulevard exit ramp (refer to Figure 2, page 10 for location of these ramps). Table 6 lists travel times and computed speeds observed during January 1975 for this 6.3 mile section of completed busway. As indicated, the busway provides for very high line haul speeds which approach the 55 mph speed limit of the highway.

[3]Similar trips are defined as trips which are approximately equal in terms of average patronage per bus and route length, with comparable percentages of suburban collection, line haul, and downtown distribution route segments.

Table 6

Average Busway Line Haul Speeds
Between Turkeycock and Washington Boulevard[a]

TIME PERIOD	NUMBER OF OBSERVATIONS	AVERAGE TIME (Minutes)[b]	AVERAGE SPEED (mph)
6:30-7:00	9	7.57	49.9
7:01-7:30	16	7.52	50.3
7:31-8:00	23	7.34	51.5
8:01-8:30	15	7.40	51.1
8:31-9:00	5	6.99	54.1

[a]Distance between ramps is 6.3 miles.

[b]Standard deviations ranged from .46 to .79 minutes.

3.2.2 Perceived Travel Time

Questions on the on-board bus survey form (see Appendix G) were designed to yield information concerning passengers' reported total trip time. By examining reported bus travel times from selected Corridor origins, equidistant from downtown Washington and served only by busway or non-busway service (but not both), an indication could be obtained of whether or not passengers perceived the shorter travel times afforded by busway service.

Table 7 lists mean reported door-to-door trip times for three pairs of census tracts with busway and non-busway origins. For all pairings, reported travel times on busway buses were shorter than those on non-busway buses, with the differences ranging from eight to eleven minutes. This indicates that not only did busway service provide shorter measured travel times than non-busway service, but also that the difference was perceived by the passengers.

Table 7

Mean Reported Trip Times by Bus From Selected Corridor
Origin Census Tracts to Downtown Washington, D.C.[a]

CENSUS TRACT	DISTANCE FROM CBD (Miles)	MEAN PERCEIVED TRAVEL TIME (Minutes)	NUMBER OF OBSERVATIONS	TYPE OF SERVICE
4002.00	8.0	62.0	20	Non-Busway
2001.03	7.4	51.0	45	Busway
4010.00	11.7	65.7	14	Non-Busway
4034.00	11.3	54.9	26	Busway
4011.00	13.4	65.4	13	Non-Busway
4038.00	13.1	56.9	76	Busway

[a]See census tracts in map on page 33.

Another comparison made was between reported bus and auto travel times from origin census tracts served exclusively by either busway or non-busway service. In all cases, the perceived difference between bus trip time and auto trip time was less for origins served by busway routes than for those served by non-busway routes. While neither busway service nor non-busway service was reported to be faster than auto, reported travel times via busway service more closely matched those by auto.

3.3 Improvement in Bus Passenger Convenience

Passenger convenience, as defined previously, is dependent upon the location of bus service relative to potential commuters, the frequency of that service, and the directness of routing of the service. During the life of the project, the expansion of bus service, both in coverage and frequency, affected each of these determinants of passenger convenience.

3.3.1 Bus Service Coverage

Bus service coverage is a broad term which attempts to depict the extent of the bus service area in the Corridor. It depends upon the number and geographic locations of bus routes as well as the location of park-and-ride facilities.

Route miles is one indication of the extent of bus service and hence its service coverage. Figure 4, page 13 depicts project routes in June 1971, just after the inception of the project. At that time there were approximately 122 route miles of service, concentrated primarily in the northern portion of the Corridor. Of that total, about 60 route miles comprised service that was routed over at least a portion of the busway. Figure 5, page 14 depicts project routes in September 1974 when the service had been expanded to approximately 260 route miles. Most of the expansion of 138 route miles occurred in the southern and western portions of the Corridor and was due to the increase in express busway routes developed by the Demonstration Project. (During 1974, WMATA added new express bus routes to satisfy patronage demands stimulated by the project routes.) Concurrent with the increase in bus route miles was the increase in bus trips. The number of bus trips (during each peak period) using the busway and entering the reversible lanes at all entrances from Shirlington southward increased from 96 in September 1970 to 297 in September 1974, a more than two-fold increase.

Another indicator of the extension of bus service in the Corridor is obtained from an examination of one busway route over the lifetime of the project. Route 18 services the West Springfield area of Fairfax County with trips to the Pentagon and the District of Columbia via the busway. (See Figure 5, page 14.) Figure 9 shows the Route 18 schedule as of July 1969. At that time, there were seven trips during the A.M. rush period (6:00-9:00 A.M.) serving either the Pentagon, or Washington Terminal. Also shown in Figure 9 is the Route 18 schedule for September 1974 when there were 57 trips during the A.M. rush period to destinations which included the Pentagon, Crystal City, Washington Terminal, Southwest Mall, and Farragut Square. Between July 1969 and September 1974 one-way route mileage on Route 18 doubled, going from 13 to 26. The dramatic increase in the Route 18 service over the life of the project is representative of the expansion which occurred on routes in the southern and western portions of the Corridor.

ROUTE NO.	WEST SPRINGFIELD GREELY & KEENE MILL (START OF LOOP)	FRANCONIA RD & PIONEER DR.	HANOVER & FLOYD	LEESVILLE BLVD. & BACKLICK ROAD	BERYLE & SHELDON	EDSALL & SHIRLEY	PENTAGON Lane B - Platform 5	YARDS & DOCKS	VIRGINIA END OF BRIDGE	ARRIVE WASHINGTON 12th St. Term-Platform 1
A.M. PEAK PERIOD SCHEDULE JULY 1969										
18A	...	6:30	6:36	6:42	6:50	6:53	...	...	7:18	7:30
18P	...	6:35	6:41	6:47	6:55	6:58	7:33	...	...	...
18D	6:33	...	6:51	6:57	...	7:04	7:39	7:42	7:44	7:56
18B	...	6:55	7:01	7:07	7:15	7:18	7:53	7:56	7:58	8:10
18P	6:53	...	7:11	7:17	7:25	7:28	8:03	...	...	...
18A	...	7:15	7:21	7:27	7:35	7:38	...	...	8:03	8:15
18D	7:13	...	7:31	7:37	...	7:44	8:19	8:22	8:24	8:36

ROUTE NO.	KEENE MILL & GREELEY	FORRESTER & ROLLING RD.	KEENE MILL & ROLLING RD.	KEENE MILL & GREELEY	KEENE MILL & HANOVER	SPRINGFIELD PARKING LOT	BACKLICK & LEESVILLE	BERYLE & SHELDON	BUSWAY AT TURKEYCOCK	LANDMARK	PENTAGON	14TH & CONSTITUTION	WASHINGTON TERMINAL	FARRAGUT SQUARE *
A.M. PEAK PERIOD SCHEDULE SEPT. 1974														
18G	5:53	6:00	6:02	6:09	6:12	...	...	...	6:21	...	...	6:41	...	6:50
18X	...	(Springfield Plaza 6:13)			...	6:22	6:24	...	6:28	...	...	6:48	...	6:57
18X/	...	...	...	...	...	6:24	6:26	...	6:30	...	6:44	...	...	...
18G	6:13	6:20	6:22	6:29	6:32	...	...	...	6:41	...	...	7:01	...	7:10
18A	(Fran. & Pioneer 6:30)				6:34	...	6:43	6:49	6:53	...	...	7:13	7:15	...
18P	6:16	6:23	6:25	6:32	6:35	...	6:44	...	6:45	...	7:02	...	...	...
18X/	...	...	...	...	...	6:46	6:48	...	6:52	...	7:06	...	...	...
18P	(Fran. & Pioneer 6:36)				6:40	...	6:49	6:55	6:59	...	7:13	(Crystal City 7:18)		
18X	...	(Springfield Plaza 6:40)			...	6:49	6:51	...	6:55	...	...	7:15	...	7:24
18D	6:33	...	6:40	6:47	6:50	...	6:59	...	7:03	...	7:17	7:27	7:29	...
18X/	...	...	...	...	...	7:00	7:02	...	7:06	...	7:20	...	...	...
18B	(Fran. & Pioneer 6:55)				6:59	...	7:03	7:14	7:18	...	7:32	7:42	7:44	...
18H (Orange Hunt 6:45)			6:52	6:55	6:58	...	...	...	7:07	...	7:21	7:31	...	7:40
18G	6:43	6:50	6:52	6:59	7:02	...	...	...	7:11	...	...	7:31	...	7:40
18P	6:45	6:52	6:54	7:01	7:04	...	7:13	7:19	7:23	...	7:37	...	...	...
18K	6:52	6:59	7:01	7:04	7:07	...	...	...	7:16	...	...	7:36	...	7:45
18X	...	(Springfield Plaza 7:02)			...	7:11	7:13	...	7:17	...	...	7:37	...	7:46
18G	6:53	7:00	7:02	7:09	7:12	...	...	...	7:21	...	...	7:41	...	7:50
18X/	...	...	...	...	...	7:14	7:16	...	7:20	...	7:34	...	...	...
18P	6:57	...	7:04	7:11	7:14	...	7:23	7:29	7:33	...	7:47	(Crystal City 7:57)		
18A	(Fran. & Pioneer 7:10)				7:14	...	7:23	7:29	7:33	...	...	7:53	7:55	...
18X	(Springfield Plaza 7:12)				...	7:21	7:23	...	7:27	...	...	7:47	...	7:56
18M	6:58	...	7:05	7:12	7:15	7:25	7:27	...	7:31	(S.W. Mall 7:50)		(4th & C 7:56)		
18G	7:03	7:10	7:12	7:19	7:22	...	...	...	7:31	...	...	7:51	...	8:00
18X/	...	...	...	...	...	7:28	7:30	...	7:34	...	7:48	...	...	...
18D	7:07	...	7:14	7:21	7:24	...	7:33	7:39	7:43	...	...	8:03	8:05	...
18X	...	(Springfield Plaza 7:22)				7:31	7:33	...	7:37	...	...	7:57	...	8:06
18P	7:06	7:13	7:15	7:22	7:25	...	7:34	...	7:38	...	7:52	...	...	...
18G	7:08	7:15	7:17	7:24	7:27	...	...	...	7:36	...	...	7:56	...	8:05
18H (Orange Hunt 7:15)			7:22	7:25	7:28	...	...	...	7:37	...	7:51	8:01	...	8:10
18G	7:13	7:20	7:22	7:29	7:32	...	...	...	7:41	...	...	8:01	...	8:10
18X	...	(Springfield Plaza 7:32)				7:41	7:43	...	7:47	...	...	8:07	...	8:15
18M	7:18	...	7:25	7:32	7:35	7:45	7:47	...	7:51	(S.W. Mall 8:10)		(4th & C 8:16)		
18A	(Fran & Pioneer 7:30)				7:34	...	7:43	7:49	7:53	...	...	8:13	8:15	...
18P	7:19	...	7:26	7:33	7:36	...	7:45	...	7:49	...	8:03	...	...	...
18G	7:18	7:25	7:27	7:34	7:37	...	...	...	7:45	...	...	8:06	...	8:15
18D	7:23	...	7:30	7:37	7:40	...	7:49	...	7:53	(Via. Mem. Br.)		8:17	8:19	...
18K	7:25	7:32	7:34	7:37	7:40	...	...	...	7:49	...	...	8:09	...	8:18
18G	7:33	7:40	7:42	7:49	7:52	...	...	...	8:01	...	...	8:21	...	8:30
18X	...	(Springfield Plaza 7:44)				7:53	7:55	...	7:59	...	...	8:19	...	8:28
18P	7:28	7:35	7:37	7:44	7:47	...	7:56	8:02	8:06	...	8:20	(Crystal City 8:25)		
18M	7:33	...	7:40	7:47	7:50	8:00	8:02	...	8:06	(S.W. Mall 8:25)		(4th & C 8:31)		
18X/	...	...	...	...	...	7:56	7:58	...	8:02	...	8:16	...	...	...
18G	7:38	7:45	7:47	7:54	7:57	...	...	...	8:06	...	...	8:26	...	8:35
18X	...	...	...	...	...	8:00	8:02	...	8:06	...	...	8:26	...	8:35
18X	...	(Springfield Plaza 7:57)				8:06	8:08	...	8:12	...	...	8:32	...	8:41
18H (Orange Hunt 7:45)			7:52	7:55	7:58	...	...	...	8:07	...	8:21	8:31	...	8:40
18X/	...	...	...	...	...	9:10	8:12	—	8:16	...	8:30	...	...	...
18G	7:48	7:55	7:57	8:04	8:07	...	...	...	8:16	...	...	8:36	...	8:45
18M	7:53	...	8:00	8:07	8:10	8:20	8:22	...	8:25	(S.W. Mall 8:45)		(4th & C 8:51)		
18X	...	(Springfield Plaza 8:12)				8:21	8:23	...	8:27	...	...	8:47	...	8:56
18G	7:58	8:05	8:07	8:14	8:17	...	...	...	8:26	...	...	8:46	...	8:55
18G	8:08	8:15	8:17	8:24	8:27	...	...	...	8:35	...	...	8:56	...	9:05
18X/	...	...	...	...	...	8:30	8:32	...	8:36	...	8:50	...	...	...
18X	...	(Springfield Plaza 8:27)			...	8:36	8:38	...	8:42	...	...	9:02	...	9:11
18G	8:23	8:30	8:32	8:33	8:42	...	...	...	8:51	...	...	9:11	...	9:20
18X	...	(Springfield Plaza 8:43)			..	8:52	8:54	...	8:58	...	9:12	9:22	...	9:31
18G	8:53	9:00	9:02	9:07	9:10	9:17	9:19	9:25	...	9:33	9:45	9:55	...	10:04

Figure 9. Route 18 Schedules for July 1969 and September 1974

The extent of bus service coverage can also be roughly shown by patronage density changes. Patronage density is defined here as the number of bus passengers per acre and is computed for each origin census tract. This measure attempts to define the geographic market area of the bus service, and the intensity of transit usage by geographic area. Figures 10 and 11 show patronage density by origin census tract for November 1971 and November 1974, the dates of two major on-board surveys. The figures show that from 1971 to 1974 there was a marked increase in patronage density in the western portion of the Corridor. By examining Figure 5, it can be seen that this is also the area where new routes were added.

Figure 10. Fall 1971 Patronage Density by Origin Census Tract

Figure 11. Fall 1974 Patronage Density by Origin Census Tract

About 10 percent of transit passengers in the Corridor were transported via private carriers (see Table 48, page 104). Greyhound, Continental Trailways, and Colonial Transit serve the satellite communities of Woodbridge-Dale City on I-95 and Manassas-Warrenton on I-66 with trips to the Pentagon, Crystal City, and Washington Terminal (see Figure 6, page 17). While perhaps not as dramatic as the increase in service provided by WMATA, there was a substantial increase in private carrier service, from 12 A.M. peak period trips in July 1969 to the 57 as of September 1974.

Along with the increase in service stimulated by the project was an improvement in the directness of routing. Directness of routing refers to the number of bus trips which could be served without transfers. Eighty-six percent of the home to work trips (determined from the Fall 1974 bus survey) made via busway service required no transfers as compared with only sixty-nine percent via non-busway service.

3.3.2 Park-and-Ride Coverage

Another means for increasing the service coverage of fixed route bus systems is to promote park-and-ride service from outlying suburban areas, and one of the important goals of the project was to implement and evaluate park-and-ride service in the Corridor. This aspect of the project has been reported in detail earlier.[4] The specific concern of Paragraph 3.3.2 is to demonstrate that park-and-ride facilities did extend Corridor bus service coverage beyond the immediate vicinity of the system of fixed routes.

There are three officially designated park-and-ride lots in the Corridor: designated parking spaces at Springfield Plaza Shopping Center and at Shirley Plaza Shopping Center, both opened in June 1971; and the Backlick park-and-ride lot, a permanent parking facility constructed at Backlick Road and Industrial Drive and opened in October 1972. All three of these lots are served by Route 18 service, and late in 1974, Route 16G service from the Backlick lot was added.

In addition to the three offical park-and-ride locations, there were over twenty consistently used unofficial locations, ranging from shopping center lots to on-street parking near bus stops. About 21 percent of all park-and-riders used the official lots, with the remainder patronizing unofficial locations. Figure 12 shows the location of the three official lots as well as the locations of the most widely used unofficial park-and-ride areas as reported in the 1973 bus survey.

Since bus routes can serve walk-on passengers only within a limited distance from the route itself, park-and-ride access can significantly extend the market area of bus transit. That this was the case for Corridor park-and-ride facilities is illustrated in Figure 13, which indicates the origins of commuters who utilized two park-and-ride facilities, one official, the other unofficial. Persons in census tracts without direct bus service utilized the bus system by patronizing park-and-ride facilities. Persons from census tracts which were contiguous with tracts served by busway routes used the park-and-ride service to reduce their walking distance to the bus stop.

[4] "A Study of Park-and-Riding," Interim Report 6.

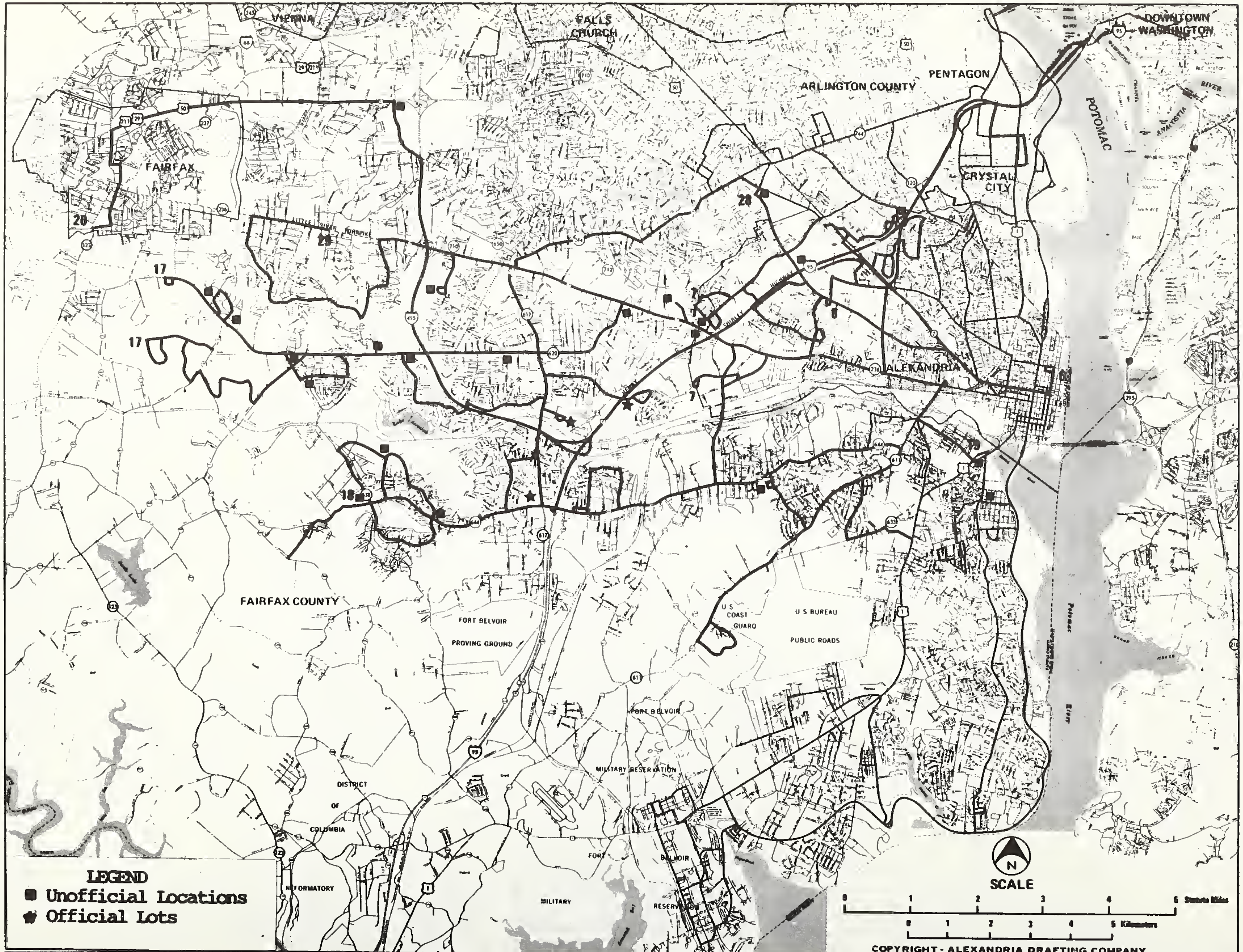

Figure 12. Park-and-Ride Locations

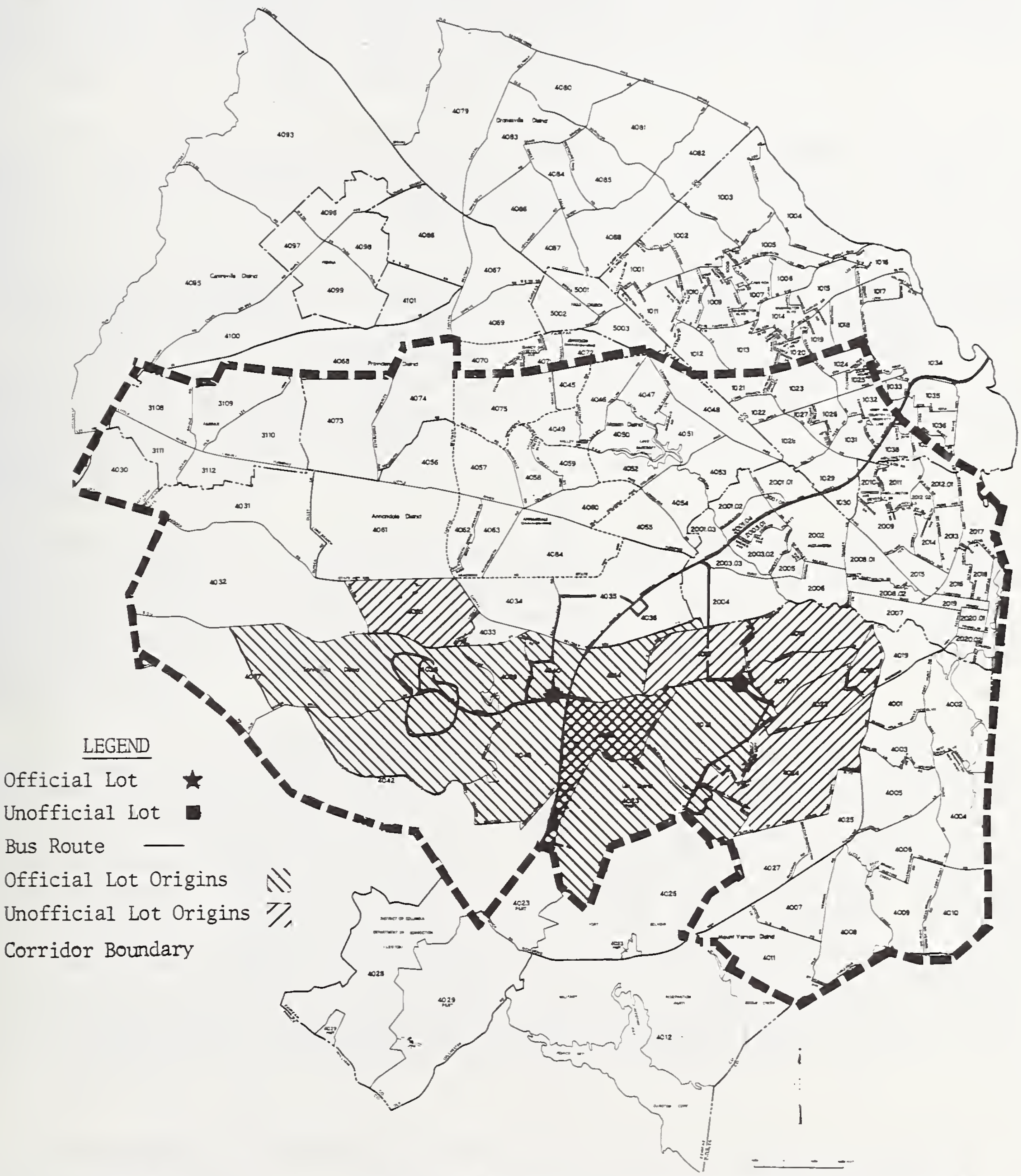

Figure 13. Origins of Park-and-Riders Using Two Selected Park-and-Ride Locations

3.3.3 Perceived Convenience

Another perspective on the project's effect upon convenience of bus service is gained by examining user perceptions of convenience aspects of the service. The convenience aspects investigated include the time spent walking to and from buses, time spent waiting for buses, and the time park-and-riders spent driving to the bus stop. Also included are riders' reactions to the scheduling of bus service, i.e., bus arrival and departure times.

The November 1974 on-board bus survey form asked the following question about walking and waiting time: "When you made this trip how much time did you spend walking to and from bus stops and waiting for buses?" Distributions of passengers' responses to this question, stratified by busway buses and non-busway buses, are presented in Table 8. Approximately 70 percent of busway bus users reported less than 15 minutes total time to walk to and wait for buses, as compared with 64 percent of non-busway bus passengers.

Table 8

Distributions of Bus Riders' Access and Wait Times

	BUSWAY			NON-BUSWAY		
MINUTES	NUMBER OF PASSENGERS RESPONDING	PERCENT OF PASSENGERS	CUMULATIVE PERCENT	NUMBER OF PASSENGERS RESPONDING	PERCENT OF PASSENGERS	CUMULATIVE PERCENT
Total Walk and Wait Time						
0-4	617	18.4	18.4	187	13.2	13.2
5-9	868	25.9	44.3	349	24.7	37.9
10-14	849	25.3	69.6	365	25.8	63.7
15-19	512	15.3	84.9	240	17.0	80.7
20-24	285	8.5	93.4	165	11.7	92.4
25-29	98	2.9	96.3	52	3.7	96.1
30-34	73	2.2	98.5	38	2.7	98.8
≥35	54	1.5	100.0	17	1.2	100.0
Auto Access Time for Park-and-Riders						
0-4	73	6.7	6.7	25	8.7	8.7
5-9	465	42.5	49.2	74	25.8	34.5
10-14	218	19.9	69.1	52	18.1	52.6
15-19	88	8.0	77.1	36	12.5	65.1
20-24	66	6.0	83.1	31	10.8	75.9
25-29	19	1.7	84.8	13	4.5	80.4
30-34	41	3.7	88.5	19	6.6	87.0
35-39	20	1.8	90.3	7	2.4	89.4
≥40	104	9.6	99.9	30	10.5	99.9

Another aspect of bus convenience is perceived auto access times of park-and-ride passengers. Table 8 also presents the distributions for busway and non-busway bus park-and-riders. Sixty-nine percent of park-and-riders on busway bus service reported traveling less than 15 minutes to reach a bus stop as compared with only 53 percent of non-busway park-and-ride passengers. Two factors contributed to this difference: one, service from the official park-and-ride lots was planned and implemented as a part of the project whereas only ad hoc service was available from the unofficial lots; two, non-busway park-and-ride locations were situated in traffic-congested areas of the Corridor (non-busway routes primarily served close-in Arlington and Alexandria), and hence their auto access times were longer than those to the suburban busway park-and-ride locations.

The final aspect of bus convenience considered in this study was bus arrival and departure times. An on-board survey of park-and-riders at the Springfield Plaza and Backlick park-and-ride lots conducted in February 1973 solicited satisfaction ratings of the convenience of bus arrival and departure times from the lots. The study concluded that rider satisfaction with the arrival and departure times was quite high.[5]

3.4 Changes in Bus Passenger Comfort and Seat Availability

Comfort is perhaps the most subjective element of the quality of bus service. It is the passengers' perceptions of bus vehicle characteristics such as climate control, design of seating, interior noise level, and other such factors. Interim Report 5 investigated passenger perceptions of various bus features in terms of satisfaction and importance of individual features. The report concluded that passengers were highly satisfied with bus interior features such as design of seating and interior noise levels. However, with one exception, they did not consider these features nearly as important as service features such as departure and arrival reliability and travel time. The exception was heating/air conditioning.

Since that study, subsequent on-board surveys have revealed that passengers place a high value on being able to obtain a seat. Because the project stimulated a large increase in patronage, it was important to examine seating availability. Two measures are employed in the determination of seating availability. One is the measured average number of passengers per bus, which when compared with potential seats available per bus, yields an average seating surplus or deficit per bus. The second measure is passenger perception of seat availability.

Average passengers per bus over the life of the project is shown for busway routes in Figure 20 on page 51. It is noted that for busway buses, the average passengers per bus remained at or slightly above the seating capacity of the buses. This does not necessarily mean that, with very high probability, passengers are seated when riding a busway bus. Certain routes were consistently more crowded than others and passenger load varied with time so that passengers may have been more or less likely to obtain a seat depanding upon where and when they boarded a bus.

The following question was asked on all three on-board bus surveys conducted since the project began: "On an average day when you board this bus, do you find a seat? /__/ never /__/ seldom /__/ usually /__/ always." The distribution of responses to this question yields a measure of passenger perceptions of seat availability. Reported seat availability remained high (greater than 80 percent for always or usually finding a seat) in spite of the fact that patronage increased dramatically during the same time period. When reported seat availability on busway buses was compared with reported seat availability on non-busway routes (from the Fall 1974 survey), non-busway bus riders reported higher seat availability. Ninety-one percent of non-busway passengers reported always or usually finding a seat versus 84 percent for busway users. This is understandable in that the average number of passengers per bus on non-busway routes was only 36.4 compared with 45.8 for busway routes in Fall 1974. The average number of passengers per bus remained relatively constant over the life of the project and reported seat availability remained high, indicating that the rapidly increasing demand for service was accommodated by an increased supply of buses.

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[5] The reader is referred to Section Four of Interim Report 4, "Second Year Results": Park-and-riders were queried about their satisfaction with the convenience of bus arrival and departure times at the lots and given five reponse options: 1) very satisfied, 2) satisfied, 3) neutral, 4) unsatisfied, and 5) very unsatisfied; 88 percent of the riders responded either "very satisfied" or "satisfied."

Further insights concerning perceived comfort were obtained by examining reasons reported for switching modes from auto to bus. In response to the following question from the Fall 1974 on-board bus survey: "If prior to riding this bus you commuted regularly by automobile (as either driver or passenger), why did you switch to bus?" the single reason cited most (by 33 percent of those answering the question) was the discomfort of commuting by auto. Another frequently cited reason was traffic congestion encountered when driving.[6] This information indicates that the express bus service was perceived as being more comfortable and less stressful than driving by a substantial fraction of those who switched from auto to bus.

[6]For more details, see Table 21 on page 65.

4.0 INCREASE IN PEOPLE MOVING CAPABILITY OF THE SHIRLEY HIGHWAY CORRIDOR

A principal objective of the Shirley Highway Express-Bus-on-Freeway Project was to demonstrate that high quality bus service and preferential treatment for buses and carpools lead to an increase in the people moving capability of a Corridor. People movement was measured in terms of total person trips, bus person trips, bus market-share, and auto occupancy. Section 4 examines project stimulated changes in the people moving capability of Corridor transportation facilities. The section is divided into three major subsections: Subsection 4.1 describes the upward trends in total Corridor-wide people movement. Subsection 4.2 examines the trends in people movement on the Shirley Highway and compares them with the trends from the rest of the Corridor. These subsections show that the Shirley Highway, in particular the strategies on the Highway's reversible lanes, were primarily responsible for the increase in the Corridor's people moving capability. Subsection 4.3 examines the impacts of the priority strategies on other commuters and their effectiveness as means of increasing the Corridor's people moving capability.

4.1 Trends in Corridor-Wide People Movement

Corridor traffic flows were monitored through a program of periodic counts of all person and vehicular volumes crossing a seven station screenline (see Figure 24, page 99).[1] Trends in inbound person trips crossing the seven station screenline daily during the A.M. peak period (6:30-9:00 A.M.) are presented in Figure 14.[2] (Tables presenting details of Corridor screenline counts are presented in Appendix A.) Between April 1970 and June 1972, total daily person trips crossing the seven station screenline remained fairly constant at about 63,000. Since then, total daily person trips increased to approximately 76,000 person trips in November 1974, when the last screenline counts were made.

Most of this increase was produced by a steady increase in daily bus person trips, from about 14,300 in April 1970 to about 24,300 in November 1974. (These totals include bus riders carried by private companies.) In contrast to the steady increase in bus person trips, auto person trips declined from 48,500 in April 1970 to about 44,000 in June 1972, followed by an increase up to about 50,000 in November 1974. Thus, there was a net increase of only 1500 auto person trips during the life of the project. As a result of the large increases in bus person trips and the slight increases in auto person trips, the "bus percentage" of the total person trips crossing the screenline increased from 23 percent in April 1970 to 33 percent in November 1974.

4.1.1 Trends in Corridor-Wide People Movement by Bus

For various reasons, bus is regarded as a more effective means of carriage than auto; thus, increasing bus's share of commuters increases the effectiveness of the transportation system. Bus market-share is defined as the percentage of "project trips" that are made by bus. A project trip was defined as a person trip by either auto or bus, beginning and ending in the project area and crossing the screenline during the A.M. peak period, 6:30 to 9:00 A.M. The project area was defined as the area where commuters had the potential to use buses and was described in Section 2.

The "bus percentage" of the total person trips crossing the screenline would equal the bus market share if all of the auto and bus person trips counted at the screenline actually began in the Corridor and ended in the destination areas. However, such was not the case. Some trips crossing the screenline did not begin in the Corridor. These were primarily auto through-trips beginning in the southern counties of Virginia or in other states, and bus trips beginning in southern Virginia. They also included some trips along Arlington Boulevard and Columbia Pike which originated outside the residential portion of the Corridor. Some trips crossing the screenline also did not end in the project destination areas. These were primarily auto trips but also included bus person trips that involved transfer to buses that travel outside the project employment areas. Removing from the screenline counts all of the non-project trips leaves the remaining person trips crossing the screenline as those that could have been made by bus. (However, this ignores some persons' need for a car during the work day.) Bus market share is the percentage of these remaining trips that are in fact made by bus.

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[1]See Appendix A for a description of the counting program.

[2]Person trips across an eighth screenline station, on the northbound ramp connecting the Woodrow Wilson Bridge with the Anacostia Freeway (I-295), are not included in Corridor person trips because very few persons traveling on I-295 travel through the Corridor.

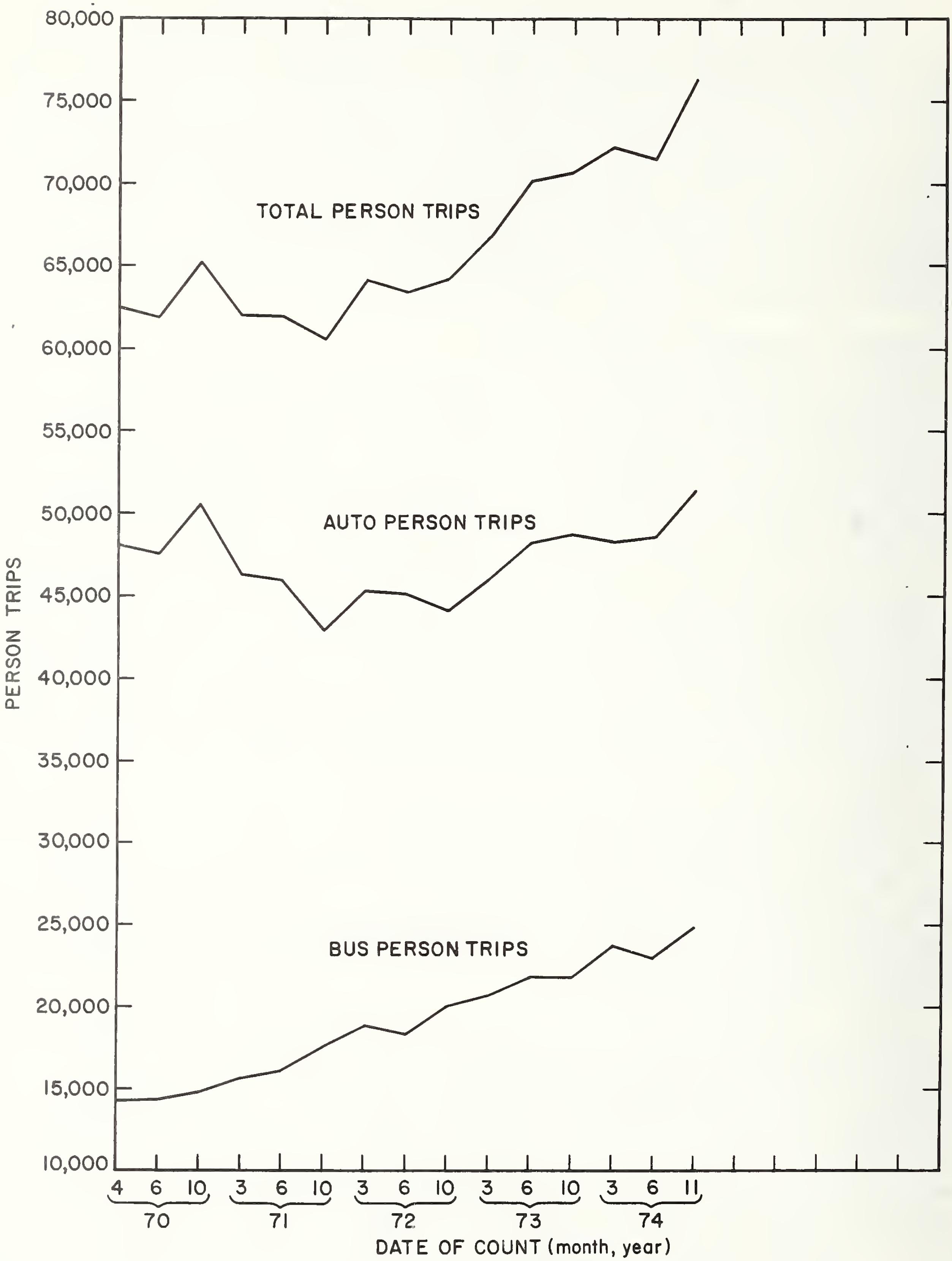

Figure 14. Trends in Person Trips Crossing Screenline (Inbound 6:30-9:00 A.M.)

Table 9 summarizes the computations of this procedure. Columns 2 and 3 of the table present the screenline person trip totals for October 1970, October 1971, October 1972, October 1973, and October 1974.[3] Columns 4 and 5 are estimates of the project trips. The 1970, 1971, and 1972 estimates are based upon the appropriate screenline counts and the project trip percentages obtained from the October 1971 surveys (54.7 percent for auto persons and 88.8 percent bus persons).

The 1973 and 1974 estimates are based upon 1973 and 1974 screenline counts and project trip percentages obtained from the November 1974 surveys (53.8 percent for auto persons and 84.6 percent for bus persons). The resultant market share estimates are shown in Column 7. Figure 15 displays the changes over time in these (estimated) bus market shares, and includes a value for 1968, before the project began. The 1968 value of 27 percent was obtained from estimates of auto and bus person project trips from the Metropolitan Washington Council of Governments (COG) 1968 home interview survey.[4]

Table 9

Estimates of Corridor Bus Market Share from 1970-1974

DATE	AUTO PERSONS AT SCREENLINE	BUS PERSONS AT SCREENLINE[a]	PROJECT AUTO PERSON TRIPS	PROJECT BUS PERSON TRIPS	TOTAL PROJECT PERSON TRIPS	BUS MARKET SHARE ESTIMATE (PERCENT)
Oct 70	55,708	14,768	30,776	13,114	43,890	29.8
Oct 71	48,008	17,577	26,260	15,608	41,868	37.7
Oct 72	48,336	20,050	26,440	17,804	44,244	40.2
Oct 73	53,264	21,864	28,656	18,497	47,153	39.2
Oct 74	56,071	24,883	30,166	21,051	51,217	41.1

[a]Includes passengers on buses of private companies.

The estimates indicate that the bus market share increased from 27 percent before the project began to around 40 percent in 1974. This substantial growth indicates the success of the project in increasing the effectiveness of Corridor people movement. The leveling off of the bus market share after October 1972 (at around 40 percent) masks the continued substantial growth in the number of persons crossing the screenline by bus. While the number of bus persons continued to mount, the number of auto persons also began to increase during 1973 and 1974.

[3]Persons crossing the eighth screenline station (the ramp to I-295) were included in bus market share estimates. Although persons traveling on I-295 were not traveling through the Corridor, some of them were making project trips.

[4]"The Home Interview Survey-What and Why," Information Report No. 5, by the Transportation Planning Board, Metropolitan Washington Council of Governments, Washington, D.C., February 1968.

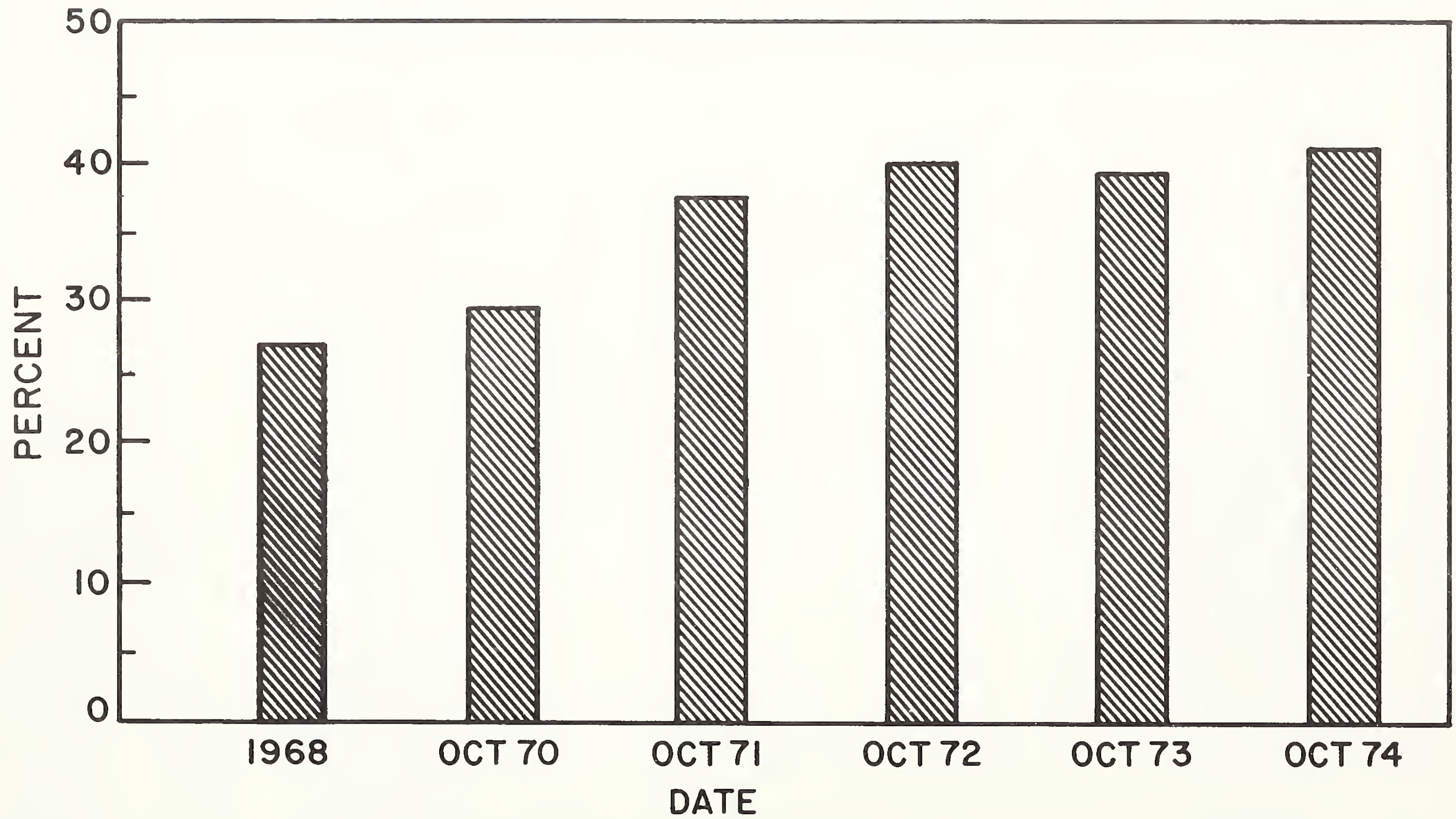

Figure 15. Trends in Bus Market Share

Ratios of the number of project trips to the number of trips counted at the screenline are the principal source of potential error in the estimates of bus market share. The estimated ratios will be in error if the actual ones fluctuate widely over time or if data used to measure the ratio (at a particular point in time) are inaccurate or incomplete. Since there is little difference between the 1971 and 1974 ratios for bus or for auto, it is plausible to assume that the ratios of the number of project trips to the number of trips counted at the screenline are stable over time. With respect to the data for a particular ratio, data used for the bus ratio are sufficient to assure reasonably precise measurement. This is not the case with the ratio for auto. Of the autos which crossed the screenline, only those with Virginia license plates could be mailed survey forms. To estimate the percentage of autos with Virginia tags crossing the screenline, license tags were recorded and these tag numbers were matched against the Virginia Department of Motor Vehicles records of registered owners' addresses in the counties of Fairfax, Arlington, and Prince William, and in the cities of Fairfax, Alexandria, and Falls Church. The percentage of licenses that did not match the addresses in these nearby counties and cities was taken as an estimate of the fraction of Virginia auto trips that did not begin in the area influenced by the busway.

For autos with non-Virginia license plates, it could not be determined how many, if any, of these persons were making project trips; however, a high turnover rate exists among Corridor residents, and many military personnel living in the Corridor legally retain out-of-state license plates. On this basis, it was assumed that many of the persons in autos with non-Virginia license plates were making project trips, and the ratio for the autos with Virginia license plates was assumed to also apply for autos with non-Virginia plates.

Therefore, in terms of possible errors in the ratios of project trips to trips counted at the screenline, the ratio for bus is probably quite accurate. Because the nature of trips by persons in autos with non-Virginia license plates could not be determined, such a confident statement cannot be made regarding the ratio for auto. The effect on market share of the uncertainty associated with the ratios was investigated by varying those estimated from the October 1974 survey, bus by ±2 percent and auto by ±10 percent. Results from this analysis of the sensitivity of bus market share to the ratio estimates (presented in Table 10) indicate that the October 1974 market share lay between 35 and 47.7 percent. The lowest, 35 percent, is distinctly higher than the 30 percent figure which existed in 1970 prior to the beginning of the project.

Table 10

Sensitivity Analysis of Bus Market Share Estimates

RATIOS VARY BY	NOV. 74 (PERCENT)
0% Auto 0% Bus	41.1
- 5% Auto +2% Bus	44.4
+ 5% Auto -2% Bus	38.1
-10% Auto +4% Bus	47.7
+10% Auto -4% Bus	35.1

4.1.2 Trends in Corridor-Wide People Movement by Auto

Carpools transport travelers efficiently, and so auto occupancy (the average number of persons per auto) is a measure of the people moving effectiveness of Corridor automobiles. Corridor-wide auto occupancy rates, which are presented in the bottom portion of Figure 16,[5] showed a downward trend between 1970 and 1972, going from an average of 1.42 in April 1970 (at the beginning of the screenline counts) to 1.34 by the end of 1972. For the next year, auto occupancy remained fairly constant. Then it rose, going to 1.47 in November 1974, when the last screenline counts were taken. During the period between April 1970 and November 1974, the daily number of autos remained relatively constant at 34,000.

[5] See also Tables 46 and 49 in Appendix A, which summarize the auto occupancy trends.

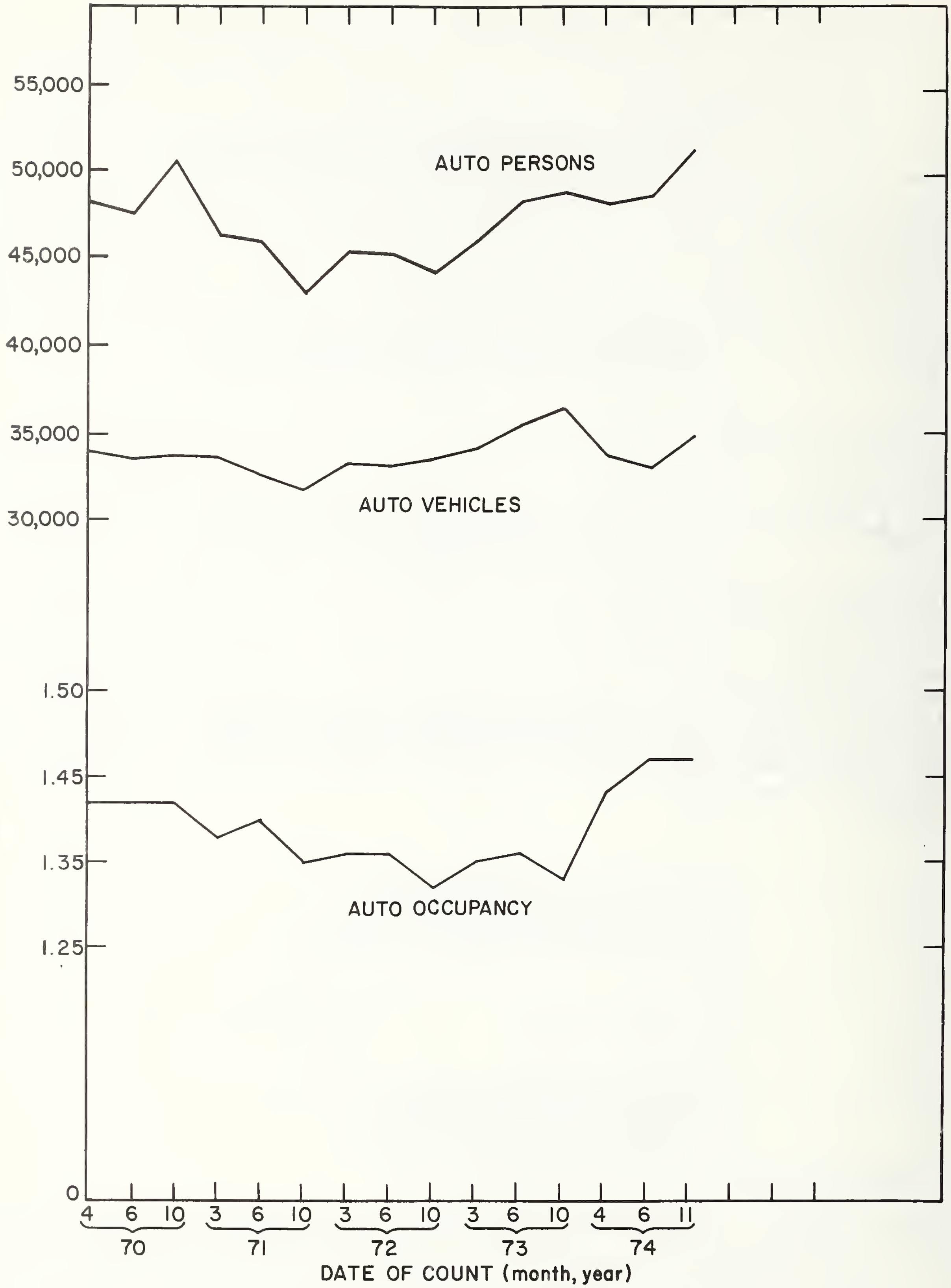

Figure 16. Trends in Corridor Auto Usage (Inbound 6:30-9:00 A.M.)

Of particular interest was the increase in auto occupancy from the October 1973 level to the 1974 levels,[6] after the steady downward trend between 1970 and 1972. This was in large part due to the gasoline shortage and to the energy conservation strategies of the winter of 1973-74 which encouraged the formation of carpools. These strategies included the opening of the Shirley Highway busway to carpools of four or more persons in December 1973. See Paragraph 4.2.2 for further information on this matter.

4.2 Comparison of People Movements on Shirley Highway and Other Corridor Arterials

Corridor person trips crossing the seven-station screenline inbound during the A.M. peak period (6:30-9:00 A.M.) increased from 62,400 in April 1970 to 76,400 in November 1974. All of this increase occurred on the Shirley Highway, where the person trips increased from 16,900 in April 1970 to 36,900 in November 1974. (Reconstruction of the highway was progressing during this period and capacity was being increased.) On the other Corridor arterials, person trips actually decreased, going from 45,500 in April 1970 to 39,500 in November 1974. Figure 17 illustrates these trends. (See also Table 49 in Appendix A.)

4.2.1 People Movement by Bus on Shirley Highway Compared with Other Corridor Arterials

As described earlier, Corridor bus person trips crossing the seven station screenline inbound during the A.M. peak period increased from about 14,300 in April 1970 to 24,300 in November 1974. All of this increase occurred on the Shirley Highway, with the number of bus person trips increasing from 4,400 in April 1970 to 15,800 in November 1974. On the other Corridor arterials, bus person trips decreased from 9,900 in April 1970 to 8,500 in November 1974. Figure 18 illustrates these trends and details are presented in Table 46 in Appendix A. (A detailed analysis of this increase is presented in Section 5.) All of the bus trips on the Shirley Highway were made on the exclusive busway, which became operational in increments, beginning with the southern portions. Buses that had been entering the Shirley Highway south of Shirlington Circle began using the busway in September 1969 when the first section (the section south of Shirlington Circle) was opened. (See Figure 2, page 10 for locations.) Buses that had been entering Shirley Highway at Shirlington Circle began using the busway in September 1970 when the second section (between Shirlington Circle and the Pentagon) was opened. When the last section of the busway (between the Pentagon and the 14th Street Bridge) was opened in April 1971, buses that had been entering the Shirley Highway at the Pentagon began using the busway. However, these buses were not considered Shirley Highway buses (and were not included in the patronage figures for the Shirley Highway), as they did not cross the seven station screenline while on the Shirley Highway and used the busway for only a short distance.

The trends in inbound A.M. peak period bus patronage on the Shirley Highway busway are presented in Figure 19. Patronage is divided into the two classifications: ridership on buses entering the busway south of Shirlington Circle and that on buses entering the busway at Shirlington Circle. (See also Table 48 in Appendix A.) The figure shows that all of the busway patronage growth is attributable to the routes which enter south of Shirlington. Most of the growth occurred after September 1970, after the opening of the second section of busway which bypassed a highly congested area on the Shirley Highway.

Nearly all of the buses added to service since the busway became operational were placed on routes entering the busway south of Shirlington. Although the bus service was continually expanded, the busway buses always operated, at or above, seated capacity. This is highlighted in Figure 20 (see also Table 48 in Appendix A).[7] The dip in passengers per bus around June 1971 is due to the lag in market adjustment to the increased capacity afforded by the 30 additional buses being placed into service. Thus, it appears that the number of buses in service acted as a constraint on patronage, and as bus fleet size was expanded, peak period bus patronage increased. (A.M. peak period bus patronage on control counts made outside of the Corridor was about 3,300 in March 1971 prior to introduction of demonstration service and about 3,400 in December 1974 at the end of the project. The stability of these figures suggests that patronage was not being diverted from non-Corridor bus service.)

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[6] According to unpublished data from the District of Columbia Department of Highways and Traffic, the rate of decline in auto occupancy also slowed considerably on other approaches to Washington, D.C., during 1974.

[7] See also the "Second Year Results Report" for an examination of this phenomenon on selected WMATA bus routes.

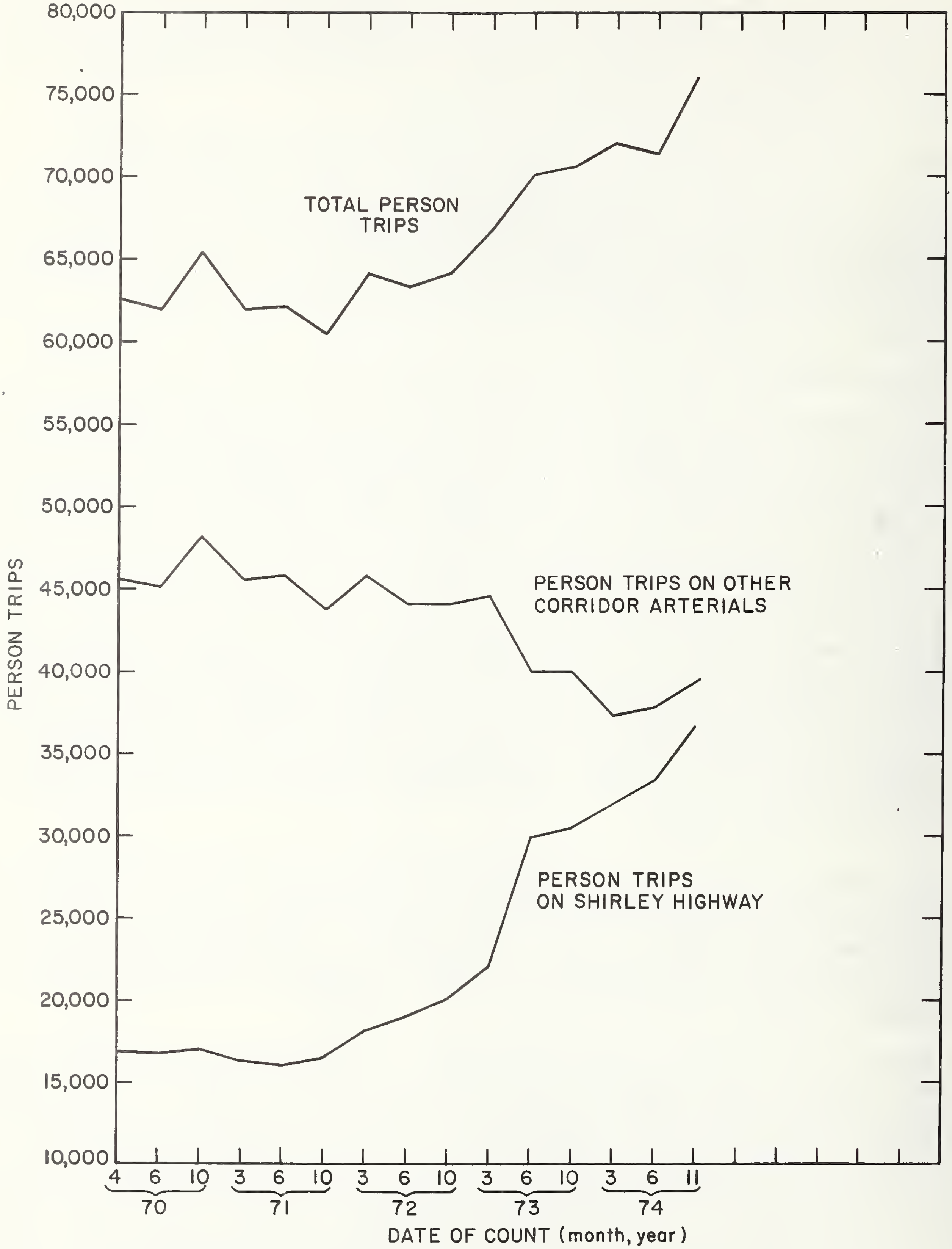

Figure 17. Trends in Person Trips on Shirley Highway and Other Corridor Arterials (Inbound 6:30-9:00 A.M.)

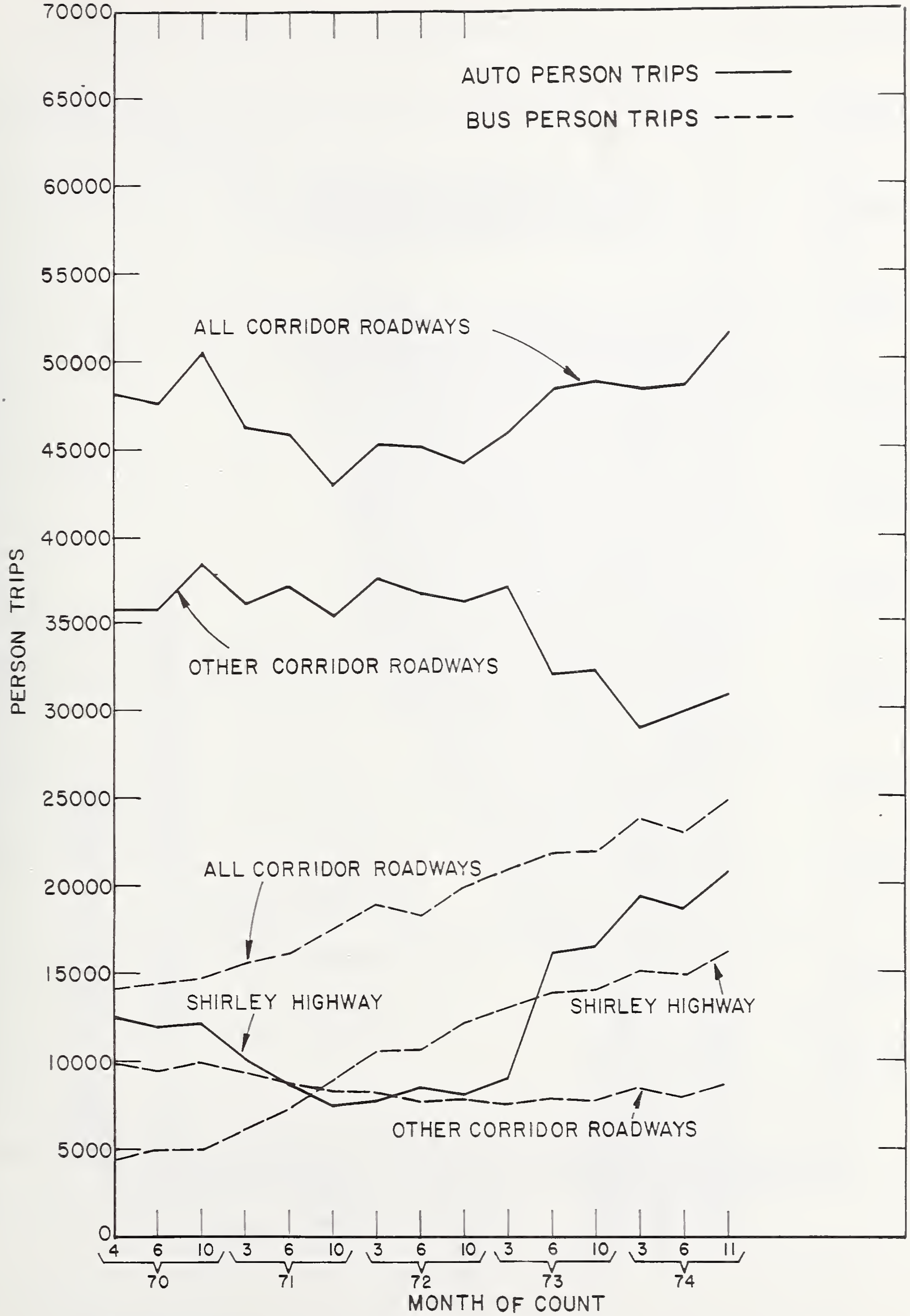

Figure 18. Trends in Bus and Auto Person Trips on Shirley Highway and Other Corridor Arterials (Inbound 6:30-9:00 A.M.)

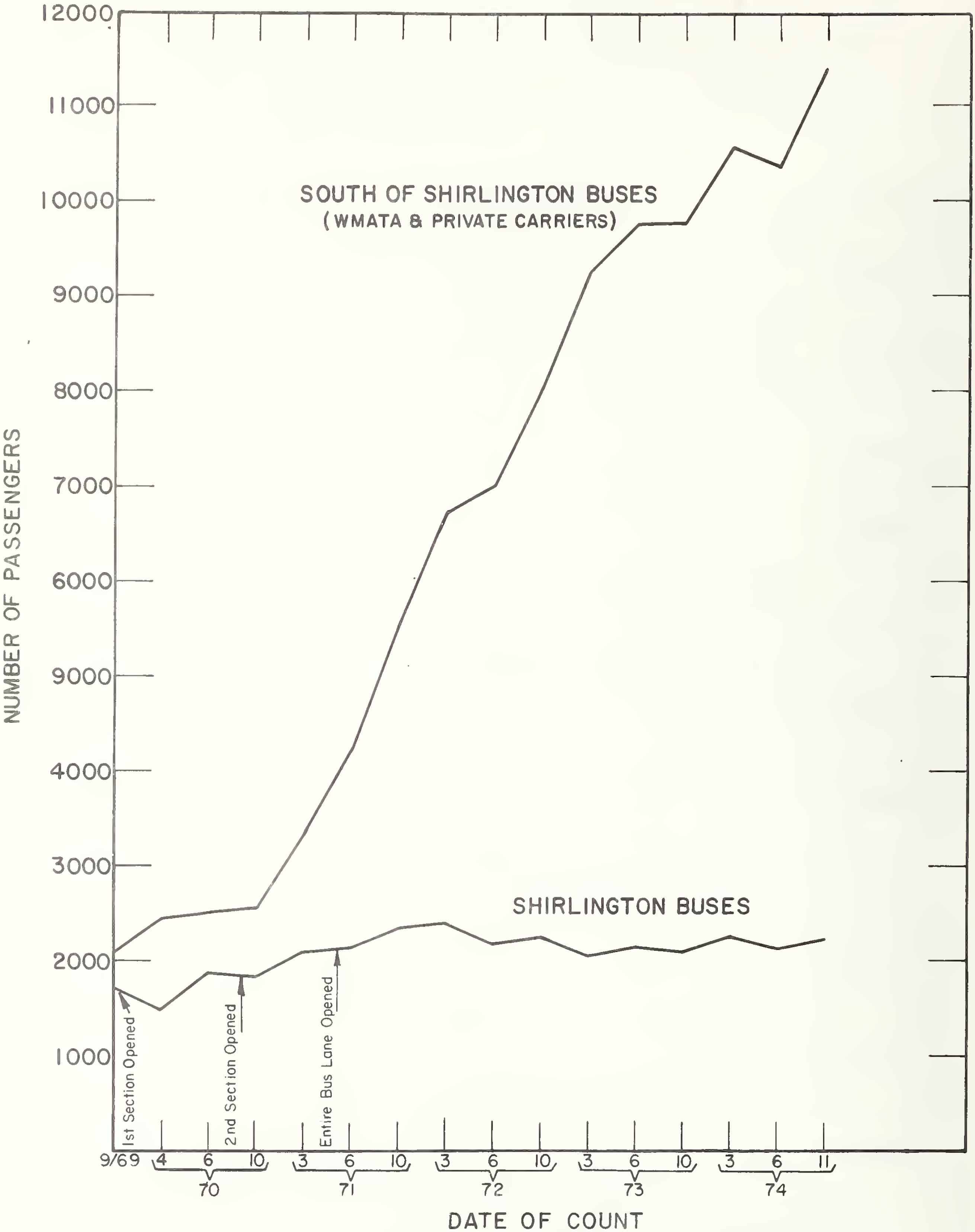

Figure 19. Trends in Busway Patronage Growth (Inbound 6:30-9:00 A.M.)

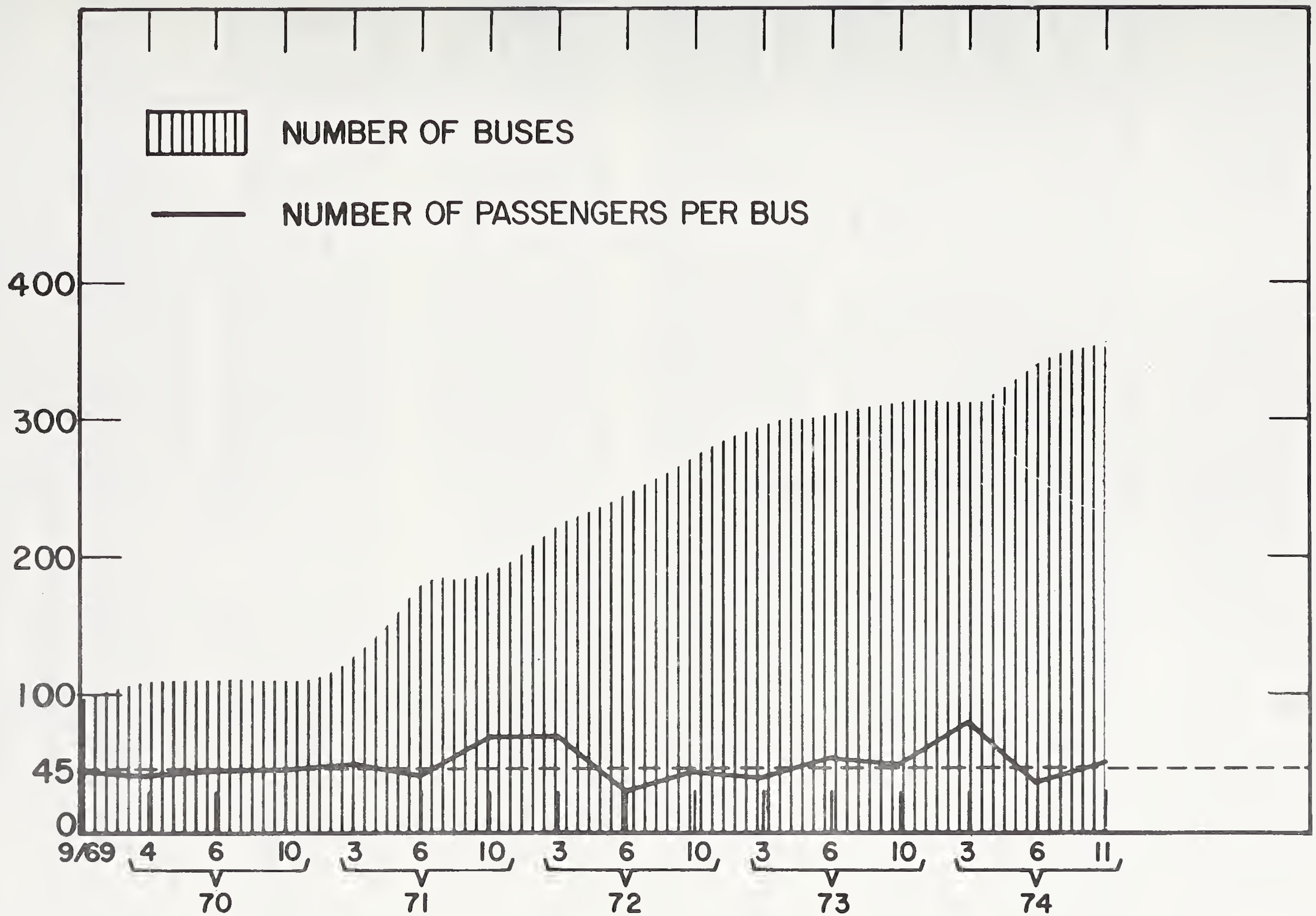

Figure 20. Trends in Busway Passengers Per Bus (Inbound 6:30-9:00 A.M.)

4.2.2 People Movement by Auto on Shirley Highway Compared with Other Corridor Arterials

Corridor auto person trips crossing the seven station screenline inbound during the A.M. peak period (6:30-9:00) increased from 48,300 in April 1970 to about 50,000 in November 1974. During this period, auto volumes remained relatively constant at about 34,000. All of the increase in auto person trips occurred on the Shirley Highway, where they grew from 12,500 in April 1970 to 20,000 in November 1974; correspondingly, the number of auto vehicles increased from 8,400 to 12,800. On the other Corridor arterials, auto person trips decreased from 25,600 to 22,000. Figure 18 on page 49 illustrates these trends in auto person trips. (See also Tables 46 and 49 in Appendix A for details of the trends in auto volumes and auto occupancy on the Shirley Highway and other Corridor arterials.)

Corridor-wide auto person trips and auto volumes were significantly affected by the construction work in widening the Shirley Highway from a four lane facility to eight lanes. Between April 1970 and October 1970, when construction extended only as far north as Glebe Road, auto person trips and auto volumes on the Shirley and the other Corridor arterials remained fairly level. As the construction activity moved farther north, past Glebe Road, and congestion increased in the area of the notorious "Mixing Bowl," auto person trips and auto volumes on the Shirley Highway decreased sharply (from about 12,000 person trips and 8,500 autos during the A.M. peak period at the end of 1970 to under 8,000 person trips and 6,000 autos by late 1971). Auto person trips on the Shirley Highway remained under 9,000 and auto volumes under 6,400 through April 1973, while the section between Glebe Road and the Mixing Bowl was under construction. During this period, auto person trips and auto volumes on the other Corridor arterials, where congestion was already high, remained fairly constant.

Construction was completed in May 1973 on the segment between Glebe Road and the Mixing Bowl. This changed that segment of the main roadway from a four lane facility encumbered with construction to a new six to eight lane facility, and the number of auto persons and auto volumes on the Shirley Highway nearly doubled. Coupled with the increase of over 9,000 person trips and nearly 6,000 autos on the Shirley Highway was a decrease of over 4,000 person trips and 3,000 autos on the other Corridor arterials, as many auto trips switched from the other Corridor arterials to the improved Shirley Highway.

Between October 1973 and November 1974, auto person trips and auto volumes on the Shirley Highway increased by about another 3,000 and 1,500, respectively; auto person trips and auto volumes on the other Corridor arterials decreased by about 2,000 and 2,500 respectively. The shift of auto persons to the Shirley Highway from the other Corridor arterials was primarily due to the opening of the reversible lanes on the Shirley Highway to carpools of four or more persons in December 1973, as auto occupancy on that Highway (including the reversible lanes) increased from 1.35 to 1.61. On the other arterials, auto occupancy increased from 1.32 to 1.40.

4.2.3 Increase in A.M. Peak Period People-Moving Productivity Per Lane on Shirley Highway

Another measure of people moving capability is people movement per lane or lane productivity. Figure 21 illustrates these trends for the reversible lanes and for the main roadway of Shirley Highway during the single hour (7:00-8:00 A.M.) when the highest number of person trips was counted. The figure clearly shows that the lane productivity of the busway was from two to three times greater than that of the main roadway.

Values for peak hour lane productivity were calculated for the period October 1970 through November 1974. For lane productivity calculations for periods before May 1973 when the completed eight lane Shirley Highway was extended north through the Mixing Bowl, the busway was considered to have been a single lane facility. Even though the southern part of the busway had two lanes of completed reversible roadway, the northern part, in the region of maximum flow, consisted of only a single temporary lane.

The busway was considered as a two lane facility for the calculation of productivity during periods after May 1973, when the temporary busway as far north as the Mixing Bowl was replaced with two lanes of completed reversible roadway. (The section of busway extending from just north of the Mixing Bowl to the 14th Street Bridge is still temporary.) As shown in Figure 21, these changes in the computation of busway lane productivity reduced it by one-half. Carpools of four or more persons, which began using the busway in December

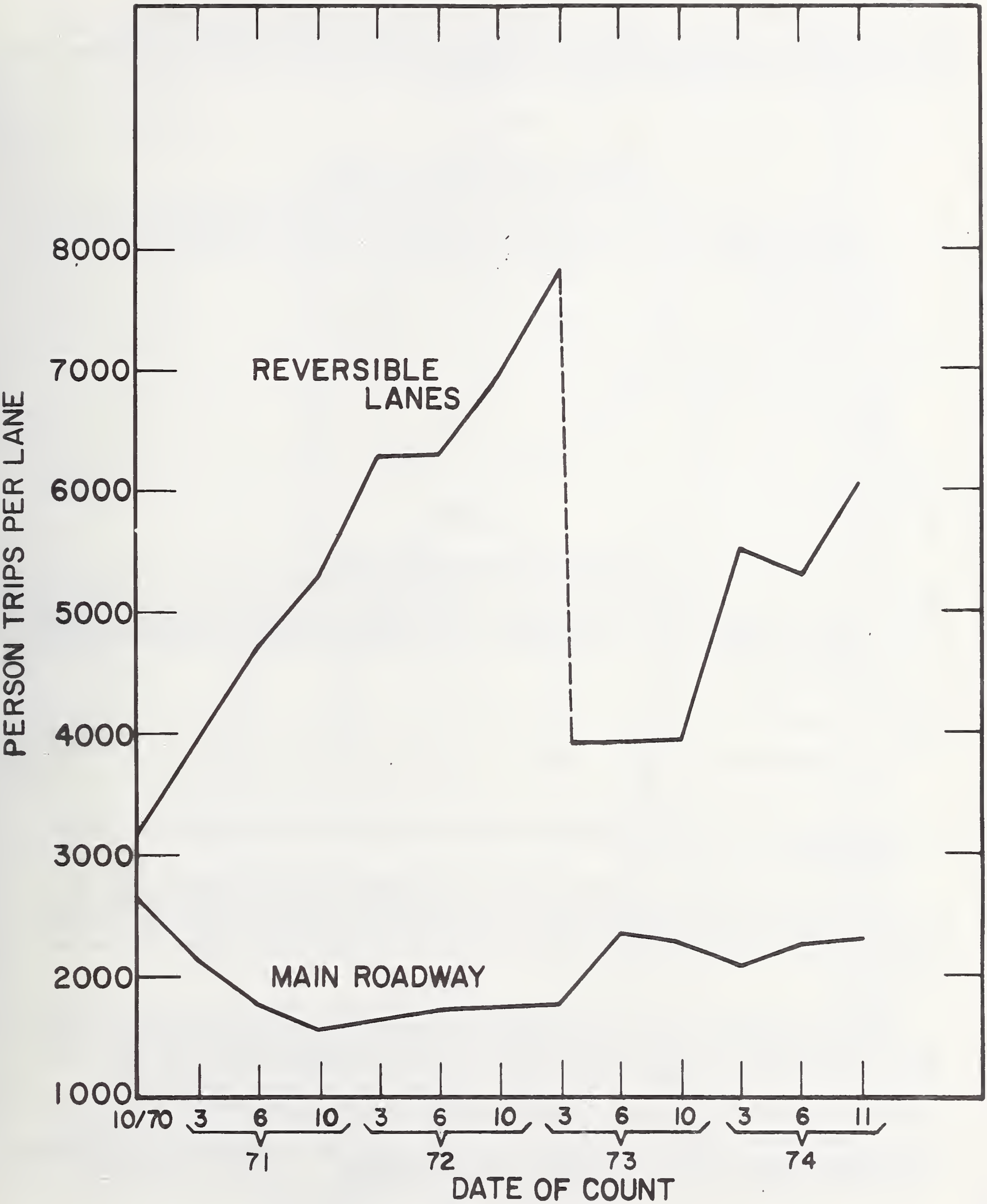

Figure 21. Peak Hour Throughput on Shirley Highway (Inbound 7:00-8:00 A.M.)

1973, were responsible for the sharp increases in busway lane productivity during 1974 (see Tables 11 and 12). However, regardless of whether the busway was considered a one or two lane facility, the lane productivity of the busway was always much greater than the lane productivity of the main roadway during the peak hour.

Table 11

Trends in Busway Carpool Usage
During the A.M. Peak Hour (7:00-8:00)

MONTH OF COUNT	CARPOOLS	CARPOOL PERSONS	CARPOOL OCCUPANCY
March 1974	499	2231	4.47
June 1974	526	2399	4.56
November 1974	758	3404	4.49

Table 12

Trends in Busway Carpool Usage
During the Entire A.M. Peak Period (6:30-9:00)

MONTH OF COUNT	CARPOOLS	CARPOOL PERSONS	CARPOOL OCCUPANCY
March 1974	698	3133	4.49
June 1974	757	3472	4.59
November 1974	1050	4630	4.41

4.3 Effectiveness of the Shirley Highway Strategies for Increasing Corridor People Moving Capability

The study of peak hour lane productivity on the Shirley Highway indicates that the reversible lanes with bus and carpool priority treatment had a greater people moving capability than the lanes on the main roadway which carried only autos. At the same time, the travel speed and reliability on the reversible lanes were consistently higher than on the main roadway.

Figure 22 demonstrates the large travel time savings that were realized on the busway during the peak period. On the 6.3 mile stretch between the Turkeycock ramp and the Washington Boulevard exit (the northernmost and most congested segment of the completed portion of the Shirley Highway), travel time savings as great as 19 minutes during the peak hour (7:00-8:00 A.M.) were possible on the busway. Because vehicles on the busway were not affected too adversely by inclement weather or accidents, travel time reliability was also high. By contrast, vehicles on the main roadway were consistently affected by inclement weather and accidents. Under such conditions, travel times on the main roadway were often considerably greater than they were under normal conditions.

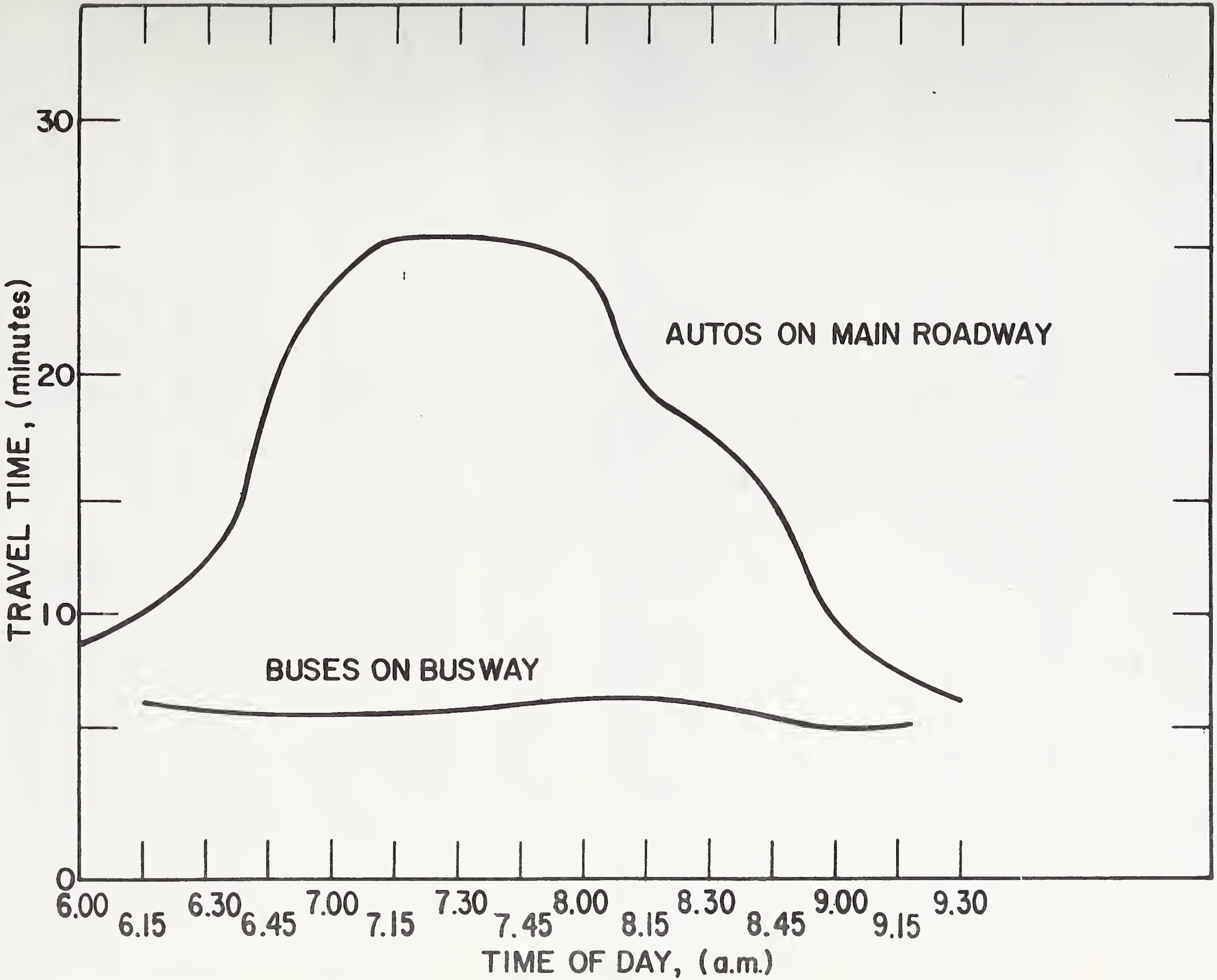

Figure 22. Mean Travel Times on Shirley Highway Inbound Between Turkeycock and Washington Boulevard Ramps (6.3 miles)

Some motorists on the main roadway might have felt that their travel times were increased because not all autos were allowed to use all of the existing lanes.[9] To examine this contention, a computerized mathematical model was used to estimate the travel times for bus, carpool, and auto users over the 1.3 mile section of the completed Shirley Highway between Glebe Road and the Washington Boulevard exit. The model estimated these travel times both under the bus and carpool priority operations existing in 1974 and under those conditions that could have expected had all lanes (including the reversible lanes) been opened to all vehicles.

For these calculations, existing conditions under priority operations in 1974 were assumed to be those observed in June 1974 during the A.M. peak period (6:30-9:00), when 45 percent of the person trips on the Shirley Highway were by bus and the average auto occupancy on the Shirley was 1.49. It was assumed that had there been no project, the total number of peak period person trips on the Shirley Highway would have been the same as with the priority operations (33,800 with 18,500 during the peak hour), and the number of bus passengers would have been about the same as existed prior to the project, about 5,000 (the average in 1970 was 4,800). This means that only 15 percent of the total person trips would have been by bus, and auto volumes would have been considerably higher. The average auto occupancy was assumed to have been the same as existed prior to the project, 1.44 (about the average in 1970).

The estimates of travel times obtained from the computer model indicated that, along the 1.3 mile stretch of highway, the 1974 priority operations for buses and carpools of four or more persons saved over 1,400 total person hours daily during the A.M. peak when compared with the expected mixed traffic conditions on all lanes (including the two reversible ones)[10] without the project. A savings of 1,400 person hours is large, about equal to the total time spent on that stretch by all commuters under existing priority conditions. In terms of travel time savings per person, it represented not only over a three minute saving for each bus rider and carpool user, but also a nearly two minute saving for each person traveling by auto. It is important to realize that this large daily time savings still underestimates the benefits of the priority lanes because it refers only to the 1.3 mile section between Glebe Road and the Washington Boulevard exit and does not consider the P.M. peak period. For a further discussion of this point and a general discussion of the model, see Appendix B.

The model clearly demonstrated that the 1974 priority operation for buses and carpools saved considerable amounts of time not only for both the bus and carpool users on the busway, but also for auto users on the main roadway. Thus, the 1974 priority operation for buses and carpools was a highly effective strategy for increasing the Corridor's people moving capability.

Another consideration was whether it was more effective to allow only buses on the reversible lanes, rather than both buses and carpools of four or more persons. Clearly, the members of the carpools using the busway realized considerable time savings and improvements in reliability. At issue is whether the presence of the carpools significantly lowered bus operating speeds on the busway and increased bus accidents. Preliminary data from the Virginia Department of Highways and Transportation and WMATA indicate that there were no major accidents between buses and carpools on the reversible lanes as of December 1974. Four sideswipe-type collisions were reported; however, no injuries were involved.

Table 13 shows that the average bus speeds on the completed section of busway between Turkeycock and Washington Boulevard during the A.M. peak period declined slightly from about 56 mph in November 1973, before carpools were allowed on, to about 51 mph in January 1975 with carpools using the busway. This decline did not appear to be a consequence of the carpools on the busway but rather a result of the lowering early in 1974 of the speed

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[9] It should be noted that prior to June 1973, before the Shirley Highway was completed as far north as the Mixing Bowl, the provision of the temporary busway did not reduce the number of lanes available to autos on the highway. The temporary busway could not have been safely or efficiently operated as a high volume auto lane. Only after June 1973 was it physically possible to accomodate autos on the busway. Like the carpools that were using the busway, the autos would have been required to exit at Washington Boulevard, just south of the remaining stretch of temporary busway.

[10] An analysis of the sensitivity of these results to alternative assumptions is presented in Appendix B.

limit on the highway from 60 mph to the national 55 mph speed limit. This is supported by the bus speed observations in Table 13, which shows that the decline in speed between 1973 and 1975 during the 6:30-7:00 and 8:30-9:00 time periods when few carpools were on the busway was about the same as the decline in speed during the 7:00-8:00 time periods when most of the carpools (758 out of 1050) were on the busway.

Table 13

Average Bus Line Haul Speeds on the Busway Between Turkeycock and Washington Boulevard (Inbound 6:30-9:00 A.M.)

TIME PERIOD	AVERAGE SPEED (MPH)[a] NOVEMBER 1973	AVERAGE SPEED (MPH)[a] JANUARY 1975
6:30 - 7:00	54.3	49.9
7:00 - 7:30	57.7	50.3
7:30 - 8:00	55.5	51.5
8:00 - 8:30	55.5	51.1
8:30 - 9:00	60.8	54.1

[a]Based on a total of over 65 observations throughout the peak period.

Thus, the carpools did not lower the bus operating speeds or increase bus accidents on the reversible lanes. At the same time, the approximately 4500 carpool persons using the reversible lanes realized the same travel time savings and improvements in reliability that had been accruing to the bus riders. It is clear that it was more effective to allow carpools of four or more persons to join the buses on the reversible lanes.

5.0 CORRIDOR COMMUTERS AND THEIR MODE CHOICE DECISIONS

Section 5 describes Corridor bus and auto commuters and examines their mode choice decisions. Particular attention is devoted to the influence of the project on these decisions. The information used in this section comes primarily from commuter surveys conducted during Fall 1974. Subsection 5.1 describes the survey procedures and presents selected characteristics of Corridor commuters. Subsection 5.2 uses the survey data in an investigation of commuter travel behavior and mode choice decisions.

The primary objective in Subsection 5.2 is to provide insight into why commuters use bus or carpool. To this end, the reasons given by bus users for riding bus and reasons given by carpoolers for carpooling were examined. To isolate the effects of the priority treatment, bus users and carpoolers were stratified into those using the reversible lanes (busway bus users and busway carpoolers) and those using all other Corridor roads (non-busway bus users and non-busway carpoolers). Reasons given by commuters who drive alone for not using bus or carpooling were also examined. The subsection concludes with a summary which provides a brief statement of the factors which were found to be important in the mode choice decisions of Corridor commuters. A discussion of the implications of these findings for mode choice modeling is also included.

5.1 Fall 1974 Commuter Surveys

The 1974 surveys were conducted during the last week in October and the first two weeks in November. (Similar surveys were conducted during October 1971.) Survey objectives were to provide information on: 1) the demographic characteristics of Corridor commuters, 2) the characteristics of their trips, and 3) the factors influencing these commuters' mode choice decisions. Subsection 5.1 describes the survey procedures, including steps taken to check for potential bias due to non-respondents. The subsection concludes with a brief discussion of the demographic and trip characteristics of the surveyed commuters.

5.1.1 Description of Survey Procedures

The surveys of bus and auto commuters involved different procedures. For the bus survey, mail-back questionnaire forms were distributed by bus drivers to passengers on a sample of peak period buses. The auto survey was more involved. A sample of license plates of autos crossing the screenline (see Screenline in Figure 24, page 99) was observed and recorded. Mail back questionnaire forms were sent to the addresses of owners of those autos which were registered in Virginia. If passengers were observed in a sample auto, a carpool driver questionnaire form and the appropriate number of carpool passenger forms (based on the number of passengers observed) were mailed. If no passengers were observed, a "driver alone" questionnaire form was mailed. Copies of the four survey questionnaire forms are presented in Appendix G. Sampling and response rates are presented in Tables 14 and 15.

Table 14

Sample Rates for Fall 1974 Commuter Surveys

SURVEY GROUP	POPULATION SIZE	SAMPLE SIZE	PERCENT OF POPULATION SAMPLED
Driver Alone	22,556	2,951	13.1
Busway Carpool Driver	946	625	66.1
Non-Busway Carpool Driver	9,171	1,378	15.0
Busway Carpool Passenger	3,223	2,131	66.1
Non-Busway Carpool Passenger	11,790	1,778	15.0
Busway Bus Passenger	16,106	5,259	32.7
Non-Busway Bus Passenger	8,777	3,021	34.5

Table 15

Response Rates from Fall 1974 Commuter Surveys

SURVEY GROUP	NUMBER[a] SAMPLED	NUMBER RESPONDING	PERCENT RESPONDING
Driver Alone	2,587	1,230	47.6
Busway Carpool Driver	599	360	60.1
Non-Busway Carpool Driver	1,180	388	32.9
Busway Carpool Passenger	2,043	1,125	55.0
Non-Bus Carpool Passenger	1,522	461	30.3
Busway Bus Passenger	5,259	3,401	64.7
Non-Busway Bus Passenger	3,026	1,429	47.2

[a]Since some of the observed person trips were not being made by Corridor commuters, these numbers are smaller than the intended sample figures in Table 14.

A 30 percent sample of Corridor buses resulted in sampling rates of 32.7 and 34.5 percent for busway and non-busway passengers respectively. A 20 percent sample of non-busway autos was attempted. (Because of the speeds of the autos when they pass the observation stations, this (1 of 5 autos) is about the maximum sampling rate.) Due to observation and recording errors, and to autos with non-Virginia license plates, the actual sampling rate was 13 percent for drivers alone and 15 percent for carpoolers. Because of the small number of carpools on the busway, and a bottleneck at the observation station, a 100 percent sample of busway carpoolers was attempted. Out-of-state autos, and observation and recording errors resulted in an actual sample rate of 66 percent for busway carpoolers.

Survey response rates ranged from 30 to 64 percent. Commuters directly benefiting from the busway had the highest response rates and non-busway carpoolers had the lowest response rates. Two short studies were conducted to investigate potential bias due to survey non-respondents. These investigations, one for the bus survey and the other for auto drivers (carpool and drivers alone) indicated little statistical difference (based on chi-square tests at the 5 percent level) between respondents and non-respondents. (Details are presented in Appendix C.) Thus, it was concluded that the responding commuters represented a random sample of Corridor commuters.

5.1.2 Characteristics of the Surveyed Commuters

The Fall 1974 commuter surveys provided the latest description of Corridor commuters. The "typical" Corridor commuter came from a household which owned two autos, and had an annual household income of between $15,000 and $30,000. This "typical" commuter was a male between 21 and 39 years old.

Except for income and auto ownership, demographic characteristics of Corridor commuters in 1974 were essentially unchanged from 1971. The 1971 survey showed that 62 percent of bus riders had annual household incomes in excess of $15,000 as compared to 79 percent in 1974; 34 percent were from households which owned two or more autos (with an average of 1.32 autos/household) as compared to 44 percent in 1974 (with an average of 1.47 autos/household). In 1971, 72 percent of auto commuters had annual household incomes in excess of $15,000 as compared with 85 percent in 1974; the percentage of households owning two or more autos increased from 61 to 66 percent, and average household auto ownership increased from 1.72 to 1.80.

Table 16

Selected Demographic Characteristics of Corridor Commuters (1974)

CHARACTERISTICS	BUS PASSENGER BUSWAY	BUS PASSENGER NON-BUSWAY	DRIVER ALONE (ALL)	CARPOOLER BUSWAY	CARPOOLER NON-BUSWAY
	Percent	Percent	Percent	Percent	Percent
Household Income					
< $5,000	0%	2%	0%	0%	0%
$5,000 - $15,000	21	37	23	7	18
$15,000 - $30,000	61	44	45	61	51
> $30,000	18	17	32	32	31
	100%	100%	100%	100%	100%
Age					
< 21 yrs.	3%	5%	1%	1%	2%
21 - 39 yrs.	59	53	47	46	45
40 - 65 yrs.	37	41	51	53	52
> 65 yrs.	0	14	1	0	1
	100%	100%	100%	100%	100%
Sex					
Male	62%	51%	73%	85%	65%
Female	38	49	27	15	35
	100%	100%	100%	100%	100%
Auto Ownership					
0	5%	15%	0%	1%	2%
1	51	56	35	30	40
2	37	24	55	56	47
3	6	4	9	11	9
4	1	1	1	2	2
	100%	100%	100%	100%	100%
Mean Autos per Household	1.47	1.20	1.76	1.83	1.48

Table 17

Selected Trip Characteristics of Corridor Commuters (1974 Survey)

	BUS PASSENGERS BUSWAY	BUS PASSENGERS NON-BUSWAY	DRIVER ALONE	CARPOOLERS BUSWAY	CARPOOLERS NON-BUSWAY
Transfers Per Trip	**Percent**	**Percent**	**Percent**	**Percent**	**Percent**
0	86	69			
1	13	29	NA	NA	NA
2 or more	1	2			
	100	100			
Access Mode					
Walk	67	83	NA	NA	NA
Auto	33	17			
	100	100			
Daily Parking Cost					
None			45	58	45
$0.01-.49			4	22	12
$0.50-.99			8	7	7
$1.00-$1.49	NA	NA	17	7	20
$1.50-$1.99			6	2	2
$2.00-$2.99			14	3	10
$3.00 or more			6	1	4
			100	100	100
Parking Location					
Street			6	0	1
Employer	NA	NA	53	84	68
Commercial			36	11	26
Other			5	5	5
			100	100	100
Weekly Commute Mode[a]					
Days Use Bus					
0	0	1	87	95	97
1	1	1	2	4	3
2	2	3	2	0	0
3	2	3	3	0	0
4	5	5	3	0	0
5 or more	90	87	3	1	0
	100	100	100	100	100
Days Drive Alone					
0	92	92	2	94	87
1	5	5	7	5	11
2	1	1	7	1	2
3	1	1	4	0	0
4	0	0	2	0	0
5 or more	1	1	78	0	0
	100	100	100	100	100
Days Carpool					
0	97	96	85	0	0
1	1	1	1	1	0
2	0	1	1	0	0
3	1	1	3	1	3
4	0	0	5	6	9
5 or more	1	1	5	92	88
	100	100	100	100	100

NA - Not applicable.

[a]Survey question: "How often do you use each of the following means to travel from home to work?"

Table 16 presents selected demographic characteristics of Corridor commuters. Among the commuters, bus passengers were the youngest and least affluent. In addition, the bus passenger population had the most females and owned the fewest autos. Busway carpoolers were the most affluent and owned the most autos. This group also contained the fewest females.

Table 17 presents selected trip characteristics of the commuters. Those who drove alone (hereafter referred to as "drivers alone") used their primary mode least regularly. When not driving alone, they used bus and carpool on an almost equal basis. About 86 percent of Busway bus riders did not transfer during their commute and about 33 percent used park-and-ride access (25 percent in 1971). Fifty-three percent of drivers alone used employer-provided parking as compared with 84 percent for busway carpoolers and 68 percent for non-busway carpoolers. As a group, Corridor auto commuters experienced an increase in daily parking costs between 1971 and 1974. During this period, the percentage parking without charge declined from 56 to 50 percent, and the percentage paying more than $2.00 daily increased from 6 to about 15 percent.

5.2 Mode Choice Decisions of Bus and Auto Commuters

The commuter surveys conducted during Fall 1974 provided considerable information on commuter travel behavior within the Corridor. Subsection 5.2 uses this information in an examination of the mode choice decisions of Corridor commuters, with emphasis on the influence of project elements. The subsection is divided into three major paragraphs. Paragraph 5.2.1 examines the mode choice decisions of bus commuters, in particular the significance of project elements in the attraction of former auto users. Paragraph 5.2.2 examines the mode choice decisions of auto commuters who used carpools, and Paragraph 5.2.3 examines the mode choice decisions of commuters who drove alone. Paragraph 5.2.4 summarizes the decisions of bus users, carpoolers and drivers alone in an attempt to present a complete picture of the mode choice decisions made by Corridor commuters. Paragraph 5.2.4 concludes with a brief discussion of the implications of the findings for mode choice modeling.

5.2.1 Mode Choice Decisions of Persons Commuting by Bus

After the entire Shirley Highway busway was opened in April 1971, and service was expanded on routes using the busway, daily peak period patronage (6:30-9:00 A.M.) on busway buses increased from under 5,000 in October 1970 to about 16,000 in November 1974 (including patronage on private carriers). During the same time period, daily peak period patronage declined on non-busway buses (where service was not significantly changed) from 10,000 to 9,000. (These trends were discussed in Paragraph 4.2.1.)

Those changes in patronage do not reflect the dynamic nature of the bus user population. Of the November 1974 bus riders, 92 percent of the busway riders and 78 percent of the non-busway riders began using their present bus after the entire busway was opened in April 1971. Even more dramatic is the fact that more than 46 percent of all Corridor bus riders surveyed in November 1974 began using the bus service during 1974. (Table 18 summarizes responses to the survey question: "When did you begin to regularly use this bus to commute from home to work?") The large percentage of bus riders new to the system and the patronage changes on busway and non-busway routes indicate that busway buses attracted new riders at a much greater rate than they lost old riders, while non-busway buses lost old riders at a slightly greater rate than they gained new ones.

Table 18

Year Bus Riders Began Using Their Current Service

YEAR	BUSWAY	NON-BUSWAY
1969 or earlier	5%	18%
1970	3	4
1971	6	7
1972	16	9
1973	22	16
1974	48	46
	100%	100%

Some bus commuters did not have an auto available with which to commute to work on a regular basis. These were "captive" riders who had to use a mode in which they were dependent on others regardless of whether or not they were satisfied with the service provided. Table 19 summarizes responses to the survey question: "Is an auto available for you to regularly drive alone from home to work?". These responses give an indication of the percentage of captive riders. Based on bus riders who answered either that an auto was definitely not available or that they didn't drive, 19 percent of busway and 30 percent of non-busway bus riders were considered to be captive. (For 1971, 21 percent of busway and 36 percent of non-busway bus riders were considered to be captive.)

Table 19

Reported Auto Availability of Bus Users

	BUSWAY	NON-BUSWAY
Not Available	16%	24%
Available, But Inconvenient	25	23
Available, and Not Inconvenient	56	47
Don't Drive	3	6
	100%	100%

Responses to the question, "If you could not commute from home to work by means of this bus, how would you usually make the trip?", suggest that not all of these captive riders were totally dependent on bus transit. Only five percent of busway riders and 10 percent of non-busway riders indicated that they "would have been unable to make this trip" if they couldn't have used their present bus. The remaining captives, 14 percent of busway riders and 20 percent of non-busway riders, indicated that they would have used other buses or joined carpools. Thus, while not dependent solely on their present bus, their reported alternate mode would have been one in which they were still dependent on others.

While captive bus riders had to use a mode in which they were dependent on others, there was no such dependence for the large majority of bus commuters. These were the bus riders who chose to commute by bus, referred to hereafter as "choice riders." Table 20 presents the responses of these choice bus riders to the survey question: "Before you began using this bus, how did you usually commute from home to work?". Sixty percent of the choice busway riders and 56 percent of the choice non-busway riders formerly used auto. Of the commuters who had made the same trip prior to using bus, 79 percent of the busway riders and 82 percent of non-busway riders formerly used auto (excluding those responding "other"). Of the former auto commuters who had made the trip prior to using bus, 63 percent of busway riders and 68 percent of non-busway riders had driven alone.

Table 20

Prior Commute Mode of "Choice" Bus Users

	BUSWAY	NON-BUSWAY
Did not make this trip:[a]		
used auto in previous trip	30%	28%
used bus in previous trip	23	27
used other in previous trip	4	5
Drove alone	19	19
Was an alternate driver in a carpool	5	3
Drove in a carpool	3	2
Was a passenger in a carpool	3	4
Used another bus	8	6
Other	5	6
	100%	100%

[a]The trip made before using this bus was either from a different place of residence or to a different place of work (or both).

Comparing these statistics for 1971 and 1974 reveals an increased diversion of auto commuters, primarily persons driving alone, to bus. Prior mode information is available from the 1971 survey only for commuters who made the same trip prior to using bus. In 1971, of the bus riders who had made the trip prior to using bus, 60 percent of the busway riders and 63 percent of the non-busway riders had formerly commuted by auto. Of the former auto commuters who had made the trip prior to using bus, 55 percent of the busway riders and 50 percent of the non-busway riders had formerly driven alone.

To determine why a large number of choice bus riders in the Corridor had switched from auto, responses to the following survey question were examined: "If prior to riding this bus you commuted regularly by auto, why did you switch to bus?." As indicated in Table 21, among both busway and non-busway choice riders, "discomfort of driving" was given most often (by about one-third of the riders) as the reason for switching from auto. Almost 26% of the busway riders indicated that an income related feature (e.g., "car not available," "car too expensive," or "parking too expensive") was the reason for switching, while 46% of the non-busway riders indicated so. At the same time, 28% of the busway riders indicated that a feature related to priority bus operations (e.g., "reduced effect of traffic congestion on bus" and "bus express") was the reason for switching, compared with only 10% of the non-busway riders.

Data from the 1971 survey indicated that features related to express bus operations and income related features were the primary reasons for switching from auto to bus. Mode choice models developed for the Demonstration Project, using the 1971 survey data, support the finding that the expense of commuting by auto was a primary reason why auto commuters diverted to bus.[1] The models estimated that if parking costs were increased by one dollar (an "averaged out" approximation to a doubling of parking costs), bus ridership would have increased by over 50 percent.

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[1]"Mode Choice and the Shirley Highway Experiment."

Table 21

Reported Reasons Why "Choice" Bus Users Switched From Auto To Bus

REASONS	BUSWAY 71 Survey	BUSWAY 74 Survey	NON-BUSWAY 71 Survey	NON-BUSWAY 74 Survey
Car Not Available	18%	13%	42%	26%
Car Too Expensive	8	3	7	5
Parking Too Expensive	7	10	12	15
Reduced Effect of Traffic Congestion on Bus	14	20	12	9
Discomfort of Driving	7	34	4	32
Bus Faster	20	2	2	2
Bus More Reliable	NA	2	NA	2
Bus Express	11	8	2	1
Time on Bus Useable	1	2	1	0
Other	14	6	18	8
	100%	100%	100%	100%

NA - Not available.

It is significant that an analysis of the 1971 survey data did not find "discomfort of driving" to be a primary reason for switching to auto. However, special bus surveys conducted in 1972 and 1973 support the finding of the 1974 bus survey that "discomfort of driving" has become a primary reason for auto commuters' switch to bus. Results from a 1972 survey of busway bus riders revealed that the "stress and frustration of commuting" ranked as the most important factor in the mode choice decisions of former auto commuters.[2] Results from a 1973 survey of park-and-riders showed that "stress and frustration of commuting" ranked as the most important factor in the decisions of auto commuters to switch to busway bus service from the fringe park-and-ride lots.[3]

A special category of Corridor bus riders were those who "did not make the same trip prior to using their present bus." These were commuters who began riding the bus after a change in job or residence location. An examination of the dates of the most recent changes in job or employment locations by auto commuters revealed that such changes appeared to be a factor in the decisions of many auto commuters to switch to bus.

Tables 22 and 23 compare the responses of current auto users and of bus users who formerly had commuted by auto to the questions: "When was the last time you changed your place of residence?" and "When was the last time you changed your physical work location?". The auto users who switched to bus had more recent changes in employment and residence locations than the current auto user population. This finding was further supported by Chi-square tests which showed the differences to be significant at the five percent level.

[2] "Users' Reactions to Innovative Features," pp. 15, 16.

[3] "A Study of Park-and-Riding," pp. 11, 12.

Table 22

Distributions of the Dates Former Auto Users Last Changed Their Place of Residence

YEAR	AUTO USERS	AUTO USERS WHO SWITCHED TO BUS
1969 or earlier	44%	32%
1970	5	4
1971	9	7
1972	12	13
1973	15	18
1974	15	26
	100%	100%

Table 23

Distributions of Dates Former Auto Users Last Changed Their Work Location

YEAR	AUTO USERS	AUTO USERS WHO SWITCHED TO BUS
1969 or earlier	42%	30%
1970	6	4
1971	9	7
1972	12	11
1973	15	16
1974	16	32
	100%	100%

5.2.2 Mode Choice Decisions of Persons Commuting by Carpool

After a long period of decline, carpooling in the Shirley Highway Corridor began to increase after the Fall of 1973. Of the carpoolers surveyed during October 1974, more than 40 percent began carpooling during 1974. In addition, 37 percent of Corridor carpool drivers stated that their carpools had increased in size during 1974. As presented in Table 24, the main reasons given for the increase in the size of carpools were the energy crisis of the winter of 1973-74 and the opening of the Shirley Highway busway to carpoolers with four or more persons in December 1973.

Table 24

Reasons for the Increase in Carpool Size
Between December 1973 and November 1974

REASON	PERCENTAGE OF CARPOOL DRIVERS INDICATING REASON	
	BUSWAY	NON-BUSWAY
Opening of Shirley Highway express lanes to carpools	39	5
Special parking privileges for carpools	16	19
Carpool locator services	4	13
Gasoline crisis	22	22
Other	19	41

As with bus commuters, some carpool commuters were captive riders who did not have an auto available with which to commute to work on a regular basis and had to use a mode in which they were dependent upon others. An indication of the percentage of riders who were captives can be obtained from Table 25 which presents responses to the survey question: "Is an auto available for you to regularly drive alone from home to work?"

Table 25

Reported Auto Availability for Carpoolers

	CARPOOL DRIVERS		CARPOOL PASSENGERS	
	BUSWAY	NON-BUSWAY	BUSWAY	NON-BUSWAY
Not available	5%	3%	10%	20%
Available, but inconvenient	21	15	28	19
Available, and not inconvenient	74	82	62	61
	100%	100%	100%	100%

Few of these captive carpoolers were totally dependent on their present carpool. Table 26 summarizes responses to the survey question: "If you could not commute from home to work by means of this carpool how would you usually make this trip?" The responses indicated that almost no carpoolers "would have been unable to make this trip" if they couldn't have used their present carpool. While not dependent solely on their carpool, however, their reported alternate mode would have been one in which they were still dependent on others.

Table 26

Reported Alternate Mode of Carpoolers

ALTERNATIVE MODE	CARPOOL DRIVERS		CARPOOL PASSENGERS	
	BUSWAY	NON-BUSWAY	BUSWAY	NON-BUSWAY
Join or form another carpool	55%	29%	44%	29%
Drive alone	26	24	43	41
Use bus	18	43	12	28
Would be unable to make trip	1	1	0	1
Other	0	3	1	1
	100%	100%	100%	100%

While captive carpoolers had to use a mode in which they were dependent on others, for the large majority of carpoolers there was no such dependence. These were the "choice" carpoolers. To determine why Corridor commuters chose to carpool, responses to the survey question which asked them to identify how important each of several factors were in their decision to join or form their present carpools were examined. Table 27 summarizes these responses. Among both busway and non-busway carpool drivers and passengers, "reduction in commuting cost," "special parking privileges," and "convenient work locations of other carpool members" were the factors most often reported as "very important." "Availability of Shirley Highway express lanes for carpool usage" was also considered by over two-thirds of busway carpool drivers and passengers to have been very important in their decisions. Only a small percentage considered either the "availability of carpool locator service" or the "loss of flexibility in working hours" to be very important.

An examination of selected characteristics of the previous commute and present carpool trips of carpoolers revealed that their parking conditions and travel times had been improved. Eighty-five percent of busway carpool drivers reported that they used employer-provided parking; by contrast, of those who had commuted by auto prior to joining their present carpool, only 59 percent had used employer-provided parking. For non-busway carpool drivers, the figures were 69 and 47 percent respectively.

Table 28 shows that more than 60 percent of busway carpoolers reported travel times lower than those usually experienced in traveling by their previous mode. By contrast, a majority of non-busway carpoolers reported travel times higher than those usually experienced on their previous commute trips. These differences probably result from the higher line haul speeds possible on the busway, which allow busway carpools to overcome time lost in picking up and discharging passengers. These high speeds are not possible for non-busway carpools, hence the resultant increases in travel time.

Table 27

Factors Important to"Choice"Carpoolers When They First Decided to Join or Form Their Present Carpools

FACTORS	CHOICE CARPOOLERS RESPONDING "VERY IMPORTANT"							
	CARPOOL DRIVERS				CARPOOL PASSENGERS			
	BUSWAY		NON-BUSWAY		BUSWAY		NON-BUSWAY	
	Percent	Rank	Percent	Rank	Percent	Rank	Percent	Rank
Reduction in commuting cost	71	1	50	3	62	2	52	3
Special parking privileges	70	2	52	2	61	3	53	2
Convenient work location of other carpool members	65	4	63	1	59	4	58	1
Reduction in gasoline usage	53	5	42	4	53	5	44	4
Availability of Shirley Highway express lanes for carpool usage	69	3	9	12	72	1	12	12
Reduced stress and frustration in commuting	42	6	25	6	46	6	40	5
Concern for energy and air pollution problems	26	7	30	5	26	8	29	7
Reduced use of an auto or making the purchase of an auto unnecessary	21	8	20	9	28	7	26	8
Availability of good bus service as a "back-up"	15	9	23	7	26	8	30	6
Characteristics of other carpool members	12	11	21	8	18	10	23	9
Comfort of vehicles used by carpool	13	10	11	11	13	11	15	10
Loss of flexibility in working hours	8	12	20	9	7	12	14	11
Additional trip time resulting from passenger pick-up and discharge	4	15	8	13	4	15	8	13
Availability of carpool locator services	5	13	3	17	6	13	7	15
Additional risk to personal safety	3	17	6	14	5	14	8	13
Loss of personal privacy	5	13	5	15	2	17	7	15
Additional auto insurance required	4	15	5	15	3	16	3	17

NOTE: For each group of carpoolers, the factor with highest percentage of "very important" is ranked First. Ties are assigned the same rank.

Table 28

Distributions of Door-to-Door Travel Time Savings of Carpoolers
(Previous Commute and Surveyed Carpool Trips)

	MINUTES SAVED		MINUTES LOST		
	30-15	15-1	0-15	15-30	30-45
	Percent of Respondents				
Carpool Drivers					
Busway (208)	17	37	29	7	9
Non-Busway (224)	5	18	42	21	16
Carpool Passengers					
Busway (560)	22	40	24	6	1
Non-Busway (212)	12	30	41	14	3

(·) Number of Respondents

Since there was a sharp increase in carpooling during 1974, the carpooling factors discussed in the previous paragraph were examined separately for persons who began carpooling during that year and for those who began carpooling earlier. In both groups, the same factors -- "reduction in commuting cost," "special parking privileges" and "convenient work locations of other carpool members" -- were most often reported as very important.

The availability of the Shirley Highway Express lanes to carpools was the factor most often cited as very important by busway carpoolers who joined their present carpool during 1974. (The busway was opened to carpools on December 10, 1973.) In addition, the express lane factor was ranked fourth in importance by busway carpoolers who joined their present carpool before January 1974. While this was probably an attempt by respondents to insure that the busway would remain open to carpools, it is also an indication of the importance attached to the busway by carpoolers who had established carpools prior to the opening of the busway to them.

While a majority of the choice carpoolers had commuted by auto prior to joining their present carpools, a substantial percentage had formerly used bus. Table 29 summarizes responses of choice carpoolers to the survey question: "Before you began using this carpool how did you usually commute from home to work?" Former auto users comprised 75% of busway and 83% of non-busway carpool drivers, and 60% of busway and 61% of non-busway carpool passengers. Former bus users comprised 21% of busway and 15% of non-busway carpool drivers, and 33% of busway and 28% of non-busway carpool passengers. With respect to the busway carpoolers, it is significant that the residences of over 90% of these carpoolers were located in the service area of the busway bus operation (see Figure 23). Thus, the busway carpool operation was in competition with busway bus service, and many of the former bus commuters in these carpools had probably switched from the high quality express bus service of the project.

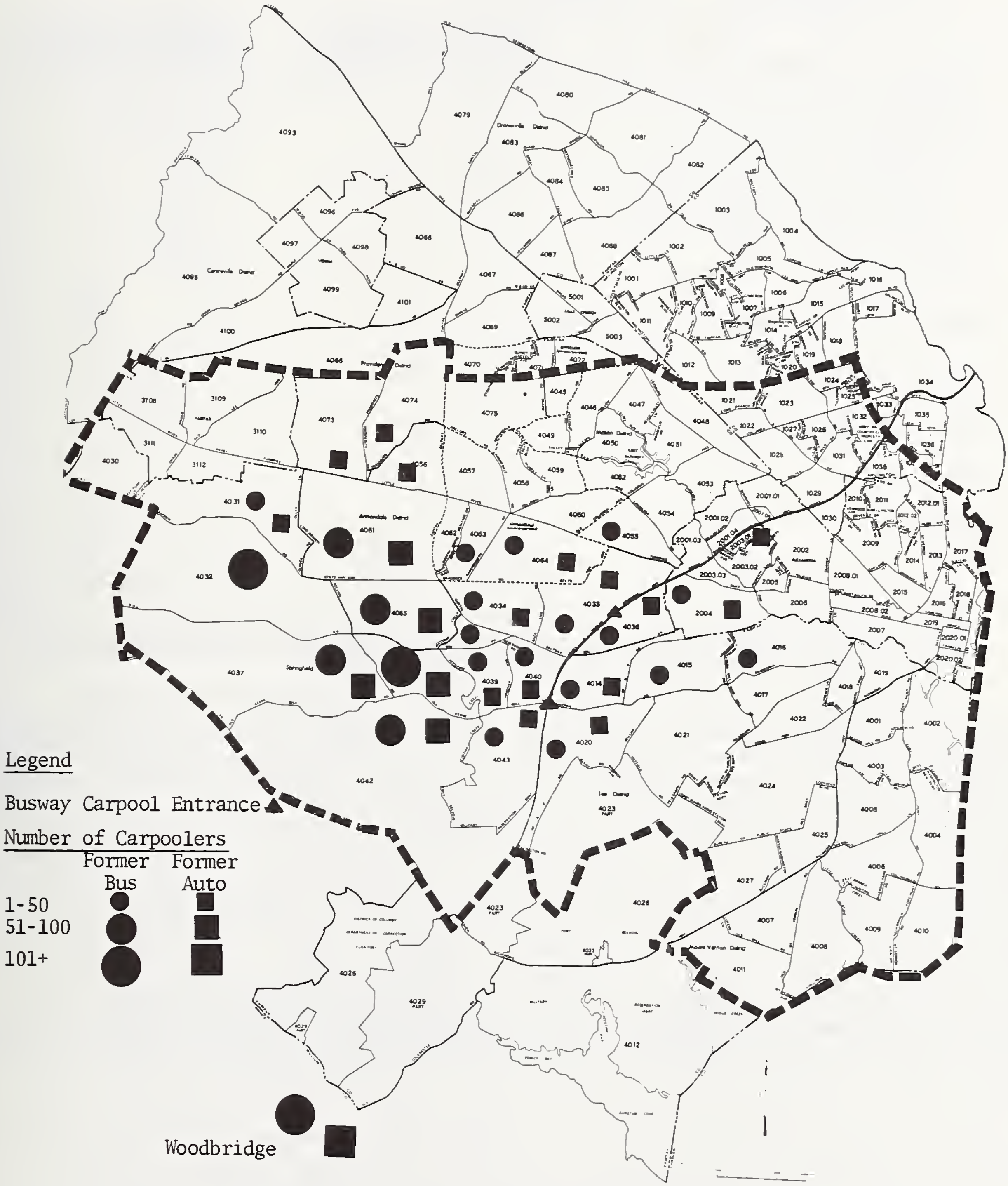

Figure 23. Origins of Busway Carpoolers

Table 29

Prior Commute Mode of "Choice" Carpoolers

	CARPOOL DRIVERS		CARPOOL PASSENGERS	
	BUSWAY	NON-BUSWAY	BUSWAY	NON-BUSWAY
Did not make this trip:[a]				
used auto in previous trip	22%	10%	18%	16%
used bus in previous trip	9	3	9	17
used other in previous trip	1	1	2	5
Drove alone	23	51	16	27
Was an alternate driver in a carpool	23	13	20	13
Drove in a carpool	3	4	2	2
Was a passenger in a carpool	4	5	4	3
Used bus	12	12	24	11
Other	3	1	5	6
	100%	100%	100%	100%

[a]The trip made before using this carpool was either from a different place of residence or to a different place of work (or both).

Of the 4200 carpool commuters (about 460 of the carpoolers were not commuting) using the busway in Fall 1974, about 28 percent had formerly commuted by bus (20 percent of non-busway carpoolers had formerly commuted by bus). A special category of busway carpoolers are those who joined their present (surveyed) carpool during 1974 (after the opening of the busway to carpools), and reported that the availability of the busway to carpools was "very important" in that decision. These are referred to as carpoolers diverted by the availability of the busway to carpools. Of an estimated 2400 carpoolers diverted by the availability of the busway to carpools, approximately 32 percent had switched from Corridor bus service. Tables 30 and 31 present selected demographic and trip characteristics of carpoolers who formerly commuted by bus and those who formerly commuted by auto. (This analysis focuses on commuters who switched to carpools and does not include commuters who reported that they had not previously made the same trip.) Generally the former bus riders are younger, less affluent and own fewer autos than the former auto users. Predictable, a higher percentage of the former bus users perceived bus as a commuting alternative.

Table 30

Selected Demographic Characteristics of Corridor Carpoolers

CHARACTERISTIC	BUSWAY Formerly Used Bus	BUSWAY Formerly Used Auto	NON-BUSWAY Formerly Used Bus	NON-BUSWAY Formerly Used Auto
	Percent of Respondents			
Household Income				
<$ 5,000	0	0	0	0
5- 15,000	8	6	24	18
15- 30,000	70	59	41	51
> 30,000	22	35	25	31
Age				
< 21	0	0	0	1
21-39	59	39	60	41
40-65	41	60	40	57
> 65	0	1	0	1
Sex				
Male	84	90	62	72
Female	16	10	38	28
Average Autos per Household	1.65	1.90	1.68	1.95
Number of Respondents	212	379	56	169

Other statistics in Table 31 provide clues as to why carpoolers switched from bus. Carpooling is faster than bus; more than 70 percent of the former bus riders reported a door-to-door travel time for their present (carpool) commute trip that was lower than the travel time of their previous bus commute trip. The availability of the busway to carpools appears to have been a major factor: more than two-thirds of the former bus riders joined their present carpools after the opening of the busway. The other significant factor was the preferential parking privileges extended to carpoolers. Overall, about 85 percent of the former bus riders received special parking privileges; and for those using the high speed busway, 90 percent of the former bus users received special parking privileges. Corresponding figures for former auto users are 80 and 85 percent respectively.

Table 31

Selected Trip Characteristics of Corridor Carpoolers

CHARACTERISTIC	BUSWAY		NON-BUSWAY	
	Formerly Used		Formerly Used	
	Bus	Auto	Bus	Auto
	Percent of Respondents			
Began Carpooling After December 1, 1973	69	43	41	41
Reported that Bus Could be Used for Present Trip	97	76	91	70
Reported Bus As Backup Mode	76	17	73	16
Use Employee-Provided Parking[a]				
Previous Trip	--	69	--	47
Surveyed Trip	90	85	64	69
Changes in Travel Time				
Saved 15-30 minutes	30	20	25	3
Saved 0-15 minutes	41	43	61	17
Lost 0-15 minutes	23	31	10	58
Lost 15-30 minutes	6	6	4	17
Lost 30-45 minutes	0	0	0	4
Number of Respondents	212	379	56	169

[a]Carpool drivers only.

Some insight into why these former bus riders began carpooling can also be gained from an analysis of responses to the survey question which asked for an importance rating for each of several factors in the decision to join or form their present carpools (does not include commuters who reported that they had not previously made the same trip). Summarized in Tables 32 and 33, these responses are quite similar to those of the entire carpool population, as presented in Table 28, page 70 . Among former bus riders, "reduction in commuting cost," "special parking privileges," and "convenient work locations of other carpool members" were the factors most often reported as very important. Availability of Shirley Highway express lanes for carpool usage was reported as "very important" by more than two thirds of the former bus riders.

5.2.3 Mode Choice Decisions of Persons Commuting by Driving Alone

Throughout the Shirley Highway Express-Bus-on-Freeway Project, the number of persons driving alone in the Shirley Highway Corridor remained relatively constant at about 23,700. To gain insight into why such a large segment of the Corridor commuters continued to drive alone when preferential treatment was being given to buses and carpools, the Fall 1974 mode choice decisions of drivers alone were examined.

Prior to their October 1974 commute trip, some of these drivers had used a bus or carpool to make their present home to work trip.[4] Table 34 summarizes responses to the survey question: "When was the last time you regularly used the bus to commute from your present home to your present work place?" Table 35 summarizes responses to the survey question: "When was the last time you regularly used a carpool to commute from your present home to your Work place?" Thirty-one percent of these commuters had regularly used a bus after the project

[4]Captivity had not been an issue with these present drivers alone. Only one percent of them indicated that an auto had not been available for them to regularly drive alone from home to work. Also, only four percent indicated that one had been available, but inconvenient.

Table 32

Factors Important to Carpool Drivers When They First Decided to Join or Form Their Present Carpools

FACTORS	CARPOOL DRIVERS RESPONDING "VERY IMPORTANT"							
	BUSWAY				NON-BUSWAY			
	Formerly Used				Formerly Used			
	Bus		Auto		Bus		Auto	
	Percent	Rank	Percent	Rank	Percent	Rank	Percent	Rank
Reduction in commuting cost	77	1	63	4	57	2	45	3
Availability of Shirley Highway express lanes for carpool usage	73	2	63	2	16	8	7	13
Special parking privileges	57	3	66	2	44	3	56	2
Convenient work location of other carpool members	57	3	69	1	61	1	62	1
Reduced stress and frustration in commuting	37	5	35	6	35	4	21	9
Reduction in gasoline usage	33	6	57	5	35	4	44	4
Reduced use of an auto or making the purchase of an auto unnecessary	33	6	24	8	15	9	22	6
Concern for energy and air pollution problems	30	8	25	7	15	9	32	5
Characteristics of other carpool members	20	9	10	11	31	6	18	10
Comfort of vehicles used by carpool	11	10	17	9	8	11	9	12
Availability of good bus service as a "back-up"	10	11	16	10	23	7	22	6
Additional trip time resulting from passenger pick-up and discharge	7	12	4	15	0	15	12	11
Loss of personal privacy	5	13	10	11	0	15	7	13
Availability of carpool locator system	3	14	5	14	8	13	2	17
Loss of flexibility in working hours	3	15	9	13	12	11	22	6
Additional risk to personal safety	0	16	3	16	0	15	5	16
Additional auto insurance required	0	16	3	16	4	13	7	13

NOTE: For each group of carpoolers, the factor with highest percentage of "very important" is ranked first. Ties are assigned the same rank.

Table 33

Factors Important to Carpool Passengers When They First Decided to Join or Form Their Present Carpools

FACTORS	CARPOOL PASSENGERS RESPONDING "VERY IMPORTANT"							
	BUSWAY				NON-BUSWAY			
	Formerly Used				Formerly Used			
	Bus		Auto		Bus		Auto	
	Percent	Rank	Percent	Rank	Percent	Rank	Percent	Rank
Availability of Shirley Highway express lanes for carpool usage	83	1	66	1	4	17	17	10
Reduction in commuting cost	59	2	66	1	48	4	56	3
Special parking privileges	57	3	65	3	62	1	63	2
Convenient work location of other carpool members	56	4	61	4	55	2	64	1
Reduction in gasoline usage	47	5	58	5	28	6	56	3
Reduced stress and frustration in commuting	44	6	45	6	52	3	38	5
Availability of good bus service as a "back-up"	35	7	16	10	32	5	24	8
Concern for energy and air pollution problems	24	8	25	8	28	6	33	6
Reduced use of an auto or making the purchase of an auto unnecessary	20	9	35	7	21	11	27	7
Characteristics of other carpool members	13	10	20	9	28	6	18	9
Comfort of vehicles used by carpool	13	10	13	11	10	14	11	14
Loss of flexibility in working hours	6	12	8	12	7	16	17	10
Availability of carpool locator services	5	13	7	13	10	14	7	16
Additional trip time resulting from passenger pick-up and discharge	4	14	4	15	24	9	13	12
Additional risk to personal safety	4	15	5	14	24	9	11	13
Additional auto insurance required	3	16	2	17	11	13	4	17
Loss of personal privacy	1	17	3	16	14	12	10	15

NOTE: For each group of carpoolers, the factor with highest percentage of "very important" is ranked first. Ties are assigned the same rank.

began, and 18 percent had regularly used a carpool after the energy crisis began and the reversible lanes were opened to carpools.

Table 34

Last Time Drivers Alone Regularly Used
A Bus To Make Present Home To Work Trip

YEAR	PERCENT
Never	49%
Not Within the Last 5 Years	20
1970	2
1971	1
1972	3
1973	4
1974	21
	100%

Table 35
Last Time Drivers Alone Regularly Used
A Carpool To Make Present Home To Work Trip

YEAR	PERCENT
Never	59%
Not Within the Last 5 Years	16
1970	1
1971	2
1972	1
1973	3
1974	18
	100%

To investigate why those drivers alone who had tried commuting to work using bus or carpool returned to their autos and why the remaining drivers alone never used these modes, responses to the following survey questions were examined: "If you do not now regularly commute from home to work by bus, why not?" and "If you do not now regularly commute from home to work by carpool, why not?." Tables 36 and 37 summarize the responses to these questions. There did not seem to be any significant difference in the reasons given for not commuting by bus between those who had tried commuting by bus in the Corridor since 1970 and those who had not. Among both groups, "loss of flexibility in working hours," "bus takes too long," "too much time spent waiting at bus stops," and "need car during work day" were the reasons given most often for not commuting by bus. "Bus unreliable" was also frequently given as a reason for not commuting by bus.

Reasons given for not commuting by bus were also investigated for drivers alone who had last regularly commuted by bus during 1973 or 1974. "Loss of flexibility in working hours," "bus takes too long," "too much time spent waiting at bus stops," and "bus unreliable" were the reasons given most often for not commuting by bus. Significantly, an analysis of the locations of the residences of these diverted bus riders revealed that at least two-thirds lived in areas served by non-busway bus routes. Since it was shown previously in Subsection

Table 36

Reasons Drivers Alone Did Not Regularly Commute By Bus

REASONS	DRIVERS ALONE INDICATING REASON			
	DRIVERS ALONE WHO HAD TRIED REGULARLY COMMUTING BY BUS IN THE SHIRLEY CORRIDOR SINCE 1970		DRIVERS ALONE WHO HAD NOT TRIED REGULARLY COMMUTING BY BUS IN THE SHIRLEY CORRIDOR SINCE 1970 OR WHO HAD NEVER TRIED IT THERE	
	Percent	Rank	Percent	Rank
Loss of Flexibility in Working Hours	35[a]	3	48[a]	1
Bus Takes Too Long	42	1	40	2
Too Much Time Spent Waiting at Bus Stops	42	1	32	3
Need Car During Work Day	29	5	30	4
Bus Unreliable	30	4	14	8
Too Much Walking Necessary	20	7	22	5
Bus Too Expensive	19	8	16	7
No Seats Available On Bus	22	6	8	9
Bus Not Available	7	9	17	6
No Personal Privacy on Bus	6	10	8	9

NOTES: For each group of drivers alone, the reason given most often is ranked first. Ties are assigned the same rank.

[a]Estimated from a visual inspection of several survey forms that had "other" checked and a reason specified afterwards.

Table 37

Reasons Drivers Alone Did Not Regularly Commute By Carpool

REASONS	DRIVERS ALONE INDICATING REASON			
	DRIVERS ALONE WHO HAD TRIED REGULARLY COMMUTING BY CARPOOL IN THE SHIRLEY CORRIDOR SINCE DECEMBER 1973		DRIVERS ALONE WHO HAD NOT TRIED REGULARLY COMMUTING BY CARPOOL IN THE SHIRLEY CORRIDOR SINCE DECEMBER 1973 OR WHO HAD NEVER TRIED IT THERE	
	Percent	Rank	Percent	Rank
Loss of Flexibility in Working Hours	71	1	67	1
Inability to Locate Others Willing to Carpool	34	2	21	4
Need Car During Work Day	32	3	26	2
Too Much Time Required to Pick Up and Discharge Carpool Passengers	9	4	22	3
No Personal Privacy in Carpool	0	7	10	5
Too Much Auto Insurance Required	7	5	4	7
Too Much Risk to Personal Safety	5	6	5	6

NOTES: For each group of drivers alone, the reason given most often is ranked first. Ties are assigned the same rank.

3.2 that busway bus service is faster than non-busway service, the slowness of non-busway service may have contributed to this loss of bus passengers to auto.

As with the reasons given for not commuting by bus, there did not seem to be any significant difference in the reasons given for not using carpool between those who had commuted by carpool in the Corridor since December 1973 and those who had not. Among both groups, "loss of flexibility in working hours" was, by far, the reason given most often (by over two-thirds of the respondents). "Inability to locate others willing to carpool" and "need car during work day" were also given by many as reasons.

Notice that "loss of flexibility in working hours" was given considerably more often as a reason for not carpooling than as a reason for not using bus. While Corridor bus service afforded some flexibility of work hours (i.e., there was usually a choice of buses operating at different times), carpooling probably afforded less flexibility since the carpools would usually leave at a fixed time.

5.2.4 Summary of Corridor Commuter Mode Choice Decisions

Paragraph 5.2.4 compares the mode choice decisions of bus users, carpoolers, and drivers alone, to provide greater insight into why buses or carpools were or were not used by Corridor commuters. The paragraph concludes with a brief statement about the implications for mode choice modeling of this investigation of commuters' mode choice decisions.

Generally, our examination of Corridor commuter mode choice decisions suggests that the greatest contributors to increased bus usage and carpooling are the discomfort and expense involved in driving alone, and the priority treatment given to buses and large carpools. The results also suggest that the perceived inflexibility in arrival and departure times of buses and carpools are the greatest barriers to increasing utilization of these high occupancy modes.

In 1974, about 61 percent of Corridor bus commuters had formerly commuted by auto, and about 54 percent of these former auto users had driven alone to work. Most of the former auto users reported that they switched to bus because of the discomfort (or stress) and expense of their prior auto commute trip, and the express features of the bus-on-freeway operation. The results of mode choice models developed for the Demonstration Project are consistent with the survey finding that expense of commuting by auto was a primary reason why auto commuters switched to bus.[5] These models estimated that a doubling of auto commuting costs would have increased bus ridership by over 50 percent.

A comparison of the demographic characteristics of bus riders diverted from auto and of current auto commuters revealed that the diverted auto commuters had more recent changes in jobs and residences. This finding indicates that many commuters used a job or residence change to experiment with commuting by bus, and suggests that areas of high mobility (such as Washington, D.C.) are potentially fertile transit markets.

While a large number of bus riders had been diverted from auto, some drivers of single occupant autos had been diverted from bus. The reported reasons for this "reverse" diversion were the excessive travel and waiting times by bus and poor bus reliability. Although most of these former bus riders had probably used the non-busway bus service, their reasons for switching suggest that waiting time, door-to-door travel time, and reliability of bus service are important factors in deciding whether or not to use bus. In this instance, the level of non-busway bus service was such that the former bus riders chose to drive alone.

During 1974, Corridor carpooling increased significantly. (Auto occupancy went from 1.33 to 1.47.) Corridor carpoolers reported that the availability of the busway to carpools and the onset of the gasoline crisis were the primary reasons for the increased carpooling. Carpoolers also reported on the factors important in their mode choice decisions. Factors cited most often as very important when they decided to join or form their carpools were: 1)"special parking privileges," 2)"reduction in commuting costs," 3)"convenient work locations of carpool members," and 4)"availability of reversible lanes to carpools" (by carpoolers using busway). The primary reason given by drivers alone who stopped carpooling during 1974 involved their frequent need for a car on short notice.

[5]"Mode Choice and the Shirley Highway Experiment."

An examination of the present (surveyed) commute trips of carpoolers and their previous trips by other modes revealed some of the benefits enjoyed by carpoolers. One was employer-provided parking. Prior to joining their present carpool, 47 percent of the former auto commuters used employer-provided parking; after joining the carpool, this figure rose to 69 percent. Another benefit was travel time savings, with more than 60 percent of busway carpoolers reporting a door-to-door travel time lower than that of the previous commute trip.

The benefits of carpooling also attracted bus riders. About 25 percent of the carpoolers had commuted by bus prior to carpooling. Of the carpoolers attracted by the policy allowing carpools with four or more members to use the busway, about 32 percent had formerly commuted by bus. The factors cited most often by the former bus users as important in their decision to carpool were the same as those reported by other carpoolers. About 85 percent of the former bus riders used employer-provided parking and more than 70 percent reported a travel time lower than that of the travel time by their previous bus commute trip.

The results of this investigation of Corridor commuter mode choice decisions have significant implications for the variables and modes (travel options) to be included in mode choice models. Most models only include time and cost as travel variables (as opposed to socio-economic variables).[6] By contrast, six factors were found to be important in Corridor commuters' mode choice decisions: 1) stress and frustration of commuting, 2) expense of commuting, 3) flexibility of arrival and departure times, 4) reliability, 5) waiting time and door-to-door travel time, and 6) preferential parking privileges. With mode choice models which consider only travel time and cost, it will be difficult to accurately estimate the patronage potential of transportation operations such as the Demonstration Project.

Another problem involves the representation of auto commuters. In most mode choice models, all auto commuters are handled as a single group. However, the results from this section strongly suggest that auto commuters should be divided into carpoolers and drivers alone. Not only do the two groups have different demographic and trip characteristics, but current transportation policies differ in the treatment accorded them, generally encouraging carpooling and discouraging driving alone.

[6] See Dan Brand, "Travel Forecasting: Some Foundations and a Review of Urban Travel Demand Forecasting", Special Report 143, Transportation Research Board, Washington, D.C., 1973.

6.0 ENVIRONMENTAL, SOCIAL AND ECONOMIC IMPACTS OF THE PROJECT

The project affected the environmental and social conditions of the Corridor, the economic situation of the bus operator, and the level of service provided by the Corridor auto system. Project-stimulated changes in auto travel times were investigated in Subsection 4.1, with a finding that the project resulted in a reduction in auto travel times for motorists on all Corridor roadways (below what they would have been had there been no project).

This section is divided into three parts: Subsection 6.1 discusses the environmental impacts of the project and estimates reductions in peak period auto usage, auto pollutant emissions and gasoline usage attributable to the project. Subsection 6.2 discusses the impact of the project on the transportation disadvantaged (i.e., the physically handicapped, the auto-less, etc.). Subsection 6.3 discusses the economic impacts of the project and estimates project costs and revenues.

6.1 Reductions in Auto Usage, Auto Pollutant Emissions, and Gasoline Consumption

The project had a positive impact on the Corridor environment. Diversion of motorists to buses and carpools resulted in reductions in the use of autos for commuting. The reduction in auto usage led to reductions in pollutant emissions and gasoline consumption. This subsection summarizes estimates of reductions in auto usage attributable to the project and presents associated estimates of reductions in pollutant emissions and gasoline consumption.

6.1.1 Reductions in Peak Period Auto Volumes

In the absence of the project, approximately 7600 additional autos would have used Corridor roadways during each peak period (as of October 1974). This reduction in auto usage was caused by the diversion of motorists to the express bus service and into carpools which used the busway. Auto diversion attributable to the project can be approximated by the product of (1) the number of diverted auto commuters, and (2) the reciprocal of auto occupancy for diverted auto commuters which was estimated from responses to the "prior mode" question of the 1971 and 1974 commuter surveys. The "prior mode" question on the 1974 survey was: "Before you joined this carpool (began riding this bus, for bus riders), how did you commute from home to work?"[1]

- /_/ did not make this trip (from your present home to your present work place); how did you commute prior to changing your place of residence or work?
  /_/ auto /_/ bus /_/ other
- /_/ drove alone
- /_/ was an alternate driver in a carpool with ____ other person(s)
- /_/ drove in a carpool with ___ other person(s) (always or nearly always drove)
- /_/ was a passenger in a carpool with ____ other person(s) (never or almost never drove)
- /_/ used bus (specify route) ________________
- /_/ other (specify) ________________

[1]Responses to a similar question on the 1971 survey questionnaires were used to estimate a value for auto occupancy for diverted auto commuters for 1971 and 1972. See "Second Year Results Report," pp. 69, 70.

The magnitude of auto commuter diversion attributable to the express bus service is estimated as the difference between the October 1974 express bus patronage and the number of bus riders who utilized pre-project bus service.[2] An estimated 5440 commuters used pre-project bus service -- 4370 from routes which used the Shirley Highway prior to the construction of the reversible lanes, and 1070 from bus routes which used other Corridor arterials.

The second factor, the reciprocal of auto occupancy, was estimated from an analysis of the "prior mode" responses of bus riders who formerly commuted by auto. (See Appendix D for a detailed explanation of the procedure.) A value of .6 was estimated from the 1971 bus survey responses; this value was used to estimate auto diversion for 1971 and 1972. A value of .68 was estimated from the 1974 bus survey responses; this value was used to estimate auto diversion for 1973 and 1974. The higher value in 1974 reflects an increase in the percentage of bus riders who had formerly driven alone to work.

As of October 1974, 7253 autos had been removed from Corridor roadways because of the express bus service. Estimates of reductions in auto usage were computed for the month of October for the years 1971 through 1974. (The 1971 and 1974 commuter surveys were conducted in October.) The computational procedures are summarized in Table 38 along with the estimates of reductions in auto usage.

Table 38

Summary of Estimates of Bus-Stimulated Reduction in Auto Usage

ESTIMATES	October 1971	October 1972	October 1973	October 1974
Total Daily AM Peak Busway Users	9,093	12,105	14,042	16,106
Users of Non-Shirley Highway Buses Prior to Busway Opening, Now Using Busway Service	1,070	1,070	1,070	1,070
Users of Shirley Highway Buses Prior to Busway Opening	4,370	4,370	4,370	4,370
Estimated Former Auto Users	3,653	6,665	8,602	10,666
Estimated Diverted Autos	2,192	3,999	5,849	7,253

As of October 1974 an estimated 323 autos had been removed from Corridor roadways because autos with four or more occupants were allowed to use the reversible lanes. The reduction in auto usage attributable to carpools on the reversible lanes was computed as the difference between the number of diverted autos (347 autos) and the number of autos required for newly formed carpools (24 autos). As with the express bus service, the estimate of diverted autos is computed using (1) the number of auto commuters diverted to carpools because of the reversible lanes, and (2) the reciprocal of their auto occupancy. An estimated 610 auto commuters were diverted to carpools because of the availability of the reversible lanes to carpools. This number is the total of auto commuters who met all of the following conditions: (1) regularly carpooled on the reversible lanes; (2) joined their carpool after the reversible lanes were opened to carpools (December 1973); and (3) cited the reversible lanes as a very important reason in the decision to join their present carpool. Using the "prior mode" responses of these carpoolers to the October 1974 survey,

[2] This approach assumes that all new commuters (prior bus and auto users) would have used auto and that all prior bus riders would have remained on the bus service. Since bus patronage had been declining in years prior to the project, the likely effect of this assumption is that diversion from auto to bus will be understated.

it was estimated that 347 autos had been diverted from daily peak period traffic because of carpooling on the reversible lanes.

If all of these commuters had joined existing carpools, 347 would have been correct as an estimate of autos removed from the roadway because carpools with four or more members were allowed to use the busway. However, one of these autos was used on a daily basis by each of the newly formed carpools. Daily requirement for autos for the new carpoolers was estimated after an analysis of changes in carpool size since the reversible lanes opened to carpools. When a change did occur in the size of a carpool which used the reversible lanes, more than 80 percent of the time a new member joined an existing carpool of at least three members. Twenty-four was the estimated daily auto requirement of the 20 percent of these commuters forming new carpools.

6.1.2 Reductions in Auto Pollutant Emissions

The reduction of auto pollutant emissions is a major objective of programs to improve air quality in the Washington metropolitan area. The success of the project in reducing peak period auto emissions demonstrates the potential of bus transit in such programs. This paragraph summarizes procedures for estimating reductions in auto pollutant emissions and presents estimates of reductions in pollutant emissions attributable to the project.

The quantity of pollutants emitted by corridor traffic is a function of the following factors: (1) number of vehicle trips, (2) miles of vehicular travel, (3) mix of vehicular traffic (auto, buses, truck, etc.), (4) vehicle speeds and highway levels of service, and (5) effectiveness of the vehicle emission control devices. The project directly affected factors 1 through 3 and indirectly affected the fourth. The reduction in auto pollutant emissions attributable to the project occurred because of:

(1) The reduction in both the number of vehicular trips and the miles of vehicular travel;

(2) The removal of all buses from the main roadway of the Shirley Highway; and

(3) The increase in attainable vehicle speeds because of changes in factors 1 and 2.

Estimates of daily and annual reductions in pollutant emissions are presented in Tables 39 and 40 respectively. These estimates are obtained as follows (see Appendix E for a detailed explanation of procedures):

(1) Estimates for auto exhaust emission rates of carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_X), and auto crankcase-evaporative hydrocarbons (HC°) are assembled in Table 59.

(2) The effectiveness of CO, HC, and NO_X exhaust emission control devices diminishes as vehicle age increases, and so deterioration factors for each pollutant type (listed in Table 60) are applied to the exhaust emission rates for each model year to compute "adjusted" exhaust emission rates.

(3) For each pollutant, an emission rate for the "typical corridor commuter auto" is computed based upon the "adjusted" emission rate and percentage of travel for each model year (see Figure 26).

(4) CO and HC exhaust emission rates are affected by vehicle operating speed. Speeds and auto volumes (listed in Table 61), observed during half hour intervals from 6:30-9:00 AM on the Shirley Highway (inbound between Route 7 and the Virginia side of the 14th Street Bridge), were chosen as representative of average peak period conditions for all project commuters. The vehicle speeds are used to specify the emissions adjustment factors to be applied to the "typical auto" emission rates in computing peak period auto emission rates. Peak period emission

rates (in Table 62) for the typical Corridor commuter auto were computed using the speed-adjusted emission rates and the half-hour distribution of auto volumes on Shirley Highway.

(5) Estimates of reductions in pollutant emissions resulting from the project during 1971 and 1972 assumed an average roundtrip commute distance of 19.8 miles and auto reduction estimates of 2,192 for October 1971, and 3,999 for October 1972. Estimates for 1973 and 1974 assumed a roundtrip distance of 25 miles, and auto reduction estimates of 5,849 for October 1973 and 7,600 for October 1974 (from paragraph 6.1.1).[3] The product of these figures and peak period pollution emission rates for the "typical" auto represents the estimated reduction in air pollution for one day during each of these months (presented in Table 39). Estimates of annual reductions in pollutant emissions in Table 40, are based upon a 200 day work year.

Table 39

Estimates of Daily Reductions in Auto Pollutant Emissions

(Pounds)

POLLUTANT	OCT 71	OCT 72	OCT 73	OCT 74	TOTAL FOR ALL CORRIDOR COMMUTERS IN OCT 1974
Carbon Monoxide	6,733	11,679	22,100	32,240	122,708
Hydrocarbons (Exhaust)	689	1,194	2,168	3,089	11,777
Nitrogen Oxides	511	853	1,576	2,048	7,799
Hydrocarbons (Evaporative)	314	417	567	711	2,706

Table 40

Estimates of Yearly Reductions in Auto Pollutant Emissions

POLLUTANT	JUL 71 - DEC 71 TONS	JAN 72 - DEC 72 TONS	JAN 73 - DEC 73 TONS	JAN 74 - DEC 74 TONS	JUL 71 - DEC 74 TONS
Carbon Monoxide	168	920	1,721	2,717	5,526
Hydrocarbons(Exhaust)	17	94	171	263	545
Nitrogen Oxides	13	68	124	181	386
Hydrocarbons(Evaporative)	8	37	52	64	161

Estimates of the October 1974 reductions in daily pollutants are 32,240 pounds of carbon monoxide; 3,800 pounds of hydrocarbons and 2,048 pounds of nitrogen oxides.[4] The October 1974 figures represent about 26 percent of the auto pollutants generated by Corri-

[3] These assumed roundtrip distances were the respective averages of the estimated roundtrip distances of diverted commuters using the 1971 and the 1974 survey results.

[4] An estimate was made of the increase in the amount of pollutants attributable to the additional bus trips that were added as a result of the project. For all types of pollutants, the increases due to buses were less than five percent of the total decrease attributable to diverted autos.

dor commuter traffic crossing the screenline (or about a 21 percent reduction in what auto pollutants would have been in the absence of the project).

6.1.3 Reduction in Gasoline Consumption

As present day awareness of the limited nature of energy resources has increased, public transportation has been looked to as a means for reducing the energy requirements of urban travel. One of the goals of the project was to demonstrate that increased use of public transportation does reduce the amount of fuel consumed by Corridor commuters.

Corridor gasoline usage depends upon the amount of auto travel and the rate at which the gasoline is consumed. The rate of gasoline consumption is dependent upon both the characteristics of individual vehicles and the roadway conditions under which the vehicles operate. The two primary vehicle characteristics are weight and model year, the latter being a surrogate for design modifications which affect fuel consumption. Roadway operating conditions determine the applicable speed and level of service, and are dependent upon the type, volume, and capacity of the roadway.

The project resulted in a diversion of autos from Corridor roadways during peak periods, and in hourly auto volumes which were lower than they would have been in the absence of the project. As those volumes decreased, speeds increased to a more efficient fuel consumption range. While auto speeds increased because of the reduction in auto volume, lack of data prevents the estimation of lessened gasoline consumption due to these higher speeds. For this reason, estimates of savings in gasoline consumption were based solely on reductions in auto usage and are therefore conservative. An outline of this estimation procedure follows (for a summary of computations, see Appendix E):[5]

(1) For 1971 and 1972, an average round trip distance of 19.8 miles was estimated using the trip lengths of diverted auto commuters as reported in the 1971 commuter surveys. For 1973 and 1974, a distance of 25 miles was estimated from the 1974 commuter surveys.

(2) Distributions of the fraction of total vehicles in each weight class and model year were determined based upon national data for model years 1960 through 1974 and for eleven weight categories. (Refer to Table 63.) data were combined with the estimated number of diverted autos and the average roundtrip distance to produce an estimate of the daily reduction in vehicle miles traveled by autos in each model year-weight class category.

(3) Average base fuel consumption rates were obtained for each model year-weight class category (see Table 64). These rates, expressed in gallons per mile, were then multiplied by the vehicle miles of travel for each vehicle category to obtain base fuel consumption.

(4) The base consumption figures were multiplied by adjustment factors (see Tables 65 and 66) which reflect the effects of traffic volume and road type (freeway or arterial) on fuel consumption. Estimated daily gasoline savings attributable to the project are: 3,433 gallons for October 1971, 6,209 gallons for October 1972, 13,232 gallons for October 1973, and 17,166 gallons for October 1974.[6] The October 1974 estimate represents 30 percent of the total estimated consumption for all Corridor commuter traffic across the screenline (or about a 23 percent reduction in what gasoline consumption would have been in October 1974 in the absence of the project).

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[5] Also see "A Procedure for Estimating Automobile Fuel Consumption on Congested Urban Roads," report prepared for the Urban Mass Transportation Administration, Department of Transportation, by the Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234, 1974. Available from NTIS, Springfield, Virginia, COM-75-10057.

[6] An estimate was made of the increase in fuel consumption attributable to the additional bus trips that were added as a result of the project. The increase in fuel consumption due to buses was less than five percent of the total decrease attributable to diverted autos.

(5) Estimated savings attributable to the project are: 394,600 gallons for July 1971 through December 1971; 1,155,000 gallons for January 1972 through December 1972; 2,218,000 gallons for January 1973 through December 1973; and 3,138,200 gallons for January 1974 through December 1974. Total gasoline savings for the period July 1971 to December 1974 is estimated at 6,905,800 gallons.

6.2 Changes in Mobility of the Transportation Disadvantaged

Another objective of the project was to improve the mobility of persons dependent upon public transportation to carry out their daily activities. (Hereafter such persons are referred to as "transit dependents.") A bus passenger was characterized as transit dependent if he was very old, very young, handicapped, or from an auto-less household. Relative to the large number of bus riders who benefitted from the project, only a few could be characterized as transit dependent. Although no data exist on project ridership by physically handicapped persons, experience from several on-board surveys suggests that few handicapped persons used the peak period express bus service. The small percentage of riders from auto-less households, or who were very young or very old, is documented in Table 16, page 60.

There are several reasons for the mobility of transit dependents to have been unaffected by this peak period oriented project. First, peak period buses were very crowded (during 1974, they averaged approximately 45 persons per bus); this would discourage their usage by handicapped persons. Second, project service was provided in residential areas with high incomes and high auto ownership; as a result, there were considerably fewer potential riders from auto-less households. Finally, project service was commuter oriented, and such markets contain few very young or very old persons.

Two extensions of project operations, a mid-day service and a reverse commute service, did improve the mobility of some Corridor transit dependents. Relative to peak period express bus service, the scope of these operations was limited, and patronage was very low. Nonetheless, both provided vastly improved bus service to their users.

Mid-day project service was of two primary types: 1) radial service between Northern Virginia and the District of Columbia and 2) cross-corridor service within Northern Virginia. The socio-economic characteristics of the two groups of riders were quite different: Users of the cross-corridor service (approximately 300 riders on 61 daily bus runs in early 1973) were older and poorer, and owned fewer cars than the users of the radial service (approximately 500 on 63 daily trips). Demographic characteristics of the users of the mid-day services are presented in Table 41. Note the similarity between the users of mid-day radial service and those of the peak period express bus service (see Table 16, page 60).

Table 41

Selected Demographic Characteristics of Users of Mid-Day Bus Service

CHARACTERISTIC	CROSS-CORRIDOR ROUTES[a]	RADIAL ROUTES[b]
Sex		
Male	32%	49%
Female	68%	51%
	100%	100%
Age		
< 21	23%	10%
21-31	41	51
40-65	26	39
> 65	10	-
	100%	100%
Household Income		
< $5,000	22%	4%
$5-10,000	35	12
$10-15,000	17	19
$15-30,000	20	47
> $30,000	6	18
	100%	100%
Percent Auto-less Households	40	7
Mean Autos/Household	.8	1.65
Number of Respondents	126	144

[a]Metrobus Routes 26, 29L

[b]Metrobus Routes 17G, 18G

The reverse commute service operated between Washington, D.C. and selected areas in Northern Virginia. This operation provided approximately 400 riders on 20 peak period trips with bus service that was a substantial improvement over that available prior to the project. With the reverse commute service, waiting and in-vehicle travel times were lower, the number of transfers and the time spent transferring were reduced, and walking distances to jobs were shorter.

Demographic characteristics of the users of the reverse commute service are presented in Table 42. Average auto ownership among these commuters is lower than either the District or the Corridor-wide average. Thus, the reverse commute service did increase the mobility of this small group of transit dependents.

Table 42

Selected Demographic Characteristics of Users of the Reverse Commute Service

CHARACTERISTIC	PERSONS BOARDING IN	
	WASHINGTON, D.C.	VIRGINIA
Age		
< 21	4%	6%
21-39	25	39
40-65	69	53
> 65	2	2
Total	100%	100%
Sex		
Male	34%	48%
Female	66	52
Total	100%	100%
Autos Owned Per Household		
0	49%	33%
1	42	41
2	9	18
3	0	6
4	0	2
Total	100%	100%
Mean Household Auto Ownership	.59	1.04
Number of Respondents	87	53

6.3 Economic Consequences of Project

The implementation and operation of this project involved expenditures for each of its elements. Funds were expended for: 1) the acquisition of right-of-way and the construction and operation of the reversible lanes, 2) the purchase of new buses and operation of the express bus service, and 3) the operation of fringe park-and-ride lots. Of the three official project fringe park-and-ride lots, funds were expended only for the Backlick lot, a fringe parking lot for the future WMATA rail rapid transit system (see Subsection 2.3). Under the terms of a lease agreement with WMATA, the Demonstration Project paid $52,000 per year for the use of the lot. Subsection 6.3 discusses expenditures for the priority and transit elements and concludes with a brief summary of the economic impact of the project on the bus operator.

6.3.1 Reversible Lanes

Expenditures involving the reversible lanes include right-of-way acquisition, operating, and construction costs. Data on right-of-way acquisition costs are not available; however, the reversible lanes follow what was the median strip of the Shirley Highway prior to construction, and land acquisition was therefore minimal.[7] Data from the Virginia Department of Highways and Transportation (VDH&T) indicate that operating costs--the labor costs involved in the manual opening and closing of the reversible lanes for each peak period--averaged about $10,000 per year. VDH&T also estimated that the reversible lanes will require resurfacing every 6 to 8 years at a cost of from $150,000 to $200,000 for each operation.

Construction cost information is available only for the entire roadway. Thus, it is not possible to identify and separate the actual costs of the reversible lanes. In order to approximate these costs, 30 percent of the total construction costs of the entire roadway from just south of the Springfield interchange to eight-tenths miles north of the Glebe Road interchange was allocated to the reversible lanes. This figure was chosen because the reversible lanes account for about 30 percent of the width of the roadway cross section. The reversible lanes are 44 feet wide (two 12 foot lanes and two 10 foot shoulders) and the regular roadway is 108 feet wide (six 12 foot lanes, two 10 foot shoulders, and two 8 foot shoulders). The busway, therefore, represents approximately 30 percent (44/108) of the total roadway width. On this basis, $27.4 million (30 percent of the total construction costs of $91.2 million) or $3 million per mile was allocated to the reversible lanes (see Table 43). Allocating the costs on a simple relative width basis may misrepresent the actual costs where special structural costs occur because of the reserved lanes. In addition, the number and type of interchanges and ramps significantly affect the costs of expressway. Although these are noted with each segment's cost data (in Table 43), no detailed study was attempted to isolate the effect of ramps and interchanges.

The remaining 2.3 miles of reversible lanes pass through the Mixing Bowl interchanges. The total cost of these interchanges is approximately $106 million (1972 dollars), or about $46 million per mile. Some of these interchanges do not involve the reversible lanes. While it is obvious that the busway accounts for less than 30 percent of the construction in the Mixing Bowl area, the situation was so complicated that attempts to determine a rational allocation of the costs were abandoned.

If the $5 million per mile upper bound on construction costs cited in NCHRP Report 143 is accepted,[8] then it is possible to bound the estimate of construction costs attributable to the reversible lanes. This would mean that a maximum construction cost of $43 million ($15.5 million for the Mixing Bowl portion and $27.4 million for the southern portion) could be allocated to the reversible lanes.

6.3.2 Transit Element

Expenditures attributable to the bus transit element of the project were for the purchase of 90 new-feature buses and six bus shelters and the operating costs of providing express bus service within the Corridor. The 90 buses were purchased incrementally between June 1971 and February 1973, totalling $3.8 million. Total purchase and installation cost for the six bus shelters was $16,000.

As Corridor express bus service was expanded, operating costs increased. Table 44 summarizes trends in fleet size, total bus miles of operation, operating costs and passenger revenues for each six month interval between June 1971 and December 1974. An estimated $6.7 million was expended for bus operating costs during this 42 month period.

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[7] The Virginia Department of Highways and Transportation estimates that the total right-of-way acquisition cost for the entire roadway was at least $10 million.

[8] "Bus Use of Freeways - State of the Art," p. 31.

Table 43

SHIRLEY HIGHWAY CONSTRUCTION COSTS AND ESTIMATED BUSWAY COSTS PER MILE

SEGMENT	LENGTH (MILES)	INTERCHANGES	ENTRANCE LANES OR RAMPS	TOTAL CONSTRUCTION COST[a] ($MILLION 1972, PRICES)[b]	ESTIMATED BUSWAY COST PER MILE ($MILLION 1972, PRICES)
1	1.99	2-Springfield, Capital Beltway	1 Ramp and Merge Lane	11.55	1.74
2	2.16	1-Edsall Road	2 Ramps (Turkeycock Run)	12.295	1.71
3	1.11	1-Duke Street	None	8.255	2.22
4	1.33	1-Seminary Road	1 Special Bus Ramp	10.596	2.40
5	.85	1-King Street	None	7.063	2.50
6	1.71	2-Shirlington, Glebe Road	1 Special Bus Ramp	41.444	7.30
Total	9.15	8	3 Ramps and Merge Lane 2 Special Bus Ramps	91.208	2.99

[a] From Virginia Department of Highways and Transportation.

[b] Converted from actual date of construction to 1972 using Engineering News Record Building Cost Index.

Table 44

Summary of Project Economic Indicators

	Buses Owned by Demonstration Project	Total Bus Miles	Bus Operating Cost	Total Revenue
Jan - Dec 71	30	434,340	$362,149	$ 345,195
Jan - Jun 72	60	674,237	$613,742	$ 538,816
Jul - Dec 72	76	975,422	$807,613	$ 812,453
Jan - Jun 73	90	1,412,139	$1,105,293	$1,127,784
Jul - Dec 73	90	1,460,261	$1,181,170	$1,220,377
Jan - Jun 74	90	1,482,752	$1,288,892	$1,277,061
Jul - Dec 74	90	1,495,890	$1,340,927	$1,234,578
Total Jun 71 - Dec 74	-	7,935,041	$6,699,786	$6,556,264

This expansion in bus service has affected the bus operator in several ways, the most important being: 1) operator income, 2) peak period labor and vehicle requirements, and 3) productivity. In examining the impact of the project on the bus operator, only costs and revenues properly charged against the demonstration project grant are considered.[9] This means that costs and revenues of the WMATA Metrobus routes, or those of private carriers are not considered (see discussion in Subsection 2.3).[10]

As noted previously in this Section, the expansion of express bus service required substantial operating expenditures. Nonetheless, these expenditures have nearly been equaled by the revenues from the associated growth in bus patronage. Over the life of the project, revenue averaged $.83 per mile, compared with $.84 for costs. The total operating deficit of $143,000 (slightly more than one cent per bus-mile) is attributable to two factors: 1) fares frozen at 1970 levels and steadily rising operating costs, and 2) losses resulting from mid-day bus service. During the 42 month life of the demonstration project, fares remained at their 1970 levels, averaging $.70 per trip. During the same period, driver wages increased from $4.20 per hour to $6.72 per hour (an increase of 60 percent), and the price of diesel fuel rose from $.11 per gallon to $.29 per gallon (an increase of 166 percent). Losses attributable to the mid-day service totaled an estimated $218,000 between June 1971 and December 1972 alone. Although data are not available for the estimation of the costs and revenues attributable to the mid-day service during 1973 and 1974, the service was not reduced, and a dramatic reduction in the losses of the mid-day service for this period is quite unlikely.

Table 45 presents an allocation of project revenues and operating costs between peak and mid-day bus service for each six month interval between July 1971 and December 1972.[11] (The procedure used to allocate costs and revenues is presented in Appendix F.) Because peak periods require a large number of vehicles and drivers which cannot be economically used at other times, about 40 percent of total operating cost was allocated to peak period service alone. The remaining 60 percent was allocated between peak and mid-day service, resulting in approximately 80 percent of total operating costs being attributed to peak period service.

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[9] These are the bus operations administered by the Northern Virginia Transportation Commission. Initially AB&W Transit Company operated these bus operations. Since January 1973 they have been operated by the Alexandria Division of the Washington Metropolitan Area Transit Authority.

[10] The available data did not allow an investigation of the project's impact on the private carriers or on other WMATA busway service. Nonetheless, it is quite likely that the net effect was favorable. During the project period, both operations experienced rapid patronage growth and higher average bus speeds.

[11] Separate cost and operating statistics for peak and mid-day project bus services have not been available since WMATA purchased the AB&W Co. in January 1973.

Table 45

PROJECT OPERATING STATISTICS

PERIOD OF OPERATION	AVERAGE DAILY BUS-MILES[a]	AVERAGE NUMBER OF DAILY REVENUE TRIPS[b]	AVERAGE DAILY PATRONAGE	AVERAGE RUNNING SPEED (MPH)[c]	AVERAGE NUMBER OF PASSENGERS PER BUS-MILE	AVERAGE NUMBER OF PASSENGERS PER TRIP	AVERAGE REVENUE PER PASSENGER ($)	AVERAGE REVENUE PER BUS-MILE[a] ($)	AVERAGE COST PER BUS-MILE ($)
PEAK SERV.									
JUL71-DEC71	2312	84	3708	17.4	1.6	44.1	.70	1.12	1.01
JAN72-JUN72	3517	122	5648	18.4	1.6	46.3	.69	1.11	1.09
JUL72-DEC72	5682	190	8803	19.8	1.6	46.1	.70	1.08	.95
MID-DAY SERV									
JUL71-DEC71	1159	46	270	14.6	.23	5.9	.61	.15	.48
JAN72-JUN72	1777	98	545	15.1	.31	5.6	.52	.16	.55
JUL72-DEC72	2241	120	786	16.7	.35	6.5	.62	.33	.56

Source: Computed from unpublished data from the Northern Virginia Transportation Commission 1971 and 1972.

[a] Sum of revenue and non-revenue bus miles on the route.

[b] A revenue trip is made whenever a bus traverses a route to pick up passengers.

[c] Travel time between first and last stop on the route divided by route distance.

The statistics in Table 45 highlight differences in the economic viability of peak and mid-day Demonstration Project bus operations. Even with continued increases in bus service, and steadily increasing operating costs (with no associated increase in bus fare), the peak period bus service operated at a profit. By contrast, the mid-day service, with an allocation of only 20 percent of project operating costs, always operated at a deficit. Although these statistics only cover the first 18 months of the Demonstration Project, a reasonable assumption for the remaining 24 months is that peak period service continued to operate at a profit while mid-day service operated at a deficit.

With respect to the cost of mid-day operations it seems appropriate to expand on an observation from Table 45. The average per mile costs of mid-day (non-peak) operations were about one-half those of corresponding peak periods. Thus, the mid-day service could have broken even carrying fewer passengers per bus. This suggests that well designed off-peak bus service can be paired with peak period service and operated at a lower average cost per bus-mile than the associated peak period service.

With respect to productivity, Subsection 3.2 documented the higher speeds of buses which used the reversible lanes (relative to buses that did not). The higher speeds of project buses increased scheduling flexibility and allowed the operator to provide a high level of service with fewer buses than would have been possible at lower speeds. This translated into gains for the bus operator because more revenue service was provided with the available buses. The data required for a direct analysis of operator productivity were not available. However, the staff at WMATA was able to provide estimates of vehicle requirements with and without the higher operating speeds possible with the reversible lanes.

To maintain the November 1974 peak period headways with the higher speeds would require approximately 20 additional buses. This represents monthly savings of approximately $31,000 in both capital and operating costs. It should be noted that without the higher speeds, these headways would probably not be required since the passenger demand would not require such capacity.

7.0 CLOSURE

At the conclusion of so long an evaluation, it would be useful to review in detail what was learned from this demonstration project. Unfortunately, circumstances preclude such a review,[1] and we can offer only brief comments on: (1) the demonstration project's performance and the implications of that performance, and (2) possibly desirable changes in evaluation methodology for such projects suggested by hindsight and our experiences.

Since the demonstration project achieved its principal pre-set goals in high measure, it must certainly be judged a "success." The likely prominence of this successful first-of-its-kind effort, given even higher "visibility" by its association with the Nation's capital, may, however, tend to promote uncritically optimistic expectations about the potential of bus-on-freeway operations in other--possibly less propitious--settings. It is therefore necessary to emphasize here that the effectiveness and suitability of this promising new operating technology should be gauged by the results from the full range of recently implemented bus-on-freeway activities,[2] including, but not dominated by, those from the Shirley Highway express bus project.

In "Bus Use of Highways: Planning and Design Guidelines," National Cooperative Research Program Report 155, five factors were found to characterize the pre-project corridor conditions of successful bus-on-freeway operations: (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 physical barriers which limit road access to downtown and channel bus flows; and (5) fast nonstop bus runs for considerable distances. With respect to these five factors, pre-project conditions within the Shirley Highway Corridor (including the area of its trip destinations) were highly conducive to the success of this bus-on-freeway project; see Subsection 2.3. If a similar operation had been implemented in an urban corridor offering less favorable conditions, it is unlikely that the results would have been as impressive.

Therefore, prudence must be exercised in judging the applicability of this project's results to any other specific planning situation. In particular, pre-project conditions in the corridor under consideration should be compared with those in the Shirley Highway Corridor prior to April 1969.

We turn now to desirable changes in the evaluation approach. During the years of the project, a number of improvements were developed and added to the original evaluation program; these appear elsewhere in our documentation and will not be repeated here. Instead, we briefly identify two additional areas in which modifications would be made if we could "start all over again."

First, a sharper analysis of bus operations requires methods for estimating those reductions in driver and vehicle requirements attributable to the higher speeds on the busway. Such techniques would have permitted a more thorough assessment of the busway's impact and would facilitate the evaluation of similar projects. Developing soundly based methods, for this purpose, is also an interesting research challenge.

The second area in which hindsight suggests changes concerns our surveys of project commuters. These provided valuable information, but only on a special subgroup of Corridor commuters--those commuting to the Pentagon, Crystal City, or Downtown Washington, D.C. No corridor-wide household surveys were conducted. The changes suggested here

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[1]The Technical Analysis Division (the organization conducting the evaluation and preparing this report) was administratively abolished effective June 30, 1975. This not only required completion of the report earlier than the previously planned date, but also caused a gradual exodus of project staff during the final phases of the work, increasing the operational burden on those who remained and ruling out the period of calm reflection needed for a thoughtful review-in-depth.

[2]For an enumeration of these projects, see "Bus Use of Highways: State of the Art."

would augment our present surveys of project commuters with simultaneous small samples of household data to permit a more complete analysis of the project's influence (or lack of influence). Household surveys in the area of project impact would provide, at small additional cost, useful information about those commuters who were not affected by the project. This information would complete the data required for an area analysis.

In summary: As a demonstration project, the Shirley Highway Express-Bus-On-Freeway Project was a success in that it showed local authorities the effectiveness of this new operating technology. Our evaluation effort has attempted both to document the project's performance and to provide some insights into the key factors which determined that performance.

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APPENDICES

APPENDIX A

TRAFFIC COUNTING PROGRAM AND DATA

This appendix describes the screenline counting program, presents trends in screenline volumes, and discusses two problems in the counting program -- variation due to periodic counting, and "leaks" in the screenline. Tables 46 through 49 present the trends in screenline volumes.

A.1 Screenline Counting Program

In 1970, the Metropolitan Washington Council of Governments (COG) began a monthly counting program to monitor person and vehicular volumes in the Shirley Highway Corridor. A screenline was established which intercepts the major radial traffic arteries in the Corridor. Counting stations were located on (1) Arlington Boulevard (Route 50) at Highland Street; (2) Columbia Pike (Route 244) at Walter Reed Drive; (3) Shirley Highway (I-95) just north of Glebe Road; (4) Army-Navy Drive at 28th Street; (5) Arlington Ridge Road just north of Glebe Road (Route 120); (6) Jefferson Davis Highway (U.S. 1) at Glebe Road; and (7) George Washington Parkway at Four Mile Run. An eighth station on the north-bound ramp connecting the Woodrow Wilson Bridge with the Anacostia Freeway (I-295) was added in 1971. Figure 24 shows the locations of the counting stations.

Roadside counts of all inbound buses and passengers were made at each station from 6:30 to 9:00 A.M.[1] During the same period, counts were made and recorded for autos and auto persons at 30 minute intervals. Each station's counts were made on the same day of the week, to minimize the effect of day-of-the-week variation, and counts were not made during inclement weather or other unusual conditions (i.e., accidents, holidays, etc.). Counts (at each station) were made during one morning peak period of each month from March through November 1970. During 1971, counts were made for one morning peak period during March, June, and October. The 1972, 1973 and 1974 counting schedules were identical to those for 1971. A complete listing of all A.M. peak period traffic data for each screenline count is presented in Table 47, page 102. For each count, auto persons, autos, bus passengers, and buses were tabulated.

A.2 Variability of Screenline Counts

As noted earlier, screenline bus and auto volume counts are ordinarily made three times a year (one day in March, June, and October) at each of the eight sites. To examine the reliability of these morning peak period counts, observations were performed on the same day for three successive weeks at the four major stations (Columbia Pike, Shirley Highway, Jefferson Davis Highway, and George Washington Parkway) for the October 1972 and March 1973 counting periods.

The variability analysis, presented in the "Second Year Results Report,"[2] showed that for the three October 1972 counts, the mean variation on Columbia Pike, Jefferson Davis Highway, and Shirley Highway for auto, and auto and bus person totals was less than 10 percent. For the four March 1973 counts, even less variation was observed, and mean variation on the four major roadways was generally less than five percent for auto, and auto and bus person trip totals.

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[1] Bus passenger data for the express buses on the reversible lanes are collected by WMATA.

[2] "Second Year Results Report, Interim Report 4," page 60.

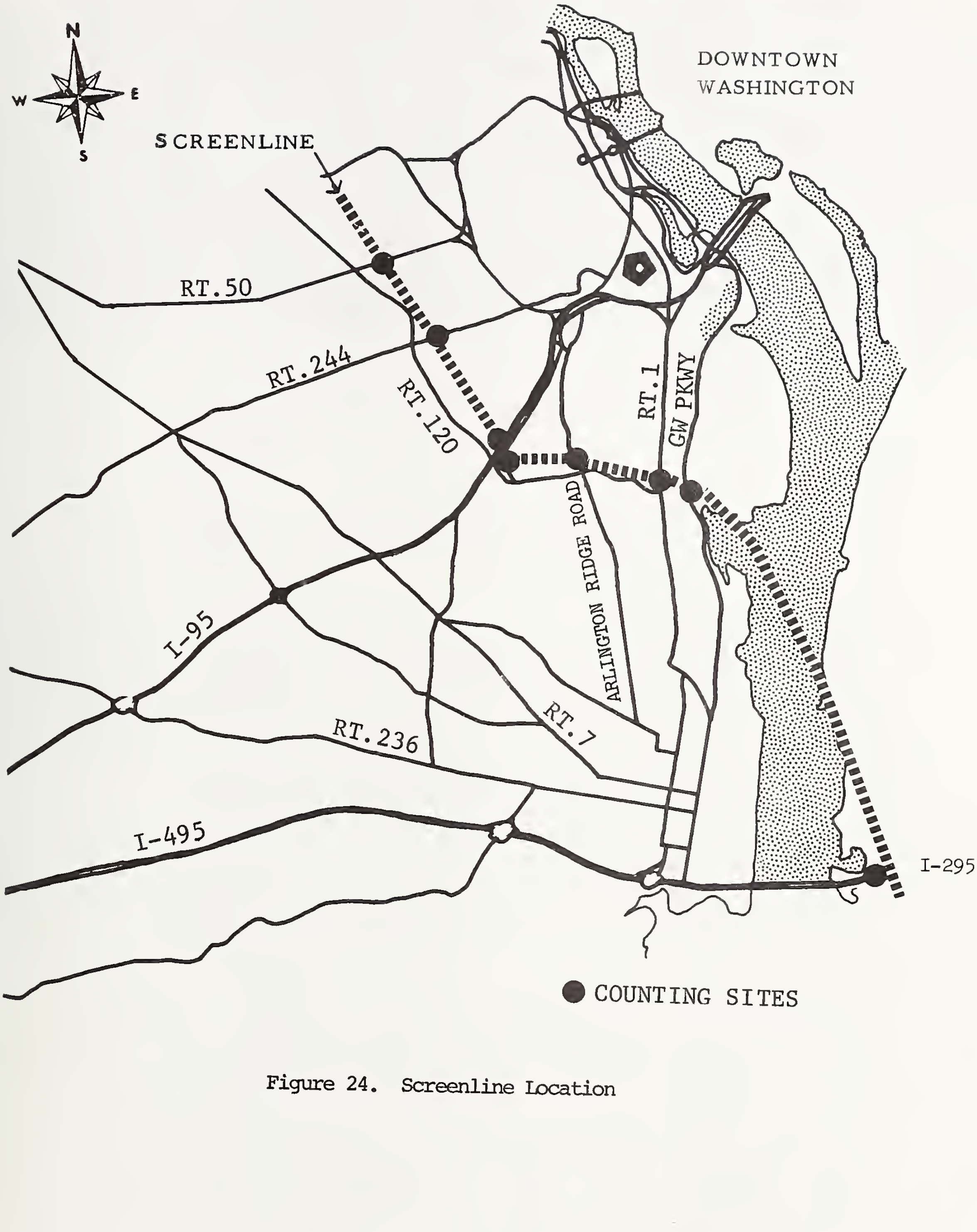

Figure 24. Screenline Location

A.3 Potential Screenline Leaks

The screenline counting sites were located so that essentially all inbound A.M. peak period Corridor-wide traffic could be observed. All of the buses were counted at these locations, but there were a few secondary streets which represented potential "leaks" for auto trips through the screenline. Inspection revealed that there were eight such streets, but that each was unlikely as a portion of Corridor commute trips; all are narrow and wind through residential areas with frequent stops at intersections. In March 1972, vehicle counts were made at four of the major "leak" locations:[3] Second and Eighth Streets between screenline stations 1 and 2; Ridge Road extending to Glebe Road between stations 4 and 5; and Eads Street between stations 5 and 6. About 2500 autos were observed at these four sites. It is unlikely that many commuters would have been willing to include these circuitous routes as parts of their commuting trips, and that most of the 2500 autos were for trips destined for internal locations and as such are properly excluded from the screenline count total. Nonetheless, even if <u>all</u> of these autos were involved in Corridor commuting trips, they would represent only about nine percent of the potentially affected autos crossing the screenline.

[3] Details are presented in the "Second Year Results Report, Interim Report 4," page 18.

Table 46

Trends in People Movement on Shirley Highway Compared With All Other Major Radial Corridor Arterials
(Inbound 6:30-9:00 AM)

SURVEY DATE	TOTAL PERSONS			TOTAL BUS PASSENGERS			TOTAL AUTO PERSONS		
	ALL CORRIDOR ARTERIALS	SHIRLEY HIGHWAY	OTHER CORRIDOR ARTERIALS	ALL CORRIDOR ARTERIALS	SHIRLEY HIGHWAY	OTHER CORRIDOR ARTERIALS	ALL CORRIDOR ARTERIALS	SHIRLEY HIGHWAY	OTHER CORRIDOR ARTERIALS
Apr 70	62,533	16,936	45,597	14,261	4,407	9,854	48,272	12,529	35,743
Jun 70	61,966	16,834	45,132	14,400	4,892	9,508	47,566	11,942	35,624
Oct 70	65,341	17,083	48,258	14,768	4,873	9,895	50,573	12,210	38,363
Mar 71	62,008	16,454	45,554	15,637	6,194	9,443	46,371	10,260	36,111
Jun 71	62,001	16,126	45,875	16,149	7,348	8,801	45,852	8,778	37,074
Oct 71	60,504	16,647	43,857	17,577	9,093	8,484	42,927	7,554	35,373
Mar 72	64,144	18,289	45,855	18,889	10,521	8,368	45,255	7,768	37,487
Jun 72	63,409	19,165	44,244	18,345	10,626	7,719	45,064	8,539	36,525
Oct 72	64,222	20,205	44,016	20,050	12,105	7,945	44,172	8,100	36,072
Mar 73	66,729	22,159	44,570	20,736	13,105	7,631	45,993	9,054	36,938
Jun 73	70,094	29,992	40,102	21,844	13,769	8,075	48,250	16,223	32,027
Oct 73	70,581	30,562	40,019	21,864	14,042	7,822	48,717	16,520	32,197
Mar 74	72,023	34,562	37,461	23,721	15,092	8,629	48,302	19,470	28,832
Jun 74	71,466	33,492	37,974	22,965	14,839	8,126	48,501	18,653	29,848
Nov 74	76,338	36,848	39,490	24,883	16,106	8,777	51,455	20,742	30,713

Table 47

Corridor Screenline Counts By Station (Inbound 6:30-9:00 AM)

MONTH OF COUNT	AUTO PERSONS	TOTAL AUTOS	AUTO OCCUPANCY	BUS PASSENGERS	TOTAL PERSONS	BUS PERCENT	PASSENGERS PER BUS
			MT. VERNON DRIVE				
Apr 70	3628	2426	1.50	1633	5261	31.0	34.0
Jun 70	3505	2331	1.50	1560	5065	30.8	29.4
Oct 70	4104	2671	1.54	1708	5812	29.4	34.9
Mar 71	3678	2531	1.45	1429	5107	28.0	33.2
Jun 71	4265	2930	1.46	1291	5556	23.2	30.0
Oct 71	3658	2649	1.38	1274	4932	25.8	29.0
Mar 71	3655	2737	1.34	1360	5015	27.1	28.9
Jun 72	3494	2537	1.38	1127	4621	24.4	26.2
Oct 72	3832	2830	1.35	1156	4988	23.2	26.9
Mar 73	3696	2719	1.36	1181	4877	24.2	27.5
Jun 73	2647	2055	1.29	1034	3681	28.1	25.9
Oct 73	2431	1882	1.29	1191	3622	32.9	28.4
Mar 74	2251	1637	1.38	1409	3660	38.5	34.4
Jun 74	1986	1415	1.40	1341	3327	40.3	32.7
Nov 74	2002	1411	1.42	1223	3225	37.9	31.4
			JEFFERSON DAVIS HIGHWAY				
Apr 70	6868	4756	1.44	727	7595	9.6	23.5
Jun 70	6923	4880	1.42	894	7817	11.4	34.4
Oct 70	7762	5039	1.54	1003	8765	11.4	33.4
Mar 71	7075	4986	1.42	911	7986	11.4	27.6
Jun 71	6821	4649	1.47	793	7614	10.4	29.4
Oct 71	6993	4971	1.41	930	7923	11.7	38.7
Mar 72	8179	5660	1.45	967	9146	10.6	31.2
Jun 72	7616	5385	1.41	951	8567	11.1	32.8
Oct 72	7644	5472	1.40	829	8473	9.7	28.0
Mar 73	6841	4898	1.40	801	7643	10.5	26.7
Jun 73	6279	4646	1.35	888	7167	12.4	29.6
Oct 73	5662	4099	1.38	648	6310	10.3	19.6
Mar 74	5947	4183	1.42	615	6562	9.4	19.2
Jun 74	5988	4261	1.41	853	6841	12.5	29.4
Nov 74	6042	4366	1.38	764	6806	11.2	34.7
			GEORGE WASHINGTON PARKWAY				
Apr 70	10831	7633	1.42	1701	12532	13.6	40.5
Jun 70	11094	7797	1.42	1658	12752	13.0	36.8
Oct 70	10810	7688	1.41	1549	12359	12.5	39.7
Mar 71	10789	7982	1.35	2014	12803	15.7	42.0
Jun 71	10912	7885	1.38	1848	12760	14.5	39.3
Oct 71	10299	7753	1.33	1706	12005	14.2	36.3
Mar 72	11049	8200	1.35	1617	12666	12.8	35.2
Jun 72	10560	8061	1.31	1619	12179	13.3	33.7
Oct 72	9035	7276	1.24	1615	10650	15.2	34.4
Mar 75	10682	7916	1.35	1639	12322	13.3	34.9
Jun 73	10376	7545	1.38	1805	12181	14.8	37.6
Oct 73	10721	7814	1.37	1732	12453	13.9	36.9
Nov 74	9339	6594	1.42	2028	11367	17.8	43.2
Jun 74	10304	7013	1.47	1916	12220	15.6	41.7
Nov 74	10038	7068	1.42	2304	12342	18.6	41.9
			I-295 (WILSON BRIDGE)				
Mar 71	5403	4396	1.23	0	5403	0	0
Jun 71	5481	4282	1.28	0	5481	0	0
Oct 71	5081	4274	1.19	0	5081	0	0
Mar .72	5039	4274	1.18	0	5039	0	0
Jun 72	4316	3679	1.17	0	4316	0	0
Oct 72	4163	3590	1.16	0	4163	0	0
Mar 73	4200	3649	1.15	0	4200	0	0
Jun 73	4421	3770	1.17	0	4421	0	0
Oct 73	4557	3860	1.18	0	4557	0	0
Mar 74	3396	2900	1.17	0	3396	0	0
Jun 74	4521	3604	1.25	0	4521	0	0
Nov 74	4616	3736	1.25	0	4616	0	0

Table 47 (Cont'd.)

Corridor Screenline Counts By Station (6:30-9:00 AM)

MONTH OF COUNT	AUTO PERSONS	TOTAL AUTOS	AUTO OCCUPANCY	BUS PASSENGERS	TOTAL PERSONS	BUS PERCENT	PASSENGERS PER BUS
				ARLINGTON BLVD.			
Apr 70	7578	5720	1.32	1619	9197	17.6	34.4
Jun 70	7630	5711	1.34	1424	9054	15.7	31.0
Oct 70	7943	5878	1.35	1438	9381	15.3	33.4
Mar 71	8324	6335	1.31	1421	9745	14.6	34.7
Jun 71	8182	6057	1.35	1211	9393	12.9	36.7
Oct 71	7485	5761	1.30	1204	8689	13.9	34.4
Mar 72	7543	5935	1.27	1253	8796	14.2	36.9
Jun 72	7949	6021	1.32	1246	9195	13.6	35.6
Oct 72	7990	6320	1.26	1101	9091	12.1	32.4
Mar 73	8031	6302	1.27	1143	9174	12.5	32.7
Jun 73	6775	5532	1.22	1010	7785	13.0	28.9
Oct 73	6743	5719	1.18	1318	8061	16.4	37.7
Mar 74	6826	4825	1.41	1230	8056	15.3	36.2
Jun 74	7060	5334	1.32	1129	8189	13.8	31.4
Nov 74	7710	5769	1.34	1065	8775	12.1	38.0
				COLUMBIA PIKE			
Apr 70	4889	3687	1.33	3684	8573	43.0	38.4
Jun 70	5116	3799	1.35	3563	8673	41.1	36.4
Oct 70	6218	4421	1.41	3807	10025	38.0	39.2
Mar 71	4291	3207	1.34	3274	7565	43.3	40.9
Jun 71	4345	3139	1.38	3324	7669	43.3	38.2
Oct 71	4339	3187	1.36	2984	7323	40.7	36.8
Mar 72	4468	3233	1.38	2865	7333	39.1	36.3
Jun 72	4456	3383	1.32	2473	6929	35.7	30.5
Oct 72	4910	3762	1.31	2910	7820	37.2	34.4
Mar 73	4865	3781	1.29	2493	7358	33.9	30.7
Jun 73	4123	2916	1.41	3016	7139	42.2	36.8
Oct 73	4475	3339	1.34	2666	7141	37.3	32.5
Mar 74	3716	2627	1.41	2993	6709	44.6	37.4
Jun 74	3833	2560	1.50	2576	6409	40.2	33.9
Nov 74	4344	3029	1.43	3064	7408	41.4	36.9
				SHIRLEY HIGHWAY			
Apr 70	12529	8420	1.49	4407	16936	26.0	40.8
Jun 70	11942	8029	1.49	4892	16834	29.1	43.7
Oct 70	12210	8916	1.37	4873	17083	28.5	44.7
Mar 71	10260	7262	1.41	6194	16454	37.6	48.0
Jun 71	8778	6295	1.39	7348	16126	45.6	40.8
Oct 71	7554	5662	1.33	9093	16647	54.6	46.9
Mar 72	7768	5604	1.39	10521	18289	57.5	47.0
Jun 72	8539	5941	1.44	10626	19165	55.4	43.4
Oct 72	8100	5897	1.37	12105	20205	59.9	44.3
Mar 73	9054	6419	1.41	13105	22159	59.1	44.0
Jun 73	16223	11392	1.42	13769	29992	45.9	45.3
Oct 73	16520	12192	1.35	14042	30562	46.0	45.0
Mar 74	19470	13412	1.45	15092	34562	43.7	47.9
Jun 74	18653	11939	1.56	14839	33492	44.3	43.6
Nov 74	20742	12864	1.61	16106	36848	43.7	45.1
				ARMY-NAVY DRIVE			
Apr 70	1949	1337	1.46	490	2439	20.1	32.7
Jun 70	1356	1032	1.31	409	1765	23.2	29.2
Oct 70	1526	1121	1.36	390	1916	20.4	26.0
Mar 71	1954	1295	1.51	394	2348	16.8	28.1
Jun 71	2549	1721	1.48	334	2883	11.6	23.9
Oct 71	2599	1757	1.48	386	2985	12.9	27.6
Mar 72	2593	1898	1.37	306	2899	10.6	21.9
Jun 72	2450	1805	1.36	303	2753	11.0	21.6
Oct 72	2660	1952	1.36	333	2993	11.1	22.2
Mar 73	2822	2145	1.32	373	3195	11.7	28.7
Jun 73	1827	1405	1.30	322	2149	15.0	24.8
Oct 73	2165	1485	1.46	267	2432	11.0	19.1
Mar 74	753	511	1.47	354	1107	32.0	25.3
Jun 74	627	450	1.50	311	988	31.5	25.9
Nov 74	577	387	1.49	357	934	38.2	25.5

Table 48

Trends in Busway Bus Assignments and Patronage Growth
(Inbound 6:30-9:00 AM)

Date of Count	BUS TRIPS				PASSENGERS			
	South of Shirlington Circle (WMATA)	South of Shirlington Circle (Private)[a]	Shirlington Circle (WMATA)	Total	South of Shirlington Circle (WMATA)	South of Shirlington Circle (Private)[a]	Shirlington Circle (WMATA)	Total
Sep 69	39	11	48[b]	98	2,095	440	1,703[b]	4,238
Apr 70	48	12	48[b]	108	2,456	470	1,481[b]	4,407
Jun 70	48	12	49[b]	109	2,504	500	1,888[b]	4,892
Oct 70	49	13	47	109	2,539	520	1,816	4,875
Mar 71	62	19	48	129	3,313	800	2,081	6,194
Jun 71	103	24	53	180	4,211	1,000	2,137	7,348
Oct 71	109	28	57	194	5,551	1,200	2,342	9,093
Mar 72	133	36	55	224	6,724	1,400	2,397	10,521
Jun 72	149	38	58	245	6,937	1,500	2,189	10,626
Oct 72	170	45	58	273	8,132	1,750	2,223	12,105
Mar 73	199	45	54	298	9,259	1,800	2,046	13,105
Jun 73	199	49	56	304	9,729	1,900	2,140	13,769
Oct 73	201	55	58	314	9,751	2,200	2,091	14,042
Mar 74	202	56	57	315	10,541	2,300	2,251	15,092
Jun 74	226	57	57	340	10,362	2,350	2,127	14,839
Nov 74	239	58	60	357	11,494	2,400	2,212	16,106

[a]Estimates based on weekly passenger counts taken in May and October of each year.

[b]Shirlington buses did not use busway until second section was opened in September 1970.

Table 49

Trends in Corridor Auto Volumes and Auto Occupancy

Date of Count	CORRIDOR TOTAL		SHIRLEY		ALL OTHER CORRIDOR ARTERIALS	
	Total Autos	Auto Occupancy	Total Autos	Auto Occupancy	Total Autos	Auto Occupancy
Apr 70	33,979	1.42	8,420	1.49	25,559	1.40
Jun 70	33,579	1.42	8,029	1.49	25,550	1.39
Oct 70	35,734	1.42	8,916	1.37	26,818	1.43
Mar 71	33,598	1.38	7,262	1.41	26,336	1.37
Jun 71	32,676	1.40	6,295	1.39	26,381	1.41
Oct 71	31,740	1.35	5,662	1.33	26,078	1.36
Mar 72	33,267	1.36	5,604	1.39	27,663	1.36
Jun 72	33,133	1.36	5,951	1.44	27,192	1.34
Oct 72	33,510	1.32	5,897	1.37	27,613	1.31
Mar 73	34,181	1.35	6,419	1.41	27,761	1.33
Jun 73	35,491	1.36	11,392	1.42	25,099	1.33
Oct 73	36,530	1.33	12,192	1.35	24,338	1.32
Mar 74	33,789	1.43	13,412	1.45	20,377	1.41
Jun 74	32,972	1.47	11,939	1.56	21,033	1.42
Nov 74	34,894	1.47	12,864	1.61	22,030	1.39

APPENDIX B

DETAILS OF THE PROCEDURE FOR ESTIMATING AUTO COMMUTER TRAVEL TIME SAVINGS

This appendix describes the model used to estimate the auto commuter travel time savings presented in Subsection 4.3. The appendix also describes an analysis undertaken to determine the sensitivity of the estimates of travel time savings to possible errors in either the assumptions or parameter values used in the model.

B.1 Model Description

The model is that developed by Sparks and May,[1] and uses a specified speed-flow relationship to determine the travel time over a section of roadway. So long as the flow or demand remains below the capacity of the roadway, speed decreases as flow increases. If the demand is greater than capacity, then a deterministic queuing approach is utilized; a queue will form at the beginning of the section, and all vehicles on the section will travel at a speed corresponding to flow at roadway capacity for the duration of the queue.

To compute the total passenger hours of travel time over a given section of roadway, the following information is required:

(a) Total person demand -- number of persons per hour throughout the peak period;

(b) Bus share -percentage of the total persons that will use buses;

(c) Auto occupancy distribution and average bus occupancy - relating person demand to vehicle flow rate; and

(d) Roadway characteristics such as length, number of lanes and lane capacity - utilized with the vehicular speed-flow relationship to determine the total travel time if there is no queuing and with the deterministic queuing approach when lane capacity is exceeded. For a complete description of the relationships and assumptions in the model, see Sections 2 and 6 of the Sparks and May report.

B.2 Applying the Model to the Shirley Highway

To calculate the total travel time savings on the Shirley Highway for the existing priority operation and for the condition without exclusive lanes requires two sets of model parameters. These inputs are described below and the model results are presented in Paragraph B.2.2. In the last paragraph, the sensitivity of the savings to different assumed conditions is examined.

B.2.1 Model Input Parameters for the Existing and Expected Conditions

The total passenger demand curve is based upon the June 1974 screenline counts. Figure 25 depicts the distributions of bus, auto, and total person volumes during the A.M. peak period. The flow curves are assumed to be the same for the expected mixed traffic situation on all six lanes as for the existing two priority lanes condition. Although the bus curve is slightly more peaked than the auto curve, the model assumes that bus flow

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[1] Sparks, G. A. and May, A. D., "A Mathematical Model for Evaluating Priority Lane Operations on Freeways," The Institute of Transportation and Traffic Engineering, University of California, Berkeley, June 1970, Report No. FH-11-7186.

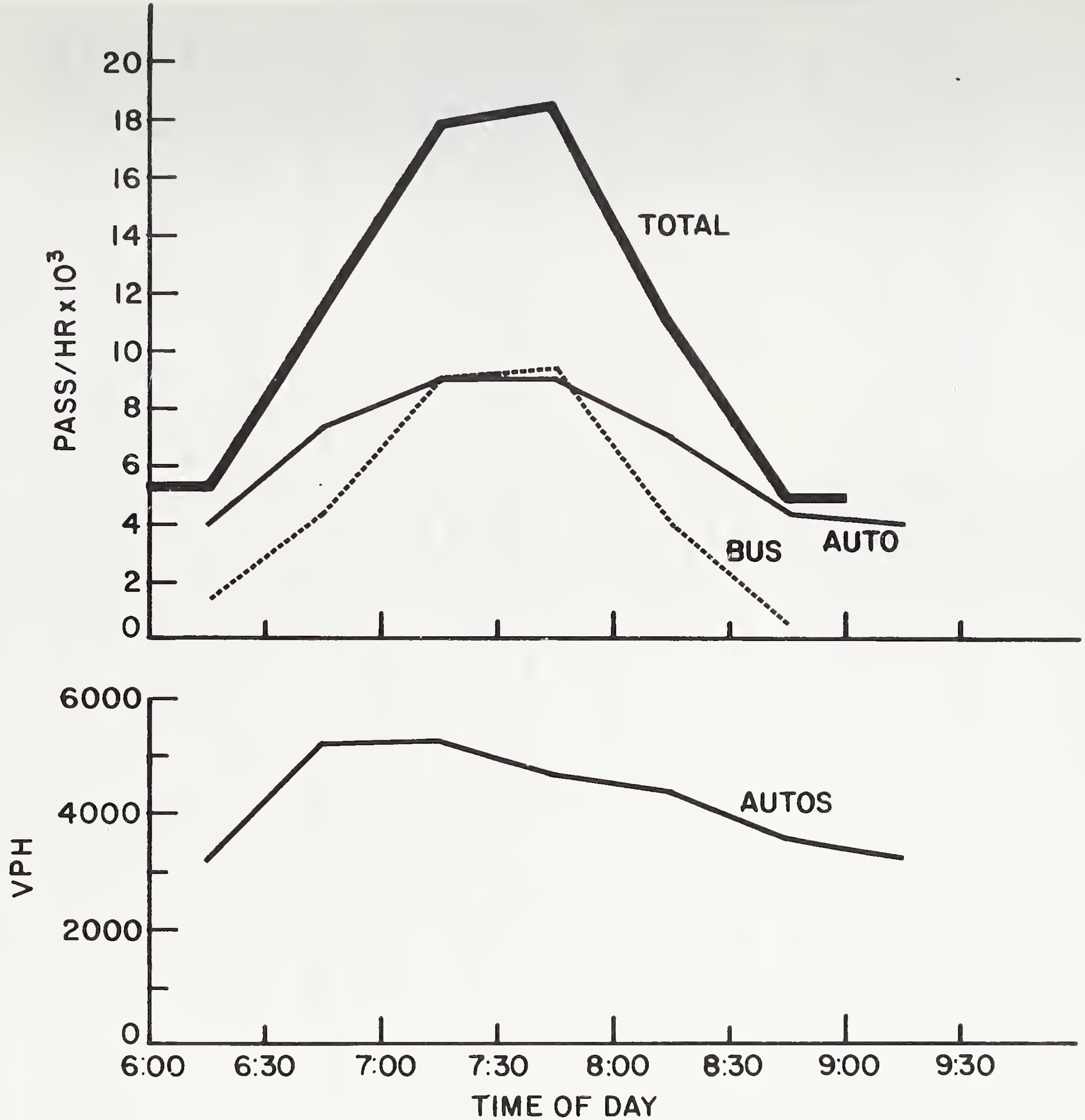

Figure 25. Distributions of Peak Period Volumes on Shirley Highway

comprises a constant percentage of total flow. The effect of this assumption is to overstate peak hour traffic volumes and to understate non-peak hour traffic volumes. Thus, it is implicitly assumed that the net effect is zero.

The model was not applied to the entire length of the Shirley Highway because of insufficient traffic volume data and because of difficulties in determining the capacity of the long roadway with its many ramps and merges and varying number of lanes. However, volume data were collected at the screenline station on a section of the Highway between Glebe Road and Washington Boulevard. This led to the selection of that 1.3 mile section between Glebe Road and the Washington Boulevard off-ramp as the section on which to apply the model.

This section has six lanes - four regular inbound and the two-lane reversible express roadway in the center. Before Glebe Road there are three regular lanes, but the single lane on-ramp joins them and forms four lanes to Washington Boulevard. Taking into account the effects of ramp merging, the average lane capacity for each of the six lanes under priority and regular operation was determined to be 1550 equivalent vehicles per hour. The speed-flow curves from the Highway Capacity Manual indicate for Level of Service E (approaching capacity) a speed of about 28 miles per hour.[2] In June 1974 the highest observed average vehicle flows per lane on the four lane section were 1200 - 1400 vehicles per hour and the speeds varied between 25 and 35 mph.

A summary of the conditions on the roadway for the existing priority operation and the expected situation had there been no bus expansion and priority lanes is presented in Table 50. To calculate the total travel time under existing conditions, the following parameters are used. There are six lanes: four regular and two priority lanes. Four or more member carpools and buses are allowed in the priority lanes. The bus share is 45 percent of the total volume and the auto occupancy distribution is as observed in June 1974. (Average auto occupancy = 1.49.)

To estimate the total travel time under expected conditions without the priority lanes and expanded bus service requires a set of assumptions about the probable values of the model parameters. It is assumed that the mixed traffic for buses and autos would be allowed in the six lanes, and that there would be about the same number of bus riders as existed prior to the demonstration project. This assumes about 5,000 riders (average in 1970 was 4800) or a 15 percent bus share. The auto occupancy distribution would have an average of 1.44 (about the average of 1970).

B.2.3 Sensitivity of Total Savings to Different Expected and Existing Conditions

With the above parameter values as inputs, the model estimated a daily travel time savings of 1409 person hours. However, the parameters used to determine the travel time under non-priority conditions are assumptions for the probable situation. Since it is impossible to know what condition would have actually occurred, we should also examine the total time savings under different assumed conditions for the non-priority operation.

If the bus share (assumed 15 percent) would have increased to 20 percent without priority operations then the daily savings would have been about 650 person hours. If the average auto occupancy would have increased to 1.49 then the daily savings would have been about 1000 person hours. On the other hand, if bus share would have decreased to 10 percent then the savings would be over 2200 person hours. If auto occupancy would have decreased then the savings would also have increased.

[2]See Figure 9.1 in the "Highway Capacity Manual," Special Report 87, Highway Research Board, Washington, D.C., 1965.

Table 50

Summary of Conditions on Shirley Highway With and Without Reserved Lanes for Buses and Carpools

PARAMETERS	EXISTING WITH PRIORITY OPERATION	EXPECTED WITHOUT PRIORITY OPERATION
Number of Lanes	four regular two priority	six regular
Priority Operation	Buses and four or more member carpools	mixed traffic
Length of Section	1.3 miles	1.3 miles
Bus Share	45% (16,000 riders)	15% (5,000 riders)
Ave. Auto Occupancy	1.49	1.44
Peak Demand Rate	18,400 persons/hour	18,400
Ave. Bus Occupancy	48	48

If the Shirley Highway did not have priority lanes for buses and carpools, then fewer people in the corridor might use it and would travel instead on the other congested roadways. It is not clear whether this would reduce the total travel time throughout the corridor (and it could increase the total time as well as the vehicle miles of travel), but if we assume that 10 percent of the persons on the Shirley under priority conditions would have been diverted to the other roadways then the daily savings would have been about 100 person hours. This is still significant and does not consider the project's beneficial effects on travel time on the other routes.

It is interesting to consider the effect on travel time savings if there were a 10 percent diversion of persons from the other corridor roadways to the Shirley Highway under priority operations and the same existing bus share and auto occupancy rate were attained. The Highway could carry 10 percent more people than currently and still save about 650 person hours compared with the current person demand under non-priority operation. If there were a 10 percent increase in demand there would be over 3100 person hours saved each day under the priority situation.

Increases in the existing bus share will increase the time savings, while a drop in current bus ridership will decrease them. If the bus share (currently 45 percent) decreases to below 35 percent, then there will be no time savings. If the average auto occupancy increases then the daily savings will increase. Should it decrease drastically, to the lowest ever observed (1.33), then the daily savings would still be about 650 person hours.

Finally, if carpools of three or more members are allowed to use the priority lanes, then the total time savings would be about 100 person hours per day more than for the existing four or more member carpool priority operation.

In summary, under different assumed conditions of bus share, auto occupancy, and total person demand for both non-priority operations and the existing priority situation, the estimated total travel time savings was significant. The bus estimate is over 1400 person hours daily in the A.M. peak period, and the computed range of savings varied from 130 to over 3100 person hours.

APPENDIX C

AN INVESTIGATION OF POTENTIAL NON-RESPONSE BIAS IN SURVEY RESULTS

Whenever some members of a sample population cannot be accounted for, there is a possibility that they may differ significantly from the remainder of the sample. The absence of these members can introduce bias and thus limit the validity of results attributed to the entire population. To investigate this potential "bias" attributed to the non-respondents, two studies were undertaken - one for the survey of bus passengers and the other for the surveys of commuting auto drivers.

C.1 Bus Survey

For a bus survey performed during October 1973, survey personnel distributed a short questionnaire along with the longer mail back questionnaire to all seated passengers on ten buses representative of a cross-section of the entire set of buses using the reversible lanes.[1] This "short form" contained a subset of the questions appearing in the mail back questionnaire. Unlike the mail back questionnaire however, this form was designed to be filled out on the bus and returned upon leaving the bus. Of the 459 people on the ten buses given both the mail back questionnaire and the short form, 93 percent (425) returned the short form and 66 percent (304) returned the longer mail back questionnaire forms; 124 of the 155 bus riders (about 80 percent) who did not return the longer mail back questionnaire completed and returned the short form.

Five characteristics were covered in the short form. These characteristics were selected as being important to the determination of whether or not bus passengers who returned the mail back questionnaire differed significantly from those who did not: 1) year began riding bus, 2) days ride bus per week, 3) household auto ownership, 4) sex and 5) age. For each characteristic, the short form responses of those who returned the mail back questionnaire are compared with the short form responses of those who did not. Table 51 compares the responses of the two groups.

No statistically significant difference was found between the distributions of the responses of the two groups for any of the five characteristics (based on Chi-square statistics computed at the five percent level for each characteristic). Thus, it was inferred that data contained in the returned mail back questionnaires were representative of the characteristics of all (respondent and non-respondent) passengers on the 10 buses.

A further analysis was made to determine whether this conclusion could be expanded to include passengers on all WMATA buses using the reversible lanes. Using the questions common to both the mail back and short form questionnaires, responses from the returned mail back questionnaires of bus riders who also answered the short form were compared with responses from the returned mail back questionnaires of the entire Shirley bus population. Table 52 shows the distributions of the responses of these two groups.

[1] The response rate for the Fall 1973 bus survey was 62 percent compared with the 59 percent response rate for the Fall 1974 bus survey. The questionnaire used in the 1973 survey was only slightly different from the one used in the 1974 survey. The 1973 survey sample size and the manner in which that sample was chosen differed little from those of the 1974 surveys.

Table 51

Distributions of Responses to Short Form Questionnaire

	DID NOT ANSWER THE MAIL BACK QUESTIONNAIRE	DID ANSWER THE MAIL BACK QUESTIONNAIRE
Year Began Riding Bus		
1970 or earlier	4%	10%
1971	13	15
1972	26	30
1973	57	45
	100%	100%
Days Riding Per Week		
1	1%	2%
2	1	1
3	3	1
4	3	6
5	92	89
6 or 7	0	1
	100%	100%
Auto Ownership		
0	7	8
1	53	49
2	35	36
3	1	5
>3	4	2
	100%	100%
Sex		
Male	59%	63%
Female	41	37
	100%	100%
Age		
<21	7%	2%
21-39	70	65
40-65	23	33
>65	0	0
	100%	100%
Number of Respondents	121	304

Table 52

Distributions of Responses to Mail Back Questionnaire

	RESPONDENTS WHO ANSWERED THE SHORT FORM	RESPONDENTS FROM ENTIRE BUSWAY BUS POPULATION
Year Began Riding Bus		
1970 or earlier	10%	17%
1971	15	11
1972	30	26
1973	45	46
	100%	100%
Days Riding Per Week		
1	2%	1%
2	1	1
3	1	2
4	6	5
5	89	89
6 or 7	1	2
	100%	100%
Autos Owned		
0	8%	6%
1	49	57
2	36	31
3	5	5
>3	2	1
	100%	100%
Sex		
Male	63%	59%
Female	37	41
	100%	100%
Age		
<21	2%	3%
21-39	65	61
41-65	33	36
>65	0	0
	100%	100%
Number of Respondents	425	2,238

Except for "year began riding bus,"[2] no significant difference was found between the responses of the two groups for any characteristic (based on Chi-square statistics computed at the five percent level). The responses of the group of passengers who were given short forms as well as mail back forms did not differ from those of the entire population of passengers on WMATA buses using the reversible lanes. Thus, it was inferred that data contained in the received mail back questionnaires are representative of the characteristics of passengers on all WMATA buses which use the busway (reversible lanes).

C.2 Auto Surveys

A follow-up survey of non-respondents to the Fall 1974 auto commuter surveys was conducted by telephone interview. The interviewers were given lists of the names and telephone numbers of all of the people who were mailed but did not return driver alone or carpool driver questionnaires. The interviewers were instructed to complete 150 randomly selected interviews from each of the lists, i.e., the driver alone non-respondent list and the carpool driver non-respondent list. The 150 interviews represented a sampling rate of 11.1 percent of the driver alone non-respondents and 14.5 percent of the carpool driver non-respondents.

To complete the 150 interviews, the interviewers had to select 482 driver alone and 434 carpool driver non-respondents from the lists (or 35.6 percent of the driver alone non-respondents and 42.1 percent of the carpool driver non-respondents). These outcomes are summarized in Table 53.

Table 53

Outcome of Random Selection of Non-respondents

OUTCOME	NUMBER OF DRIVER ALONE NON-RESPONDENTS SELECTED	NUMBER OF CARPOOL DRIVER NON-RESPONDENTS SELECTED
Could not be contacted	237	186
Refused interview	21	5
Had sent in form	7	6
Business or government car	13	10
Do not commute to areas indicated	34	11
Do not use the indicated commute mode	20	62
Other	0	4
Completed interviews	150	150
Total	482	434

[2]The "year began riding bus" distributions were different because no regard was given to when the bus routes of the ten buses on which the short forms were given out were put into service. These ten buses were actually servicing newer Shirley Highway bus routes. Hence, the responses to the "year began riding bus" on these buses reflect the fact that people began riding these buses recently.

It was encouraging that the interview was refused by only a few of the non-respondents who were contacted. Otherwise, this would have left unaccounted-for a large group of commuters whose attitudes were likely to be significantly different from the commuters who did respond to the survey. Nearly half of the non-respondents could not be contacted either because their telephone number was unlisted, their telephone number had been disconnected, they were temporarily out of the area, or they no longer lived at the number. Most of the non-respondents who were reached but did not complete the interview didn't do so because either they did not commute to the project destinations or they did not use the indicated commute mode (used carpool when it was indicated they drove alone, or vice versa). The percentage of non-respondents who fell into this category is nearly equal to the corresponding percentage for commuting auto drivers who gave these reasons for not completing (but did return) the mail back questionnaire form.

The characteristics listed in Tables 54 and 55 were selected for the determination of whether or not the commuting drivers who returned the mail back questionnaire differed significantly from those who did not. Three categories comprise commuting drivers: 1) drivers alone, 2) carpool drivers on the reversible lanes (busway carpool drivers), and 3) carpool drivers on other roadways, including the Shirley Highway (non-busway carpool drivers). For each combination of commuting driver category and driver characteristic, the distribution of responses from the completed interviews is compared with the distribution of responses from the returned mail back questionnaires. Tables 54 and 55 present these comparisons.

Except for "Could you have ridden a bus to work?" and "In what year did you join this carpool?", no significant difference was found between the distributions of either of the two groups of commuting drivers (based on a Chi-square test at the five percent level).

With respect to the question: "Could you have ridden a bus to work?", the respondent and non-respondent distributions were found to be statistically significantly different for all three commuting driver categories. A much higher percentage of non-respondents than respondents indicated that they couldn't ride a bus to work. It is possible that non-respondents would have had a "bias" against bus travel. It is also possible that when confronted by interviewers who knew who they were, non-respondents were reluctant to indicate that they could have used a bus but didn't do so.

The only other characteristic for which the two distributions were found to be significantly different involved the responses of busway carpool drivers to the question: "In what year did you last change your residence?" The very samll size of the sample of non-respondent carpool drivers may have been responsible for this difference.

With the exception of the question: "Could you have ridden a bus to work?", all of the questions asked the non-respondents were factual questions. Thus, there does not appear to be any non-response bias in drivers' alone and carpool drivers' response distributions to factual questions. By contrast, it is quite likely that respondents have a more positive attitude toward bus than do non-respondent commuting auto drivers. This also suggests that the respondents may be more likely to view bus as a potential commuting alternative and therefore the interpretation of the main survey may be slightly more favorable in this respect than it should be.

Table 54

Distributions of Driver Alone Responses

	RESPONDENTS[a]	NON-RESPONDENTS[b]
How Often Drive Alone		
1	7%	3%
2	7	6
3	5	3
4	2	3
5 or more	79	85
	100%	100%
Where Auto Is Parked		
Commercial Lot	38%	26%
Employer Provided Space	55	58
On Street	7	16
	100%	100%
Could Bus Have Been Used		
Yes	72%	39%
No	21	60
Don't Know	7	1
	100%	100%
Year Last Changed Residence		
Prior to 1970	42%	40%
1970-72	30	31
1973-74	28	29
	100%	100%
Auto Ownership		
0	0%	0%
1	35	27
2	54	56
3 or more	11	17
	100%	100%
Age		
< 21	1%	1%
21-39	47	49
40-65	51	48
> 65	1	2
	100%	100%
Number of Respondents	1230	150

[a]Respondents to the Mail Back Questionnaire.

[b]Non-respondents Who Completed Telephone Interview.

Table 55

Distributions of Carpool Driver Responses

	BUSWAY		NON-BUSWAY	
	RESPONDENTS[a]	NON-RESPONDENTS[b]	RESPONDENTS[a]	NON-RESPONDENTS[b]
Year Joined Present Carpool				
Prior to 1970	20%	12%	16%	19%
1970-72	20	12	19	19
1973-74	60	76	65	62
	100%	100%	100%	100%
How Often Driver of Carpool				
Almost Never	2%	8%	4%	8%
Alternately	80	73	50	41
Nearly Always	18	19	46	51
	100%	100%	100%	100%
Where Auto is Parked				
Commercial Lot	11%	26%	27%	25%
Employer Provided Space	84	70	72	72
On Street	5	4	1	3
	100%	100%	100%	100%
Could Bus Have Been Used				
Yes	81%	54%	70%	45%
No	12	42	23	52
Don't Know	7	4	7	3
	100%	100%	100%	100%
Year Last Changed Residence				
Prior to 1970	51%	19%	47%	38%
1970-72	27	50	23	24
1973-74	22	31	30	38
	100%	100%	100%	100%
Auto Ownership				
0	0%	0%	0%	0%
1	24	16	35	40
2	64	60	52	47
3 or more	12	24	13	13
	100%	100%	100%	100%
Age				
< 21	1%	0%	1%	1%
21-39	45	46	43	56
40-65	54	54	54	41
> 65	0	0	2	2
	100%	100%	100%	100%
Number of Respondents	231	26	231	124

[a]Respondents to the Mail Back Questionnaire.

[b]Non-respondents Who Completed Telephone Interview.

APPENDIX D

DETAILS OF PROCEDURES FOR ESTIMATING REDUCTION IN AUTO USAGE

The reduction in auto usage stimulated by the project is evaluated by estimating the number of autos that would have been in operation on Corridor roadways if the project had not been undertaken. For the express bus operation, this involves the motorists who switched to the new bus service. For carpools, this involves motorists who switched to larger carpools in order to take advantage of the time savings possible on the reversible lanes.

The basic inputs to the procedure for estimating auto reduction are: 1) the peak period bus and carpool count data, and 2) the prior mode responses of the commuter surveys. The analysis of the prior mode responses of bus riders and carpoolers provides values for estimates of auto occupancy, of which the reciprocals are applied to the bus and carpool count data to estimate auto diversion. Elements of these procedures are discussed in the remainder of this appendix.

D.1 Reduction in Auto Usage Attributable to the Express Bus Service

Express bus patronage data and prior mode data assembled during the bus surveys are used to estimate reductions in auto usage attributable to the express bus operation. Patronage data are used to estimate auto commuter diversion. Prior mode information from the 1971 and 1974 bus surveys are used to estimate auto occupancy.

Auto commuter diversion is estimated by total express bus patronage (see Table 48, page 104), minus what bus patronage would have been without the project. The estimate of what patronage would have been is approximated by the sum of bus patronage levels on Shirley Highway bus routes at the beginning of the project and the 1070 passengers diverted from other bus routes.[1]

Busway service was first initiated in September 1969 when the established bus routes originating south of Shirlington Circle were rerouted onto the completed sections. The first passenger count, in September 1969, is taken as an estimate of what bus patronage on routes south of Shirlington would have been in the absence of a busway. In September 1970 busway entrances at Shirlington Circle became operational, and Shirlington area bus routes were admitted to the busway. The September 1970 passenger count is taken as an estimate of what patronage for Shirlington routes would have been if no busway existed. The sum of these Shirlington and south of Shirlington passenger counts represents the estimated patronage level for WMATA Shirley Highway buses without the project. Buses of the patronage for these buses, taken from the appropriate company records and dispatcher notes for 1969, is taken as the estimate of their patronage without the project. See Table 56 for pre-busway patronage estimates.

Table 56

Pre-Project Bus Patronage on Shirley Highway

	WMATA	PRIVATE COMPANIES
September 1969 Busway Patronage South of Shirlington	2100	450
September 1970 Busway Patronage at Shirlington	1820	--
Total	3920	450

[1]See the "Second Year Results Report," pp. 69, 70, for details.

Auto occupancy for the diverted auto commuters was estimated using the prior mode responses from the 1971 and 1974 bus surveys, and was defined as the quotient:

$$\frac{\text{estimate of diverted auto commuters}}{\text{estimate of autos used by the diverted commuters}}$$

The October 1974 estimate of diverted auto commuters was defined as the total of all former auto commuters responding to the bus survey. (See Table 57 for summary of computations.) The estimate of diverted autos was computed as follows: For each person trip who drove alone (category 1), one fewer auto was in use. Auto usage reduction is 1/2 for each routine carpool driver (category 2) and 1/6 for each alternate carpool driver (category 3). Former carpool passengers or bus passengers had no effect on auto usage. The value of auto occupancy estimated from the 1971 survey data was 1.66, and its reciprocal was 0.6. (Computation details are presented in the "Second Year Results Report" pp. 69-70.) The value estimated using the 1974 survey data is 1.47 and its reciprocal is 0.68.

Table 57

Bus Stimulated Auto Diversion (October 1974 Survey)

CATEGORY	ESTIMATE OF DIVERTED AUTO COMMUTERS	ESTIMATE OF DIVERTED AUTOS
Drove Alone	545	545
Drove with Passengers	89	45
Alternate Driver	142	24
Auto Passenger	123	--
Total	899	614

D.2 Reductions in Auto Usage Attributable to the Carpool Policy of the Project

Prior mode data assembled during the 1974 carpool surveys and carpool volumes were used to estimate reductions in auto usage stimulated by the carpool policy of the project. This reduction in auto usage is defined as the difference between estimates of the number of diverted autos and the number of autos required to transport the new carpoolers. Steps in this procedure are outlined below (computations are summarized in Table 58):

(1) The number of auto commuters switching to carpool because of the availability of the busway is estimated as the total of all busway carpoolers who: a) previously commuted by auto, b) joined their present carpool after the busway was opened to carpools and c) indicated that the availability of the reversible lanes was very important in their decision to join their present carpool.

(2) The estimate of diverted autos is computed as follows: For each of these commuters who drove alone, one fewer auto was in use: estimates of auto usage reduction for routine carpool drivers (category 2) and alternate carpool drivers (category 3) are 1/2 and 1/6 respectively. Former carpool passengers or bus passengers had no effect on auto usage.

(3) The product of the estimates of assumed auto usage reduction factors and diverted auto commuters yields an estimate of 347 autos diverted from Corridor roadways because of the carpool policy (see Table 58).

Table 58

Carpool Stimulated Auto Diversion

CATEGORY	ESTIMATE OF DIVERTED AUTO COMMUTERS	ESTIMATE OF DIVERTED AUTOS
Drove Alone	298	298
Drove with Passengers	30	15
Alternate Driver	205	34
Carpool Passenger	85	--
Total	610	347

(4) Estimates of the number of autos used by the diverted carpoolers are determined from an analysis of project stimulated changes in carpools. An analysis of the carpool survey data indicated that at least 80 percent of the new carpoolers joined existing carpools, with no need to drive (on a daily basis) any additional autos. It was assumed that twenty percent (106 carpoolers) formed new carpools and therefore required the use of an auto. Assuming a 4.5 auto occupancy rate (October 1974 average on busway was 4.45), the daily auto requirement is an estimated 24 autos.

(5) The estimated reduction of auto usage attributable to carpooling on the reversible lanes is 323 autos, the difference between the estimated daily auto diversion (347) and the estimated extra daily auto requirement (24).

APPENDIX E

COMPUTATIONAL DETAILS OF ESTIMATING REDUCTIONS IN POLLUTANT EMISSIONS AND GASOLINE USAGE

Tables 59 through 62 contain statistics leading to the estimates of reductions in auto pollutant emissions presented in Paragraph 6.1.2.

Tables 63 through 66 contain statistics leading to the estimates of reductions in gasoline usage presented in Paragraph 6.1.3.

Table 59

Unadjusted Vehicle Emission Rates by Model Year

MODEL YEAR	CARBON MONOXIDE grams/mile	HYDROCARBONS (EXHAUST) grams/mile	NITROGEN OXIDES grams/mile	HYDROCARBONS (EVAPORATIVE) grams/mile
1963 & earlier	87	8.8	3.6	3.8
1964	87	8.8	3.6	3.8
1965	87	8.8	3.6	3.8
1966	87	8.8	3.6	3.8
1967	87	8.8	3.6	3.8
1968	46	4.5	4.3	3.0
1969	39	4.4	5.5	3.0
1970	36	8.6	5.7	3.0
1971	34	2.9	4.8	0.5
1972	19	2.7	4.6	0.2
1973	19	2.7	4.6	0.2
1974	19	2.7	4.6	0.2

Table 60

Deterioration Factors for Exhaust Pollution Control Devices

OCTOBER AGE (IN YEARS)	CARBON MONOXIDE	HYDROCARBONS
Current Year	1.18	1.05
1	1.32	1.10
2	1.38	1.13
3	1.40	1.15
4	1.68	1.23
5	1.58	1.28
6 and older	1.00	1.00

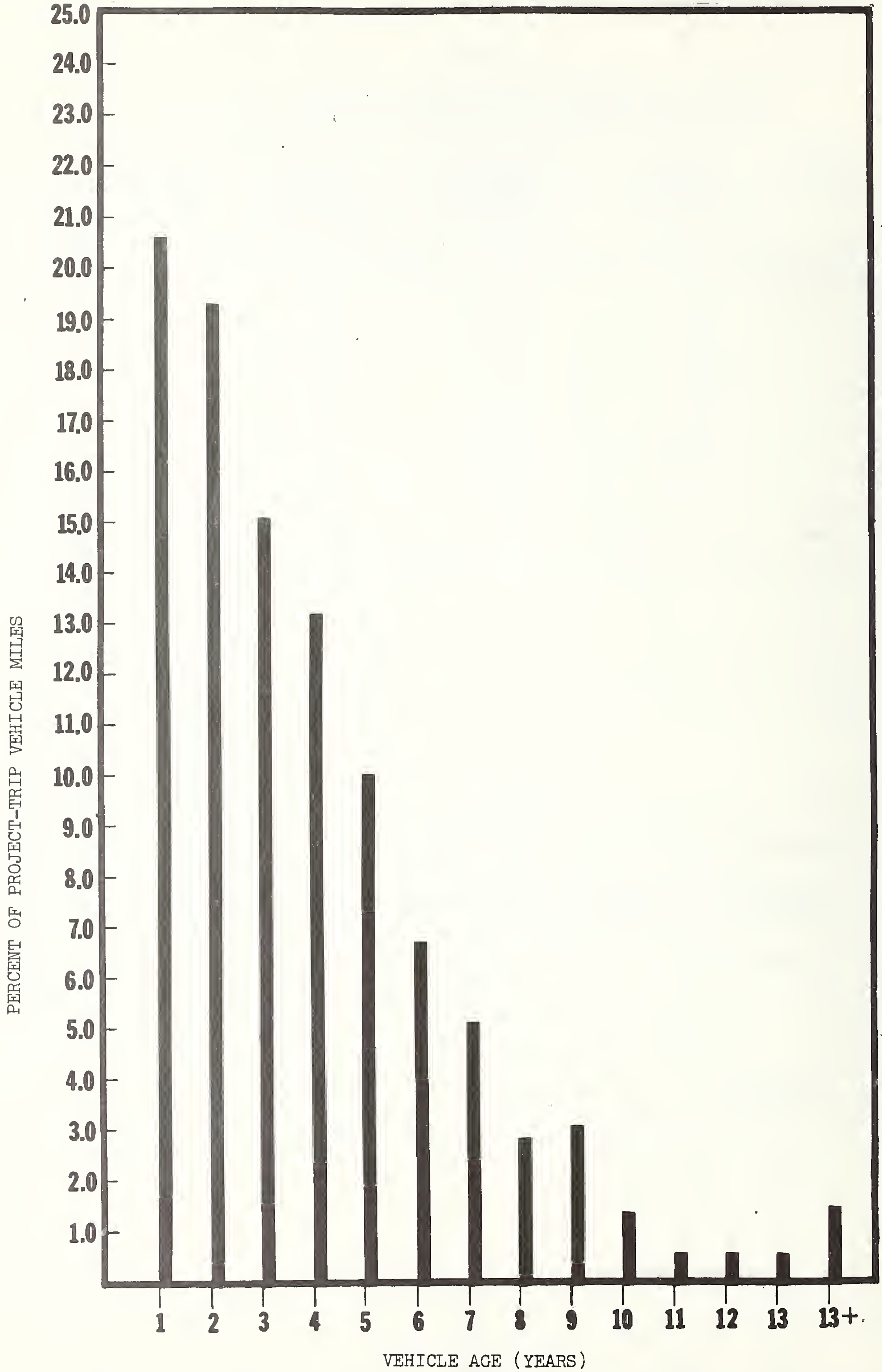

Figure 26. Distribution by Age of Vehicle Miles Traveled Within the Washington Metropolitan Area.

Table 61

Distribution of Peak Period Speeds and Volumes on Shirley Highway

30 MINUTE INTERVAL	AVERAGE SPEED (MPH)				PERCENT OF TOTAL VOLUME[a]			
	Mar 71	Mar 72	Oct 73	Oct 74	Mar 71	Mar 72	Oct 73	Oct 74
6:30-7:00A.M.	29.23	26.17	35.6	31.5	22.0	27.5	20.6	20.3
7:00-7:30	15.53	13.69	26.2	19.3	20.5	21.4	23.8	21.4
7:30-8:00	11.57	12.30	15.1	10.6	19.5	17.5	17.4	21.6
8:00-8:30	13.12	12.85	9.3	10.9	18.6	15.8	19.0	18.9
8:30-9:00	36.33	29.48	14.9	13.4	19.6	17.8	19.1	17.8

[a]Columns may not sum to 100 because of rounding.

Table 62

Corridor Emissions Rates (Grams/Mile)

	CARBON MONOXIDE				HYDROCARBONS (EXHAUST)				NITROGEN OXIDES				HYDROCARBONS (EVAPORATIVE)			
	71	72	73	74	71	72	73	74	71	72	73	74	71	72	73	74
Typical Auto without Peak Period Adjustment	63.4	55.1	50.3	50.3	6.6	5.9	5.5	5.5	4.7	4.6	4.9	4.9	2.9	2.2	1.7	1.7
Typical Auto with Peak Period Adjustment	68.5	62.4	68.7	77.1	6.9	6.4	6.7	7.4	4.7	4.6	4.9	4.9	2.9	2.2	1.7	1.7

Table 63

FRACTION OF TOTAL VEHICLES IN EACH WEIGHT AND MODEL YEAR CLASS

Weight Class (lbs.)

MODEL YEAR	1750	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500
1960	.0001	.0002	.0001	.0001	.0000	.0001	.0007	.0032	.0013	.0002	.0000
1961	.0002	.0002	.0001	.0002	.0002	.0004	.0008	.0042	.0019	.0004	.0003
1962	.0003	.0005	.0002	.0002	.0020	.0016	.0008	.0062	.0042	.0007	.0005
1963	.0002	.0009	.0002	.0002	.0041	.0040	.0017	.0100	.0063	.0010	.0003
1964	.0002	.0011	.0001	.0002	.0033	.0070	.0075	.0119	.0077	.0027	.0003
1965	.0002	.0020	.0004	.0003	.0025	.0147	.0107	.0193	.0144	.0030	.0005
1966	.0003	.0028	.0003	.0005	.0020	.0140	.0144	.0214	.0132	.0036	.0006
1967	.0002	.0028	.0004	.0004	.0003	.0105	.0154	.0208	.0145	.0042	.0005
1968	.0001	.0033	.0005	.0011	.0001	.0119	.0160	.0282	.0175	.0056	.0007
1969	.0003	.0008	.0045	.0018	.0002	.0087	.0155	.0342	.0161	.0075	.0005
1970	.0000	.0004	.0049	.0024	.0001	.0035	.0241	.0310	.0170	.0066	.0008
1971	.0001	.0011	.0052	.0020	.0028	.0029	.0216	.0149	.0307	.0098	.0009
1972	.0001	.0012	.0079	.0037	.0054	.0064	.0135	.0256	.0312	.0098	.0022
1973	.0002	.0011	.0105	.0088	.0028	.0065	.0141	.0236	.0316	.0154	.0043
1974	.0002	.0008	.0038	.0053	.0055	.0039	.0101	.0165	.0200	.0101	.0050

Table 64

BASE FUEL CONSUMPTION RATES IN GALLONS PER MILE FOR MODEL YEARS AND WEIGHT CATEGORIES

	Weight Class (lbs.)										
MODEL YEAR	1750	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500
1960	.034	.049	.043	.045	.041	.058	.064	.081	.093	.092	.105
1961	.036	.034	.047	.048	.061	.058	.088	.071	.095	.094	.112
1962	.040	.039	.048	.052	.056	.061	.077	.072	.079	.093	.101
1963	.044	.043	.051	.057	.062	.068	.079	.083	.090	.094	.109
1964	.042	.044	.050	.054	.058	.062	.073	.078	.088	.091	.103
1965	.040	.042	.049	.053	.055	.066	.073	.081	.085	.097	.108
1966	.055	.048	.061	.079	.067	.068	.072	.081	.083	.088	.108
1967	.040	.044	.039	.052	.053	.063	.076	.083	.086	.089	.097
1968	.040	.052	.049	.054	.051	.064	.075	.083	.088	.105	.114
1969	.043	.045	.049	.053	.060	.067	.075	.084	.088	.110	.093
1970	.042	.043	.052	.057	.054	.063	.075	.083	.092	.099	.101
1971	.037	.044	.047	.052	.055	.068	.082	.085	.093	.104	.092
1972	.038	.043	.046	.051	.050	.069	.075	.090	.093	.104	.108
1973	.040	.042	.046	.051	.057	.064	.072	.093	.099	.108	.116
1974	.041	.041	.047	.053	.056	.068	.073	.093	.104	.110	.122

Table 65

Correction Factors to Adjust Base Fuel Consumption for Traffic Volume on a 6-Lane Expressway

One-Way Traffic Volume (VPH)	ATTEMPTED SPEED OF AUTOMOBILES (MPH) 45	50	55	60
0-2400	(Level of Service A = free flowing traffic)			
2400-2800	1.000	1.000	1.010	1.020
2800-3200	1.000	1.005	1.015	1.025
3200-3600	1.000	1.010	1.020	1.030
3600-4000	1.000	1.015	1.030	1.045
4000-4400	1.001	1.020	1.040	1.060
4400-4800	1.002	1.030	1.050	1.070
4800-5200	1.003	1.032	1.060	1.078
5200-5600	1.004	1.036	1.070	1.085
5600-6000	1.005	1.040	1.080	1.090
>6,000	(Level of Service E = unstable flow)			

[a]Correction factors determined for standard-size U.S. cars.

Source: Paul J. Claffey, "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," National Cooperative Highway Research Program Report 111, 1971.

Table 66

Correction Factors to Adjust Base Fuel Consumption for Traffic Volume on a 6-Lane Major Street Urban Arterial with No Parking[a]

ONE-WAY TRAFFIC VOLUME (VPH)	30 MPH ATTEMPTED SPEED[b]		
	NO STOPS	1 STOP PER MILE	2 STOPS PER MILE
< 1000	1.000	1.270	1.460
1000-1200	1.000	1.270	1.460
1200-1400	1.005	1.275	1.460
1400-1600	1.005	1.280	1.460
1600-1800	1.010	1.285	1.460
1800-2000	1.010	1.290	1.460
2000-2200	1.010	1.295	1.460
2200-2400	1.020	1.300	1.460
2400-2600	1.030	1.305	1.460
2600-2800	1.040	1.305	1.460
2800-3000	1.050	1.310	1.460
> 3000	(Level of Service E = Unstable flow)		

[a]Correction factors determined for standard-size U.S. cars.

[b]Average stopped delay when stopped is 30 seconds.

Source: Paul J. Claffey, "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," National Cooperative Highway Research Program Report 111, 1971.

APPENDIX F

COST ALLOCATION

For the period of the project for which data were available, economic impacts of the project service, monthly system costs and revenues, were allocated by line and by type of service--peak and off-peak. The procedures utilized to allocate costs were developed by Mr. D. H. James, Transit Consultant, Reston, Virginia and are based upon his observations and experience. The procedure can be summarized as follows:

1. Between July 1, 1971 and December 31, 1972, the bus company posted monthly expenses for the project service in accordance with a chart of accounts established by the Interstate Commerce Commission and the Washington Metropolitan Area Transit Commission (WMATC). A definition of each account is provided in Table 67.

2. The cost allocation procedure was used to distribute total monthly (or other period) expenses in these accounts among each line for peak and off-peak periods of the day. The allocation was made on the basis of five factors (or parameters):

    a. Total miles (revenue and non-revenue) - by line peak and off-peak

    b. Platform hours[1] - by line, peak and off-peak

    c. Passengers - by line, peak and off-peak

    d. Number of bus vehicles - by line, <u>peak</u> service only

    e. Number of operators - by line, <u>peak</u> service only.

The first three parameters were used to allocate variable costs; the last two parameters to allocate certain fixed or semi-fixed costs. The allocation methodology was used to estimate the relative contribution to the accounts by each of the five parameters. For example, 58% of account 4110 (Supervision of Shops and Garage) was attributed to route mileage, and 42% to the number of vehicles required to service the route during the peak period. The percentage allocations are listed in Table 68.

For the period July 1971 to December 1972, total expenses in each account were distributed among the five parameters in accordance with these percentages. For each route, by peak period (and off-peak if applicable), total (revenue and non-revenue) miles, platform hours, number of operators (required for peak service), number of vehicles (required for peak service), and number of passengers were determined and each was expressed as a percentage of the project total for that parameter. Those percentages were used to allocate the total expenses in each account which were broken down by parameter type. Summaries of expenses allocated by each parameter are presented in Table 68.

Table 69 displays the changes in parameter values, costs allocated by each parameter, percent of total cost allocated by each parameter, and parameter unit costs from the last half of 1971 to the last half of 1972. In the latter half of 1972, 39.4% of the total costs were allocated to peak service alone (peak period vehicles and peak period operators) versus 41.4% for the last half of 1971. The net result is that in 1972 about 82% of the project service costs were allocated to peak operations versus 80% for the last half of 1971. Total costs do <u>not</u> include depreciation on project bus vehicles, diversion payments or management fees paid to the AB&W Transit Company.[2]

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[1]Platform hours include all running and layover time.

[2]Diversion payments were made to compensate the AB&W Transit Company for passengers diverted from non-project to project routes. With the acquisition of AB&W by WMATA in February 1973 these payments and the management fees were discontinued.

Table 67

Operationg and Maintenance Expense Accounts

ACCOUNT NUMBER	ACCOUNT TITLE	ACCOUNT NUMBER	ACCOUNT TITLE
	EQUIPMENT MAINTENANCE & GARAGE EXPENSES		INSURANCE AND SAFETY EXPENSES
4110	Supervision of Shop and Garage	4510	Insurance & Safety - Salaries & Expenses
4121	Repairs to Shop & Garage - Equipment	4520	Public Liability & Property Damage Insurance
4122	Operations of Service Cars & Equipment	4530	Injuries & Damages
4128	Repairs to Shop & Garage - Buildings & Grounds	4541	Workman's Compensation Insurance
4131	Light, Heat, Power, & Water; Shop & Garage	4570	Fire & Theft Insurance - Buses
4132	Other Shop & Garage Expenses	4571	Fire & Theft Insurance - Property
4140	Repairs to Revenue Equipment	4580	Other Insurance
4140-A	Repairs to Revenue Equipment		ADMINISTRATIVE & GENERAL EXPENSES
4145	Repairs to Revenue Equipment - Accidents Off Premises		
4146	Repairs to Revenue Equipment - Accidents On Premises	4611	Salaries of General Officers
4147	Recovery on Accidents	4612	Expense of General Officers
4150	Servicing of Revenue Equipment	4613	Salaries of General Office Employees
4160	Tires & Tubes - Revenue Equipment	4614	General Office, specifically NVTC
		4616	Expenses of General Office Employees
	TRANSPORTATION EXPENSES	4620	Law Expense
4210	Supervision of Transportation	4630	General Office - Supplies & Expenses
4220	Drivers' Wages	4640	Communication Expense
4230	Fuel for Revenue Equipment	4651	Outside Auditing Expense
4240	Oil for Revenue Equipment	4652	Employees' Welfare Expense- Retirement
4261	Road Expense	4652-1	Employees' Welfare Expense - Group Health & Sick
4262	Bridge & Road Tolls	4652-2	Employees' Welfare Expense - Life Insurance
4264	Other Transportation Expense	4655	Purchasing & Stores Expense
	STATION EXPENSES	4655-1	Purchasing & Stores Expense- Cash Discounts (Credit)
4311	Station Expense - Salaries & Commissions	4656	Other General Expenses
4314	Station Supplies & Expenses	4656-A	Overage & Shortages (Cashiers - Ticket Agents)
4319	Repairs to Station Buildings & Equipment	4673	Regulatory Expenses
4331	Commissions Paid	4674	NVTC Regulatory Expenses
	TRAFFIC SOLICITATION & ADVERTISING EXPENSES	4680	Uncollectable Revenues
			DEPRECIATION EXPENSE
4410	Traffic Solicitation-Advertising Salaries & Expenses		
4410-SS	Traffic Solicitation-Sightseeing-Salaries & Expenses	5011	Depreciation-Structures
4430	Tariffs & Schedules - Salaries & Expenses	5021	Depreciation - Revenue Equipment
4440	Tickets & Transfers	5031	Depreciation - Service Cars & Equipment
4470	Advertising	5041	Depreciation - Shop & Garage Equipment
4470-E	Advertising (Escrow Expense)	5051	Depreciation - Office Equipment
		5071	Depreciation - Improvements to Leasehold Property
		5091	Depreciation Adjustment

Table 67 (Cont'd.)

Operating and Maintenance Expense Accounts

ACCOUNT NUMBER	ACCOUNT TITLE
	OPERATING TAXES & LICENSES
5210	Gasoline, Other Fuel & Oil Taxes
5220	Licenses & Road Taxes
5230	Real Estate & Personal Property Taxes
5240	Payroll Taxes
5250	Other Taxes
	OPERATING RENTS
5320	Other Operating Rents - Debit
5321	Operating Rents, NVTC, e.g., AB&W Bus Rental

Table 68

Percentage Contributions to Variations in Transit Expenses

ACCOUNT NUMBER	PARAMETERS MILES	HOURS	OPERATORS	VEHICLES	PASSENGERS	TOTAL AMOUNT LAST HALF 1971	FIRST HALF 1972	LAST HALF 1972
4110	58			42		5,202.	6,444.	7,625.
4121	58			42		169.	351.	419.
4122	90			10		249.	520.	723.
4128	50			50		118.	481.	1,380.
4131	58			42		2,428.	2,806.	3,678.
4132	50			50		9,280.	13,489.	20,048.
4140	100					11,076.	32,607.	36,806.
4145	100					791.	7,774.	4,848.
4146	100					100.	243.	(8,227.)
4147	100			100		(1,117.)	(6,303.)	(5,925.)
4150				100		27,569.	37,755.	53,678.
4160	100					3,692.	6,312.	10,738.
4210	80		20			11,267.	16,664.	22,450.
4211	80		20			6,320.	9,648.	11,953.
4220		67	33			167,517.	269,932.	415,809.
4230	100					12,076.	19,825.	29,877.
4240	100					494.	1,656.	1,597.
4264		25	75			3,717.	6,664.	7,950.
4311					100	3,244.	5,534.	8,533.
4314					100	30.	39.	57.
4319					100	0.	9.	0.
4410					100			
4430		95			5	8,948.	15,018.	13,992.
4440					100	117.	867.	1,137.
4470					100		743.	0.
4510	25		25		50	839.	1,623.	2,426.
4520	33				67	9,906.	17,001.	22,090.
4541	16	3	71	9	1	939.	1,461.	2,562.
4570				100		3,954.	692.	5,268.
4571	50			50		187.	338.	624.
4580				100		68.	234.	512.
4611					100	703.	1,468.	319.
4612					100	61.	43.	22.
4613	5		10	10	75	6,365.	10,221.	14,784.
4614	5		10	10	75	4,193.	4,708.	4,605.
4616	5		10	10	75	12.	14.	45.
4620	10				90	519.	524.	2,523.
4630	5		10	10	75	504.	1,260.	1,453.
4640					100	815.	1,210.	2,299.
4651	5		10	10	75	814.	1,971.	2,519.
4652	16	3	71	9	1	18,614.	37,410.	39,671.
4655	80			20		1,614.	2,538.	3,478.
4656	5		10	10	75	917.	1,628.	2,983.
4673					100	670.	1,479.	595.
4674	20	20	20	20	20	1,540.	5,807.	786.
5011	5		10	10	75	78.	588.	910.
5031	90			10		544.	833.	1,104.
5041	58			42		194.	231.	241.
5051	5		10	10	75	353.	506.	712.
5071	58			42		476.	622.	518.
5210	100					6,947.	9,033.	2,761.
5220	25			75		1,056.	10,554.	4,145.
5230				100		2,813.	12,812.	4,176.
5240			100			12,487.	23,754.	29,839.
5250					100	286.	415.	615.
4320				100		12,875.	13,053.	12,890.
5321				100		528.	433.	1,294.

Parentheses indicates refund for period, usually an adjustment.

Table 69

Comparison of Project Bus Cost Allocations - Last Half 1971 With Last Half 1972

BASIS OF ALLOCATION	TOTAL UNITS		COST ALLOCATION		PERCENT OF TOTAL COST		UNIT COST	
	1971	1972	1971	1972	1971	1972	1971	1972
Platform Hours	26,167	53,581	121,995.	$295,296.	33.7	36.6	$ 4.66	5.51 (Hour)
Revenue and Non-revenue Miles	434,340	975,422	68,076.	140,146.	18.8	17.4	0.16	0.14 (Mile)
Number of Peak Period Vehicles	31	65	60,830.	104,740.	16.8	13.0	15.88	13.03 (Day)
Number of Peak Period Operators	31	65	88,894.	213,356.	24.6	26.4	23.21	26.53 (Day)
Passengers	496,947	1,173,496	22,312.	53,477.	6.1	6.6	0.044	0.046 (Passenger)
Total Cost			362,107.	807,015.				

APPENDIX G

COPIES OF FALL 1974
COMMUTER SURVEY
QUESTIONNAIRE FORMS

NBS-760
(9-73)

OMB No. 41-R2752
Approval Expires 12-31-76
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

☐☐☐☐☐☐ 2 – 7

Shirley Highway Corridor Bus Commuter Survey

This survey is sponsored by the U.S. Department of Commerce

THE FOLLOWING QUESTIONS CONCERN THE TRIP YOU ARE MAKING THIS MORNING

Please Answer All Questions and Mail — No Stamp Required

1. At what corner (or park-and-ride lot) did you board this bus? ☐☐☐ 8 – 10

   ____
   (specify nearest street intersection)

2. How did you get from the place where this trip began to the place where you boarded this bus? ☐ 11

   ☐ walked ☐ was driven by another person
   ☐ drove car and parked
   ☐ other (specify) ______________________

13. How often do you use *each* of the following means to travel from home to work? ☐☐☐ 18 – 20

    a) This bus ____ (0,1,2,etc.) day(s) per week
    b) Driving alone ____ day(s) per week
    c) A carpool ____ day(s) per week

14. Does this bus arrive at your *boarding* bus stop later than the scheduled time? ☐ 21

    ☐ never ☐ seldom ☐ usually ☐ always

15. Does this bus arrive at your *destination* bus stop later than the scheduled time? ☐ 22

    ☐ never ☐ seldom ☐ usually ☐ always

THANK YOU — PLEASE SEAL AND MAIL

OMB No. 41-R2752
Approval Expires 12-31-76
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

Shirley Highway Corridor Bus Commuter Survey

This survey is sponsored by the U.S. Department of Commerce

THE FOLLOWING QUESTIONS CONCERN THE TRIP YOU ARE MAKING THIS MORNING

Please Answer All Questions and Mail — No Stamp Required

☐☐☐☐☐☐ 2 7

1. At what corner (or park-and-ride lot) did you board this bus? ☐☐☐ 8 10
   _______________ (specify nearest street intersection)
2. How did you get from the place where this trip began to the place where you boarded this bus? ☐ 11
   ☐ walked ☐ was driven by another person
   ☐ drove car and parked
   ☐ other (specify) _______________
3. Where did this trip begin? (Your home address if this trip started at home)
   _______________ Street Address 12 41
   _______________ City 42 State 69 Zip Code 70 74
4. This address was ☐ home ☐ other (specify) _______________ ☐ 75
5. Time you began this trip ______ A.M. (left above address) ☐☐☐☐ 76 79
6. What was the final destination of this trip? *(Physical address of your work place if work trip)*
   _______________ Street address or building name 12 41
   _______________ City 42 State 69 Zip Code 70
7. This address was ☐ work ☐ other (specify) _______________ ☐ 75
8. Time this trip ended ______ A.M. (arrived at above address) ☐☐☐☐ 76 79
9. When you made this trip how much time did you spend driving (or being driven) from the place where this trip began to the place where you left your auto?
   ☐ not applicable, or ______ minutes ☐☐☐ 8 10
10. When you made this trip how much time did you spend walking *to and from* bus stops and waiting for buses? ______ minutes ☐☐ 11 12
11. When you made this trip how many times did you change (transfer) buses?
    ☐ none, or ______ transfers ☐ 13
12. When did you begin to regularly use this bus to commute from home to work? ☐ not applicable, or ______ month ______ year ☐☐☐☐ 14 17

PLEASE CONTINUE TO QUESTION 13 ABOVE

13. How often do you use *each* of the following means to travel from home to work?
    a) This bus ______ (0,1,2,etc.) day(s) per week ☐☐☐ 18 20
    b) Driving alone ______ day(s) per week
    c) A carpool ______ day(s) per week
14. Does this bus arrive at your *boarding* bus stop later than the scheduled time? ☐ 21
    ☐ never ☐ seldom ☐ usually ☐ always
15. Does this bus arrive at your *destination* bus stop later than the scheduled time? ☐ 22
    ☐ never ☐ seldom ☐ usually ☐ always
16. On an average day when you board this bus do you find a seat? ☐ 23
    ☐ never ☐ seldom ☐ usually ☐ always
17. If you could not commute from home to work by means of this bus how would you usually make the trip? ☐ 24
    ☐ would be unable to make this trip
    ☐ join or form a carpool ☐ use another bus
    ☐ drive alone ☐ other (specify) _______________
18. Before you began using this bus how did you usually commute from home to work? ☐☐ 25 26
    ☐ did not make this trip (from your present home to your present work place); how did you commute prior to changing your place of residence or work?
      ☐ auto ☐ bus ☐ other
    ☐ drove alone
    ☐ was an alternate driver in a carpool with ____ other person(s)
    ☐ drove in a carpool with ____ other person(s) (always or nearly always drove)
    ☐ was a passenger in a carpool with ____ other person(s) (never or almost never drove)
    ☐ used another bus (specify route) _______________
    ☐ other (specify) _______________
19. If prior to riding this bus you commuted regularly by automobile (either as a driver or passenger), why did you switch to bus? ☐☐ 27 28
    ____
20. If prior to riding this bus you commuted regularly by auto, what was the vehicle parking cost? *(Don't divide by the number of persons sharing the parking cost)*
    ☐ not applicable, or $ ______ per day. ☐☐☐ 29 31
21. During the past two years has this bus service enabled you to: ☐☐ 32 33
    a) dispose of a car which you owned? ☐ yes ☐ no
    b) avoid buying a car? ☐ yes ☐ no
22. Did this bus service influence the choice of your present address? ☐ 34
    ☐ yes, definitely ☐ slightly ☐ not at all

23. What are your regular working hours? ☐ no regular working hours, or ______ A.M. to ______ P.M. ☐☐☐☐ 35 38 ☐☐☐☐ 39 42
24. When was the last time you changed your place of residence? ☐ not within the last 5 years, or ______ month ______ year ☐☐☐☐ 43 46
25. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or ______ month ______ year ☐☐☐☐ 47 50
26. Is an auto available for you to REGULARLY drive alone from home to work? ☐ 51
    ☐ no ☐ yes, but with considerable inconvenience to others ☐ yes, and without inconvenience to others ☐ don't drive
27. How many automobiles are owned or operated by members of your household? ☐ none, or ______ auto(s) ☐ 52
28. Which of the following attitudes best expresses your opinion about using bus as a way of commuting from home to work? ☐ 53
    ☐ I am generally satisfied with using bus as a *long range* solution to my commuting problems
    ☐ I am generally satisfied with using bus as a *short term* solution to my commuting problems until I can use metro subway service.
    ☐ I am generally dissatisfied with using bus; why _______________
    ☐ Other (specify) _______________
29. Please indicate your: ☐☐ 54 55
    Sex: ☐ male ☐ female
    Age: ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65
30. What is the combined annual income of all members of your household? ☐ 56
    ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ above $30,000
31. Any comments? _______________ ☐☐ 57 58
    ____

THANK YOU — PLEASE SEAL AND MAIL

NBS 793
(8-74)

OMB No. 41-S74067
Approval Expires 12-31-74
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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Shirley Highway Corridor Carpooler Survey

This survey is sponsored by the U.S. Department of Commerce

1. Were you a *passenger* in a carpool (that is, an automobile carrying 2 or more persons, including the driver) on the morning of ______________ between 6:30 A.M. and 9:00 A.M.?
   ☐ yes; please answer the following questions and mail survey form – No Stamp Required
   ☐ no; please return survey form without answering questions.

2. LISTED BELOW ARE SEVERAL FACTORS WHICH MIGHT FIGURE EITHER POSITIVELY OR NEGATIVELY IN A PERSON'S DECISION TO FORM OR JOIN A CARPOOL. HOW IMPORTANT WAS EACH OF THESE FACTORS TO YOU WHEN YOU *FIRST DECIDED* TO USE THE CARPOOL IN WHICH YOU WERE RIDING ON THE MORNING CITED ABOVE?

7. What was the final destination of this trip? (*Physical address* of your work place, if work trip)

   ____
   Street address or building name 12 41

28 31 32 35

12. What are your regular working hours? ☐ no regular working hours, or ____ A.M. to ____ P.M.
13. When was the last time you changed your place of residence? ☐ not within the last 5 years, or ______ month ____ year 36 39
14. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or ______ month ____ year 40 43
15. Is an auto available for you to REGULARLY drive alone from home to work?
    ☐ no ☐ yes, but with considerable inconvenience to others ☐ yes, and without inconvenience to others 44
16. How many automobiles are owned or operated by members of your household? ☐ none, or ______ auto(s) 45
17. Which of the following attitudes best expresses your opinion about carpooling as a way of commuting from home to work? 46
    ☐ I am generally satisfied with carpooling as a *long range* solution to my commuting problems
    ☐ I am generally satisfied with carpooling as a *short term* solution to my commuting problems until improvements are made in mass transit.
    ☐ I am generally dissatisfied with carpooling; why? ______________________
    ☐ Other (specify) ______________________
18. Please indicate your: *Sex:* ☐ Male ☐ Female *Age:* ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65 47 48
19. What is the combined annual income of all members of your household? ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ above $30,000 49
20. Any comments? ______________________
    ______________________ 50 51

THANK YOU – PLEASE SEAL AND MAIL

NBS–793
(8 74)

OMB No. 41-S74067
Approval Expires 12 31-74
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

2 7
8

Shirley Highway Corridor Carpooler Survey

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1. Were you a *passenger* in a carpool (that is, an automobile carrying 2 or more persons, including the driver) on the morning of ________________ between 6:30 A.M. and 9:00 A.M.?
   - ☐ yes; please answer the following questions and mail survey form – No Stamp Required
   - ☐ no; please return survey form without answering questions

2. LISTED BELOW ARE SEVERAL FACTORS WHICH MIGHT FIGURE EITHER POSITIVELY OR NEGATIVELY IN A PERSON'S DECISION TO FORM OR JOIN A CARPOOL. HOW IMPORTANT WAS EACH OF THESE FACTORS TO YOU WHEN YOU *FIRST DECIDED* TO USE THE CARPOOL IN WHICH YOU WERE RIDING ON THE MORNING CITED ABOVE?

   BESIDE *EACH* OF THE FACTORS BELOW, PLACE ONE OF THE FOLLOWING "IMPORTANCE" NUMBERS.

   3 = Very Important
   2 = Moderately Important
   1 = Unimportant or Didn't Consider It
   0 = Not Applicable

   ____ Comfort of the vehicle(s) used by the carpool (e.g., leg room, air conditioning, etc.) (9)
   ____ Reduction in overall commuting costs
   ____ Loss of personal privacy
   ____ Special parking privileges provided by employer for carpools
   ____ Characteristics of the other member(s) of the carpool (e.g., personality, punctuality, sex, whether person is a smoker or objects to smoking, etc.)
   ____ Availability of Shirley Highway express lanes for carpool use
   ____ Loss of flexibility in working hours
   ____ Availability of carpool locator services
   ____ Additional trip time resulting from passenger pick up and discharge
   ____ Reduced use of an auto or making the purchase of an auto unnecessary
   ____ Additional risk to personal safety
   ____ Concern for energy and air pollution problems
   ____ Convenient work location(s) of the other member(s) of the carpool
   ____ Reduction in the use of gasoline
   ____ Additional auto insurance required
   ____ Reduced stress and frustration in commuting
   ____ Availability of good bus service as "back-up" transportation
   ____ Other factors (specify) ________________ (26)

3. How did you get from the place where this trip began to the place where you were picked up by the carpool? (27)
   - ☐ was picked up at or near *my* residence
   - ☐ was driven by another person to carpool pick-up point
   - ☐ drove car and parked at carpool pick-up point
   - ☐ other (specify) ________________

4. Where did this trip begin (Your home address if this trip started at home)

   ________________ Street Address 12 41
   ________________ City 42 State 69 Zip Code 70 74

5. This address was ☐ home ☐ other (specify) ________________ (75)
6. Time you began this trip ______ A.M. (left address) (76 79)

PLEASE CONTINUE TO QUESTION 7 ABOVE

7. What was the final destination of this trip? *(Physical address* of your work place, if work trip)

   ________________ Street address or building name 12 41
   ________________ City 42 State 69 Zip Code 70 74

8. This address was ☐ work ☐ other (specify) ________________ (75)
9. Time this trip ended ______ A.M. (arrived at above address) (76 79)
10. Could you have used a bus to make this trip? (8)
    ☐ yes ☐ no ☐ don't know
11. The following questions (a-i) refer to the carpool in which you were riding on the morning cited above. If you are not currently an active and regular member of *this* carpool please check here and return survey form without completing the remaining questions. ☐ (9)
    a) When did you begin to regularly use *this* carpool to commute from home to work? ____ month ____ year (10 13)
    b) How often are you the driver of *this* carpool? (14)
       - ☐ never or almost never drive
       - ☐ alternately drive
       - ☐ nearly always drive
    c) How often do you use *each* of the following means to travel from home to work?
       - i. *This* carpool ______ (0,1,2,etc.) day(s) per week
       - ii. Driving alone ____ day(s) per week
       - iii. Bus ____ day(s) per week (15 17)
    d) How many regular users of *this* carpool (EXCLUDING YOURSELF) are:
       - i. members of your household? ☐ none, or ______ person(s)
       - ii. employed at your place of work? ☐ none, or ______ person(s) (18 19)
    e) Did a carpool matching service assist you in forming or joining *this* carpool? (20)
       ☐ yes ☐ no
    f) If you could not commute from home to work by means of *this* carpool how would you usually make the trip? (21)
       - ☐ would be unable to make this trip
       - ☐ join or form another carpool ☐ use bus
       - ☐ drive alone ☐ other (specify) ________________
    g) Before you joined *this* carpool how did you usually commute from home to work?
       - ☐ did not make this trip (from your present home to your present work place); how did you commute prior to changing your place of residence or work? ☐ auto ☐ bus ☐ other (22 23)
       - ☐ drove alone; which roadway was used?
         - ☐ Columbia Pike ☐ Shirley Highway ☐ Route 1
         - ☐ Arlington Blvd. ☐ George Washington Parkway
         - ☐ Other (specify) ________________
       - ☐ was an alternate driver in a carpool with ____ other person(s)
       - ☐ drove in a carpool with ____ other person(s) (always or nearly always drove)
       - ☐ was a passenger in a carpool with ____ other person(s) (never or almost never drove)
       - ☐ used bus (specify route) ________________
       - ☐ other (specify) ________________
    h) Before you joined *this* carpool, how long did it take you to commute from home to work? ____ minutes (24 26)
    i) Before you joined *this* carpool, where did you park your auto? (27)
       - ☐ did not drive
       - ☐ in a space provided or subsidized by your employer
       - ☐ on the street
       - ☐ in a commercial lot/garage
       - ☐ other (specify) ________________

12. What are your regular working hours? ☐ no regular working hours, or ____ A.M. to ____ P.M. (28 31) (32 35)
13. When was the last time you changed your place of residence? ☐ not within the last 5 years, or ____ month ____ year (36 39)
14. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or ____ month ____ year (40 43)
15. Is an auto available for you to REGULARLY drive alone from home to work? (44)
    ☐ no ☐ yes, but with considerable inconvenience to others ☐ yes, and without inconvenience to others
16. How many automobiles are owned or operated by members of your household? ☐ none, or ____ auto(s) (45)
17. Which of the following attitudes best expresses your opinion about carpooling as a way of commuting from home to work? (46)
    - ☐ I am generally satisfied with carpooling as a *long range* solution to my commuting problems
    - ☐ I am generally satisfied with carpooling as a *short term* solution to my commuting problems until improvements are made in mass transit.
    - ☐ I am generally dissatisfied with carpooling; why? ________________
    - ☐ Other (specify) ________________
18. Please indicate your: *Sex* ☐ Male ☐ Female *Age* ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65 (47 48)
19. What is the combined annual income of all members of your household? ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ above $30,000 (49)
20. Any comments? ________________ (50 51)

THANK YOU – PLEASE SEAL AND MAIL

SAMPLE

NBS-793
(8-74)

OMB No. 41-S74067
Approval Expires 12-31-74
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

Shirley Highway Corridor Carpooler Survey

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This survey is sponsored by the U.S. Department of Commerce

1. Were you the *driver* in a carpool (that is, an automobile carrying 2 or more persons, including the driver) on the morning of ____________ between 6:30 A.M. and 9:00 A.M.?
   - ☐ yes; please answer the following questions and mail survey form — **No Stamp Required.**
   - ☐ no; please return survey form without answering questions

2. LISTED BELOW ARE SEVERAL FACTORS WHICH MIGHT FIGURE EITHER POSITIVELY OR NEGATIVELY IN A PERSON'S DECISION TO FORM OR JOIN A CARPOOL. HOW IMPORTANT WAS EACH OF THESE FACTORS TO YOU WHEN YOU *FIRST DECIDED* TO USE THE CARPOOL IN WHICH YOU WERE RIDING ON THE MORNING CITED ABOVE?

   BESIDE *EACH* OF THE FACTORS BELOW, PLACE ONE OF THE FOLLOWING "IMPORTANCE" NUMBERS:

   3 = Very Important
   2 = Moderately Important
   1 = Unimportant or Didn't Consider It
   0 = Not Applicable

   ___ Comfort of the vehicle(s) used by the carpool (e.g., leg room, air conditioning, etc.)
   9
   ___ Reduction in overall commuting costs

4. Where did this trip begin? (Your home address if this trip started at home)

   Street Address 12 ______________________ 41
   City 42 ______ State ______ 69 Zip Code 70 ______ 74

5. This address was ☐ home ☐ other (specify) ______________ ☐ 75

6. Time you began this trip _____ A.M. (left above address) ☐☐☐☐ 76 79

7. What was the final destination of this trip? (*Physical address* of your work place, if work trip)

   Street address or building name 12 ______________________ 41
   City 42 ______ State ______ 69 Zip Code 70 ______ 74

8. This address was ☐ work ☐ other (specify) ______________ ☐

PLEASE CONTINUE TO PART j OF QUESTION 17 ABOVE

18. Would *your* employer provide you with parking if you were not participating in a carpool? ☐ yes ☐ no ☐ don't know ☐ 52
19. What are your regular working hours? ☐ no regular working hours, or ____ A.M. to ____ P.M. ☐☐☐☐ 53 56 ☐☐☐☐ 57 60
20. When was the last time you changed your place of residence? ☐ not within the last 5 years, or _____ month _____ year
21. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or _____ month _____ year ☐☐☐☐ 61 64 ☐☐☐☐ 65 68
22. Is an auto available for you to REGULARLY drive alone from home to work?
    ☐ no ☐ yes, but with considerable inconvenience to others ☐ yes, and without inconvenience to others
23. How many automobiles are owned or operated by members of your household? ☐ none, or ____ auto(s) ☐ 69
24. Which of the following attitudes best expresses your opinion about carpooling as a way of commuting from home to work?
    - ☐ I am generally satisfied with carpooling as a *long range* solution to my commuting problems. ☐ 70
    - ☐ I am generally satisfied with carpooling as a *short term* solution to my commuting problems until improvements are made in mass transit.
    - ☐ I am generally dissatisfied with carpooling; why ______________ ☐ 71
    - ☐ Other (specify) ______________
25. Please indicate your: *Sex:* ☐ Male ☐ Female *Age:* ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65 ☐☐ 72 73 ☐ 74
26. What is the combined annual income of all members of your household? ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ above $30,000
27. Any comments? ______________ ☐☐ 75 76

THANK YOU — PLEASE SEAL AND MAIL

NBS-793
(8-74)

OMB No. 41-S74067
Approval Expires 12-31-74
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

Shirley Highway Corridor Carpooler Survey

This survey is sponsored by the U.S. Department of Commerce

1. Were you the *driver* in a carpool (that is, an automobile carrying 2 or more persons, including the driver) on the morning of ________ between 6:30 A.M. and 9:00 A.M.?
☐ yes; please answer the following questions and mail survey form – No Stamp Required
☐ no; please return survey form without answering questions

2. LISTED BELOW ARE SEVERAL FACTORS WHICH MIGHT FIGURE EITHER POSITIVELY OR NEGATIVELY IN A PERSON'S DECISION TO FORM OR JOIN A CARPOOL. HOW IMPORTANT WAS EACH OF THESE FACTORS TO YOU WHEN YOU *FIRST DECIDED* TO USE THE CARPOOL IN WHICH YOU WERE RIDING ON THE MORNING CITED ABOVE?

BESIDE *EACH* OF THE FACTORS BELOW, PLACE ONE OF THE FOLLOWING "IMPORTANCE" NUMBERS

3 = Very Important
2 = Moderately Important
1 = Unimportant or Didn't Consider It
0 = Not Applicable

___ Comfort of the vehicle(s) used by the carpool (e.g., leg room, air conditioning, etc.)
___ Reduction in overall commuting costs
___ Loss of personal privacy
___ Special parking privileges provided by employer for carpools
___ Characteristics of the other member(s) of the carpool (e.g., personality, punctuality, sex, whether person is a smoker or objects to smoking, etc.)
___ Availability of Shirley Highway express lanes for carpool use
___ Loss of flexibility in working hours
___ Availability of carpool locator services
___ Additional trip time resulting from passenger pick up and discharge
___ Reduced use of an auto or making the purchase of an auto unnecessary
___ Additional risk to personal safety
___ Concern for energy and air pollution problems
___ Convenient work location(s) of the other member(s) of the carpool
___ Reduction in the use of gasoline
___ Additional auto insurance required
___ Reduced stress and frustration in commuting
___ Availability of good bus service as "back-up" transportation
___ Other factors (specify) ________

3. What intervening stop(s) did you make between the place where this trip began and your final destination, other than to pick up and discharge carpool passengers?
☐ none ☐ restaurant
☐ babysitter ☐ other(s) (specify) ________

PLEASE CONTINUE TO QUESTION 4 ABOVE

4. Where did this trip begin? (Your home address if this trip started at home)
Street Address ________
City ____ State ____ Zip Code ____

5. This address was ☐ home ☐ other (specify) ________

6. Time you began this trip ____ A.M. (left above address)

7. What was the final destination of this trip? *(Physical address* of your work place, if work trip)
Street address or building name ________
City ____ State ____ Zip Code ____

8. This address was ☐ work ☐ other (specify) ________

9. Time this trip ended ____ A.M. (arrived at above address)

10. When you made this trip how many persons were in the auto? (EXCLUDING YOURSELF) ____ person(s)

11. When you made this trip where did you pick up carpool passengers? (EXCLUDING YOURSELF)
__ persons were picked up at or near *their* residences
__ persons were picked up at other location(s)

12. When you made this trip, how many persons in the auto were discharged before you arrived at the place where you parked your auto? ☐ none, or ____ person(s)

13. When you made this trip how long did it take you to travel from your home (or place where trip began) to the *place where the last passenger was picked up?*
☐ not applicable, or ____ minutes

14. When you made this trip, where did you park your auto?
☐ on the street ☐ in a space provided or subsidized by your employer
☐ in a commercial lot/garage
☐ other (specify) ________

15. What is the vehicle parking cost? *(Don't* divide by the number of persons sharing the parking cost) ☐ not applicable, or $____ per day

16. Could you have used a bus to make this trip? ☐ yes ☐ no ☐ don't know

17. The following questions (a-o) refer to the carpool in which you were riding on the morning cited above. If you are not currently an active and regular member of *this* carpool please check here and return survey form without answering the remaining questions. ☐

a) When did you begin to regularly use *this* carpool to commute from home to work? ____ month ____ year
b) How many persons usually commute from home to work in *this* carpool? (EXCLUDING YOURSELF) ____ person(s)
c) How often are you the driver of *this* carpool?
☐ never or almost never drive
☐ alternately drive
☐ always or nearly always drive
d) During the last year has the membership of *this* carpool increased for any reason?
☐ no
☐ yes, (EXCLUDING YOURSELF) increased from ____ person(s) to ____ person(s)
e) What motivated the increase in membership of *this* carpool?
☐ not applicable
☐ the opening of Shirley Highway express lanes to carpools
☐ an employer policy providing parking, especially to carpools with some minimum membership
☐ carpool locator services
☐ the gasoline crisis
☐ other (specify) ________
f) How often do you use *each* of the following means to travel from home to work.
i. *This* carpool ____ (0,1,2,etc.) day(s) per week
ii. Driving alone ____ day(s) per week
iii. Bus ____ day(s) per week
g) How many regular users of *this* carpool (EXCLUDING YOURSELF) are
i. members of your household? ☐ none, or ____ person(s)
ii. employed at your place of work? ☐ none, or ____ person(s)
h) Does the number of people using *this* carpool vary from day to day?
☐ stays the same from day to day (except for sick days and vacation)
☐ varies somewhat from day to day
☐ varies substantially from day to day
i) How do the participants in *this* carpool share the vehicle operating and parking costs? (e.g., share driving, pay driver fixed amount, etc.) ________

PLEASE CONTINUE TO PART j OF QUESTION 17 ABOVE

j) How often does *this* carpool make use of the Shirley Highway lanes reserved to buses and carpools of 4 or more persons?
☐ not applicable, or ____ day(s) per week. Where do you enter the reserved lanes in the morning? ________
k) Did a carpool matching service assist you in joining or forming *this* carpool? ☐ yes ☐ no
l) If you could not commute from home to work by means of *this* carpool how would you usually make the trip?
☐ would be unable to make this trip
☐ join or form another carpool ☐ use bus
☐ drive alone ☐ other (specify) ________
m) Before you joined *this* carpool how did you usually commute from home to work?
☐ did not make this trip (from your present home to your present work place); how did you commute prior to changing your place of residence or work? ☐ auto ☐ bus ☐ other
☐ drove alone, which roadway was used?
☐ Columbia Pike ☐ Shirley Highway ☐ Route 1
☐ Arlington Blvd. ☐ George Washington Parkway
☐ Other (specify) ________
☐ was an alternate driver in a carpool with ____ other person(s)
☐ drove in a carpool with ____ other person(s) (always or nearly always drove)
☐ was a passenger in a carpool with ____ other person(s) (never or almost never drove)
☐ used bus (specify route) ________
☐ other (specify) ________
n) Before you joined *this* carpool how long did it take you to commute from home to work? ____ minutes
o) Before you joined *this* carpool where did you park your auto?
☐ did not drive
☐ in a space provided or subsidized by your employer
☐ on the street
☐ in a commercial lot/garage
☐ other (specify) ________

18. Would your employer provide you with parking if you were not participating in a carpool? ☐ yes ☐ no ☐ don't know
19. What are your regular working hours? ☐ no regular working hours, or ____ A.M. to ____ P.M.
20. When was the last time you changed your place of residence? ☐ not within the last 5 years, or ____ month ____ year
21. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or ____ month ____ year
22. Is an auto available for you to REGULARLY drive alone from home to work?
☐ no ☐ yes, but with considerable inconvenience to others ☐ yes, and without inconvenience to others
23. How many automobiles are owned or operated by members of your household? ☐ none, or ____ auto(s)
24. Which of the following attitudes best expresses your opinion about carpooling as a way of commuting from home to work?
☐ I am generally satisfied with carpooling as a *long range* solution to my commuting problems.
☐ I am generally satisfied with carpooling as a *short term* solution to my commuting problems until improvements are made in mass transit.
☐ I am generally dissatisfied with carpooling, why ________
☐ Other (specify) ________
25. Please indicate your: *Sex* ☐ Male ☐ Female *Age* ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65
26. What is the combined annual income of all members of your household? ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ above $30,000
27. Any comments? ________

THANK YOU – PLEASE SEAL AND MAIL

NBS-795
(8-74)

OMB No. 041-S74076
Approval Expires 12-31-74
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

☐☐☐☐☐☐ 2 … 7

Shirley Highway Corridor Single Occupant Auto User Survey

This survey is sponsored by the U.S. Department of Commerce

☐ 8

1. Did you make a trip by *driving alone* in an automobile on the morning of ______________ between 6:30 A.M. and 9:00 A.M.?
   ☐ yes; please answer the following questions and mail survey form — No stamp required.
   ☐ no; please return survey form without answering questions.

2. What intervening stop(s) did you make between the place where this trip began and your final destination? ☐ 9
   ☐ none ☐ restaurant
   ☐ babysitter ☐ other(s) (specify) ______________

3. Where did this trip begin? (Your home address if this trip started at home)

9. When you made this trip, where did you park your auto? ☐ 8
   ☐ on the street ☐ in a commercial lot/garage
   ☐ in a space provided or subsidized by your employer
   ☐ other (specify) ______________

10. What is the vehicle parking cost? (*Don't* divide by the number of

19. When was the last time you changed your place of residence? ☐ not within the last 5 years, or _____month _____year ☐☐☐☐ 53 … 56

20. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or _____month _____ year ☐☐☐☐ 57 … 60

21. Is an auto available for you to REGULARLY drive alone from home to work?
    ☐ no ☐ yes, but with considerable inconvenience to others, ☐ yes, and without inconvenience to others ☐ 61

22. How many automobiles are owned or operated by members of your household? ☐ none, or_____auto(s) ☐ 62

23. Which of the following attitudes best expresses your opinion about driving alone as a way of commuting from home to work? ☐ 63
    ☐ I am generally satisfied with driving alone as a *long range* solution to my commuting problems.
    ☐ I am generally satisfied with driving alone as a *short term* solution to my commuting problems until improvements are made in mass transit.
    ☐ I am generally dissatisfied with driving alone; why ______________
    ☐ Other (specify) ______________ ☐☐ 64 65

24. Please indicate your: *Sex:* ☐ Male ☐ Female *Age:* ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65 ☐ 66

25. What is the combined annual income of all members of your household? ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ Above $30,000 ☐☐ 67 68

26. Any comments? ______________
____

THANK YOU — PLEASE SEAL AND MAIL

NBS-795
(8-74)

OMB No. 041-S74076
Approval Expires 12-31-74
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

2 7

Shirley Highway Corridor Single Occupant Auto User Survey

This survey is sponsored by the U.S. Department of Commerce

8

1. Did you make a trip by *driving alone* in an automobile on the morning of ____________ between 6:30 A.M. and 9:00 A.M ?
   - ☐ yes; please answer the following questions and mail survey form – No stamp required.
   - ☐ no; please return survey form without answering questions.

2. What intervening stop(s) did you make between the place where this trip began and your final destination? 9
   - ☐ none ☐ restaurant
   - ☐ babysitter ☐ other(s) (specify) ____________

3. Where did this trip begin? (Your home address if this trip started at home)

   ____
   Street Address 12 41

   ____
   City 42 State 69 Zip Code 70 74

4. This address was ☐ home ☐ other (specify) ____________ 75

5. Time you began this trip ____ A.M. (left above address) 76 79

6. What was the final destination of this trip? *(Physical address* of your work place, if work trip)

   ____
   Street address or building name 12 41

   ____
   City 42 State 69 Zip Code 70 74

7. This address was ☐ work ☐ other (specify) ____________ 75

8. Time this trip ended ____ A.M. (arrived at above address) 76 79

PLEASE CONTINUE TO QUESTION 9 ABOVE

9. When you made this trip, where did you park your auto? 8
   - ☐ on the street ☐ in a commercial lot/garage
   - ☐ in a space provided or subsidized by your employer
   - ☐ other (specify) ____________

10. What is the vehicle parking cost? (*Don't* divide by the number of persons sharing the parking cost) ☐ not applicable, or $ ____ per day. 9 11

11. How often do you use *each* of the following means to travel between home and work? 12 14
    - a) Driving alone ____ day(s) per week
    - b) Bus ____ day(s) per week
    - c) A carpool ____ day(s) per week

12. Could you have used a bus to make this trip? 15
    - ☐ yes ☐ no ☐ don't know

13. When was the last time you *regularly* used the bus to commute from your present home to your present work place? ☐ never ☐ not within the last 5 years, or ____ month ____ year 16 19

14. When was the last time you *regularly* used a carpool to commute from your present home to your present work place? ☐ never ☐ not within the last 5 years, or ____ month ____ year 20 23

15. If you do not now regularly commute from home to work by bus, why not? (Mark one or more of the following) 24 34
    - ☐ I now regularly commute by bus
    - ☐ Bus not available
    - ☐ Need car during work day
    - ☐ Bus takes too long
    - ☐ No seats available on bus
    - ☐ Bus unreliable
    - ☐ Too much time spent waiting at bus stops
    - ☐ Too much walking necessary
    - ☐ Bus too expensive
    - ☐ No personal privacy on bus
    - ☐ Other factor(s) (specify) ____________

16. If you do not now regularly commute from home to work by carpool, why not? (Mark one or more of the following) 35 43
    - ☐ I now regularly commute by carpool
    - ☐ Inability to locate others willing to carpool
    - ☐ Too much time required to pick up and discharge carpool passengers
    - ☐ Too much risk to personal safety
    - ☐ No personal privacy in carpool
    - ☐ Too much auto insurance required
    - ☐ Loss of flexibility in working hours
    - ☐ Need car during work day
    - ☐ Other factor(s) (specify) ____________

17. If you could not commute from home to work by driving alone how would you usually make this trip? 44
    - ☐ would be unable to make this trip ☐ use bus
    - ☐ join or form a carpool ☐ other (specify) ____________

18. What are your regular working hours? ☐ no regular working hours, or ____ A.M. to ____ P.M. 45 48 49 52

19. When was the last time you changed your place of residence? ☐ not within the last 5 years, or ____ month ____ year 53 56

20. When was the last time you changed your *physical work location?* ☐ not within the last 5 years, or ____ month ____ year 57 60

21. Is an auto available for you to REGULARLY drive alone from home to work? 61
    - ☐ no ☐ yes, but with considerable inconvenience to others, ☐ yes, and without inconvenience to others

22. How many automobiles are owned or operated by members of your household? ☐ none, or ____ auto(s) 62

23. Which of the following attitudes best expresses your opinion about driving alone as a way of commuting from home to work? 63
    - ☐ I am generally satisfied with driving alone as a *long range* solution to my commuting problems.
    - ☐ I am generally satisfied with driving alone as a *short term* solution to my commuting problems until improvements are made in mass transit.
    - ☐ I am generally dissatisfied with driving alone; why ____________
    - ☐ Other (specify) ____________

24. Please indicate your. *Sex:* ☐ Male ☐ Female *Age:* ☐ under 21 ☐ 21-39 ☐ 40-65 ☐ over 65 64 65 66

25. What is the combined annual income of all members of your household? ☐ $0-5,000 ☐ $5,001-15,000 ☐ $15,001-30,000 ☐ Above $30,000 67 68

26. Any comments? ____________

THANK YOU – PLEASE SEAL AND MAIL