AN ANALYSIS
OF THE
SHIRLEY HIGHWAY EXPRESS-BUS-ON-FREEWAY
DEMONSTRATION PROJECT

by

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CHAPTER I

INTRODUCTION

The continuing shift in population from the rural to urban areas is creating many problems for planners and highway engineers which cover various aspects. Many of these problems are related to a central one: how to provide sufficient facilities, especially in the urban areas, to accommodate transportation demands.

In the past, this situation has been attacked by devoting considerable capital and engineering resources to providing more highway capacity in an effort to satisfy the travel demand. In many urban areas the transportation desires cannot be completely accommodated by a single mode, and a balanced transportation system is necessitated. It is agreed that urban freeways and street networks are handling the traffic needs without much inconvenience, except for three to five hours each weekday during the peak periods. Moreover, it is the slowdowns and stoppages during the peak periods that create the critical problem.

It is recognized that the automobile and the required facilities cannot accommodate the peak demands. In 1970, Mr. Frank Turner, Federal Highway Administrator, in an article entitled "Moving People on Urban Highways" (31) concluded that " ..... it would not be financially possible and even if it were, certainly not socially desirable, to provide all of the highway facilities that would be needed

in order to satisfy the peak-hour demands, especially in our large urban areas, for all the people who wanted to drive automobiles". Emphasis is now being placed on people utilization of a transportation corridor rather than the common consideration of vehicle utilization.

The financial status of the rapid rail systems in the United States suggests that these facilities cannot be supported by the average urban area. The Massachusetts Bay Transportation Authority reported an operating deficit in 1971 of approximately $75 million. With a population of about 2.6 million in the Boston urban area, the subsidy to the Authority averaged $30 per year for every man, woman, and child in the service district (13). Similar situations exist in New York, Chicago, and Cleveland. It appears that any new system will experience the same problems. Even before the first paying passenger stops on board, there are indications that San Francisco's Bay Area Rapid Transit system will require an operating subsidy (13).

Seeking to solve the urban transportation problems in Virginia, the State Highway Commissioner, Mr. Douglas B. Fugate, in 1970, proposed more extensive use of the urban highway as an artery for mass transportation. An artery that, in conjunction with the bus, would afford a means of moving more people rather than more vehicles during the peak hours. Mr. Fugate, serving as the elected president of the American Association of State Highway Officials, urged that highway planning and community planning go hand in hand

in the hope that the urban highway could play an increasingly vital role in solving city traffic problems (8, 33).

In most every urban area, there exists a bus fleet, and much attention has been given to the promotion of bus travel because of its potential in relieving the urban transportation congestion. The area requirement of roadway per automobile passenger is approximately 21 times that of the bus passenger. McCreery has determined that the area requirement of roadway per bus passenger is 57.7 square feet compared to 1,202.4 square feet for the automobile passenger at a freeway speed of 60 miles per hour (16).

The importance of bus transit is further indicated by the fact that approximately 1,200 buses per hour can be accommodated on one freeway lane (14). Assuming a 50-passenger capacity for each bus, a single lane can accommodate 60,000 persons per hour. A facility with this capacity could provide for the present demand of virtually any urban corridor in the United States. Typical existing peak-hour demands are under 15,000 persons per hour per corridor (10).

The concept of reserving freeway lanes for buses during the peak hours utilizes the characteristics described above and has been examined in several papers, articles, and technical memoranda in recent years (1, 3, 5, 9, 10, 14, 19, 32). The consensus of these studies is that the reserved lane system achieves more efficient use of the freeway than does the conventional mixed traffic. One research study has even recommended that urban freeways be de-

signed to handle off-peak traffic and bus transit be utilized to accommodate the peak movements (11).

Due to the significance of bus transit, many types of projects have been implemented. On April 5, 1971, the last section of the nine-mile exclusive bus lane on the Shirley Highway, officially known as Interstate Route 95, in Northern Virginia was opened. The express lane allowed buses to speed past slow-moving automobiles across the Potomac River and continue into the central business district of Washington, D. C. on bus priority curb lanes (17). The completion of the exclusive busway was a major step in a four-year combined transit and roadway demonstration project of national significance.

The principal objective of the Shirley Highway Express-Bus-on-Freeway Demonstration Project, sponsored by the United States Department of Transportation, was to test the hypothesis that the provision of rapid and improved bus service over an exclusive bus lane would attract significant numbers of passengers, formerly commuting by automobiles, between concentrated employee locations and residential areas (15). The diversions from automobiles to buses would increase the "people utilization" or the "people-moving capacity" of the congested highway systems in Northern Virginia and the District of Columbia and should enable all rush-hour commuters to travel more quickly and conveniently.

The project consisted of three elements: (1) the busway,

including the exclusive lane on Shirley Highway and the bus priority lanes in the Nation's Capitol, (2) the bus transit operation, involving new buses and services, and (3) residential fringe parking where existing shopping centers and new lots will provide free parking for bus riders (15, 17). The implementation of this joint highway and mass transportation demonstration project was due to the efforts and cooperation of many federal, state and local organizations.

Study Objectives

The economic and travel forecasts in the feasibility study for the Shirley Highway Express-Bus-on-Freeway Demonstration Project indicated the exclusive busway would be economically feasible (15). It also predicted that the provision of rapid and improved bus service between the residential areas and employment centers would attract significant numbers of passengers formerly commuting by automobile. Such a diversion from the automobiles to buses would increase the "people-moving capacity" of the congested highway system and, thus, improve the level of service for all rush-hour commuters.

Since the initiation of the project, sufficient time has elapsed to allow the establishment of definite traffic patterns and the collection of reliable travel data. This study was conducted to evaluate the effectiveness of the exclusive busway.

The main objectives of this investigation were:

1. To determine the effects of the busway on bus patronage

and automobile travel trends.

2. To analyze the sources of bus patrons and determine the reduction in automobiles.
3. To use the automobile reduction in comparing the levels of service of the existing facility to the freeway without the exclusive busway.

Method of Approach

As the effectiveness of the busway varied over its entire length, a site had to be chosen which represented typical operations. It appeared that the segment of the busway just north of Glebe Road provided normal operations, therefore, it was selected. To the south of the site, the busway usage was low even though the passengers enjoyed a greater time savings. The northern portion of the busway experienced many entering buses that utilized only short sections of the exclusive lane. Another reason for choosing this site was that the Metropolitan Washington Council of Governments established a screenline in the Shirley Highway Corridor, and it intercepted the Shirley Highway at this location (7). The Council of Governments secured much reliable data at this site. The data covered only the A.M. peak period since similar service was provided during the P.M. peak hours, and the collection of data for both periods would result in much duplication. Likewise, this study includes the effects of the busway during the A.M. peak period.

The effects of the busway on bus patronage and automobile

travel were determined through an analysis of "before" and "after" passenger and vehicular counts. The analysis included the trends for the entire Shirley Highway corridor as well as the busway.

An important aspect of the evaluation was the identification of the sources of bus patrons. If the patronage increase on the exclusive lanes was due to a diversion from other buses rather than from vehicles, the project would be ineffectual as no vehicles were removed from the Shirley Highway. The sources of bus patrons were determined by an analysis of the commuter profiles secured by an "on-board" bus survey and automobile questionnaire. The reduction in automobiles from the Shirley Highway was a function of the occupancy rate. The automobile occupancy rate was determined from the travel data.

An objective of the exclusive bus lane was to improve the level of service for the automobile commuters on the Shirley Highway. The Highway Capacity Manual technique was employed in analyzing the level of service (12). Previous studies indicated that it was the most successful technique in examining the level of service. Classification traffic counts and speed studies provided the data required in the application of the Highway Capacity Manual technique.

Organization of Report

The objective of this thesis is to present an evaluation of the feasibility of the Shirley Highway express bus lane. Chapter

II reviews the background and history of the demonstration project. Chapter III contains a description of the travel data relating to the effects of the busway. An analysis of relevant variables is presented in Chapter IV. These variables include bus patronage, sources of patrons, automobile occupancy, and the reduction in automobiles on the Shirley Highway. Chapter V describes the quality of service experienced by the conventional traffic on the Shirley Highway with the busway in operation. Then, an analysis is given, assuming the elimination of the busway, in an attempt to measure the effectiveness of the bus operation in relieving the congestion on the regular roadway. Finally, Chapter VI presents the conclusion of the study and recommendations for future studies.

CHAPTER II

PROJECT BACKGROUND

The following material describes the cooperation among many participating organizations (federal, state, and local) which resulted in the successful implementation of the Shirley Highway Express-Bus-on-Freeway Demonstration Project. The Department of Transportation, through the Metropolitan Washington Council of Governments, sponsored two reports which contributed to the project and documented, in detail, the implementation recommendations. In March, 1970, the first study, "Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor" (15), was completed and contains forecasts of the increase of bus patronage and recommendations for providing the busway and fringe parking facilities. Approximately one year later, the Council of Governments published the report, "The Implementation Plan for the Shirley Highway Express-Bus-on-Freeway Project" (7), which provides detailed design and coordination re - quirements and procedures to implement the recommendations of the feasibility study. The story of the project was presented in an article in the American Road Builder magazine entitled "Bus Rapid Transit" (18), and in January, 1971, the Northern Virginia Transportation Commission published a "Factsheet" covering the project (22). The following brief history of the project draws upon these resources.

Due to the congestion on the Shirley Highway in 1962, the Virginia Department of Highways, in cooperation with the Bureau of

Public Roads, initiated a study to determine the best means of improving the existing four-lane, controlled-access highway to an eight-lane facility complying with Interstate standards. Recommendations for the 17.5-mile stretch of highway included widening to provide two three-lane directional roadways separated by a two-lane reversible express roadway between Springfield and the Potomac River. At that time, no consideration was given for exclusive or priority bus lanes, and the final design, based upon these recommendations, began.

In 1964, because of the growing interest in bus transit, a study group was formed, representing the District of Columbia and Virginia Highway Departments, the National Capitol Transportation Agency, the Transit Regulatory Agency, and the Federal Highway Administration, to investigate what special bus facilities could be accommodated by the Shirley Highway improvements. Based upon the study group's recommendations, the final design of the Shirley Highway was revised to include exclusive bus ramp connections to the reversible lanes at the Seminary Road and Shirlington Interchanges and also at the Pentagon (30). Figure 1 shows the locations of the proposed access connections.

As enthusiasm increased over other bus demonstration projects, it was suggested that some consideration be given to express bus transit in the Washington area. Since several stages of the reconstruction of the Shirley Highway were completed, the use of the reversible lanes was explored. After a comprehensive transportation

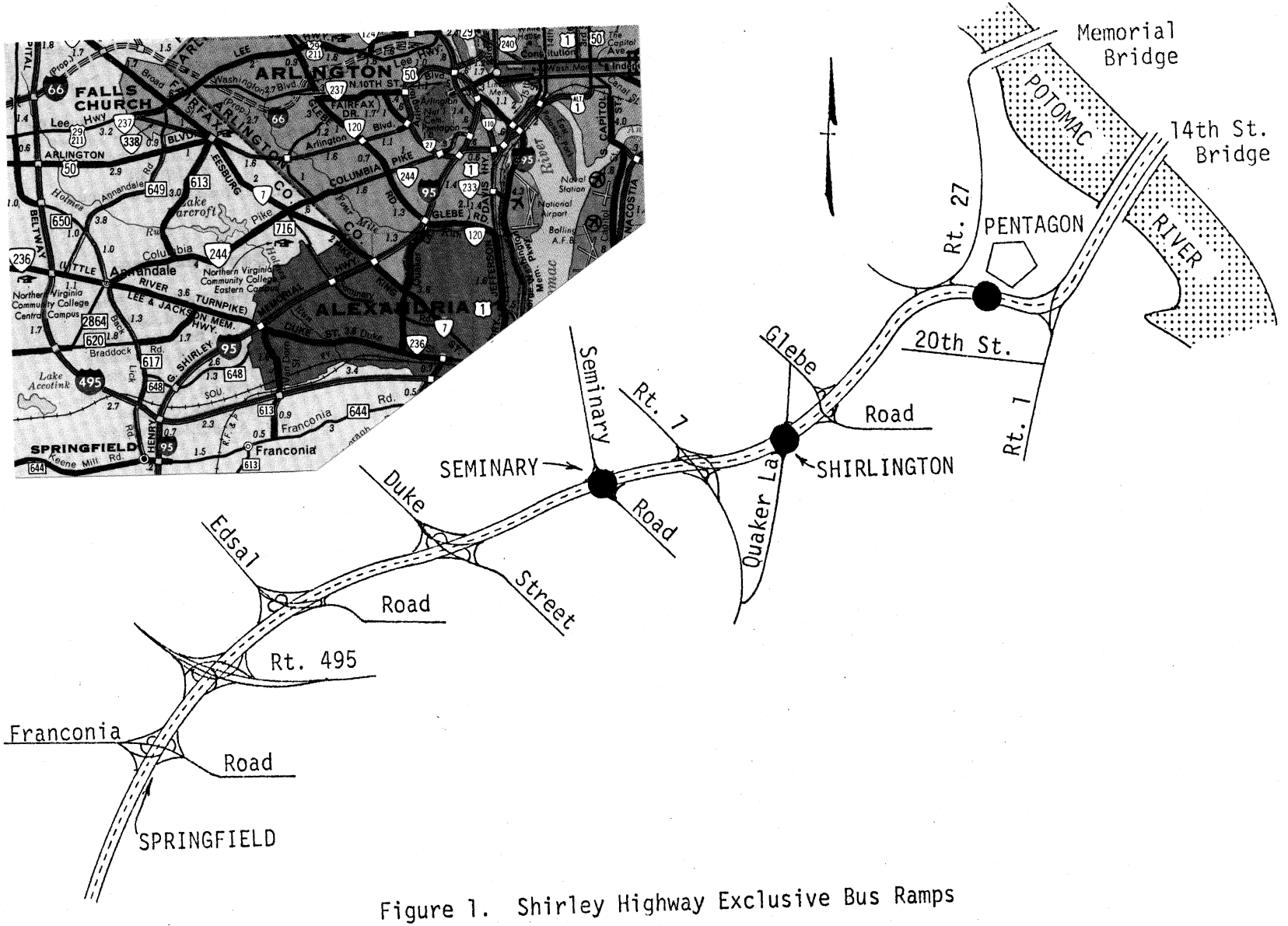

Figure 1. Shirley Highway Exclusive Bus Ramps

and economic feasibility study of express bus usage in the Shirley Highway corridor, it was recommended that the newly constructed portion of the reversible lanes between Edsal Road and Shirlington be utilized for exclusive bus transit. During the morning peak period, there was much congestion and delay just south of Shirlington, as shown in Figure 2, where the traffic was required to merge from three lanes into two lanes through a construction project that necessitated many detours. In September, 1969, the buses traveling over the express lanes bypassed this congestion which resulted in an estimated 10 - 18 minutes time savings. Bus ridership increased 20% immediately, although no time was saved during the evening peak period. The growth in patronage required that more buses be placed into service until the ridership reached a peak of about 25% increase in the first three months of the demonstration.

The initial success provided a firm basis for the cooperating agencies to accept the plan to extend a temporary busway over the remaining four-mile section of highway during the construction of permanent reversible lanes and major interchanges near the Pentagon. The temporary bus roadway was incorporated into the construction plans for the remaining part of Shirley Highway and was opened in two stages. The first 1.6 miles between Shirlington and 20th Street were completed in September, 1970, which resulted in an additional 5 - 8 minutes savings by the buses. Also, 49 additional trips were routed onto the busway at Shirlington during the morning rush hours. The last section of the exclusive bus roadway terminates at the Potomac River and continues

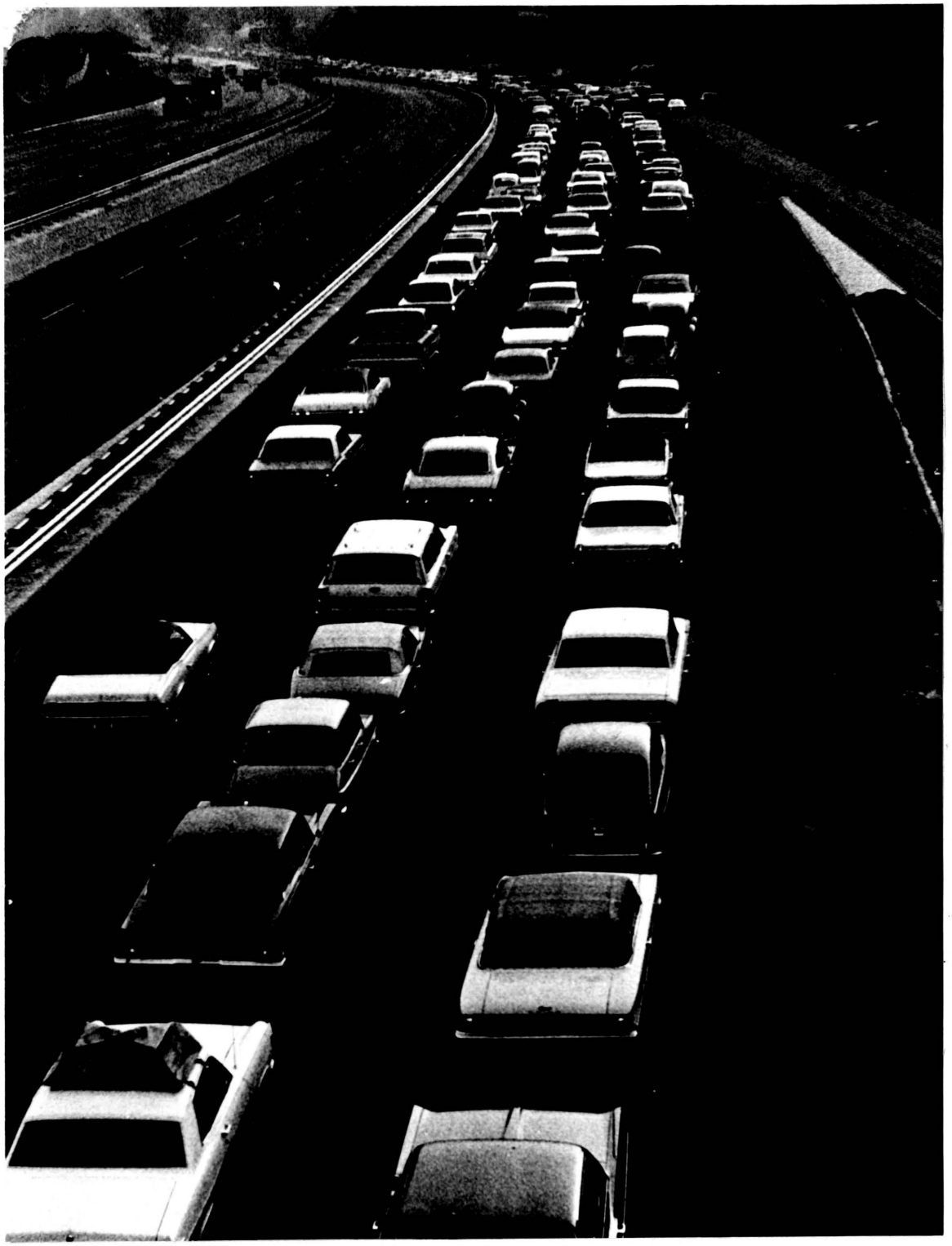

Figure 2. A.M. Peak Period Traffic Conditions
Shirley Highway - South of Shirlington

via a new bridge and priority curb lanes on 14th Street into the central business district of Washington, D. C. This section was opened on April 5, 1971. Figure 3 shows the busway access locations.

As each stage of the busway was opened in 1969 and 1970, the Alexandria, Barcroft, and Washington Transit Company (A B & W), an independent agency cooperating in the project, gradually placed more buses into service to supply the increased passenger demand. The feasibility report estimated that 90 additional buses would be required during the peak period to handle the ridership by the end of the project in 1972. This expansion would cause a major impact on the bus company's capital requirements, and in September, 1970, the Urban Mass Transportation Administration approved a grant to the Northern Virginia Transportation Commission which provided the funding for the required buses. The first increment of 30 buses was put into service in May and June, 1971, to accommodate the demand generated by the completion of the busway (23, 26). An additional 20 and 10 buses were placed into service in February and June, 1972, respectively (27, 28, 29). The Northern Virginia Transportation Commission's plans include the delivery of 16 buses in August, 1972, with the remaining 14 units to be delivered in December (29).

The availability of free fringe parking was one of the keys to market expansion, and the feasibility study recommended that "park-and-ride" and "kiss-and-ride" facilities be provided in the residential areas of the Shirley Highway corridor. With the cooperation of

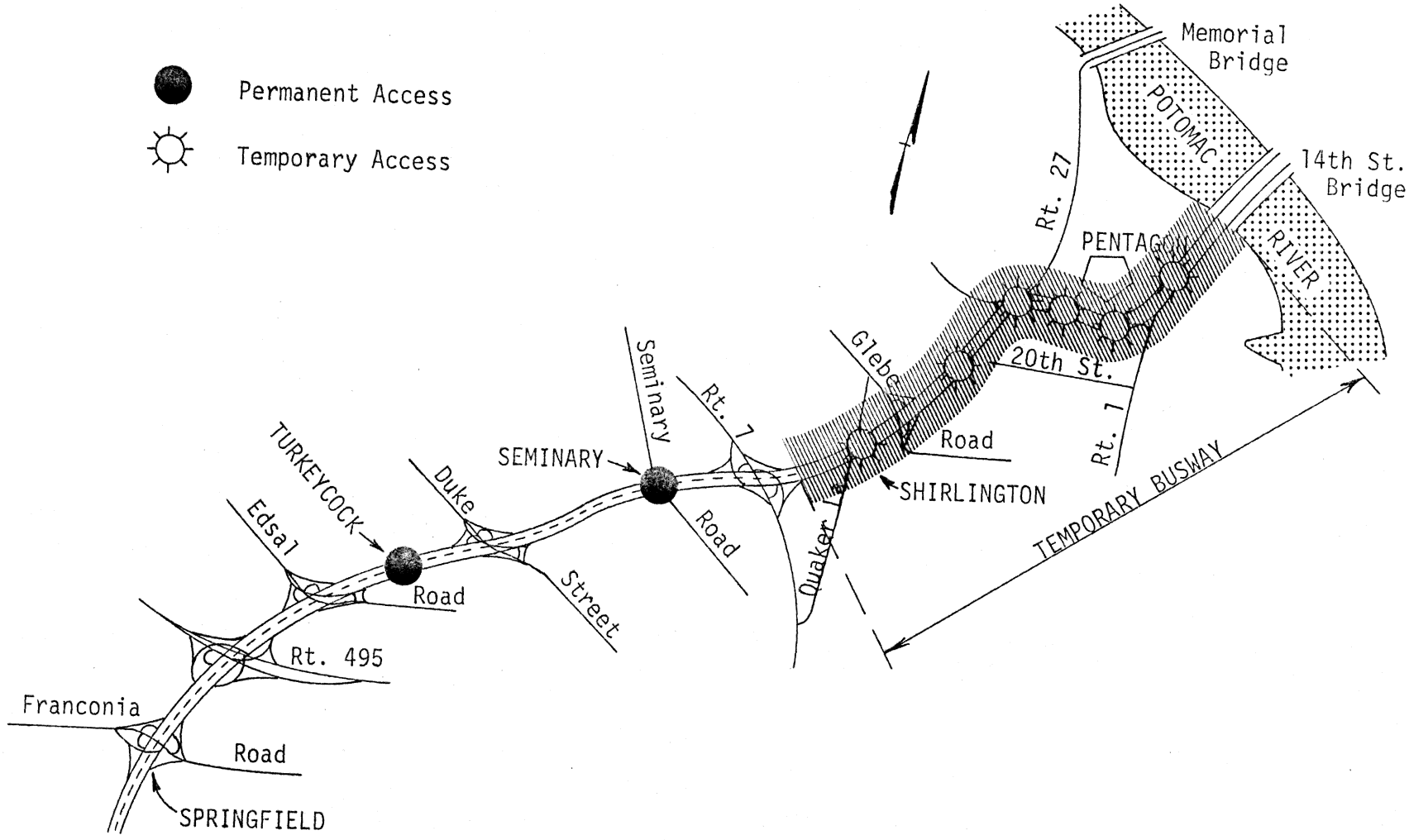

Figure 3. Shirley Highway Exclusive Busway Access Locations

the owners of Springfield and Shirley Plazas (shopping centers), fringe parking was provided in the summer of 1971 (24, 25).

The Washington Metropolitan Area Transit Authority is co-operating in the project by presently constructing parking facilities on two future rapid transit station sites. These sites were acquired through advance acquisitions and will be leased to the Northern Virginia Transportation Commission for fringe parking until needed as rapid rail facilities (21, 29).

CHAPTER III

DESCRIPTION OF TRAVEL DATA

Because of the far-ranging implications of the demonstration project, the officials of the Department of Transportation, the Metropolitan Washington Council of Governments, and other participating organizations designed a monitoring program. The objective of the monitoring program was to collect "before" and "after" travel data to permit the determination of changes in travel patterns that occurred as a result of changes in transit service (7). A variety of data was obtained during the morning peak period by several agencies. A review of the pertinent data has been conducted and is presented in this chapter.

Automobile and Bus Travel Times

While buses sped along the exclusive busway during the peak periods, automobiles and trucks encountered varying congestion levels. In the morning peak hour, speeds varied from 65 MPH south of the Seminary Road Interchange to stop-and-go conditions between Seminary Road and Shirlington. The congestion began south of Route 7 and was caused by the reduction from three lanes of completed roadway to two lanes of detour roadway in the construction area. From Shirlington to the Potomac River, speeds were low, complicated by the merging and weaving traffic at the Glebe Road, Route 27 (Washington Boulevard), and Route 1 Interchanges.

Figure 4 shows bus and automobile A.M. peak period travel times on the Shirley Highway. The bus times were the scheduled run times while the automobile times were based upon speed and delay studies made by the Council of Governments. All travel times were gathered upon the completion of the busway in April, 1971.

The automobile travel times varied considerably during the A.M. peak period as shown in Figure 5. In this figure, travel times were plotted for the peak period for the segment of the Shirley Highway between Route 7 and Potomac River. It indicates that automobiles arriving at Route 7 at 6:30 or 9:00 A.M. took about 7 minutes to travel to the Potomac River, while those arriving between 7:30 and 8:30 A.M. required 20 - 22 minutes for the same trip. The Council of Governments secured these data in March, 1972, by recording the times of arrival of automobile license plates at the termini. The travel time for the buses remained constant as the number of buses was not sufficient to create congestion in the busway. Although this segment was through the construction area, the travel times were not affected by construction activity as the contractor was not permitted to perform any work that would disrupt the flow of traffic during the peak periods.

The operating speed of buses on the temporary busway was limited to approximately 45 MPH because of curves and grades on the temporary asphalt roadway (17). On the completed reversible lanes, the buses attained normal operating speeds. In the morning, the

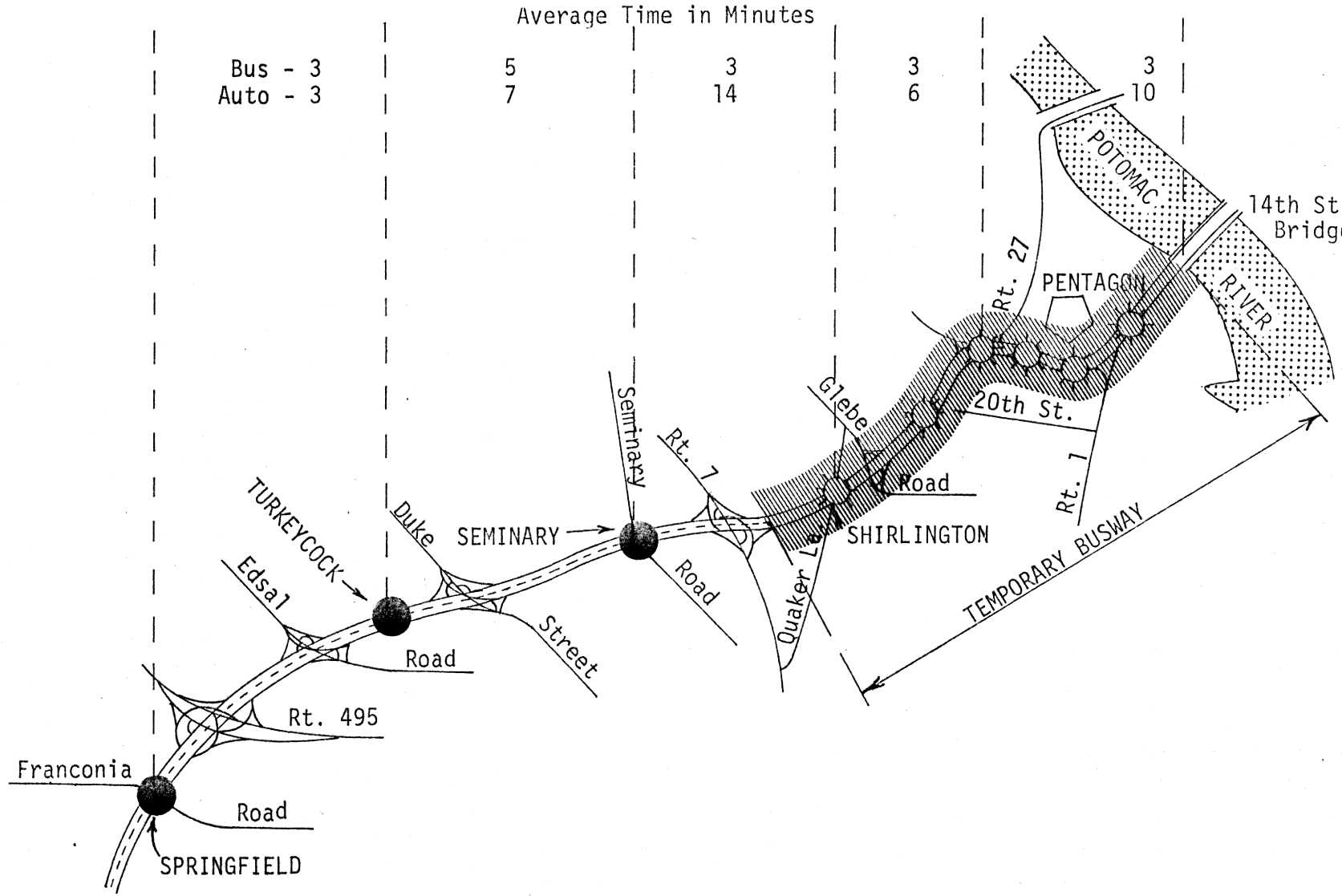

Figure 4. Automobile and Bus Peak Travel Times on Shirley Highway

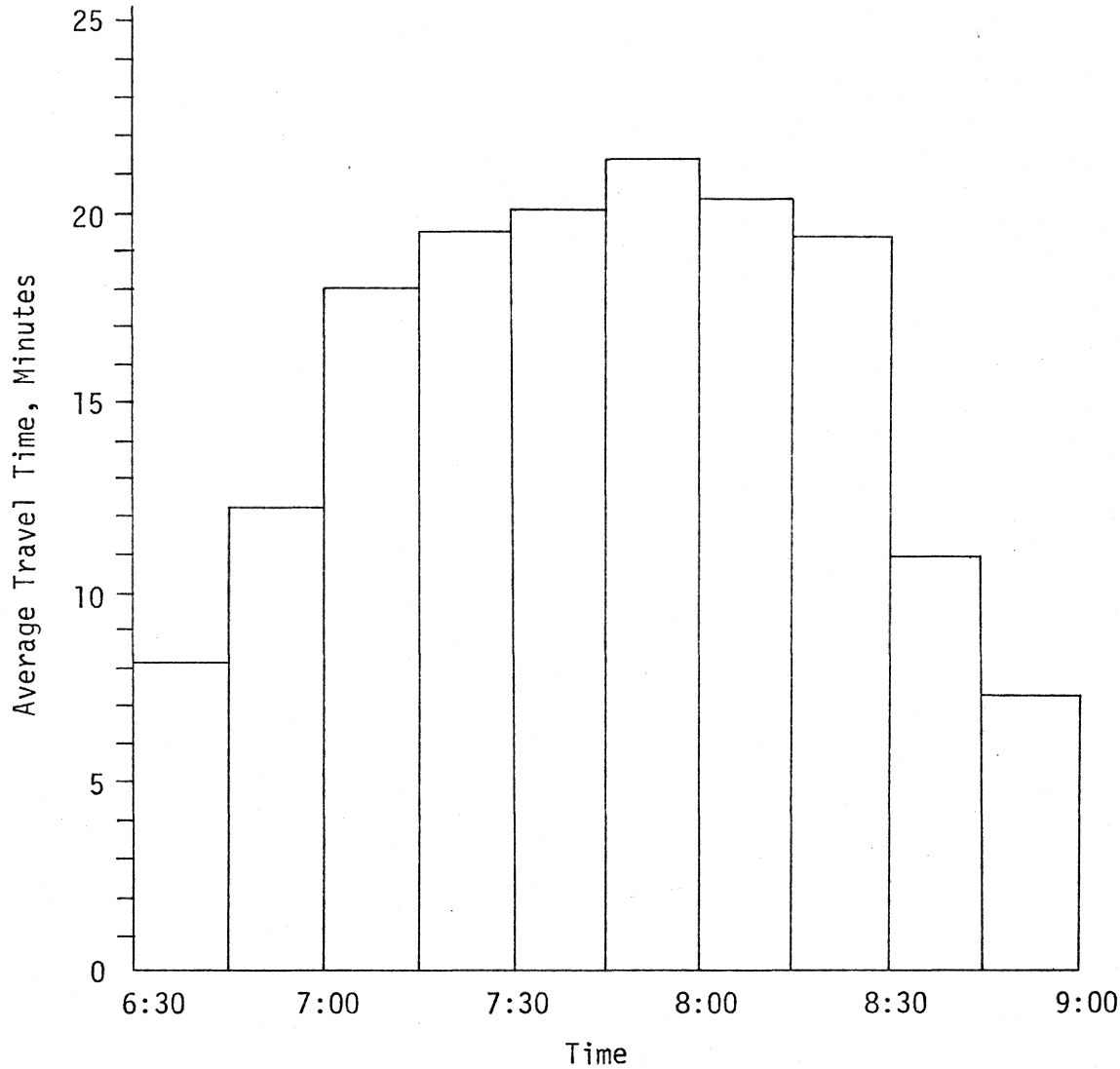

Figure 5. A.M. Peak Period Automobile Travel Times
Shirley Highway from Route 7 to Potomac River

farther south the buses entered the busway, the more time was saved with respect to automobile travel. Table I summarizes the comparison of average bus and automobile travel times.

Due to the variations in the speed along the Shirley Highway, additional speed studies were made on April 12, 1972 at the study site. These studies, conducted during the peak hour (7:15 - 8:15 A.M.), revealed an average operating speed of approximately 30 MPH (20).

Shirley Highway Corridor Passenger Trends

A single roadway cannot be evaluated without considering the adjacent facilities within the same corridor. In the "Feasibility Study for Bus Rapid Transit in the Shirley Highway Corridor", the automobile, bus, and total passenger trends for the corridor were presented. During the years 1962 through 1968, the automobile and bus passengers in the corridor experienced an annual growth of 6.1% and 0.54%, respectively. During the same period, the annual growth for the total passengers (automobile and bus) in the Shirley Highway corridor was 4% (15).

In April, 1970, as part of the monitoring program, the Council of Governments established a screenline in the Shirley Highway corridor that intercepted all major radial roadways (7). The volumes on the inbound flows between 6:30 A.M. and 9:00 A.M. were recorded at roadside stations each month from April to November, 1970. After

TABLE I

Shirley Highway Automobile and Bus A.M. Travel Times

Peak Time Between Busway

Entrances and Potomac River

Busway Entrance	Automobile (Regular Lanes) Minutes	Bus (Busway) Minutes	Savings By Bus Minutes
Turkeycock	37	14	23
Seminary Road	30	9	21
Shirlington	16	6	10
Route 27	10	3	7

November, the counts were made on a reduced frequency schedule (17). The screenline counts for the corridor are presented in the Appendix. Figure 6 shows the corridor passenger trends covering the period from April, 1970, through March, 1972. The annual increase in bus passengers was 12% while the automobile passengers decreased 5%. Instead of the anticipated increase in total passengers crossing the screenline, Figure 6 indicates an annual decrease of 1% since the initiation of the count station.

Bus Patronage Trends

The A B & W Transit Company began counting passengers on all local buses using the exclusive lanes during the A.M. peak period when the first segment was opened in September, 1969. As each section opened and more buses were able to use the busway, passenger counts were initiated on those bus routes (17).

Passenger and bus vehicle counts were made by the company on a regular basis every two weeks. Counting locations were chosen near the busway entrance at points where the buses were moving slowly or were stopped for a short period of time (17).

Buses, such as Trailways, Greyhound, school, and military, used the busway but were not recorded in the A B & W counts. Many of the trips made by those buses were chartered and unscheduled, and, consequently, the Council of Governments did not desire to include them in the monitoring program. Trips of an unscheduled nature could

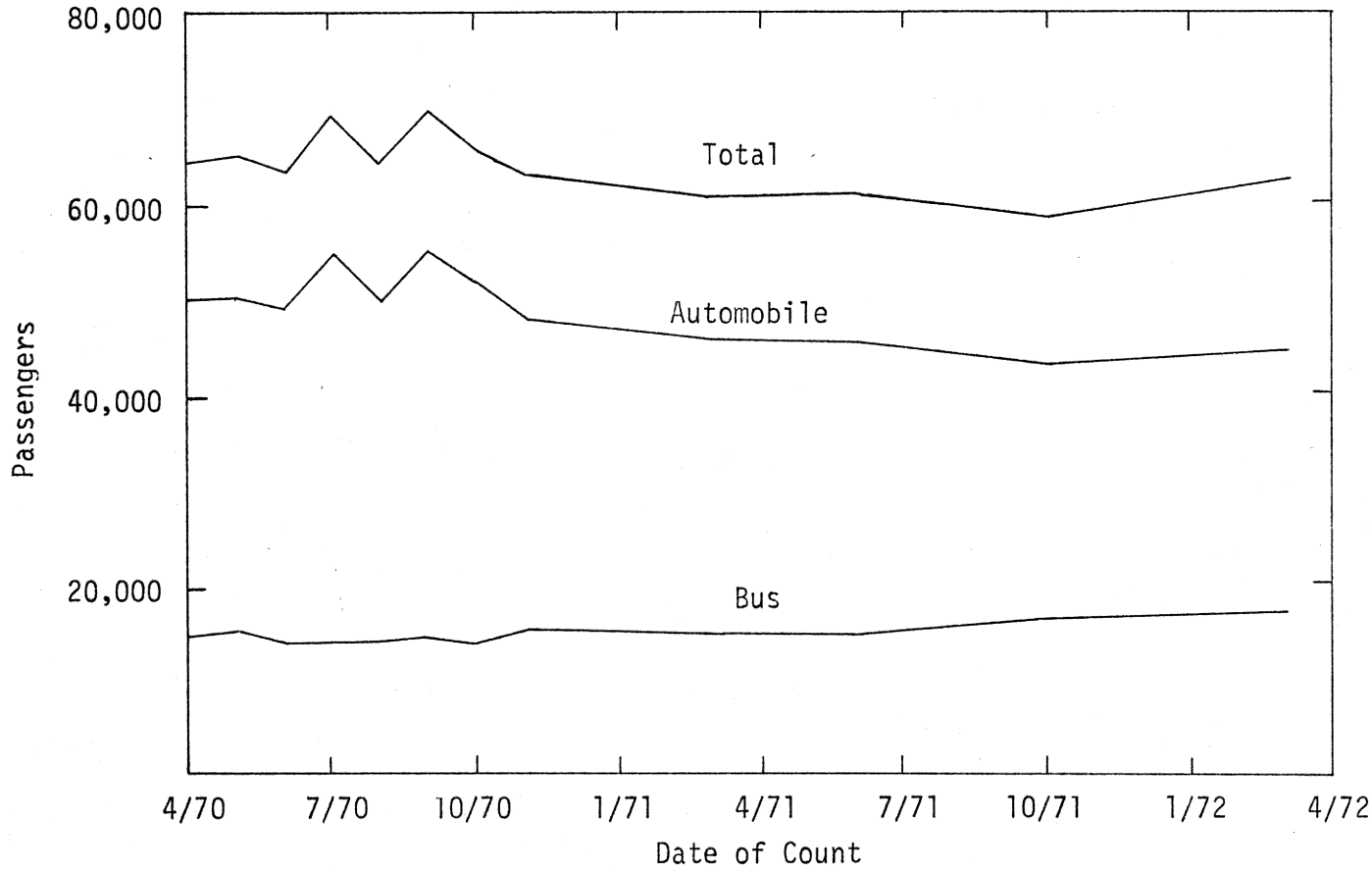

Figure 6. A.M. Peak Period Passenger Counts
Shirley Highway Corridor

destroy the effectiveness of the patronage and vehicle trends; however, many scheduled trips were not included in the survey because of the Council's action. An indication of the magnitude of the service provided by the special buses was revealed in a count taken in May, 1971, when 1,027 passengers were observed riding 35 buses during the A.M. peak period (17). Although the counts were not secured, the officials of the special bus companies stated that additional express service between Prince William County and Washington, D. C. was placed into operation due to the time savings encountered on the exclusive busway.

Figure 7 presents the bus passenger counts south of Shirlington. The first count was made in August, 1969, one month prior to the opening of the busway. The project enjoyed a large increase in patronage over the initial 2,000 passengers on opening day. In April, 1972, approximately 6,800 persons used the facility, an increase of 240% during the thirty-one month period.

The additional bus service that was provided is shown in Figure 8. The total number of bus trips, south of Shirlington, increased from 34 to 135 during the study period. Many of the added trips were made by the new buses purchased and placed into service by the Northern Virginia Transportation Commission in June, 1971, and February, 1972 (26, 28).

One of the objectives of the demonstration project was to provide comfortable, as well as rapid and convenient, service (7). Figure 9 reveals that, south of Shirlington, the average ridership

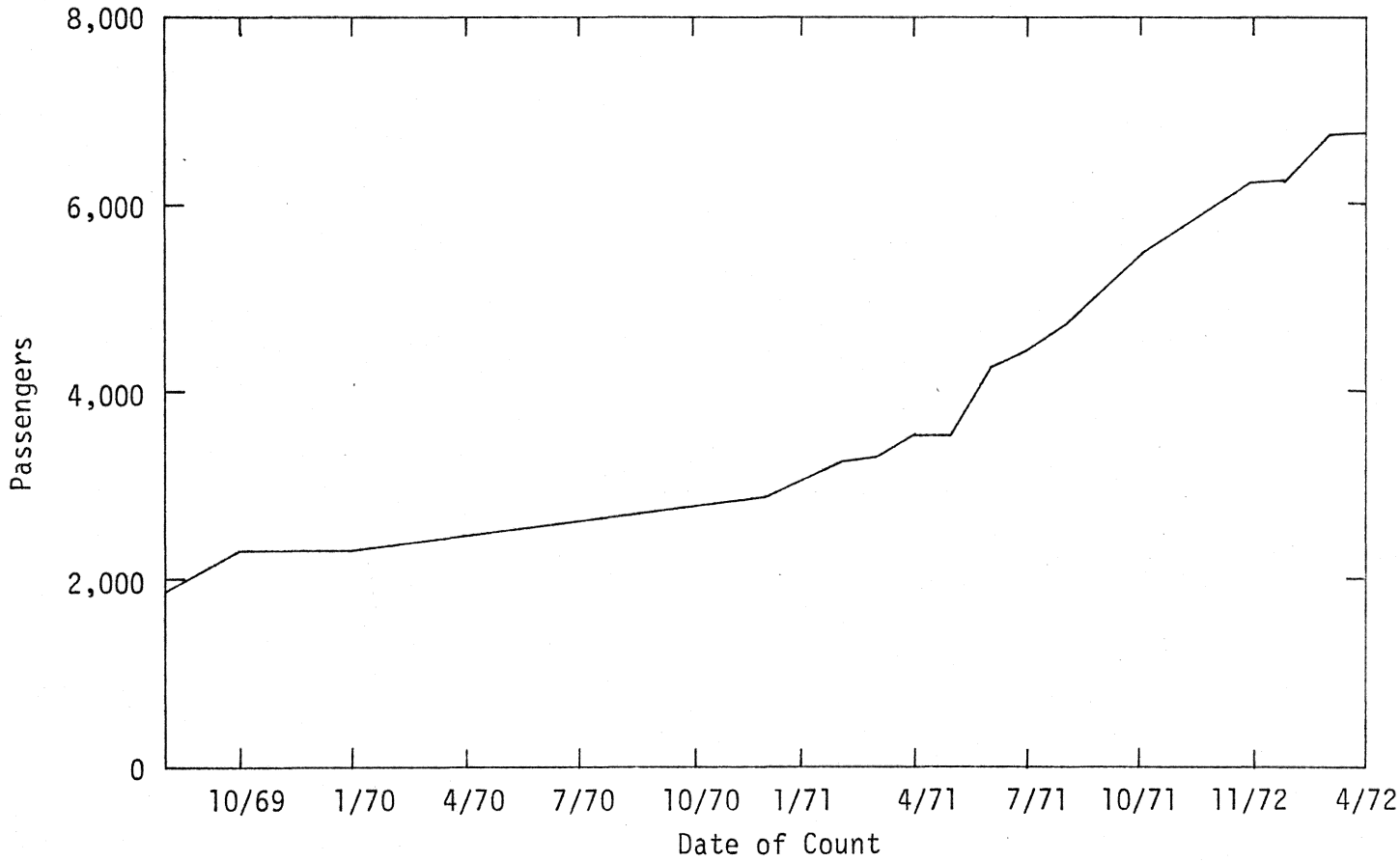

Figure 7. A.M. Peak Period Busway Passengers
Shirley Highway - South of Shirlington

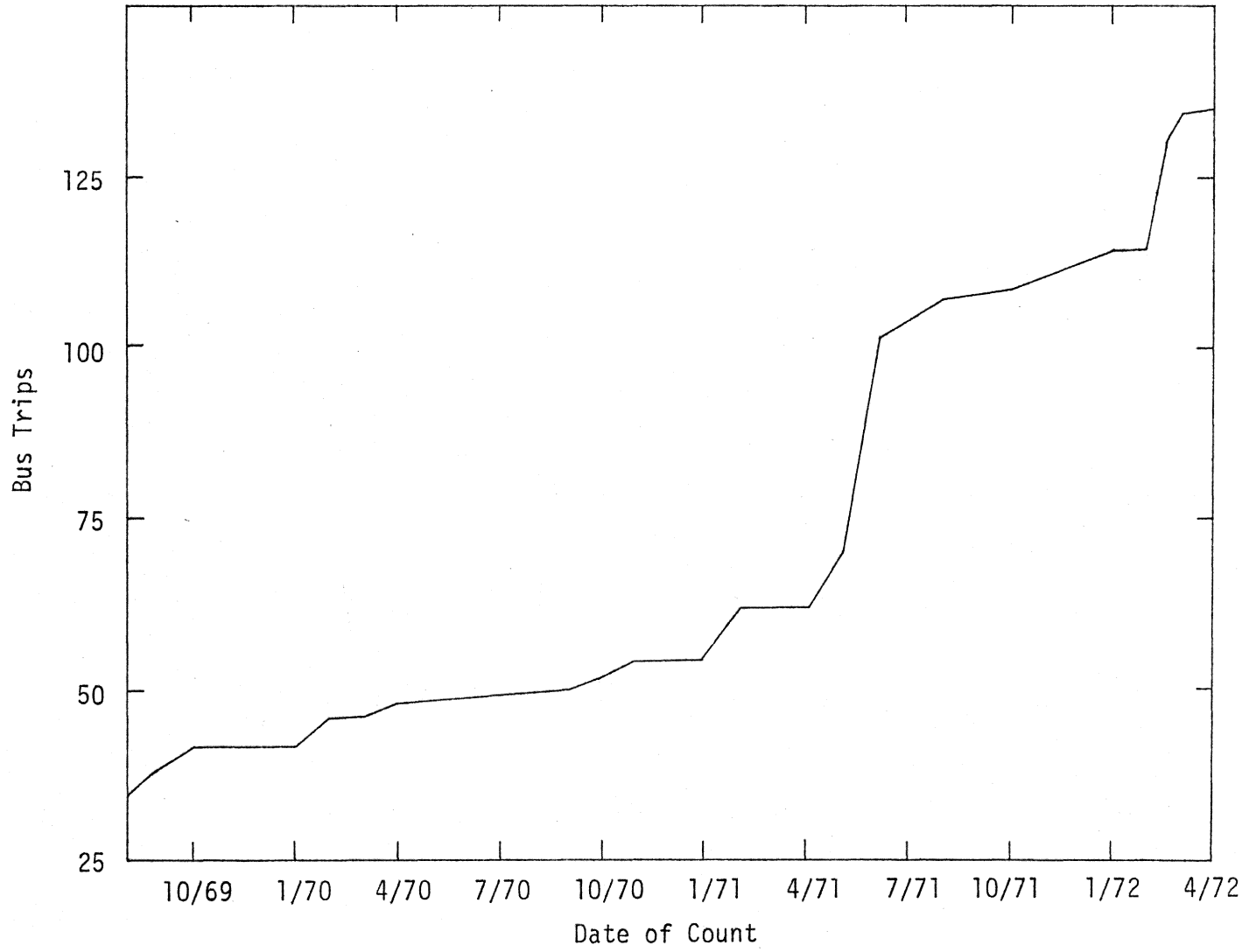

Figure 8. A.M. Peak Period Bus Trips
Shirley Highway - South of Shirlington

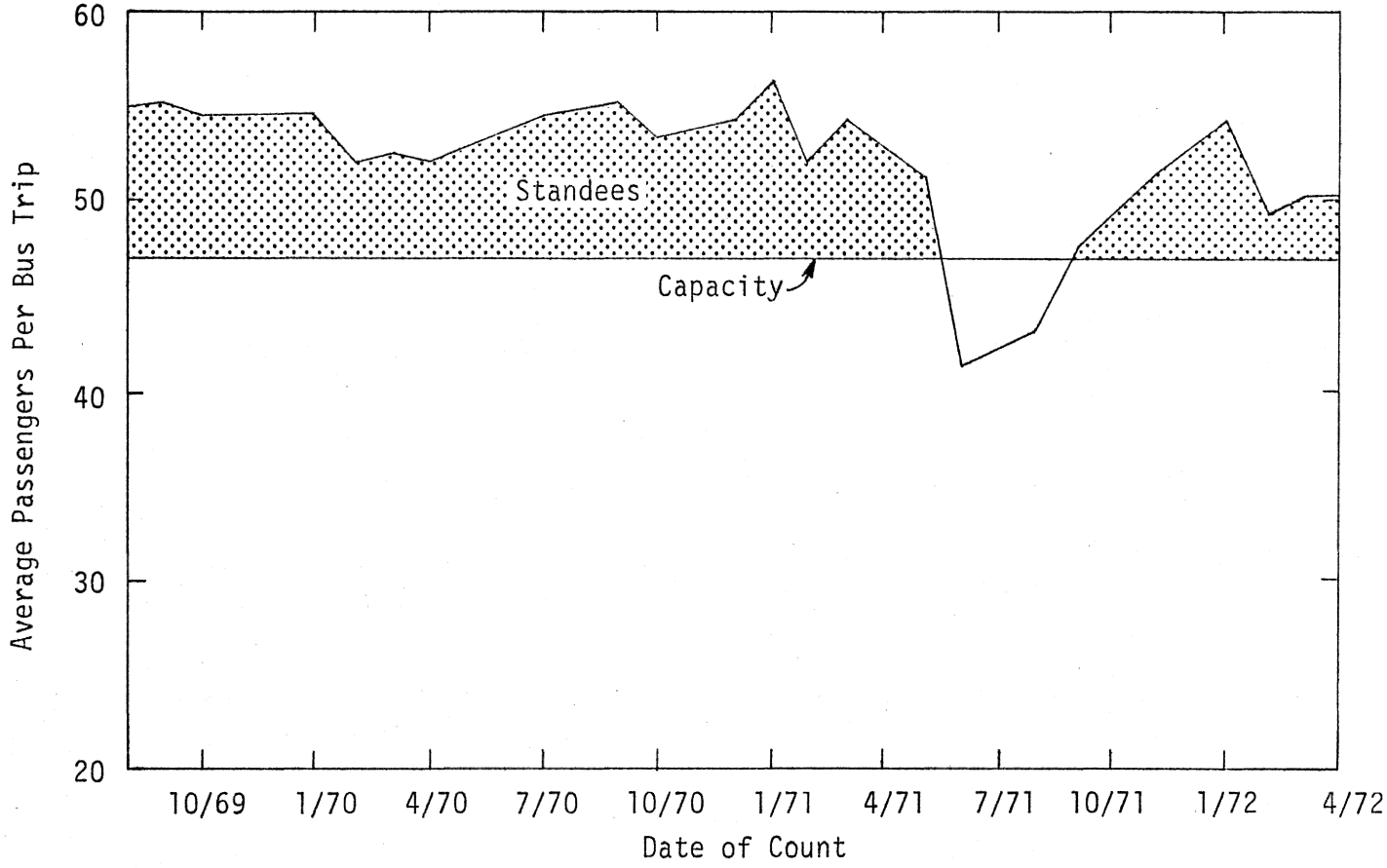

Figure 9. A.M. Peak Period Bus Occupancy
Shirley Highway - South of Shirlington

per bus exceeded the seating capacity (47 seats per bus). Many passengers were required to stand while traveling over the exclusive lanes. Except for a brief period after the 30 buses were added in June, 1971, the demand exceeded the supply. The result was a large number of standees as indicated by the shaded area in Figure 9.

The passenger trips, bus trips, and bus occupancy rates for the buses entering the busway via the ramp from Shirlington during the A.M. peak period are shown in Figures 10, 11, and 12, respectively. Figure 10 indicates that the patronage increase at Shirlington was approximately 30 percent. In April, 1971, after the entire busway opened, there was a significant drop in passengers entering at Shirlington. In May and June, the ridership was back to normal levels. The A B & W Transit Company had no explanation for the fluctuations.

Because of the increase in patronage in the Shirlington area, 8 bus trips were added during the study period, as revealed in Figure 11. The number of buses were sufficient to provide the passengers with seats. Figure 12 shows that the average occupancy rate never exceeded the seating capacity of the bus.

The passenger and bus trips at the study site were the sum of the trips entering the busway at and south of Shirlington. The study site data for the exclusive bus lane are presented in Figures 13 and 14. The patronage and service experienced much growth throughout the study period, but the greatest rate increase was realized after the entire busway was opened in April, 1971.

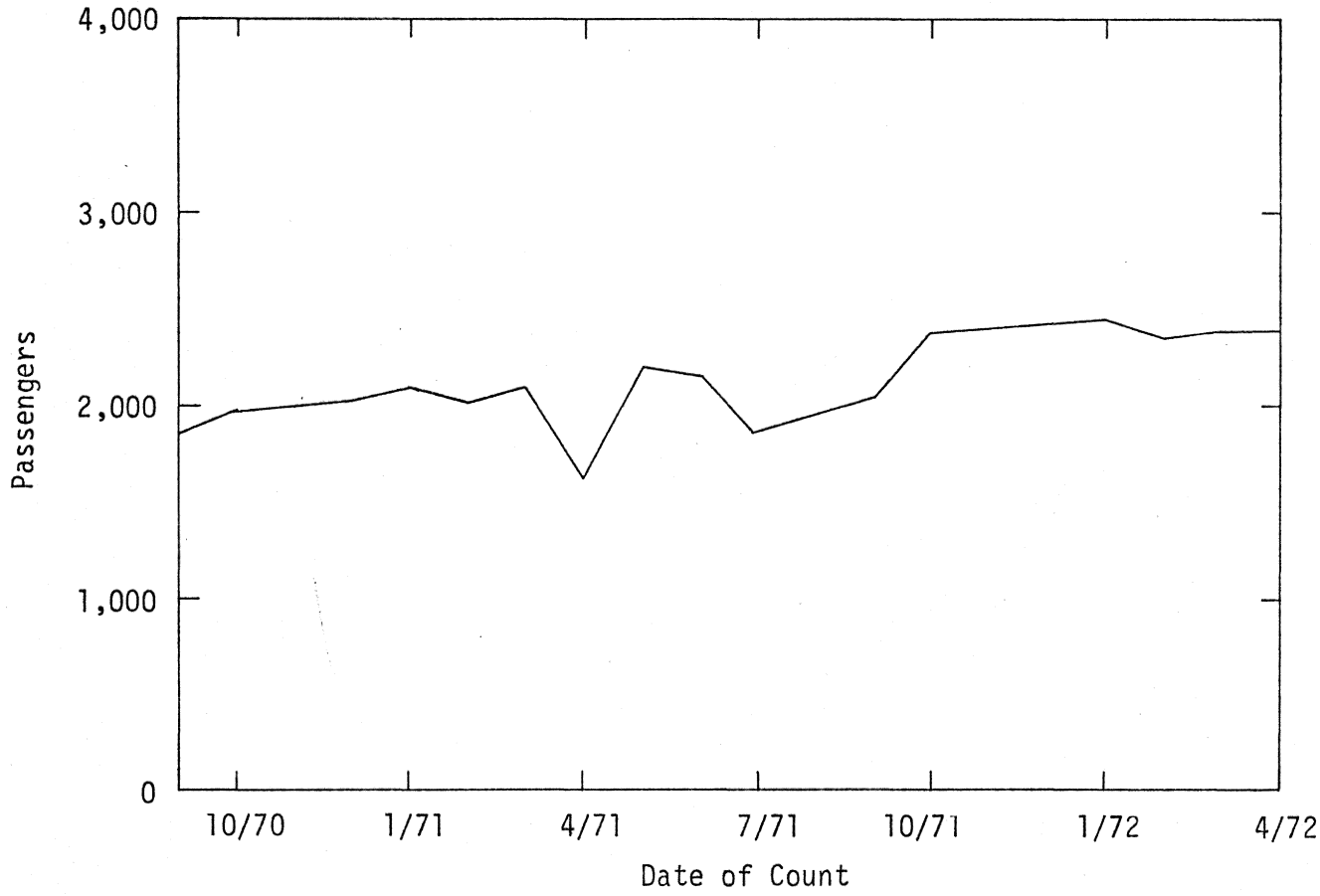

Figure 10. A.M. Peak Period Busway Passengers
Shirley Highway - Ramp from Shirlington

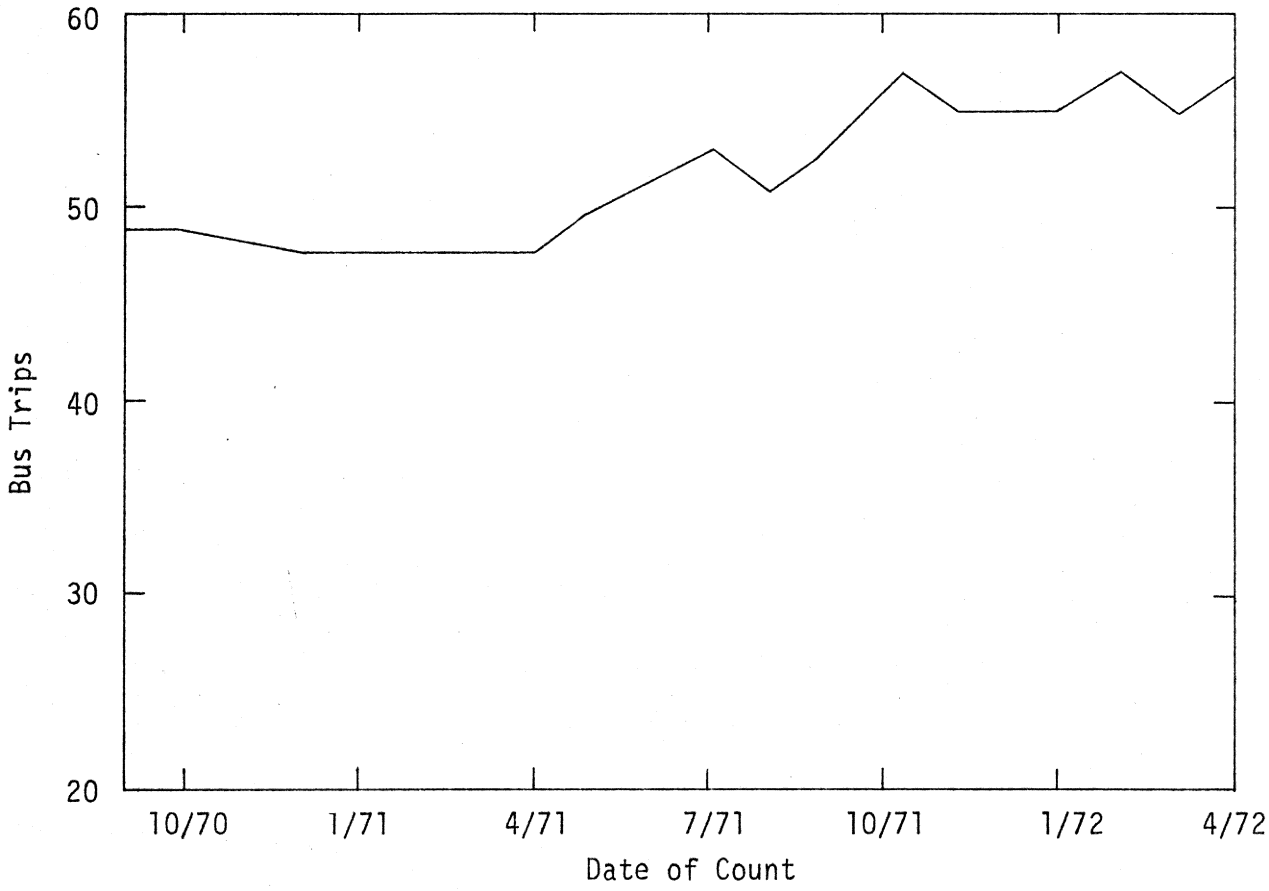

Figure 11. A.M. Peak Period Bus Trips
Shirley Highway - Ramp from Shirlington

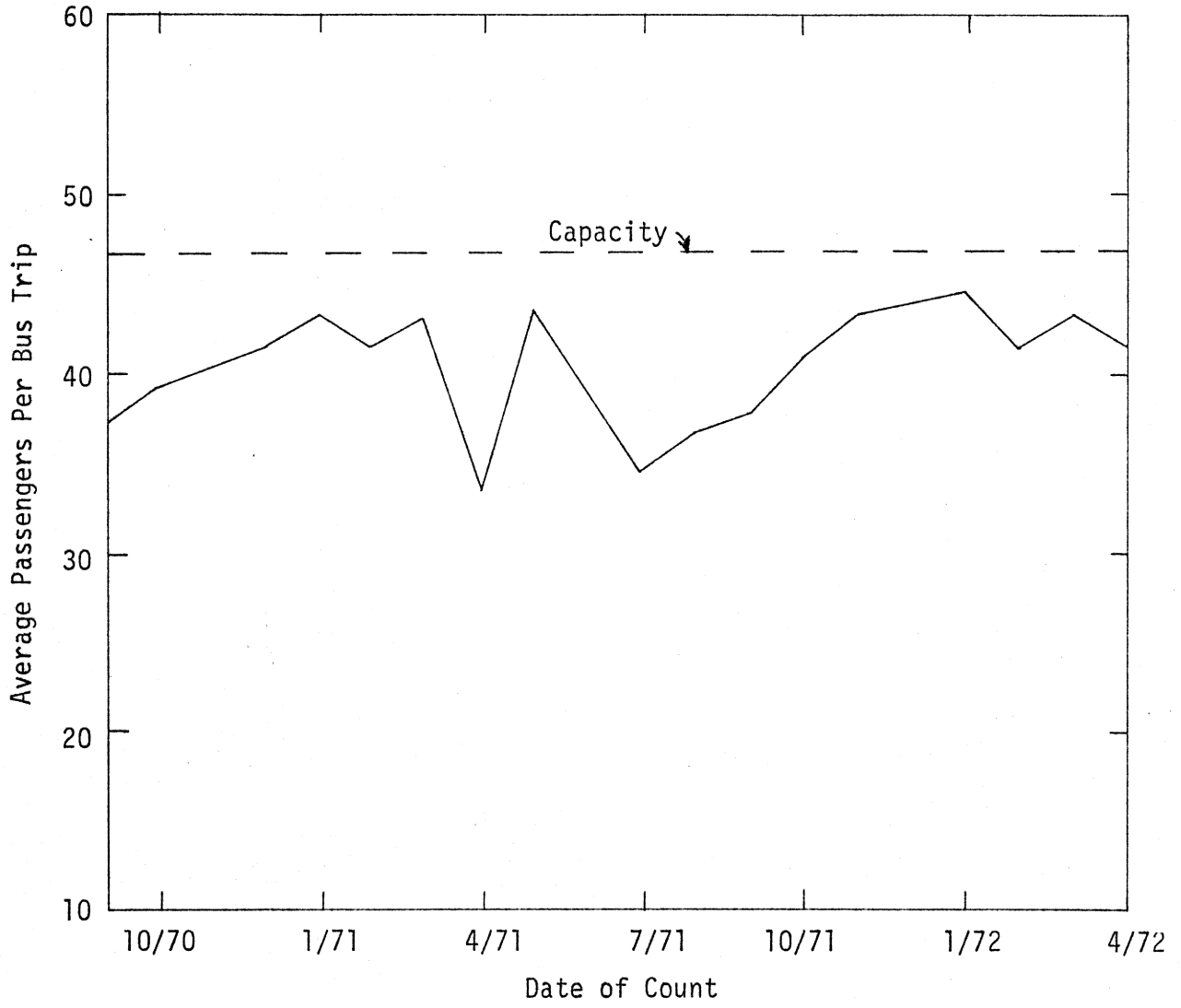

Figure 12. A.M. Peak Period Bus Occupancy
Shirley Highway - Ramp from Shirlington

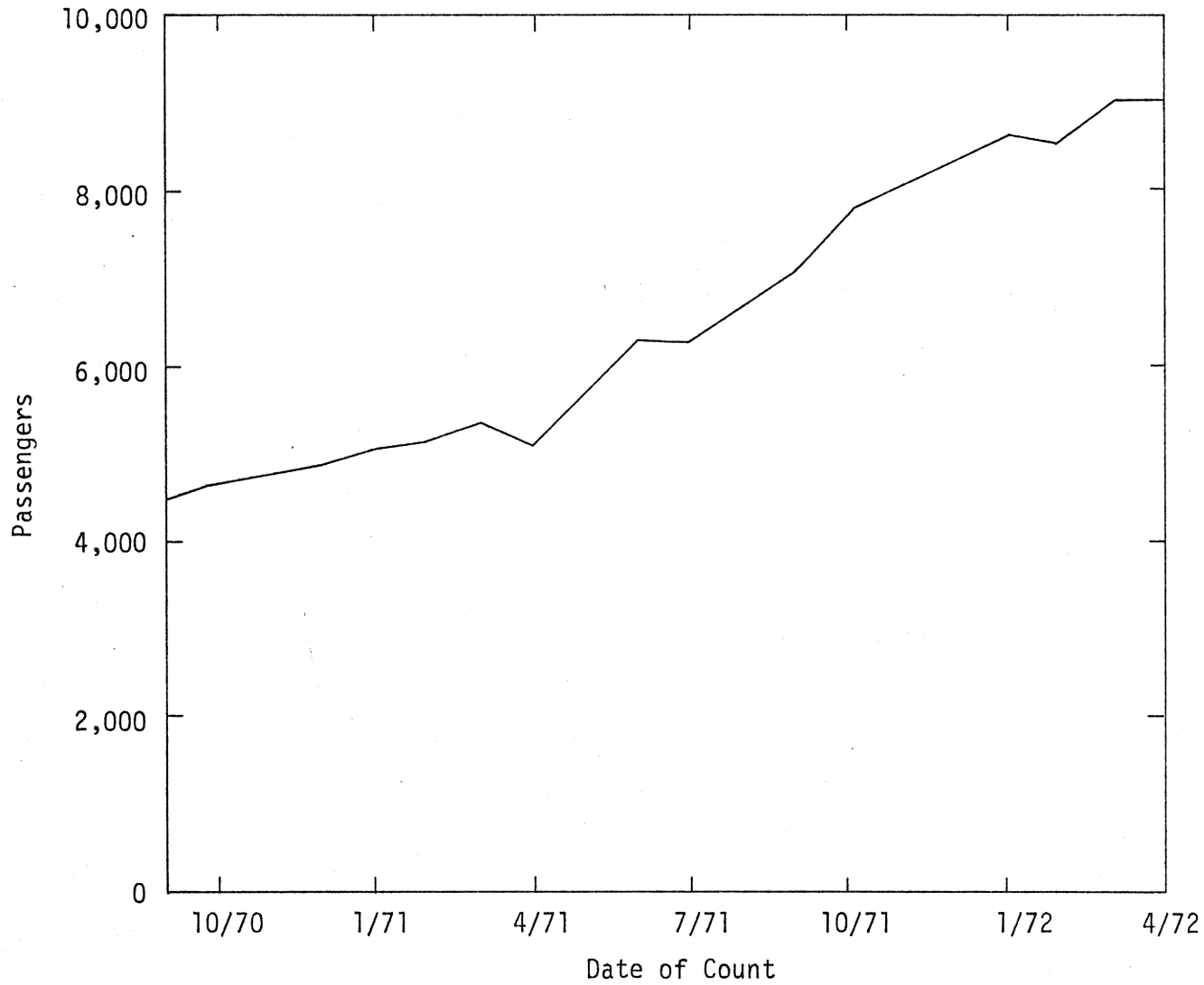

Figure 13. A.M. Peak Period Bus Passengers
Shirley Highway - Study Site

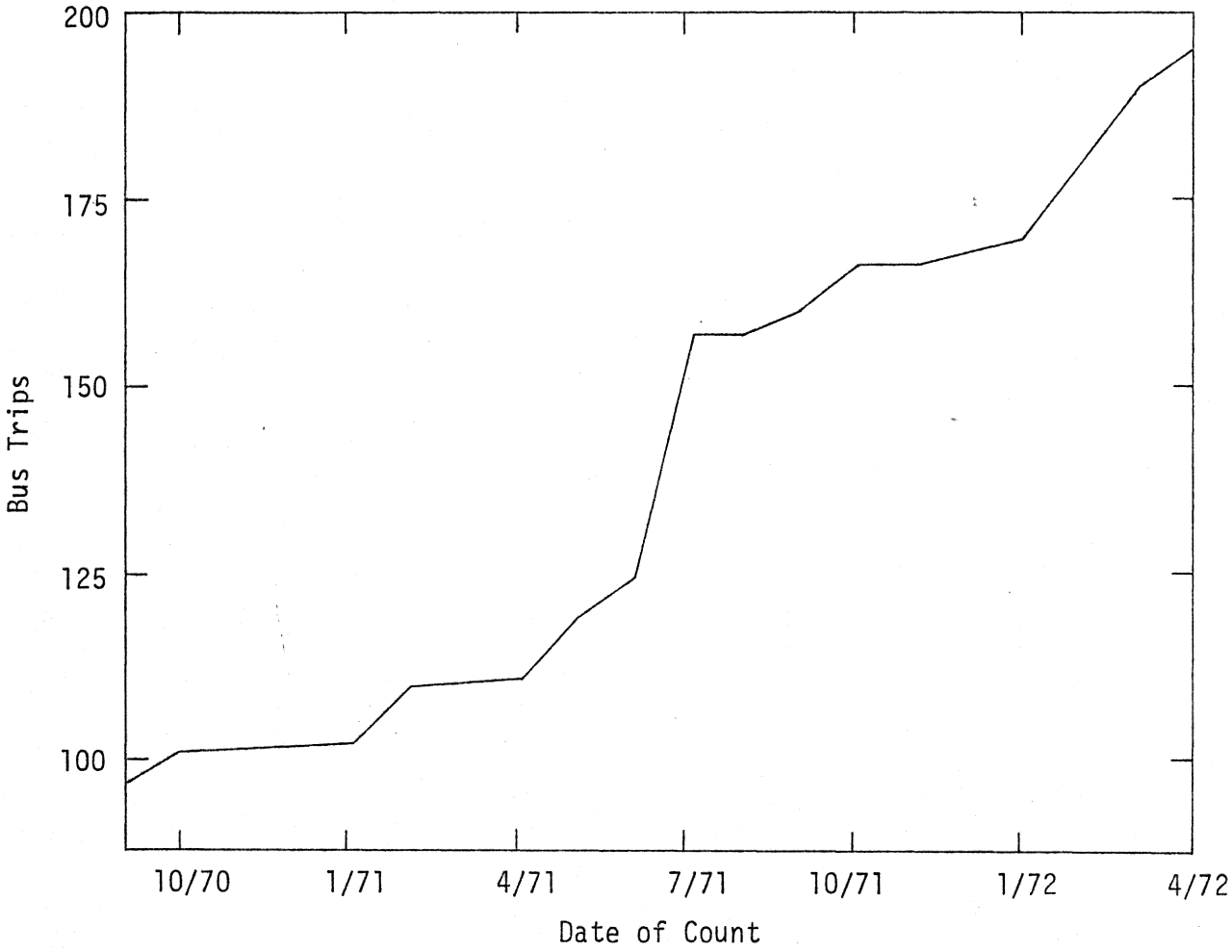

Figure 14. A.M. Peak Period Bus Trips
Shirley Highway - Study Site

In November, 1970, A B & W Transit Company increased its base fare from $0.35 to $0.50 for most riders (17). Figure 13 indicates that there was no decrease in the bus ridership because of the fare increase.

Automobile Travel Trends

Through the comprehensive count program, the Council of Governments secured automobile passenger and vehicular volumes on the Shirley Highway (7). The volumes were recorded between 6:30 A.M. and 9:00 A.M. and covered the study period from April, 1970, to March, 1972.

Figure 15 shows the automobile passenger volumes recorded at the study site during the A.M. peak period. The number of passengers reached a peak of 19,620 in July, 1970; however, at the end of the study period, the passenger trips had dropped to approximately 7,800. The vehicular trends, Figure 16, were similar to those of the passenger trips. The number of cars reached a peak of 9,300 in September, 1970; however, in March, 1972, the vehicles had decreased to approximately 5,600. The automobile occupancy rate for the Shirley Highway is shown in Figure 17.

Bus and Automobile Commuters Profiles

In October, 1971, the U. S. Department of Commerce sponsored an A.M. peak period survey of all commuters traveling through the Shirley Highway corridor.

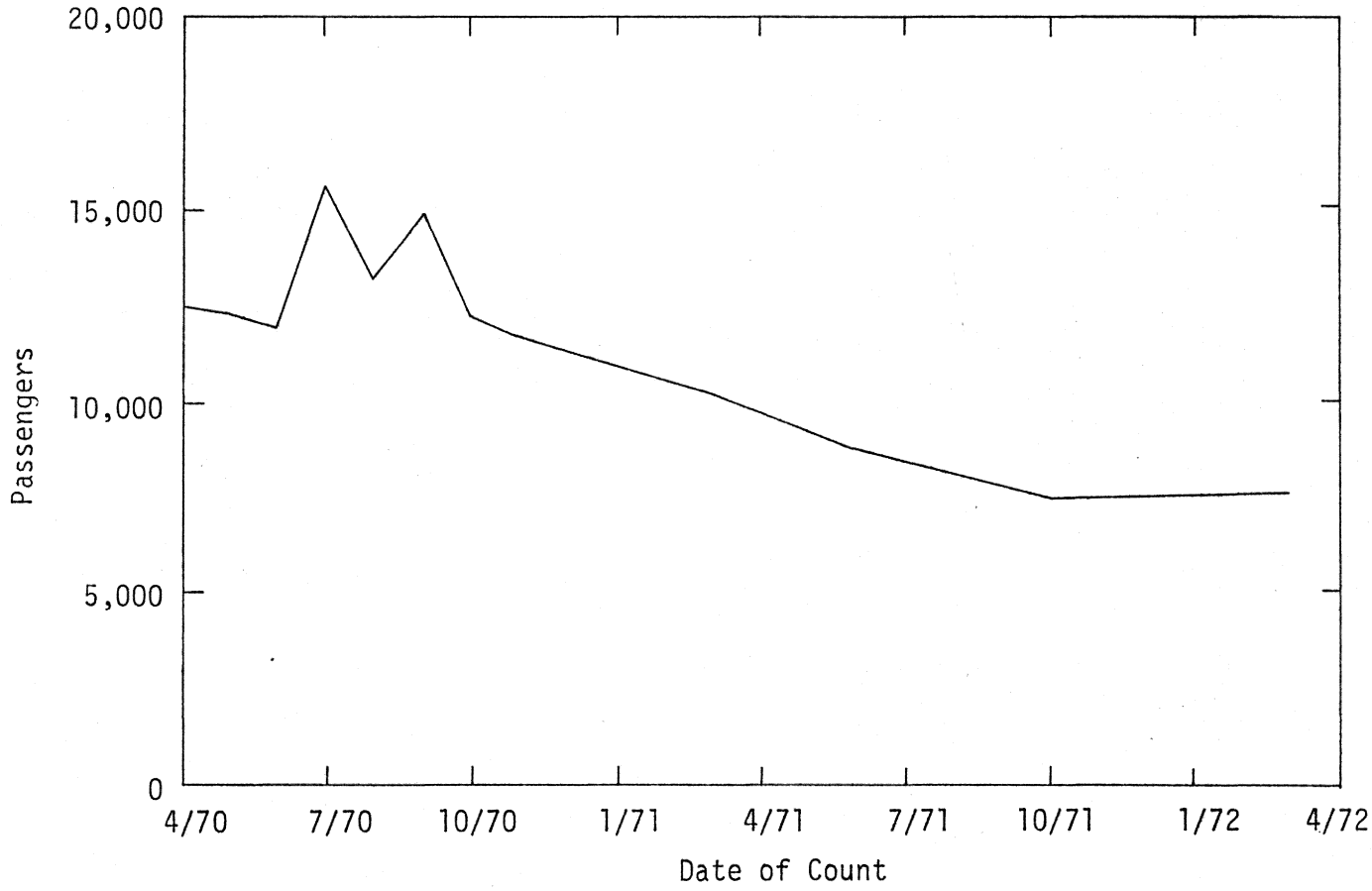

Figure 15. A.M. Peak Period Automobile Passengers
Shirley Highway - Study Site

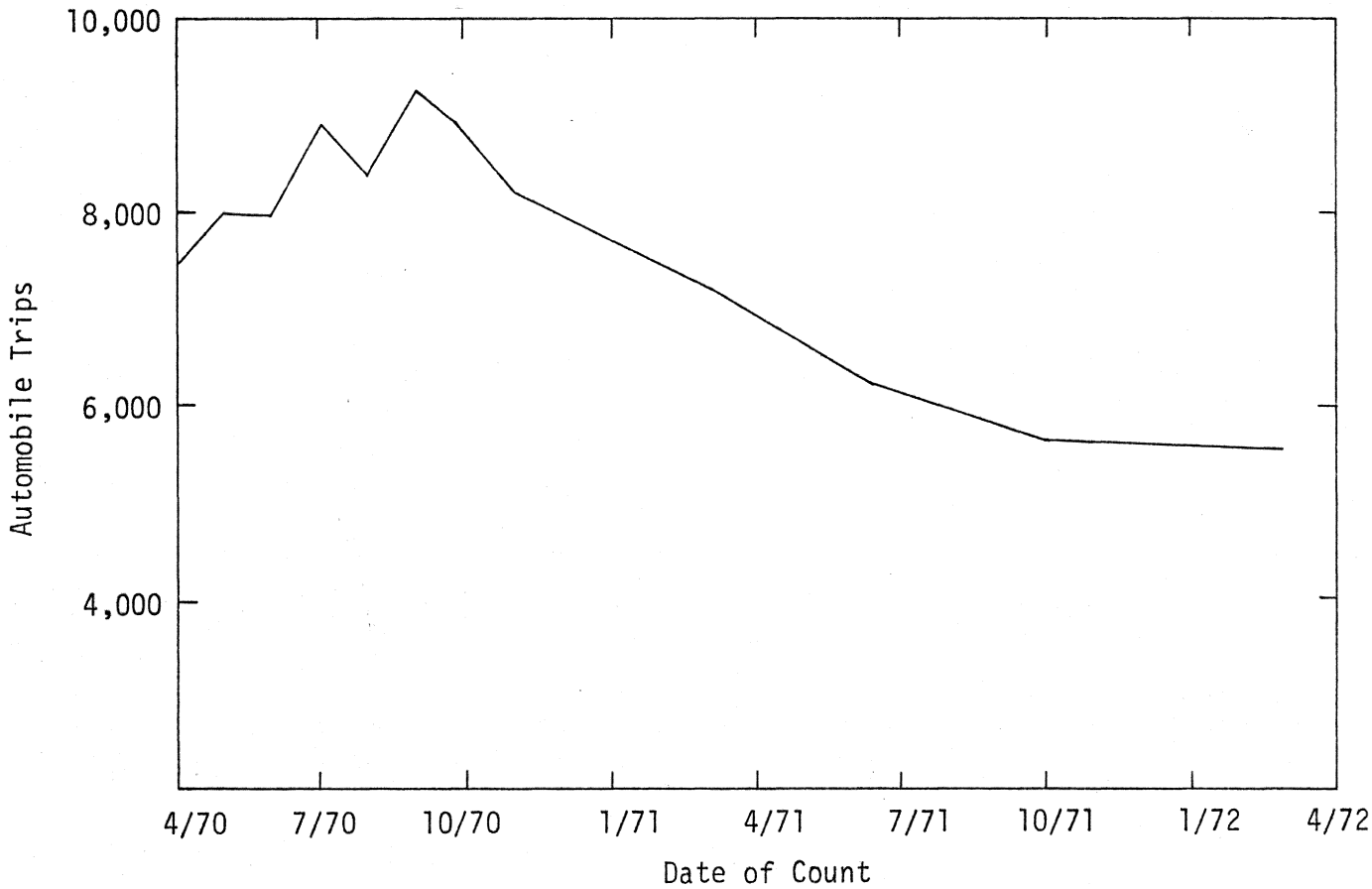

Figure 16. A.M. Peak Period Automobile Trips
Shirley Highway - Study Site

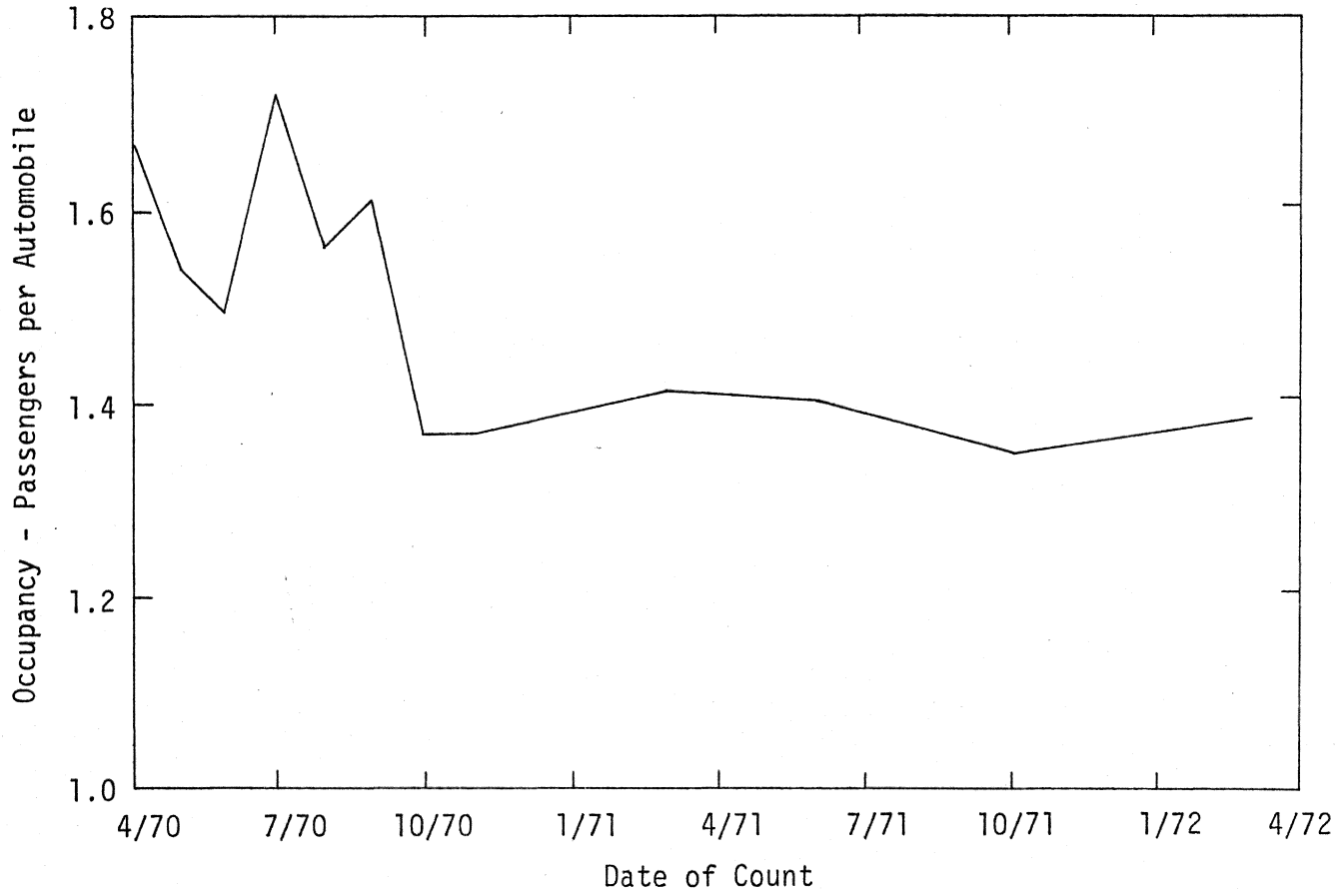

Figure 17. A.M. Peak Period Automobile Occupancy
Shirley Highway - Study Site

Mail-back questionnaires, Figure 18, were distributed to approximately 33% of all Shirley Highway bus users and 20% of all other bus users in the corridor. There was 51% response from the busway users while 58% of the non-Shirley Highway users completed the questionnaires. All bus users on local buses entering the busway south of, or at the Shirlington interchange were considered as Shirley Highway bus users. Riders on local buses that entered the busway north of Shirlington, or on buses that did not use the exclusive lane were designated as non-Shirley users.

The automobile commuter information was secured from questionnaires sent to a sample of the owners whose vehicles were observed crossing the screenline stations on the major radial routes in the Shirley Highway corridor. Figure 19 shows the automobile commuter questionnaire. A package of the survey forms was sent to the drivers of the observed vehicles. Each driver was asked to distribute the forms to passengers traveling with him on the day of the survey. The response rate was higher for automobile drivers (55%) than for automobile passengers (45%). A total of 3,130 questionnaires were returned from the automobile commuters.

Table II summarizes the data gathered in the Shirley Highway bus users survey. The majority of the bus patronage was the young working male with a good income who lived and worked within walking distance of the bus route. Almost two of every three bus users had a choice between the express bus system and their own automobiles.

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

THE FOLLOWING QUESTIONS CONCERN THE TRIP YOU ARE NOW MAKING

Please Answer All Questions and Drop in Mail-box—No Stamp Required

Form Approved
OMB No. 41-R-2555

1. What is the street address where this trip began? (your home address if this trip started at home)

17 street address (do not identify by street intersections) 46

47 City State 66 Zip

This address was:

☐ Home ☐ Other (specify) _____ 67

Time you began this trip _____ A.M. (left above address) 68 71

2. How do you usually get from this beginning address to the bus stop?

☐ Walk ☐ Driven by another person

☐ Drive car and park

☐ Other (specify) _____ 72

3. At what corner did you board this bus?

_____
(specify nearest street intersection)

PLEASE CONTINUE TO QUESTION 4 above →

4. Where did this trip end? (Your place of work address if work trip) 5 16

17 street address or building name 46

47 City State 66 Zip

This address was:

☐ Work ☐ Other (specify) _____ 67

Time this trip ended _____ A.M. (Arrived at above address) 68 71

5. How do you get from this bus to the above address? 72

☐ Walk

☐ Transfer to another bus and walk 6 16

☐ Other

6. What are your regular working hours? 17 20

_____ A.M.

_____ P.M. 21 24

PLEASE CONTINUE TO QUESTION 7 below

7. If you are a regular daily bus passenger, when did you begin using this bus? _____ month _____ year. 25 28

☐ I am not a regular bus passenger

8. How did you make this trip prior to using this bus?

☐ Didn't make this trip (from my present home to my present job location)

☐ Drove my car (carried no passengers)

☐ Was a driver carrying passengers (drove every day) 29

☐ Was an alternate driver (drove _____ days per week)

☐ Was an auto passenger

☐ Used another bus (specify route and bus company) _____ 30

9. On an average day when you board this bus do you find a seat? 31

☐ Always ☐ Usually ☐ Seldom ☐ Never

10. If you formerly drove a car or were a passenger in a car, why did you switch to the bus? _____ 32 33

_____

11. How many automobiles are owned or operated by members of your household? _____ 34

12. Was a car available to you for this trip?

☐ No (bus is only practical means)

☐ Yes, but with considerable inconvenience to others 35

☐ Yes, but I prefer to take the bus

13. How long have you lived at your present home address? _____ years _____ months. 36 39

14. Please indicate your: Sex ☐ M ☐ F Age ☐ Under 21 ☐ 21-39 ☐ 40-65 ☐ Over 65 40 41

15. What is the combined income of all members of your household?

☐ $0-$5,000 ☐ $5,001-$15,000 ☐ $15,001-$30,000 ☐ Above $30,000 42

16. Not thinking of the good or bad points of bus service in your particular area, how would you rate your general attitude toward traveling to work by bus? 43

☐ Very Positive ☐ Positive ☐ Negative ☐ Very Negative

17. What are your comments on this bus service? _____

_____

_____

THANK YOU—PLEASE SEAL AND MAIL

Figure 18. Bus Commuter Questionnaire

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

Did you make a trip by automobile on last Tuesday, Wednesday, or Thursday morning between 6:30 A.M. and 9:00 A.M.?

☐ Yes, Please Answer Questions and Drop in Mail-box—No Stamp Required

☐ No (Please Return Questionnaire Without Answering Questions)

12 13 1 16

Form Approved
OMB No. 41-R-2554

1. What is the street address where this trip began? (Your home address if this trip started at home)

17 street address (do not give street intersections) 46

47 City State 66 Zip

This address was:

☐ Home ☐ Other (specify) _____ 67

Time you began this trip _____ A.M.
(left your beginning address) 68 71

2. Where did this trip end? (Your place of work address if this is a trip to work) 2

17 street address or building name 45 16

47 City State 66 Zip

This address was:

☐ Work ☐ Other (specify) _____ 67

Time this trip ended _____ A.M.
(Arrived at above address) 68 71

CONTINUE TO QUESTION 3 above

3. When you made this trip were you 3 16
☐ the auto driver (no passengers)?
☐ a driver carrying passengers (who drives every day)?
☐ an alternate driver. How many days a week do you drive _____? 17
☐ a regular passenger. How much do you pay?
$_____ per _____ ☐ do not pay. 18 22

4. How many people regularly travel together in the automobile that you drive or ride to work? _____ 23

5. What is the vehicle parking cost?
$_____ per _____ 24 28

6. Do you usually need your car during the business day? ☐ yes ☐ no 29

7. What are your regular working hours?
_____A.M. to _____P.M. 30 33

CONTINUE TO QUESTION 8 below 34 38

8. If you formerly made this trip by bus why did you switch to auto? _____ 39

9. How many autos are owned or operated by members of your household? _____ 40

10. Please indicate your Sex: ☐ M ☐ F Age: ☐ Under 21 ☐ 21-39 ☐ 40-65 ☐ over 65 41 42

11. What is the combined annual income of all members of your household?

☐ under $5,000 ☐ $5,001 to $15,000 ☐ $15,001 to $30,000 ☐ above $30,000 43

12. Could you have used the Shirley Highway Express Bus system for this trip?

☐ Yes, but I choose not to because _____

☐ No, because _____

☐ Don't know. 44 46

13. Not thinking of the good or bad points of bus service in your particular area, how would you rate your general attitude toward traveling to work by bus?

☐ Very Positive ☐ Positive ☐ Negative ☐ Very Negative 47

14. What are your feelings toward allowing fast bus travel on the Shirley Highway through use of exclusive bus lanes?

_____

_____

_____

_____

_____

THANK YOU—PLEASE SEAL AND MAIL

Figure 19. Automobile Commuter Questionnaire

TABLE II

Shirley Highway Bus Commuter Profile

Characteristic	Type	Percentage
Sex	Male	60
Age (years)	Under 25	4
	21 - 39	59
	40 - 65	36
	Over 65	1
Income (annual family in dollars)	0 - 5,000	1
	5,001 - 15,000	37
	15,001 - 30,000	56
	Over 30,001	6
Automobiles/household	0	6
	1	59
	2	30
	3	4
	4 or more	1
Trip purpose	Work	98
Access mode	Walk	75
	Kiss and ride	9
	Park and ride	16
Egress mode	Walk	93
	Bus transfer	7
Transportation status	Captive (no automobile)	22
	Choice (automobile available)	62
	Automobile available but hardship	16
Reason for diversion to bus	Bus faster	24
	Car not available	20
	Traffic congestion	16
	Express bus	13
	Other (no parking, expense, etc.)	27
Previous mode choice	Did not make trip	50
	Drove alone	17
	Automobile passenger	6
	Alternate driver	5
	Drove with passenger	2
	Another bus	20

The majority of the "choice" riders stated that the contributing factor for their "taking-the-bus" was the fast service provided by the exclusive lanes which avoided the conventional traffic congestion.

A comparison of the Shirley and non-Shirley bus commuters is shown in Table III. In contrast to the male riders on the Shirley express system, the majority of passengers on the non-Shirley service were young females who lived near the bus routes. They owned fewer automobiles, and, therefore, a higher percentage were classified as "captive" riders. Although the non-Shirley users were less favorable to bus travel, their chances of finding a seat were superior to the Shirley service. The Shirley passengers made greater use of the fringe parking facilities and had to make fewer transfers than the conventional bus riders. The data indicated the Shirley express system was more attractive than the regular bus service.

The results of the automobile commuter questionnaire are summarized in Table IV. The automobile users in the corridor were affluent, with the majority having family incomes in excess of $15,000 per year, and owning two or more automobiles. Approximately three quarters of the automobile users were male, with the majority between 40 and 65 years of age. Only 17% of the commuters needed their vehicles during the day, and the majority made the trip alone. The majority of the automobile users did not pay any parking cost, and 28% had negative attitudes while 11% had very negative attitudes toward com-

TABLE III

Comparison of Shirley and Non-Shirley Bus Commuters

Characteristic	Shirley	Non-Shirley
Sex: Male	60%	46%
Age (years): Under 21	4%	5%
21 - 39	59%	50%
40 - 65	36%	43%
Over 65	1%	2%
Income ($/year): 0 - 5,000	1%	3%
5,001 - 15,000	37%	44%
15,001 - 30,000	56%	46%
Over 30,001	6%	7%
Automobile/household	1.32	1.25
Choice (automobile available)	62%	48%
Captive (no automobile)	22%	36%
Seat availability: Always	51%	60%
Usually	29%	33%
Seldom	11%	6%
Never	9%	1%
Access: Walk	75%	80%
Kiss and ride	9%	10%
Park and ride	16%	9%
Other	0%	1%
Egress: Walk	93%	89%
Bus transfer	7%	10%
Other	0%	1%
Previous mode: Did not make trip	49%	62%
Drove alone	17%	12%
Used another bus	20%	14%
Carpooled	14%	12%

TABLE IV

Shirley Highway Automobile Commuter Profile

Characteristic	Type	Percentage
Sex	Male	73
Age (years)	Under 21	1
	21 - 39	44
	40 - 65	54
	Over 65	1
Income (annual family	0 - 5,000	0
	5,001 - 15,000	28
	15,001 - 30,000	58
	Over 30,001	14
Automobile/household	0	2
	1	37
	2	50
	3	9
	4 or more	2
Class of traveler	Drove alone	54
	Alternate driver	18
	Driver with passenger	14
	Regular passenger	14
Automobile required during day	Yes	17
	No	83
Could use Shirley bus system	Yes	28
	No	64
	Don't know	8
Parking cost (cents)	Free (0)	56
	1 - 50	10
	51 - 100	14
	101 - 150	8
	151 - 200	6
	201 - 250	4
	Over 251	2
Attitude toward bus travel	Very positive	14
	Positive	47
	Negative	28
	Very negative	11

muting by bus. There was a good potential market for bus patronage on the Shirley exclusive lanes as 28% of the automobile commuters reported that they could use the bus service.

Classification Traffic Volumes

In the application of the Highway Capacity Manual technique for examining the level of service, data were required relating to the classification of vehicles (12). Classification volumes, recorded in 5-minute intervals, were secured at the study site on April 12, 1972, during the A.M. peak period (20). These counts are presented in Table V.

An examination of Table V reveals that the peak-hour vehicular flow occurred between 6:30 and 7:30 A.M.; however, the major consideration of this study was the movement of people instead of vehicles. The "people-moving" peak hour, shown in Table VI, was between 7:15 and 8:15 A.M. when 131 local buses utilized the exclusive bus lane.

The classification traffic data, also revealed a total of 52 special buses traveling over the busway during the A.M. peak period. Special buses consisted of Trailways, Colonial Transit, Greyhound, military, etc., which were not included in the Council of Governments' monitoring program. Unfortunately, the number of passengers on the special buses was not recorded in the classification counts.

TABLE V

Shirley Highway Classification Traffic Volumes
A.M. Peak Period

Time - A.M.	Regular Lanes			Express Busway	
	Pass. Autos and Pickups	Trucks	Total	Local Buses	Special Buses
6:30-6:35	305	5	310	0	1
6:35-6:40	332	9	341	0	1
6:40-6:45	304	9	315	2	3
6:45-6:50	271	7	378	3	0
6:50-6:55	326	6	332	5	1
6:55-7:00	284	5	289	4	1
7:00-7:05	196	0	196	4	0
7:05-7:10	213	5	218	6	1
7:10-7:15	207	5	212	7	2
7:15-7:20	191	9	200	8	3
7:20-7:25	168	2	170	11	2
7:25-7:30	172	10	182	12	3
7:30-7:35	204	6	210	10	3
7:35-7:40	217	12	229	11	4
7:40-7:45	224	10	234	10	5
7:45-7:50	184	6	190	13	1
7:50-7:55	182	4	186	11	2
7:55-8:00	212	11	223	14	3
8:00-8:05	152	18	170	11	2
8:05-8:10	108	9	117	8	2
8:10-8:15	91	11	102	12	2
8:15-8:20	110	11	121	5	1
8:20-8:25	92	8	100	7	2
8:25-8:30	78	7	85	5	1
8:30-8:35	148	10	158	3	1
8:35-8:40	153	18	171	4	1
8:40-8:45	129	15	144	3	1
8:45-8:50	126	5	131	1	2
8:50-8:55	180	15	195	1	0
8:55-9:00	140	11	151	1	1
Total	5,699	259	5,958	192	52

TABLE VI

Shirley Highway Classification Traffic Volumes
A.M. "People-moving" Peak Hour

Time - A.M.	Regular Lanes			Express Busway	
	Pass. Autos and Pickups	Trucks	Total	Local Buses	Special Buses
7:15-7:20	191	9	200	8	3
7:20-7:25	168	2	170	11	2
7:25-7:30	172	10	182	12	3
7:30-7:35	204	6	210	10	3
7:35-7:40	217	12	229	11	4
7:40-7:45	224	10	234	10	5
7:45-7:50	184	6	190	13	1
7:50-7:55	182	4	186	11	2
7:55-8:00	212	11	223	14	3
8:00-8:05	152	18	170	11	2
8:05-8:10	108	9	117	8	2
8:10-8:15	91	11	102	12	2
Total	2,105	108	2,213	131	32

CHAPTER IV

ANALYSIS OF RELEVANT VARIABLES

A major objective of the Shirley Highway Express-Bus-on-Freeway Demonstration Project was to provide rapid and convenient service that would attract a significant number of passengers who formerly commuted by automobile. The diversion of automobile passengers to buses would reduce the number of automobiles on the Shirley Highway, thereby, relieving the congestion and improving the level of service for all commuters. An analysis of the attractiveness and effects of the busway are presented in the following sections.

Bus Patronage

The bus patronage trends on the exclusive lanes were observed closely as the feasibility of the demonstration project was dependent upon an increase in ridership. To estimate the bus patronage growth at the study site during the A.M. peak period, two groups of data were reviewed and combined. The combination of data was required because the busway was opened in stages, and complete data were not gathered at the study site throughout the study period.

The first segment south of the study site was opened in September, 1969, resulting in a huge increase in patronage over the initial 2,000 passengers on opening day as shown in Figure 7. On April 11, 1972 (the end of the study period), approximately 6,800

persons used the facility; an increase of 4,800 (240%) person trips. Figure 8 shows that an additional 101 bus trips were placed into service to supply the patronage demand during the thirty-one month period.

The second segment of the busway, which included an access ramp at the Shirlington Interchange, was opened in September, 1970. At the time of implementation, an additional 1,825 bus passengers were able to receive the benefits of the busway via the Shirlington ramp. Figure 10 indicates that at the end of the study period, the ridership on the ramp had increased by 558 passengers for a total of 2,383 passengers during the A.M. peak period. To accommodate the passenger growth, 8 new bus trips were placed into service as shown in Figure 11.

In the foregoing analysis, it was determined that 558 and 4,800 passengers were attracted to the busway at and south of Shirlington, respectively. Therefore, the sum of these increases reveal that an additional 5,358 passengers (gross increase) started riding the buses during the study period at the study site.

The gross increase in bus patronage at the study site was subject to several constraints and assumptions before an estimate could be made of the passengers diverted from automobiles on the Shirley Highway.

The constraints were as follows:

1. Historical passenger trends in the Shirley Highway corridor: The feasibility study reported that the annual growth in total passengers in the corridor between 1962-68 was 4%. During the same period, bus patronage increased 0.54% (15). Surprisingly, after the initiation of the demonstration project, the total passengers crossing the Shirley Highway corridor screenline decreased. Between April, 1970 and March, 1972, the annual decline equalled 1%. The small variation in the total passenger trends during the study period indicated that the "historical" increase or decline in bus patronage was small, and in the analysis it was assumed negligible.
2. Diversion from non-Shirley Highway bus routes: The introduction of the improved service on the Shirley Highway had an impact on the adjacent bus routes. The estimate of the degree of diversion from other routes was obtained from the results of question 8 in the "on-board" bus survey (Figure 18). In answer to the question, "How did you make this trip prior to using this bus?", Table III indicates that 14% of the non-Shirley bus users and 20% of the passengers on the Shirley bus system replied, "Used another bus". The percentage on the conventional line (non-Shirley buses) described the dynamic bus market in the Shirley corridor. The commuters continuously

changed their trip patterns and travel modes. The assumption was made that the non-Shirley bus users represented the market in the corridor, as no improvements were made in their service. Therefore, the difference (6%) between the response of the Shirley and non-Shirley bus users made up the diversion of passengers from the non-Shirley routes to the Shirley express system. In other words, 6% of the total bus patronage growth on the Shirley Highway was diverted from other bus routes not served by the exclusive bus lane, and thus, did not relieve the congestion on the Shirley Highway.

3. Transient population in the Shirley Highway corridor: Table III shows that many of the bus users in the corridor did not make the trip prior to using the bus they were riding when interviewed. That indicated the transient population in the Shirley Highway corridor. During the study period, it was assumed the number of "captive" riders that moved into the area was approximately equal to the "captive" passengers that moved from the corridor. Another assumption was that the attractiveness of the busway was the same for all residents, regardless of the length of residency in the area.

Of the constraints presented, the major one was the passenger diversion (6%) from non-Shirley buses. A 6% reduction of the

busway's gross passenger growth (5,358) results in a net increase in patronage of 5,040 passengers. The net increase or growth represented the number of passengers who formerly commuted on the Shirley Highway and were attracted to the express bus system.

Source of Patrons

While a bus system should serve the demands of "captive" ridership, the fulfillment of the demonstration project objective was dependent upon a diversion of passengers from the automobile commuter population to the express bus system.

An analysis of the commuters profiles was conducted to determine the source of the patronage growth on the Shirley Highway exclusive busway. Tables II and III summarize the data gathered in the bus users survey and reveals that the Shirley Highway bus riders had a better choice of modes than the conventional bus users in the corridor. Almost 2 of every 3 Shirley Highway bus riders had a choice between the express bus system and their automobiles. The majority of the "choice" riders stated the contributing factor for their "taking the bus" was the fast service provided by the exclusive lanes which avoided the conventional traffic congestion.

The Shirley Highway express bus system attracted the young working male with a good income who lived and worked within walking distance of the bus route. The majority of bus users had annual incomes in excess of $15,000, while only 1% had incomes of less than

$5,000. Only 6% of the Shirley passengers were not automobile owners while the average automobile per household was 1.32. A large group (16%) of the Shirley bus riders used the park-and-ride facilities.

Table IV outlines the characteristics of the Shirley Highway automobile commuter, and a similarity existed among all Shirley Highway commuters. They appeared to be the more affluent citizens living in the suburbs while retaining the higher paying jobs in the downtown area.

It was concluded that the Shirley express system was an attractive travel mode, and the majority of patrons were riding the bus because of preference and choice, even though 9% never had a seat available while making their trip. Another 11% reported that a seat was seldom available when they boarded the Shirley Highway bus. Therefore, it was deduced that the net bus passenger growth was diverted from the commuting automobile population on the Shirley Highway.

Reduction in Automobiles

The reduction in the number of automobiles from the Shirley Highway was a function of the net bus passenger growth and the automobile occupancy rate. The net bus passenger growth was previously analyzed, and the diversion from automobiles to the bus system was estimated at 5,040 passengers during the A.M. peak period.

The automobile occupancy rate on the Shirley Highway was derived from the automobile passenger and vehicular counts shown in Figures 15 and 16, respectively. Figure 17 shows that the A.M. peak period automobile occupancy rate varied widely between April and October, 1970, before "leveling-off" at approximately 1.4 passengers per automobile. The average occupancy rate at the study site between April, 1970, and March, 1972, was 1.43. The data in the Appendix reveals that prior to October, 1970, the occupancy rate for the entire Shirley corridor was more stable than that of the Shirley Highway, but after that date there was little difference between the two rates.

For comparison purposes, automobile occupancy rates on other arterials in the Washington, D. C. metropolitan area were examined. The average automobile occupancy rate for all major routes entering the District of Columbia for the A.M. peak period in May, 1970, was 1.47 with a standard deviation of 0.078 (6). Therefore, about 95% of the automobile occupancy values for highways leading into Washington were between 1.63 and 1.31. Figure 17 reveals the range of occupancy rates observed on the Shirley Highway were between 1.71 and 1.34 while the rates on the other roadways in the Shirley corridor varied between 1.47 and 1.35 as shown in the Appendix. Based upon the above data, the average occupancy rate of 1.43 on the Shirley Highway appeared realistic and was selected to represent the typical occupancy rate in the study analysis.

Therefore, the estimated reduction in automobiles, RA, attributed to the busway during the A.M. peak period on the Shirley Highway was determined with Eq. 1:

$$RA = \frac{N}{AO} \qquad (1)$$

$$= \frac{5,040}{1.43}$$

$$= 3,520 \text{ vehicles/peak period.}$$

where:

N = net bus passenger growth, and

AO = average automobile occupancy.

To substantiate the above estimated reduction in automobiles, a review was made of the automobile travel trend shown in Figure 16. Figure 16 indicates that the number of automobiles reached a peak of 9,300 vehicles in September, 1970, before dropping to 5,600 vehicles in March, 1972, thus, resulting in a decrease of 3,700 automobiles. During the study period the automobile travel in the Shirley corridor decreased by 2% as shown in the Appendix. The application of this decrease to the automobiles on the Shirley Highway resulted in a further reduction of approximately 186 vehicles per peak period. Therefore, the net reduction in automobiles was estimated at 3,514 vehicles which was approximately equal to the value determined in Equation 1.

The flow during the peak period was not uniform, thus, it

was desirable to review the A.M. peak hour. Table V indicates two different peak hours. Considering only the movement of vehicles, the peak hour occurred between 6:30 and 7:30 A.M.; however, the "people-moving" peak hour was between 7:15 and 8:15 A.M. when 131 buses traveled over the exclusive bus lane. Since emphasis was on the people-utilization of the roadway, the "people-moving" peak hour was selected for consideration.

Table V indicates that 192 local bus trips were made on the busway during the peak period and Table VI shows that 131 of those were during the A.M. peak hour between 7:15 and 8:15. Assuming the number of passengers were proportional to the bus trips, the estimated reduction in automobiles, RA_h, during the A.M. "people-moving" peak hour on the Shirley Highway was calculated with Eq. 2:

$$RA_h = \frac{N\ B_h}{AO\ B} \qquad (2)$$

$$= \frac{5{,}040\ (131)}{1.43\ (192)}$$

$$= 2{,}400 \text{ vehicles/hour.}$$

where:

B_h = number of A.M. peak hour bus trips, and

B = number of A.M. peak period bus trips.

Summary

Due to the rapid service provided by the busway, it was

estimated that 5,358 passengers started riding the buses which utilized the exclusive lane in the A.M. peak period during the thirty-one month study period. Of the gross increase in patronage, 6% were bus passengers diverted from non-Shirley routes in the corridor. Therefore, it was estimated that approximately 5,040 passengers were attracted from the population who formerly did not commute by bus.

The new patronage consisted of "choice" riders as they were citizens who owned automobiles and had a choice of travel modes. Since the automobile and bus were the two predominant modes of transportation in the corridor, it was assumed that the new bus passengers were diverted from the commuting automobile population on the Shirley Highway.

A major objective of the analysis was to estimate the reduction of automobiles on the Shirley Highway attributed to the busway. The division of the net bus passenger growth by the average automobile occupancy rate (1.43) revealed that approximately 3,520 automobiles during the A.M. peak period would be required to accommodate the bus passenger growth.

The "people-moving" peak hour was between 7:15 and 8:15 A.M. Of the 192 bus trips made during the peak period, 131 were recorded during the peak hour. Assuming the number of passengers were proportional to the bus trips, the result was a reduction of 2,400 vehicles during the "people-moving" peak hour.

CHAPTER V

QUALITY OF SERVICE ANALYSIS

One study determined a definite decrease in road area required per passenger with the use of bus transit, and other reports indicated that the level of service would be improved for the entire facility through the use of exclusive bus lanes (1, 5, 14, 16, 19). This analysis was designed to determine the degree of improvement in the level of service for the conventional traffic using the Shirley Highway.

Level of service is a qualitative measure of the effect of a number of factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating cost (2). Although it is desirable to give consideration to all of the above items, when evaluating the level of service, as yet, there is insufficient data to determine values for these factors. Accordingly, operating speed and demand volume-to-capacity ratios are the major elements used (12). The volume-to-capacity ratio provides some indication of traffic densities and freedom to maneuver, while the operating speed is an indication of overall performance of a roadway. Based on speed-volume-capacity relationships obtained from extensive empirical studies, a set of operational definitions for freeway level of service was developed and reported in the Highway Capacity Manual (12).

Level-of-Service Analysis with Busway

The geometrics of the urban 4-lane divided freeway at the study site consisted of 12-foot lanes with a 10-foot shoulder on the right side and a wooden barrier guardrail, separating the conventional roadway and the busway, within 6 inches of the left edge of pavement. The ½ mile segment under consideration was in level terrain. The restricted average highway speed was approximately 50 miles per hour due to alignment, condition of pavement, and a restricted speed zone through the construction area.

In analyzing the existing level of service for the conventional traffic, the classification volumes presented in Table VI were utilized. Speed studies conducted during the "people-moving" peak hour at the study site revealed an operating speed of approximately 30 miles per hour.

The computations represent the present conventional freeway conditions. Values of the input variables were taken from Table VI and the Highway Capacity Manual (12). The capacity, C, is given by Eq. 3:

$$C = 2{,}000\ N\ W\ T_c \qquad (3)$$

$$= 2{,}000(2)\ (.90)(.95)$$

$$= 3{,}420 \text{ vehicles/hour.}$$

where:

N = number of lanes in one direction,

W = adjustment for lateral clearances, and

T_C = truck factor at capacity.

With this capacity the service volume, SV, was determined with Eq. 4:

$$SV = 2{,}000\ N\ \frac{V}{C}\ W\ T_L \qquad (4)$$

$$= 2{,}000\ (2)\ \frac{2{,}213}{3{,}420}\ (.90)(.95)$$

$$= 2{,}210 \text{ vehicles/hour.}$$

where:

V = demand volume of vehicles in traffic stream, and

T_L = truck factor at existing level of service.

The resultant volume-to-capacity ratio was 0.65.

The peak-hour factor is the ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour (12). With the data in Table VI, the peak-hour factor, PHF, was computed with Eq. 5:

$$PHF = \frac{V}{R_m\ P} \qquad (5)$$

$$= \frac{2{,}213}{234\ (12)}$$

$= 0.79$

where:

R_m = maximum rate of flow during a 5-minute interval within the peak hour, and

P = number of time intervals during peak hour.

The comparison of the above information to the standards establsihed in the Highway Capacity Manual revealed that the subject section of the Shirley Highway was operating at an E Level of Service (12). The characteristics of an E Level of Service include unstable flow, stoppages of momentary duration, operating speeds in the vicinity of 30 MPH, and volumes approaching the capacity of the roadway (4). On a field trip to the study site during the A.M. peak hour, all of these characteristics were observed.

Level-of-Service Analysis Without Busway

To estimate the effectiveness of the busway upon the level of service for the conventional traffic, an attempt was made to analyze the traffic conditions assuming the busway was not provided.

The analysis of the hypothetical roadway included the following assumptions:

1. The geometrics of the conventional roadway remained constant.
2. The reduction in Shirley Highway automobiles attributed

to the busway were placed in the conventional traffic stream along with the existing volumes shown in Table VI.

3. Because the bus passenger "historical" trends indicated a negligible variation in patronage during the study period, only the buses initially using the Shirley Highway before the implementation of the busway were added to the traffic flow. No consideration was given to special buses as complete data were unavailable.
4. It was surmised that the "people-moving" peak hour on the hypothetical roadway would be earlier than that of the existing facility as the travel time on the Shirley Highway for the automobile was greater than the bus. Theoretically, the greater travel time would require earlier travel on the Shirley Highway as the commuter's arrival time at his destination would not change. Supporting data was not available, consequently, it was assumed that the "people-moving" peak hour would remain at the same time.
5. The peak-hour factor was unchanged.

Figures 8 and 11 reveal that initially 34 and 49 bus trips entered the Shirley Highway south of and at Shirlington, respectively. Therefore, the total initial trips at the study site were 83. Assuming the ratio of peak-hour buses to peak-period buses remained constant, an estimated 57 buses initially used the Shirley Highway during the subject peak hour. Equation 2 reveals that an estimated

2,400 vehicles were removed from the Shirley Highway during the A.M. "people-moving" peak hour because of the busway.

Thus, the deletion of the busway would necessitate forcing 2,400 automobiles and 57 buses into the conventional traffic. These vehicles, added to the volumes in Table VI, result in 4,670 vehicles (4,505 automobiles and pickups, 108 trucks, and 57 buses) desiring to use the hypothetical roadway.

The new capacity was derived from Eq. 6:

$$C = 2{,}000\ N\ W\ T_C\ B_C \qquad (6)$$

$$= 2{,}000\ (2)(.90)(.98)(.99)$$

$$= 3{,}490 \text{ vehicles/hour.}$$

where:

B_C = bus factor at capacity.

The adjusted service volume was determined with Eq. 7:

$$SV = 2{,}000\ N\ \frac{V}{C}\ W\ T_L\ B_L \qquad (7)$$

$$= 2{,}000\ (2)\ \frac{4{,}670}{3{,}490}\ (.90)(.98)(.99)$$

$$= 4{,}670 \text{ vehicles/hour.}$$

where:

B_L = bus factor at existing level of service.

In this particular analysis the adjusted service volume was equal to the anticipated demand volume because there was no difference in the truck and bus factors.

On the hypothetical roadway, the volume-to-capacity ratio is 1.34, and the conclusion is that the demand volumes far exceed the capacity of the facility. Under these conditions the facility would break down - low speeds, if not zero; density extremely high and very low volumes. Under the above conditions, the Highway Capacity Manual indicates a forced flow in traffic jams and an unacceptable level of service (12).

Summary

The analysis of the roadway with the exclusive bus lane in operation revealed that the capacity and service volume were 3,420 and 2,210 vehicles per hour, respectively. The resultant volume-to-capacity ratio was 0.65 and the peak-hour factor was 0.79. The comparison of this information to the stardards established in the Highway Capacity Manual revealed that the study section of the Shirley Highway was operating at an E level of service.

In the analysis of the hypothetical roadway (assuming the busway was not provided) the number of automobiles reduced from the Shirley Highway because of the express bus service, were theoretically placed into the normal traffic flow. The capacity and service volumes of the hypothetical roadway were 3,490 and 4,670 vehicles per hour,

respectively. The resultant volume-to-capacity ratio was 1.34. Under these conditions, the demand volumes far exceed the capacity of the facility, and the Highway Capacity Manual indicates an unacceptable forced flow in traffic jams.

It was concluded that without the busway, the Shirley Highway would be presently operating under intolerable conditions, and the exclusive bus lane has contributed greatly to the level of service for the conventional traffic.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Due to the limitations of the data, especially pertaining to the special buses and "people-moving" peak hour, decisive conclusions cannot be made relative to the impact of the Shirley Highway exclusive bus lane. The growth experienced by the special bus was omitted in this study. The "people-moving" peak hour for the hypothetical roadway was assumed at the same time as that for the existing facility. Intuitively, if the bus passengers were forced into commuting by automobile, they would be required to travel the Shirley Highway earlier during the peak period as the travel time on the Shirley Highway by automobile would be greater than it was by the express bus system. Table V indicates that the A.M. "vehicle-moving" peak hour occurred before the "people-moving" peak hour, consequently, the anticipated earlier use of the Shirley Highway would necessitate many commuters to travel in a heavier flow than analyzed in this study. Subsequently, it was surmised that the foregoing analysis and the following general conclusions are conservative.

Conclusions

At the time of its inauguration, the Shirley Highway Express-Bus-on-Freeway Project was subject to considerable adverse public opinion. Many people felt that the project would be unsuccessful and, consequently, a waste of funds. With the automobile and its self-drive, instant availability, and individualized trip

characteristics being the prominent mode of transportation in this country, intuitively, it was difficult to perceive of automobile passengers diverting to the express bus. However, the preceding analysis indicated the project was successful as it attracted many former automobile passengers, thus, reducing the number of vehicles and congestion on the Shirley Highway.

In each stage of the project, when the service was improved, the patronage continued to increase and the passengers enjoyed the time savings provided by the exclusive lane. At the implementation of the project, only 25% of the total passengers using the Shirley Highway made the trip by bus. By the end of the study period, the patronage had grown to the extent that 54% of the total passengers during the A.M. peak period rode the bus.

Another factor that further revealed the effectiveness of the project was the economic groups that made up the bus patronage. The nature of the project served the more affluent economic groups who commuted from the suburbs to government and private employment establishments in the downtown area. Normally it is difficult to attract these groups to bus transportation as they usually have several automobiles available. Tables II and III indicated the popular hypothesis of urban travel - that the commuter by automobile has a higher economic status than the commuter making the same trip by bus - was incorrect in this application. One of the disturbing conclusions of the project was that it did not benefit all economic groups, espe-

cially the ones who lacked transportation facilities.

Although the buses provided a rapid movement on the exclusive lanes, it cannot be concluded that the service was comforable. The buses were crowded, and many passengers had to stand while making the trip. Because of the lack of data, valid conclusions cannot be made about the convenience of the service and the total door-to-door travel times, but apparently these factors were equivalent or better than the automobile, as many commuters stated they chose the bus because of the rapid service and the elimination of the driving discomfort through the conventional highway congestion.

The reduction in automobiles on the Shirley Highway attributed to the express bus system was of major significance. The existing facility provided an E level of service for the conventional traffic. While this service is considered undesirable by most traffic engineers, it is usually acceptable to the motoring public during the peak periods. The analysis of the hypothetical roadway, without the busway, revealed that the facility could not accommodate the demand volumes. If the busway had not been provided, it was surmised that the volumes would have increased on the Shirley Highway until an intolerable level was reached, and then the demand would have sought new routes. The switching of vehicles to the other arterials would have decreased the level of service on those facilities. Therefore, it was concluded that all commuters in the Shirley Highway

corridor benefited from the demonstration project.

Although the exact degree of improvement cannot be stated, there was reliable evidence to indicate the basic objective - to improve the level of service for all commuters on the Shirley Highway - of the demonstration project was fulfilled.

Recommendations for Further Study

The conclusions revealed by this study appear to show that the exclusive bus lane relieved the congestion on the Shirley Highway. However, additional study is necessary to extend the analysis to a more comprehensive scale. Recommendations for further research are:

1. Data should be obtained and an analysis conducted to determine the diversions of passengers from non-Shirley Highway bus routes.
2. The growth experienced by special buses should be evaluated and included in the analysis to properly measure the effectiveness of the busway.
3. The buses entering the busway south of Shirlington had a considerable number of standees while those at Shirlington did not appear to be operating at capacity. A review of the bus routing is recommended to determine if the buses are allocated to provide optimum usage, comfort, and convenience.
4. The impact of the busway upon the level of service on

other routes in the Shirley corridor should be analyzed. As the available data do not adequately cover the previous travel trends in the corridor, a modal split model should be developed to properly analyze the mode choice changes induced by the increased quality of passenger service provided by the express bus system.

5. An analysis should be conducted to determine the exact time of the peak hour on the hypothetical roadway to allow a proper evaluation of the effectiveness of the busway.
6. A transit system should serve all economic groups, however, there was an indication that the underprivileged groups received little benefit from the busway. An analysis should be made to evaluate this situation.
7. The aspects such as economics, individual level of service, and door-to-door travel times, should be evaluated as each is dependent upon the other and contributes much to the success of the project.
8. Additional community benefits, such as reduced downtown parking space demand, reduced residential street parking demand, accident reduction, and reduction in air pollution, warrant further evaluation and study.
9. An analysis should be conducted to determine the impact of the busway upon the level of service for the conventional traffic during the P.M. peak period.

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APPENDIX

Shirley Highway Corridor Travel

ROUTE	APRIL 1970				MAY 1970				JUNE 1970			
	PERSON TRIPS			TOTAL	PERSON TRIPS			TOTAL	PERSON TRIPS			TOTAL
	AUTO	BUS	TOTAL	AUTOS	AUTO	BUS	TOTAL	AUTOS	AUTO	BUS	TOTAL	AUTOS
ARLINGTON BLVD.	7,578	1,619	9,197	5,720	7,742	1,701	9,443	5,843	7,630	1,424	9,054	5,711
COLUMBIA PIKE	4,889	3,684	8,573	3,687	5,138	4,425	9,563	3,856	5,112	3,563	8,675	3,799
SHIRLEY HWY.	12,529	4,304	16,833	7,420	12,311	4,310	16,621	8,037	11,942	4,392	16,334	8,029
ARMY-NAVY DRIVE	1,949	490	2,439	1,337	1,243	452	1,695	962	1,356	409	1,765	1,032
ARLINGTON RIDGE	5,192	1,633	6,825	3,426	4,952	1,617	6,569	3,339	5,009	1,560	6,569	3,331
JEFFERSON DAVIS HWY.	6,868	727	7,595	4,756	6,798	750	7,548	4,796	7,029	894	7,923	4,882
G.W. PARKWAY	10,829	1,701	12,530	7,633	11,791	1,898	13,689	8,207	10,984	1,658	12,642	7,797
TOTAL	49,834	14,158	63,992	33,979	49,975	15,153	65,128	35,040	49,062	13,900	62,962	34,581
AUTO OCCUPANCY				1.47				1.43				1.42
% BY TRANSIT				22.1				23.3				22.1

Shirley Highway Corridor Travel (cont.)

ROUTE	JULY 1970				AUGUST 1970				SEPTEMBER 1970			
	PERSON TRIPS			TOTAL	PERSON TRIPS			TOTAL	PERSON TRIPS			TOTAL
	AUTO	BUS	TOTAL	AUTOS	AUTO	BUS	TOTAL	AUTOS	AUTO	BUS	TOTAL	AUTOS
ARLINGTON BLVD.	7,928	1,462	9,390	5,870	7,772	1,384	9,156	5,784	7,624	1,407	9,031	5,739
COLUMBIA PIKE	5,293	3,476	8,769	3,903	5,553	3,628	9,181	3,993	5,612	3,798	9,410	4,053
SHIRLEY HWY.	15,327	4,293	19,620	8,934	13,123	4,104	17,227	8,414	14,941	4,390	19,331	9,276
ARMY-NAVY DRIVE	1,447	502	1,949	1,064	1,455	414	1,869	1,066	1,508	450	1,958	1,102
ARLINGTON RIDGE	5,104	1,636	6,740	3,385	5,264	1,616	6,880	3,430	5,095	1,763	6,858	3,373
JEFFERSON DAVIS HWY.	7,129	970	8,099	4,951	6,719	1,101	7,820	4,456	8,639	987	9,626	5,397
G.W. PARKWAY	12,477	1,748	14,225	8,638	10,457	1,757	12,214	7,092	11,488	1,719	13,207	8,141
TOTAL	54,705	14,087	68,792	36,745	50,343	14,004	64,347	34,235	54,907	14,514	69,421	37,081
AUTO OCCUPANCY				1.49				1.47				1.48
% BY TRANSIT				20.5				21.8				20.9

Shirley Highway Corridor Travel (Cont.)

ROUTE	OCTOBER 1970				NOVEMBER 1970				MARCH 1971			
	PERSON TRIPS			TOTAL	PERSON TRIPS			TOTAL	PERSON TRIPS			TOTAL
	AUTO	BUS	TOTAL	AUTOS	AUTO	BUS	TOTAL	AUTOS	AUTO	BUS	TOTAL	AUTOS
ARLINGTON BLVD.	7,943	1,438	9,381	5,878	7,864	1,362	9,226	5,862	8,324	1,421	9,745	6,335
COLUMBIA PIKE	6,218	3,807	10,025	4,421	5,145	3,812	8,957	3,830	4,161	3,274	7,435	3,207
SHIRLEY HWY.	12,210	4,302	16,512	8,906	11,356	4,483	15,839	8,226	10,260	5,400	15,660	7,262
ARMY-NAVY DRIVE	1,526	390	1,916	1,121	1,630	443	2,073	1,161	1,954	394	2,348	1,288
ARLINGTON RIDGE	5,641	1,708	7,349	3,671	4,976	1,697	6,673	3,335	3,678	1,429	5,107	2,531
JEFFERSON DAVIS HWY.	7,750	1,003	8,753	5,039	6,918	1,148	8,066	4,545	7,075	911	7,986	4,986
G.W. PARKWAY	10,756	1,549	12,305	7,688	9,853	1,940	11,793	7,176	10,789	2,014	12,803	7,982
TOTAL	52,044	14,197	66,241	36,724	47,742	14,885	62,627	34,135	46,241	14,843	61,084	33,591
AUTO OCCUPANCY				1.42				1.40				1.38
% BY TRANSIT				21.4				23.8				24.3

Shirley Highway Corridor Travel (Cont.)

ROUTE	JUNE 1971				OCTOBER 1971				MARCH 1972			
	PERSON TRIPS			TOTAL AUTOS	PERSON TRIPS			TOTAL AUTOS	PERSON TRIPS			TOTAL AUTOS
	AUTO	BUS	TOTAL		AUTO	BUS	TOTAL		AUTO	BUS	TOTAL	
ARLINGTON BLVD.	8,182	1,211	9,393	6,057	7,485	1,204	8,689	5,761	7,543	1,253	8,796	5,935
COLUMBIA PIKE	4,345	3,324	7,669	3,139	4,339	2,984	7,323	3,187	4,468	2,865	7,333	3,233
SHIRLEY HWY.	8,778	6,348	15,126	6,295	7,564	7,824	15,388	5,662	7,768	9,121	16,889	5,604
ARMY-NAVY DRIVE	2,549	334	2,883	1,721	2,599	386	2,985	1,757	2,593	306	2,899	1,898
ARLINGTON RIDGE	4,265	1,291	5,556	2,930	3,658	1,274	4,932	2,649	3,655	1,360	5,015	2,737
JEFFERSON DAVIS HWY.	6,821	793	7,614	4,649	6,993	930	7,923	4,971	8,179	967	9,146	5,660
G.W. PARKWAY	10,912	1,848	12,760	7,885	10,299	1,706	12,005	7,753	11,049	1,617	12,666	8,170
TOTAL	45,852	15,149	61,001	32,676	42,937	16,308	59,245	31,740	45,255	17,489	62,744	33,237
AUTO OCCUPANCY				1.40				1.35				1.37
% BY TRANSIT				24.8				27.6				27.9

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AN ANALYSIS
OF THE SHIRLEY HIGHWAY EXPRESS-BUS-ON-FREEWAY
DEMONSTRATION PROJECT

by

Richard Neal Robertson

(ABSTRACT)

One of the most critical urban problems is the ever-increasing demand for transportation facilities. An alternative for reducing the degree of peak-hour congestion is to increase the passenger movement capability of a facility by providing exclusive bus lanes.

The Shirley Highway Express-Bus-on-Freeway Demonstration Project was implemented to test the hypothesis that the provision of rapid and convenient bus service over an exclusive lane would attract significant numbers of automobile passengers. Such a diversion would improve the passenger movement and relieve the congestion of the facility, thus, resulting in an improved level of service for all travelers.

This study was an evaluation of the project, and the main objectives were:

1. Determine the effects of the busway on bus patronage and automobile travel.

2. Analyze the sources of bus patrons and determine the reduction in automobiles.
3. Use the automobile reduction in comparing the level of service for the existing facility to the freeway without the exclusive busway.

In approaching these objectives, the study identified and evaluated such parameters as travel times, passenger and vehicular volumes, commuter profiles, and occupancy rates. Speed-volume-capacity relationships were used to compare the quality of service on the existing facility to a hypothetical roadway without an operational busway.

The analysis revealed a large increase in bus patronage and a reduction in automobiles and congestion on the Shirley Highway. The existing facility was providing acceptable service, while the demand on the hypothetical roadway exceeded the capacity.