

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

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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## ABSTRACT

The Shirley Highway Express-Bus-on-Freeway Demonstration Project was initiated 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 to:

1. Review the effects of the bus system on bus patronage and automobile travel.
2. Determine the reduction in the number of automobiles on the Shirley Highway due to the diversion of commuters from automobiles to buses.
3. Use the reduction in the number of automobiles to compare the present level of service being provided to the commuters utilizing the conventional traffic lanes to the hypothetical level of service assuming the bus system was not operational.

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 in the quality of service analysis.

The evaluation 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.



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INTRODUCTION

For many years one of the most critical problems in urban areas has been the supply of transportation facilities. The planners and traffic engineers in the past have attacked this problem by increasing the number of streets and highways, as the automobile was the predominant mode of transportation. Now it is realized that a single transportation mode cannot fulfill the demands, and a balanced multimode system is required.

In 1970, Frank Turner, Federal Highway Administrator, in an article entitled "Moving People on Urban Highways," 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 the movement of people along a transportation corridor rather than vehicle movement.

In nearly every urban area, there is a bus fleet, and much attention has been given to the promotion of bus travel because of its potential in relieving urban transportation congestion. The importance of bus transit is indicated by the fact that approximately 1,200 buses per hour can be accommodated on one freeway lane. 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.

The concept of reserving freeway lanes for buses during the peak hours utilizes the capacity characteristics described above and has been well examined. The consensus of many studies is that the reserved lane system achieves a more efficient use of the freeway than does the conventional mixed traffic. One research study has even recommended that urban freeways be designed to handle off-peak traffic and that bus transit be utilized to accommodate the peak movements.

In 1970, the Virginia State Highway Commissioner, Douglas B. Fugate, proposed more extensive utilization of the urban highway as an artery for improved bus mass transit in order to increase the people-moving capability of the freeway. Mr. Fugate, serving as the president-elect 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.

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. 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 who formerly commuted by automobiles between concentrated employment locations and residential areas. The diversions from automobiles to buses would increase the "people utilization" or the "people-moving capacity" of the congested highway systems, and thus improve the level of service for all rush-hour commuters.

The project consisted of three elements. (1) The busway, including the exclusive lane on Shirley Highway and the bus priority curb 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. The implementation of this joint highway and mass transportation project was accomplished through the efforts and cooperation of many federal, state and local organizations.

### STUDY OBJECTIVES

This investigation was conducted to determine the effectiveness of the express bus service in relieving the congestion on the Shirley Highway and the effect on the level of service experienced by the automobile commuter utilizing the conventional lanes of the facility. The main objectives of this study were to:

1. Review the effects of the busway on bus patronage and automobile travel.
2. Determine the reduction in the number of automobiles on the Shirley Highway due to the diversion of commuters from automobiles to buses.
3. Use the reduction in the number of automobiles to compare the existing level of service on the conventional lanes to the hypothetical level of service assuming the bus system was not operational.

The bus system provided similar services to the commuters during both daily peak periods, however, the scope of this investigation was limited to the study of the inbound flow during the morning peak hours in order to eliminate duplication and alleviate manpower and time constraints.

### STUDY LOCATION

As the effectiveness of the busway varied over its entire length, a site had to be chosen which represented typical operations and accordingly, the segment north of Glebe Road was selected for analysis.

The geometrics of the inbound facility at the study site consisted of two 12-foot lanes with a 10-foot shoulder on the right side. A wooden barrier guardrail separating

the conventional lanes and the busway was located within 6 inches of the left edge of pavement. The 1/2-mile segment under consideration was in level terrain. The restricted average highway speed was approximately 50 miles per hour due to alignment, the condition of the pavement, and the construction activities.

## PROJECT BACKGROUND

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 to exclusive or priority bus lanes, and the final design, based upon these recommendations was begun.

In 1964, because of the growing interest in bus transit, a study group was formed among representatives of the District of Columbia and Virginia Highway Departments, the National Capitol Transportation Agency, the Transit Regulatory Agency, and the Federal Highway Administration to investigate the feasibility of including special bus facilities in 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. 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 and economic feasibility study of the express bus usage in the Shirley Highway corridor, it was recommended that the newly constructed portion of the reversible lanes between Edsall 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 minute 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 a 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 the permanent facility. It was anticipated that the system would reduce the number of automobiles on the Shirley Highway, and thus relieve the traffic problems through the construction activities. Therefore, 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 minute time 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 was opened on April 5, 1971. Figure 3 shows the busway access locations.

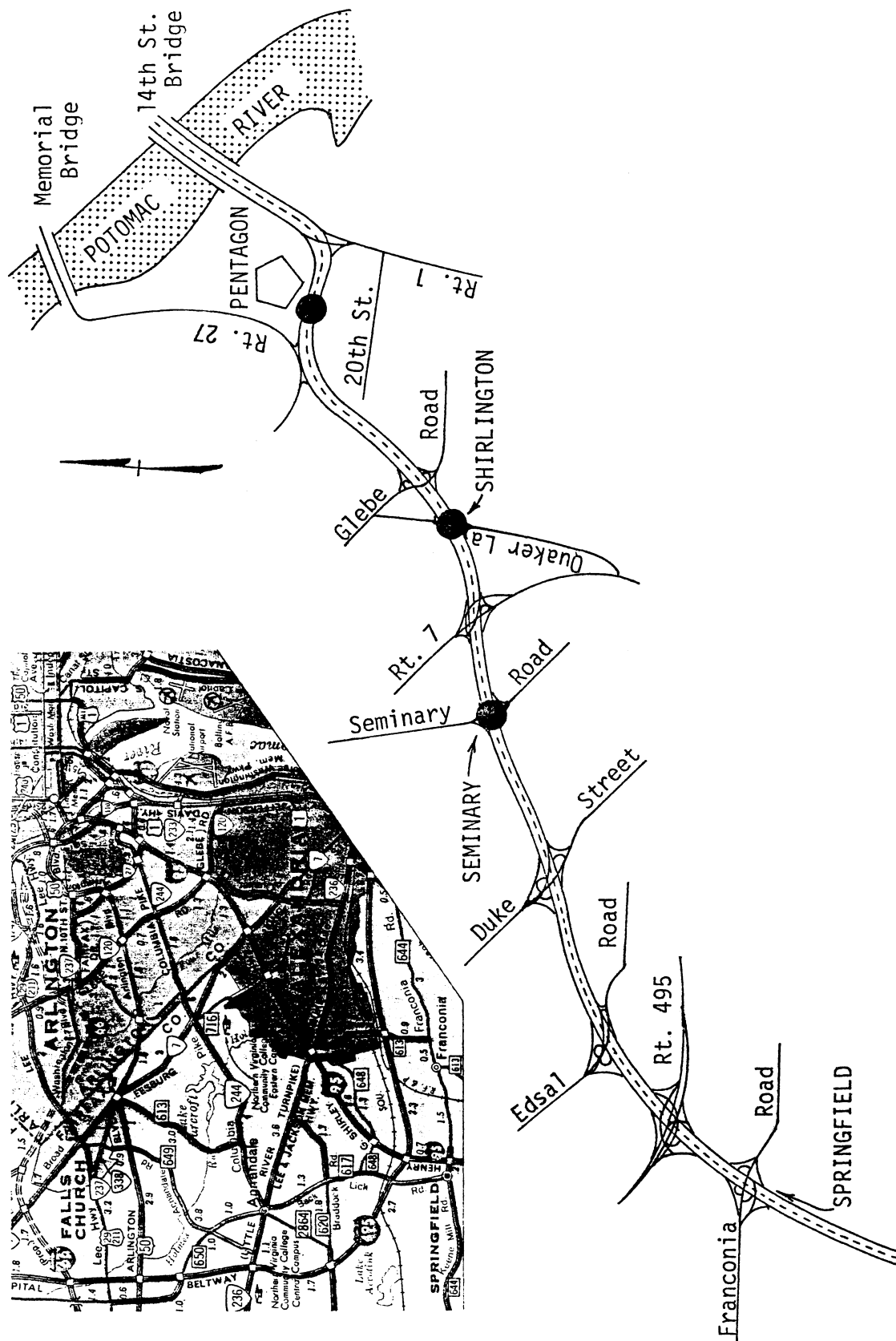


Figure 1. Shirley Highway exclusive bus ramps.



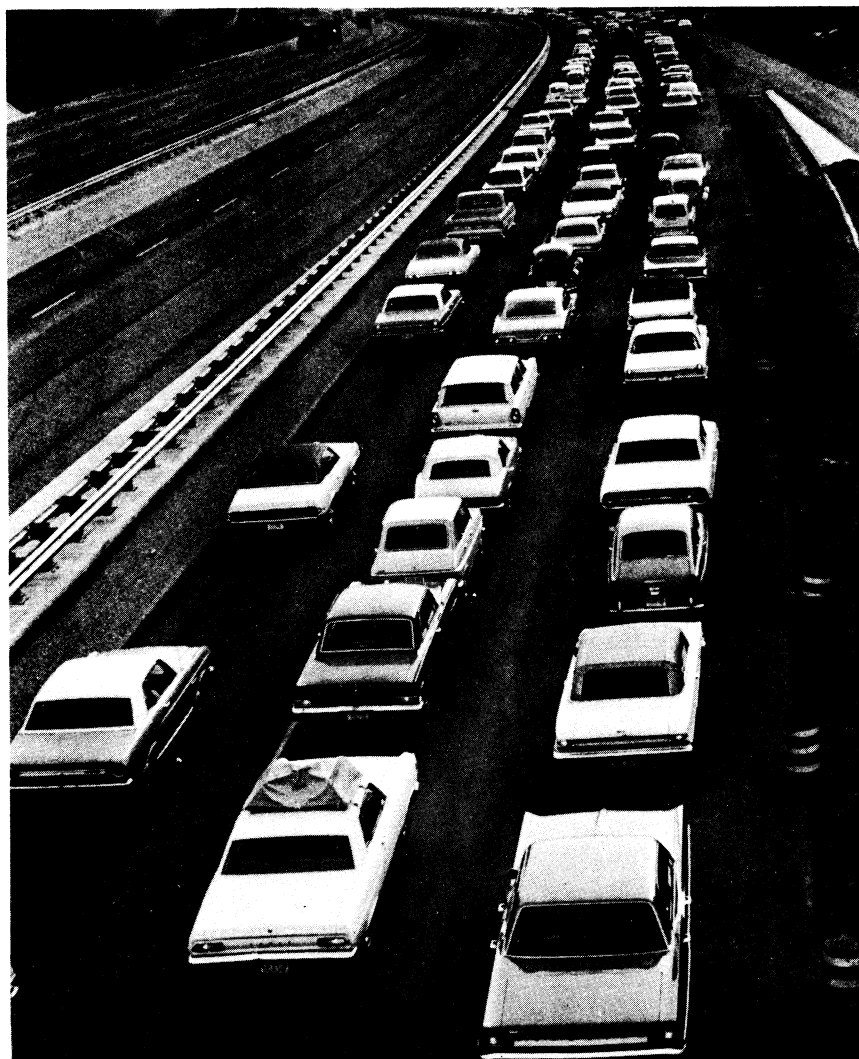


Figure 2. Morning peak period traffic conditions on Shirley Highway south of Shirlington.

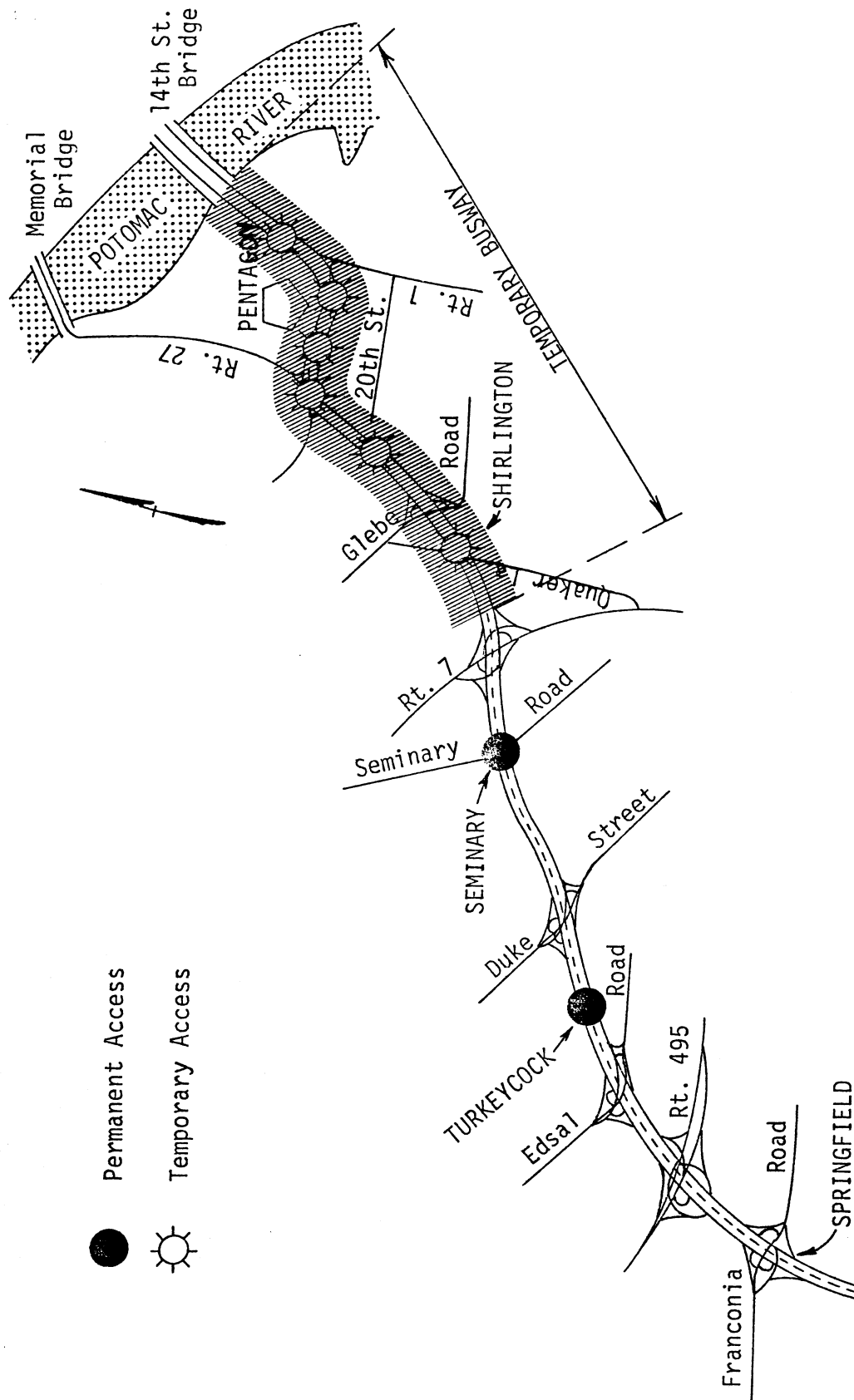


Figure 3. Shirley Highway exclusive busway access locations.

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 co-operating in the project, 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 time the demonstration project was concluded. This expansion in service would result in a major increase in the bus company's capital requirements, and in September 1970, the Urban Mass Transportation Administration (UMTA) 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 during May — June 1971 to accommodate the demand generated by the completion of the busway. An additional 20, 10, 16, and 14 buses were placed into service in February, June, August, and December 1972, respectively.

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 near the residential areas of the Shirley Highway corridor. With the cooperation of the owners of the Springfield and Shirley Plazas (shopping centers), fringe parking was provided in the summer of 1971.

The Washington Metropolitan Area Transit Authority is cooperating 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.

## ANALYSIS 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 variations in travel patterns that occurred as a result of changes in transit service. 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 section.

### Automobile and Bus Travel Times

While buses sped along the exclusive busway during the peak periods, automobiles and trucks encountered varying levels of congestion. 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, the vehicle speeds were low and the congestion enhanced by the merging and weaving traffic at the Glebe Road, Route 27 (Washington Boulevard) and Route 1 Interchanges.

Figure 4 shows bus and automobile morning 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. In the morning, the farther south the buses entered the busway, the more time was saved with respect to automobile travel. Table 1 summarizes the comparison of average bus and automobile travel times.

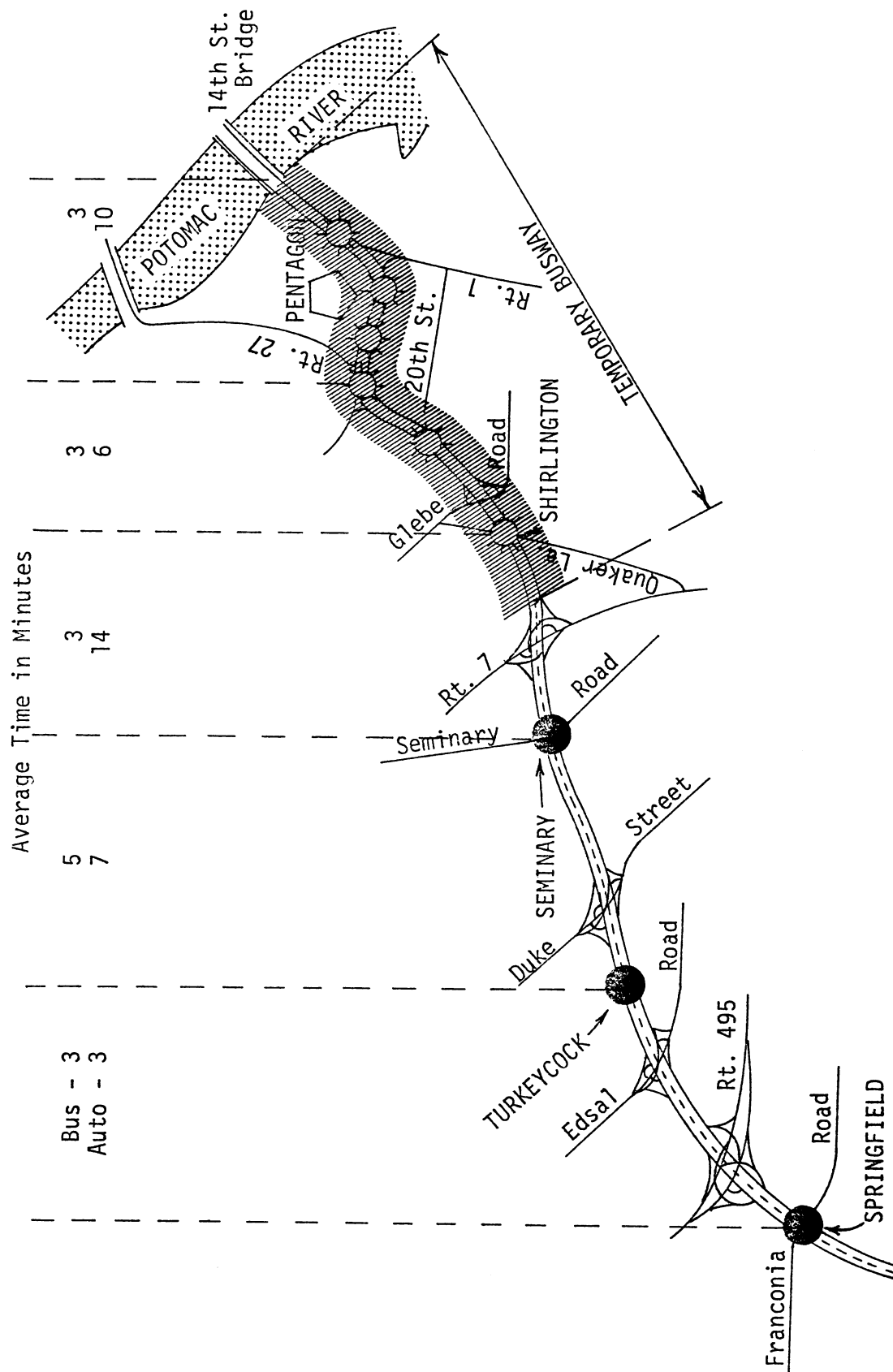


Figure 4. Automobile and bus peak travel times on Shirley Highway.

Table 1

## Shirley Highway Automobile and Bus A.M. Travel Times

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

Shirley Highway Corridor Passenger Trends

A single roadway should not be evaluated without considering the adjacent facilities within the same corridor. During the years 1962 through 1968, the automobile and bus travel 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 travel passengers (automobile and bus) in the Shirley Highway corridor was 4%.

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. 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 November, the counts were made on a reduced frequency schedule. The corridor passenger trends, shown in Figure 5, reveal an annual increase in bus passengers of 12% while the number of automobile passengers decreased 5%. Instead of the anticipated increase in total passengers within the corridor, there was an annual decrease of 1% after the initiation of the count station.

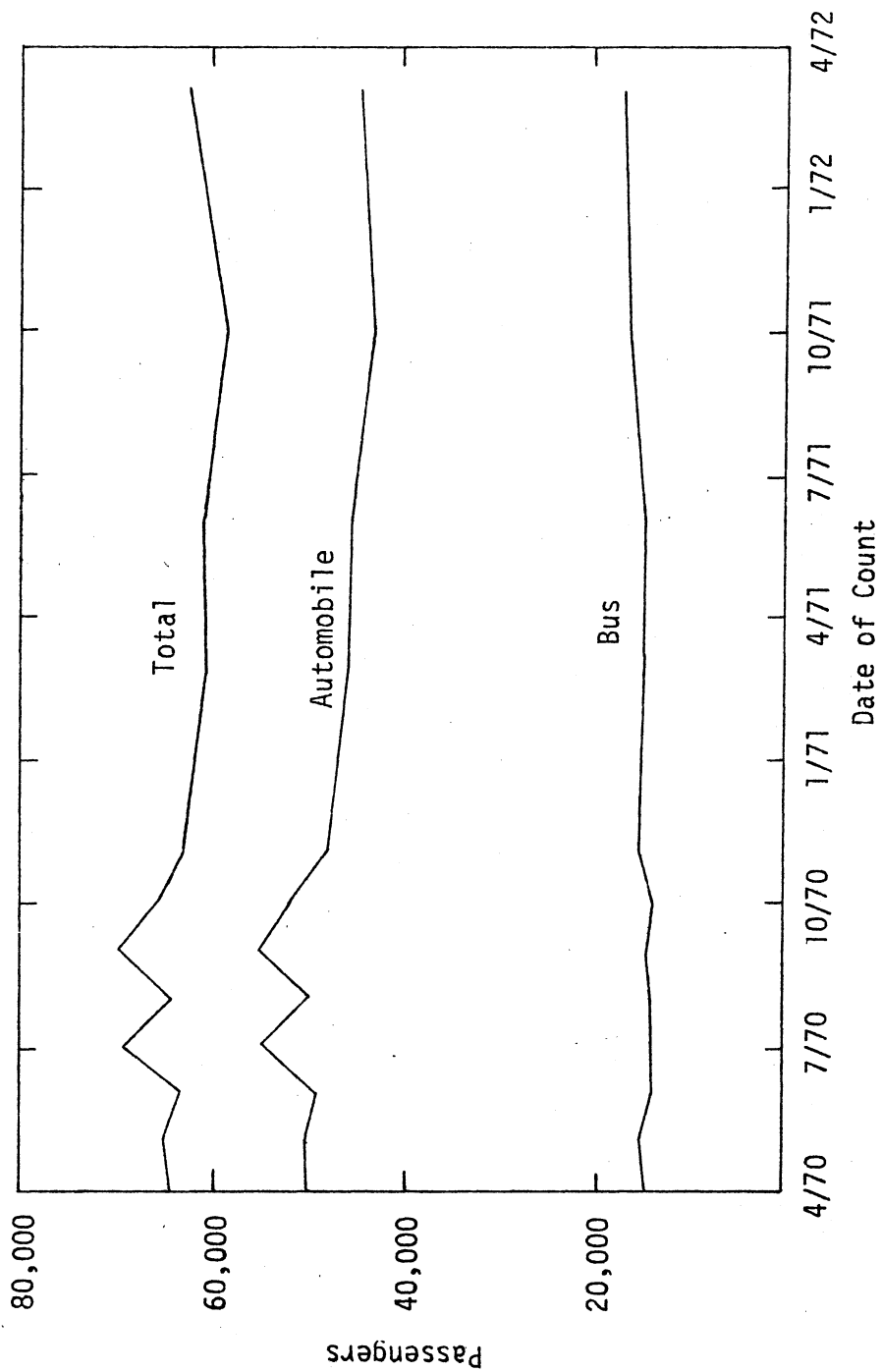


Figure 5. Morning peak period passenger counts — Shirley Highway corridor.

### Bus and Automobile Commuters' Profiles

In October 1971, a morning peak period survey of all commuters traveling through the Shirley Highway corridor was conducted.

Mail-back questionnaires were distributed to approximately 33% of the 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. Users of local buses entering the busway south of the study site were considered as Shirley Highway bus users. Riders on local buses that entered the busway north of the study site, and 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. 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 2 summarizes the data gathered in the Shirley Highway bus users survey. The majority of the bus passengers were young working males with good incomes 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. The majority of "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 even though 9% never had a seat available while making the trip.

A comparison of the Shirley and non-Shirley bus commuters is shown in Table 3. 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 many of the non-Shirley users did not prefer the bus travel, their chances of finding a seat were better than that experienced by the Shirley bus riders. 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 and that much of the patronage growth was diverted from the commuting automobile population.

The results of the automobile commuter questionnaire are summarized in Table 4. 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 being 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 commuting 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.

Table 2

## 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



Table 3

## 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 4  
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

### 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. The transit company began counting passengers on all local buses using the exclusive lanes during the morning peak period when the first segment was opened in September 1969. As each section was opened and more buses were able to use the busway, additional passenger counts were initiated. Buses other than those belonging to the transit company utilized the facility but were not recorded in the counts because many of their trips were unscheduled and external of the study area.

To estimate the bus patronage growth at the study site during the morning 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, and resulted in a significant increase in patronage over the initial 2,000 passengers on opening day, as shown in Figure 6. 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. It was also found 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 that time, an additional 1,825 bus passengers were able to receive the benefits of the busway via the Shirlington ramp. Figure 7 indicates that at the end of the study period, the ridership on the ramp had increased by 558 passengers to a total of 2,383 passengers during the morning peak period. To accommodate the passenger growth, 8 new bus trips were placed into service.

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 reveals that an additional 5,358 passengers (gross increase) started riding the buses during the study period at the study site. Figure 8 reveals the growth throughout the study period, but the greatest rate increase was after the entire busway was opened in April 1971.

In November 1970, the A B & W Transit Company increased its base fare from \$0.35 to \$0.50 for most riders. Figure 8 indicates that there was no decrease in the bus ridership because of the fare increase.

The gross increase in bus patronage at the study site was subjected to several adjustments and assumptions in making the estimate of the number of commuters diverted from automobiles to buses on the Shirley Highway.

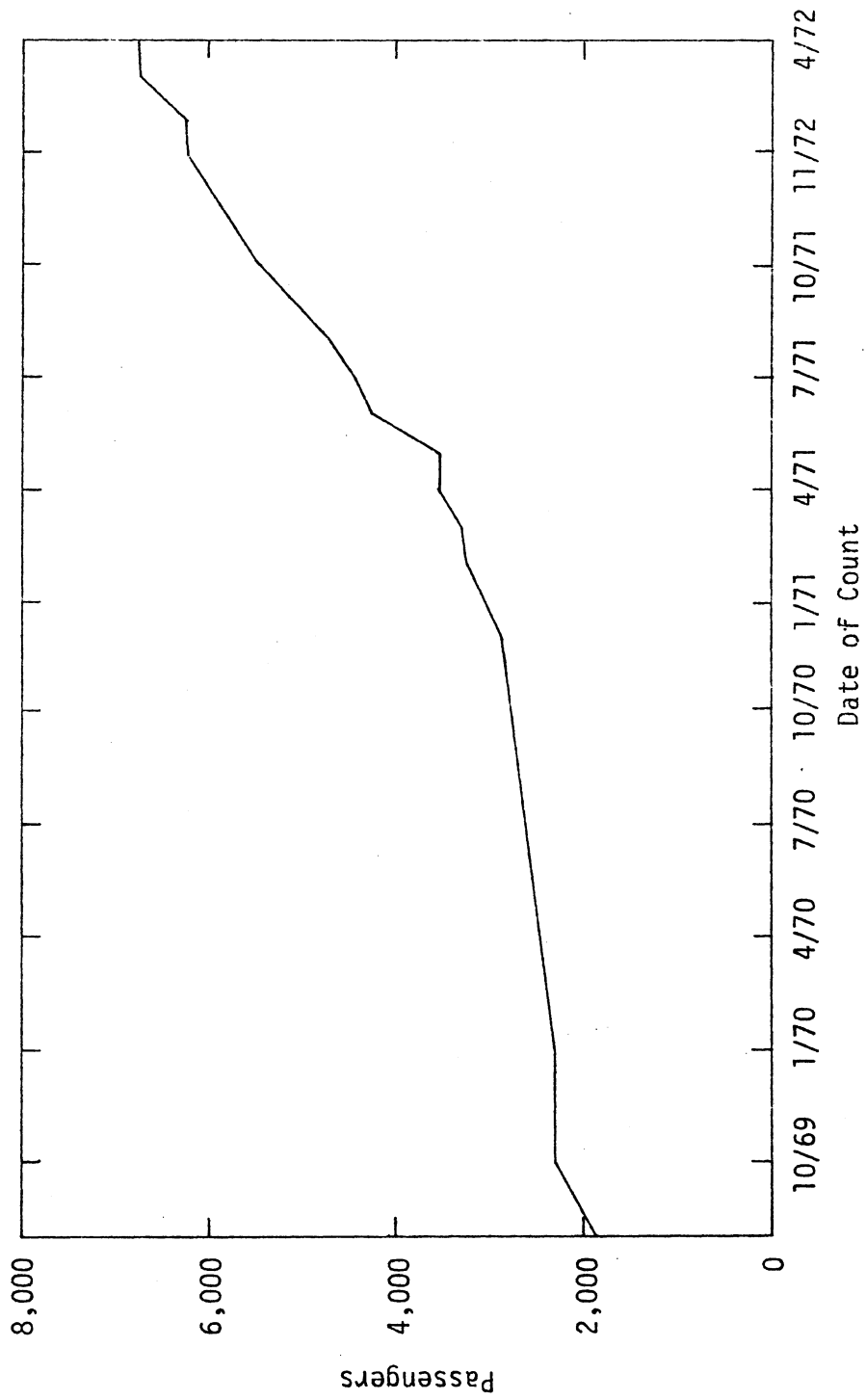


Figure 6. Morning peak period busway passengers on Shirley Highway — south of Shirlington.

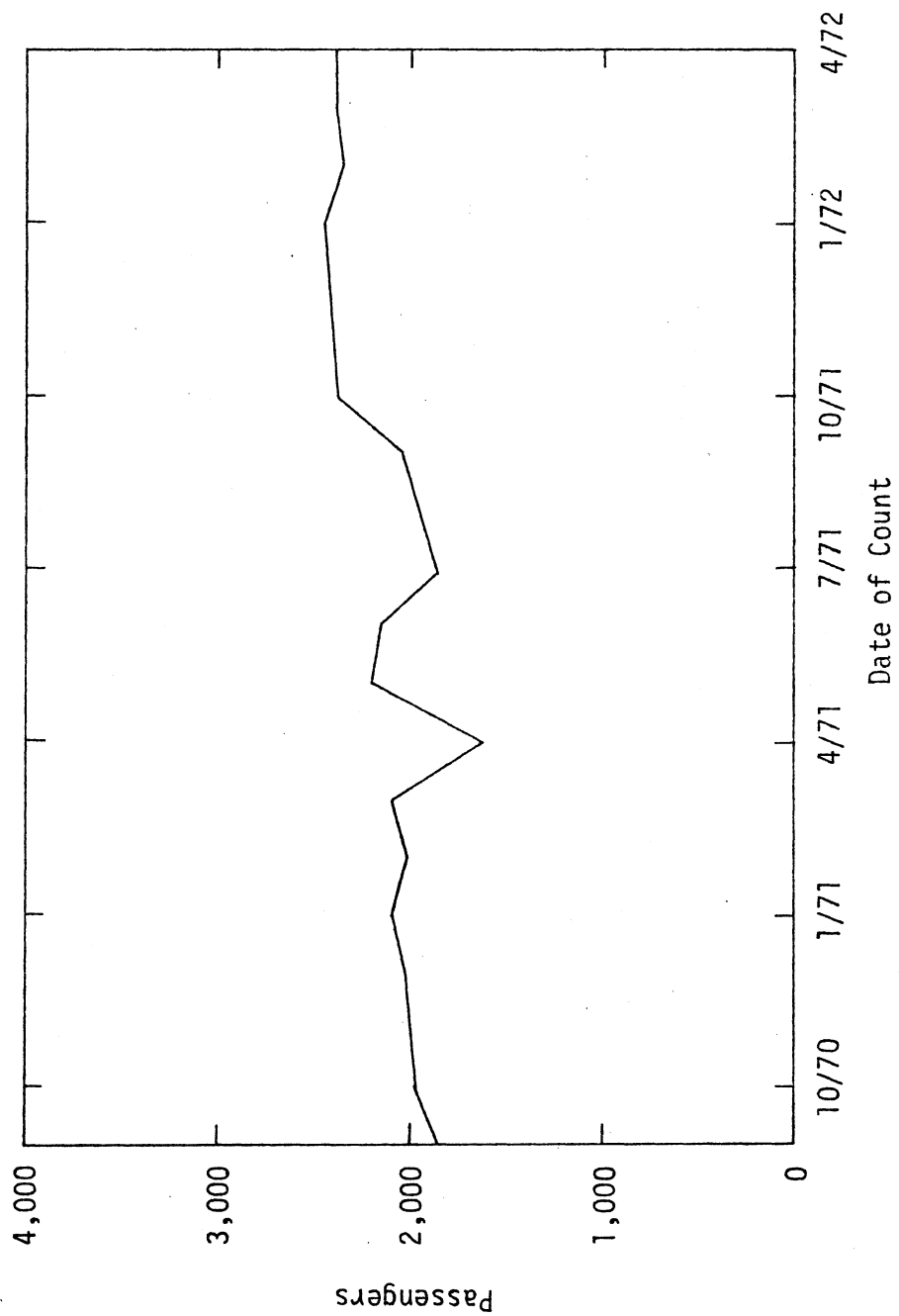


Figure 7. Morning peak period busway passengers on Shirley Highway — ramp from Shirlington.

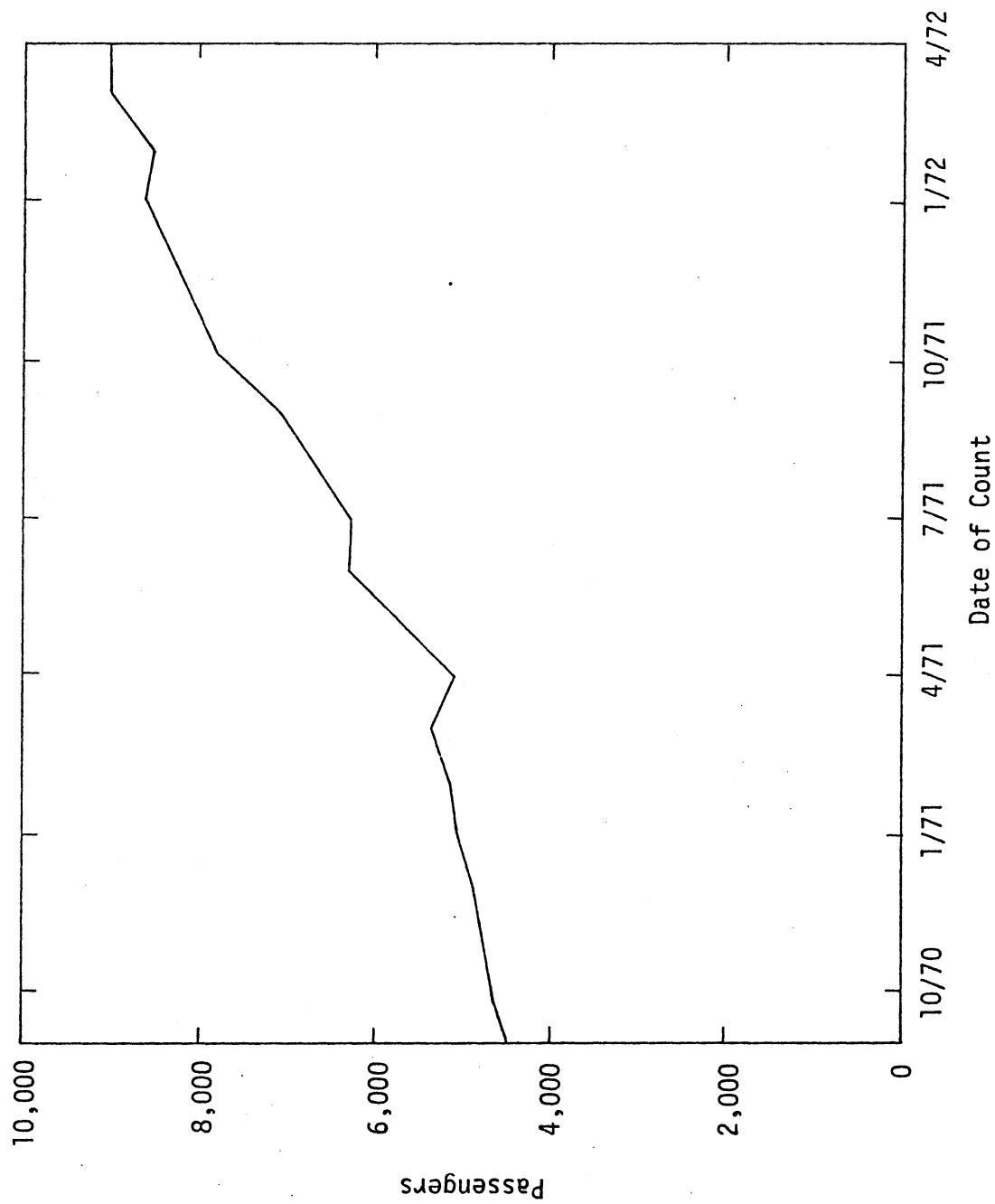


Figure 8. Morning peak period bus passengers on Shirley Highway study site.

The adjustments were as follows:

1. Growth travel considerations in the Shirley Highway corridor: The feasibility study reported that the annual growth in total person trips in the corridor between 1962-68 was 4%. During the same period, bus patronage increased 0.54%. Surprisingly, after the initiation of the demonstration project, the total person trips in the corridor decreased approximately 1% annually. Since the trips by bus were only a small percentage of the total travel in the corridor it was concluded that the "historical" variation in bus patronage would be negligible in this analysis.
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 the "on-board" bus survey. In answer to the question, "How did you make this trip prior to using this bus?", 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 lines (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: In the same survey many of the bus users in the corridor stated that they did not make the trip prior to using the bus on which they were riding when interviewed. 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 variables evaluated above, the major one was the passenger diversion (6%) from the non-Shirley buses. A 6% reduction of the busway's gross passenger growth (5,358) results in a net increase in patronage of 5,037 passengers. The net increase, or growth, represented the number of persons who formerly commuted by automobile on the Shirley Highway and were attracted to the express bus system.

## REDUCTION IN AUTOMOBILES

The number of automobiles removed 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 determined, and the diversion from automobiles to the bus system was estimated at 5,037 passengers during the morning peak period.

The automobile occupancy rate on the Shirley Highway was derived from the automobile passenger and vehicular counts shown in Figures 9 and 10, respectively. Figure 11 shows that the morning 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. 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 morning peak period in May 1970 was 1.47, with a standard deviation of 0.078. Therefore, about 95% of the automobile occupancy values for highways leading into Washington were between 1.63 and 1.31. Figure 11 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. 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 morning peak period on the Shirley Highway was determined with Eq. 1:

$$\begin{aligned}
 RA &= \frac{N}{AO} & (1) \\
 &= \frac{5,037}{1.43} \\
 &= 3,523 \text{ vehicles/peak period,}
 \end{aligned}$$

where:

$$\begin{aligned}
 N &= \text{net bus passenger growth, and} \\
 AO &= \text{average automobile occupancy.}
 \end{aligned}$$



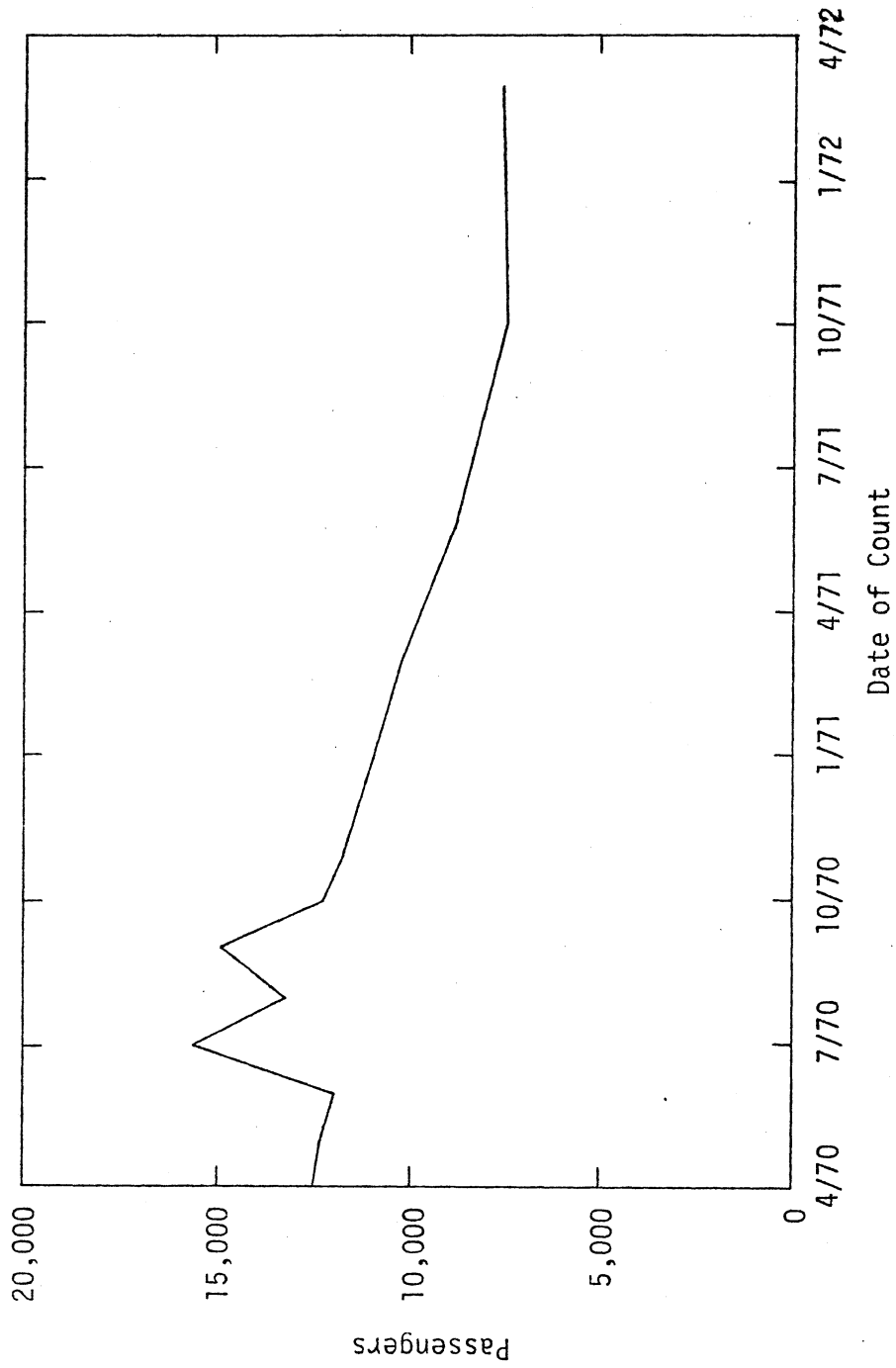


Figure 9. Morning peak period automobile passengers on Shirley Highway study site.

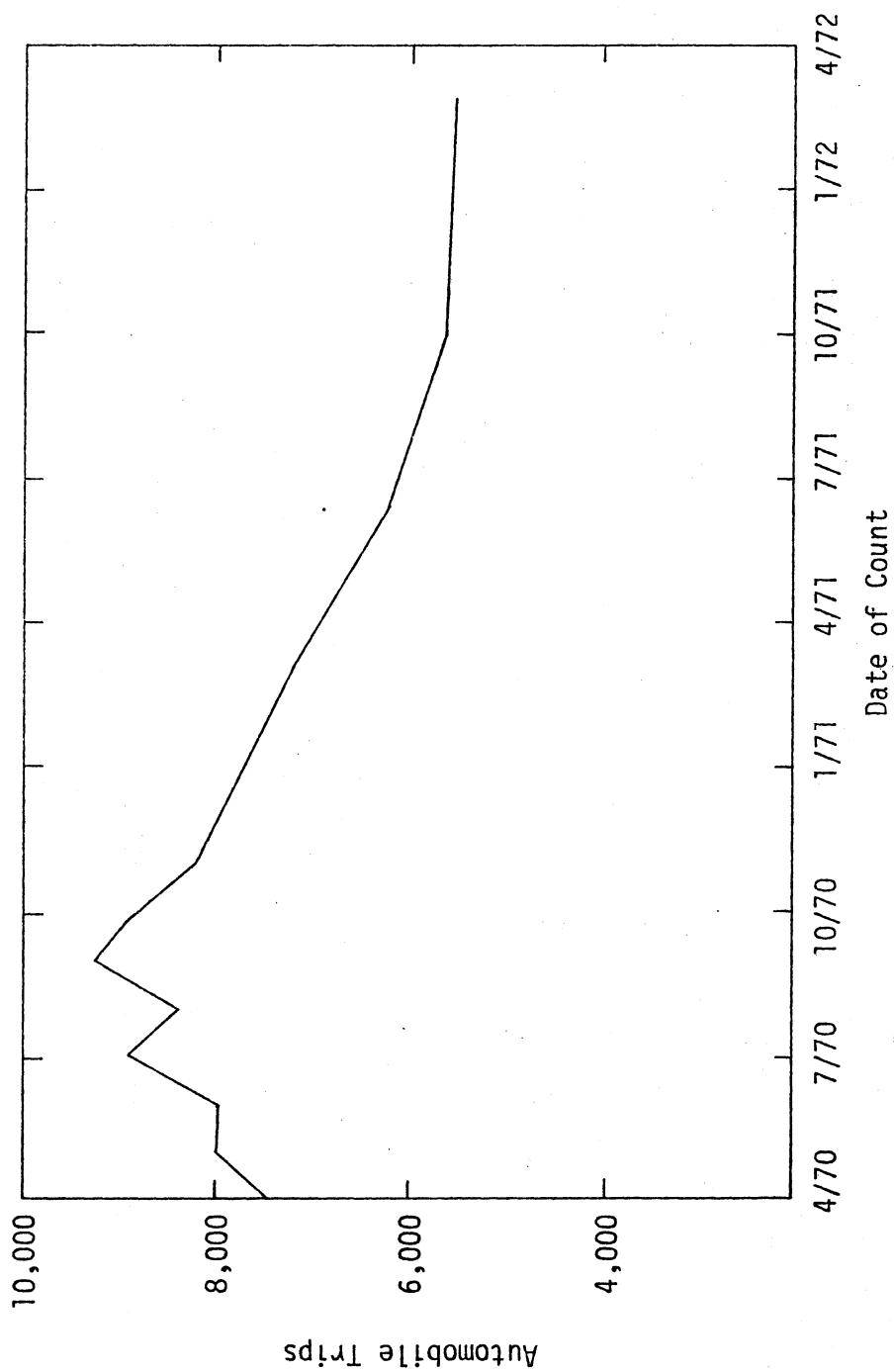


Figure 10. Morning peak period automobile trips on Shirley Highway study site.

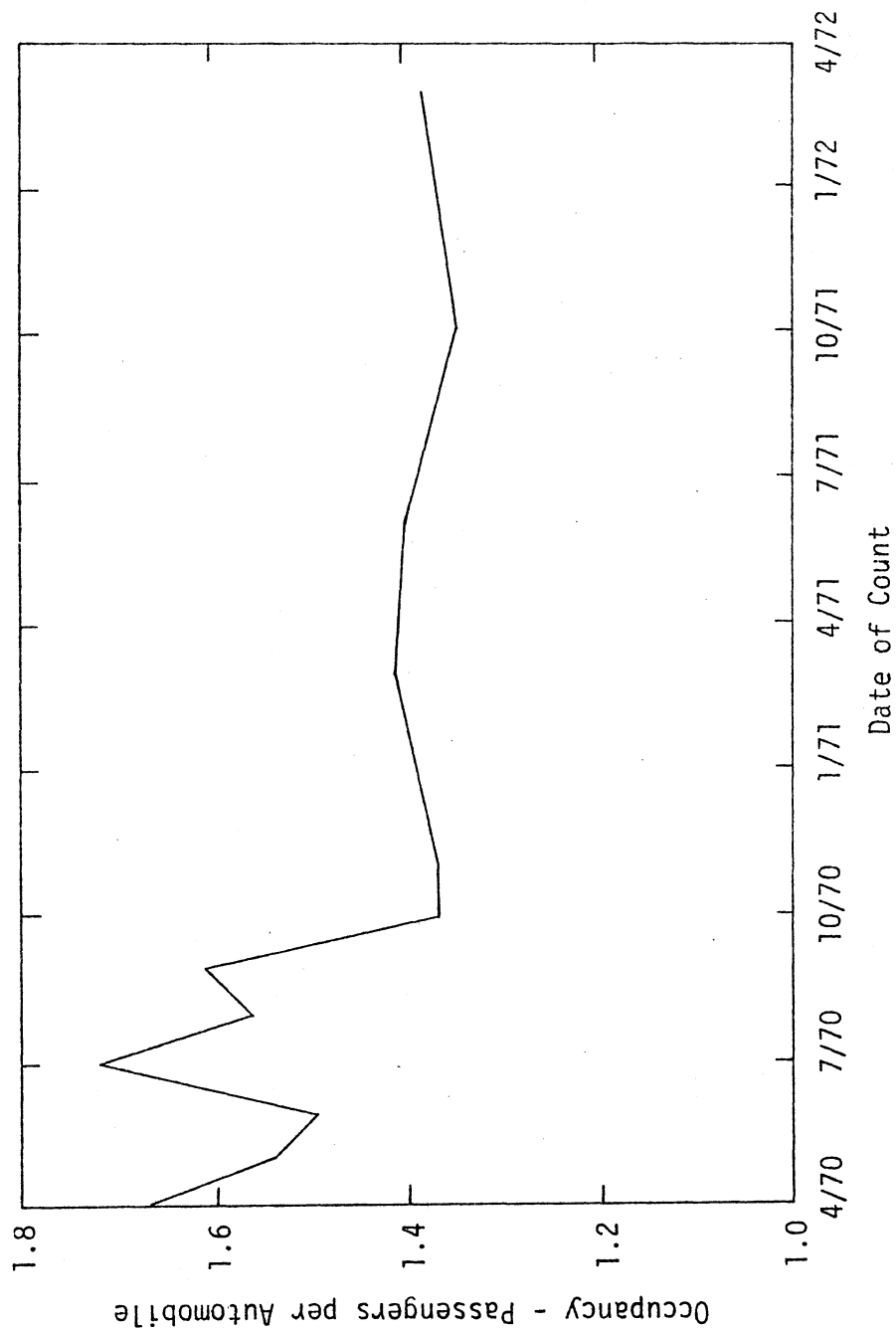


Figure 11. Morning peak period automobile occupancy on Shirley Highway study site.

To substantiate the above estimated reduction in automobiles, a review was made of the automobile travel trend. Figure 10 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%. 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 morning peak hour. A classification volume count was secured and Table 5 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 subjected to further study.

Table 5 indicates that 192 local bus trips were made on the busway during the peak period and Table 6 shows that 131 of those were during the morning peak hour between 7:15 and 8:15. Assuming the number of passengers was proportional to the number of bus trips, the estimated reduction in automobiles,  $RA_h$ , during the morning "people-moving" peak hour on the Shirley Highway was calculated with Eq. 2:

$$\begin{aligned} RA_h &= \frac{RA \ B_h}{B} & (2) \\ &= \frac{3,523 \ (131)}{(192)} \\ &= 2,403 \text{ vehicles/hour,} \end{aligned}$$

where:

$B_h$  = number of a.m. peak hour bus trips, and

$B$  = number of a.m. peak period bus trips.

Table 5

1150

**Shirley Highway Classification Traffic Volumes for  
Morning 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 6

**Shirley Highway Classification Traffic Volumes for  
Morning "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
<b>Total</b>	<b>2,105</b>	<b>108</b>	<b>2,213</b>	<b>131</b>	<b>32</b>

## QUALITY OF SERVICE ANALYSIS

The quality of traffic service being provided to the users of a highway is measured in terms of levels of service. It 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. Although it is desirable to give consideration to all of the above items, when evaluating the level of service, as yet, there are insufficient data to permit the determination of values for all of these factors. Accordingly, operating speed and demand volume-to-capacity ratios are employed here. The volume-to-capacity ratio provides an indication of traffic densities and freedom to maneuver, while the operating speed is a measure of the overall performance of a roadway.

The number of automobiles removed from the Shirley Highway due to the express bus service indicated an improvement in the level of service for the conventional traffic. In this analysis the existing level of service, with the busway in operation, is compared to the theoretical quality of service that would have been experienced if the express bus service had not been implemented.

### Level of Service Analysis with Busway

In analyzing the existing level of service for the conventional traffic, the classification volumes presented in Table 6 were utilized. Speed studies conducted during the "people-moving" peak hour at the study site revealed an operating speed of approximately 30 mph.

The computations represent the present conventional freeway conditions. Values of the input variables were taken from Table 6 and the Highway Capacity Manual. The capacity, C, is given by Eq. 3:

$$\begin{aligned} C &= 2,000 N W T_c & (3) \\ &= 2,000(2) (.90) (.95) \\ &= 3,420 \text{ vehicles/hour,} \end{aligned}$$

where:

$$\begin{aligned} N &= \text{number of lanes in one direction,} \\ W &= \text{adjustment for lateral clearances, and} \\ T_c &= \text{truck factor at capacity.} \end{aligned}$$

In this analysis the service volume equaled the demand volume (2,213 vehicles per hour) during the peak hour; therefore 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 period within the peak hour. With the data in Table 6, the peak hour factor, PHF, was computed with Eq. 4:

$$\begin{aligned} \text{PHF} &= \frac{V}{R_m P} & (4) \\ &= \frac{2,213}{234 (12)} \\ &= 0.79 \end{aligned}$$

where:

- V = demand volume of vehicles in traffic stream,
- R<sub>m</sub> = 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 established in the Highway Capacity Manual revealed that the subject section of the Shirley Highway was operating at an E Level of Service. 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. All of these characteristics were observed on a field trip to the study site during the "people moving" peak hour.

#### Level of Service Analysis Without Busway

To estimate the impact of the bus system 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 6.
3. Because the bus passenger "historical" trends indicated a negligible variation in patronage during the study period, only



the buses 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 on the existing facility, as the travel time on the Shirley Highway for the automobile was greater than that for 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 were 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.

The total initial bus 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 "people-moving" peak hour. Equation 2 reveals that an estimated 2,403 vehicles were removed from the Shirley Highway during the morning "people-moving" peak hour because of the busway.

Thus, the deletion of the busway would necessitate forcing 2,403 automobiles and 57 buses into the conventional traffic. These vehicles, added to the volumes in Table 6, result in 4,673 vehicles (4,508 automobiles and pickups, 108 trucks, and 57 buses) desiring to use the hypothetical roadway.

The new capacity was derived from Eq. 5:

$$\begin{aligned}
 C &= 2,000 N W T_c B_c & (5) \\
 &= 2,000 (2) (.90) (.98) (.99) \\
 &= 3,490 \text{ vehicles/hour,}
 \end{aligned}$$

where:

$$B_c = \text{bus factor at capacity.}$$

The adjusted service volume was determined with Eq. 6:

$$\begin{aligned}
 SV &= 2,000 N \frac{V}{C} W T_L B_L & (6) \\
 &= 2,000 (2) \frac{4,673}{3,490} (.90) (.98) (.99) \\
 &= 4,673 \text{ vehicles/hour,}
 \end{aligned}$$

where:

$$B_L = \text{bus factor at existing level of service.}$$

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, which reveals that the demand volumes far exceed the capacity of the facility. Under these conditions the facility would break down. The result would be low, if not zero, speeds; extremely high density; 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.

## CONCLUSIONS AND RECOMMENDATIONS

Due to the limitations of the data, especially those 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 buses (Trailways, Greyhound, Military, etc.) was omitted in this study. The "people-moving" peak hour for the hypothetical roadway was assumed to occur 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 5 indicates that the morning "vehicle-moving" peak hour occurred before the "people-moving" peak hour; consequently, the anticipated earlier use of the Shirley Highway would necessitate that many commuters travel in a heavier flow than analyzed in this study. Subsequently, it is assumed that the foregoing analysis and the following general conclusions are conservative.

### Conclusions

At the time of its inauguration, the Shirley Highway Express-Bus-on-Free-way 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 that automobile users would divert to the express bus. However, the preceding analysis indicated that the project was successful, as it attracted many former automobile passengers and thus reduced the number of vehicles and alleviated the 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 commuters on the Shirley Highway made the trip by bus. By the end of the study period, the bus ridership had grown to the extent that 54% of the commuters during the morning peak period rode the bus. In other words, more people were then commuting by bus than by automobile on the Shirley Highway during the rush hours.

Another finding that revealed the effectiveness of the project was the fact that the project served the more affluent economic groups, who commuted from the suburbs to government and private employment establishments in the downtown area. Historically it has been difficult to attract these groups to bus transportation as they usually have several automobiles available. Tables 2 and 3 indicated that 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.

Although the buses provided a rapid movement on the exclusive lanes, it cannot be concluded that the service was comfortable. 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 for 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 significant. 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. It was surmised that if the busway had not been provided, 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 benefitted from the demonstration project.

Although the exact degree of improvement cannot be stated, there was reliable evidence to indicate that the basic objective — to improve the level of service for all commuters on the Shirley Highway — of the demonstration project was fulfilled. More important, the project demonstrates the potential of the exclusive lane bus system as a method of public mass transportation. It appears to be feasible, practical, workable, and acceptable to the public.

#### Recommendations for Further Research

The conclusions from this study 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 and a final evaluation of the overall success of the program should await completion of the demonstration project. Recommendations for further research are:

1. 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.
2. The express bus service demand has exceeded the forecasts made in the feasibility report, thereby indicating a deficient modeling process. Several new models have been developed and an evaluation should be made to determine the feasibility of these models in the application of the reserved bus lane concept. Should such an evaluation be unsuccessful, then further research is recommended for the development of appropriate models.
3. Fringe parking facilities were an important aspect in the subject demonstration project. Models should be developed which provide guidelines in the placement of these facilities to ensure optimum usage.
4. 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.
5. Additional community benefits, such as reduced downtown parking space demand, reduced residential street parking demand, accident reduction, conservation of fuels, and reduction in air pollution, warrant further evaluation and study.

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