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The Shirley Highway Express-Bus-on-Freeway Demonstration Project/ A Study of Reverse Commute Service

Robert Waksman

National Bureau of Standards
Technical Analysis Division
Urban Systems Program Area
Washington, D. C. 20234

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Interim Report 5

Prepared for
Urban Mass Transportation Administration
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

ABSTRACT

Bus-on-freeway operations generally provide peak period commuter transit service to persons traveling from suburban residences through congested corridors to jobs in the major employment centers of metropolitan areas. In a few cases, peak period reverse commute operations may provide service to persons traveling from residences near the downtown employment centers to jobs in the suburbs. In early 1973, two major Shirley Highway Express-Bus-on-Freeway Demonstration Project reverse commute routes began service to office buildings in Northern Virginia.

An analysis of this reverse commute service revealed that it was a successful operation because it provided considerable benefits to its patrons and was slightly profitable to the bus operator on an incremental cost basis.

Four conditions which were important for the success of the service were found to be important for the success of reverse commute operations, in general. The conditions are as follows:

(1) A given route should serve a concentrated, high employment area.

(2) The route should be accessible to people currently working within the employment area and to captive riders who can fill jobs there.

(3) It should be possible to fit most of the reverse commute trips into existing bus schedules.

(4) It should be possible to pair with peak direction trips any trips that cannot be fit into existing bus schedules.

Using a procedure which incorporates these conditions, one employment area within the Shirley Highway Corridor was identified as having potential as a market for a reverse commute service.

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1. INTRODUCTION AND SUMMARY

1.1 BACKGROUND

Bus-on-freeway operations are overwhelmingly peak period oriented. In general, these operations provide commuter transit service to persons traveling from suburban residences through congested corridors to jobs in the major employment centers of metropolitan areas. The buses providing this service usually begin their morning peak period trips by proceeding from garages directly to suburban starting points of trips bound for the employment centers (e.g., the Central Business District). After completing the trips into the employment centers, the buses usually return either directly (deadhead) to the suburban origins to repeat the trips into the employment center or deadhead back to the garages. During the evening peak period, the pattern is reversed.

In a few cases, buses operating during the peak period may provide service to persons traveling from residences near the downtown employment centers to jobs in the suburbs. An operation which provides peak period transit service in the direction opposite the primary flow of peak period traffic is known as a reverse commute service.

A reverse commute service can provide benefits to both the bus operator and users of the service. Because the incremental cost to the operator of providing a reverse commute route can be small, the bus operator might realize an operating profit even if patronage is moderate. Users of the reverse commute route can benefit in the following ways: People who do not have an automobile available to get to work can be provided with a frequent and reliable means of commuting. Persons who have been using an automobile to get to work can have the opportunity to switch to an attractive bus service. Finally, the access provided by the reverse commute service can enable some center city residents who do not own cars to accept jobs that they would otherwise have to forego. In this way, employers in the areas served by the reverse commute service can also benefit by being given access to a new labor market.

In the Shirley Highway Corridor, peak period bus service has been overwhelmingly oriented towards trips made in the direction of the primary flow of peak period traffic. Thus, these bus operations serve individuals traveling between their suburban Northern Virginia homes and jobs at the Pentagon and Crystal City, and in downtown Washington, D.C. However, in early 1973, peak period reverse commute service was established on three Shirley Highway Express-Bus-on-Freeway Demonstration Project bus routes. During the morning peak period, reverse commute service is provided from downtown Washington, D.C., to suburban job centers in Northern Virginia via the Shirley Highway. The buses providing this service then proceed to residential areas in suburban Northern Virginia to make trips to downtown Washington, D.C., via the Shirley Highway exclusive bus lanes. During the evening peak period, the pattern is reversed, with inbound reverse commute trips to Washington, D.C., being followed by outbound trips to suburban Northern Virginia via the Shirley bus lanes. This report is based upon an analysis of these reverse commute routes.

1.2 PURPOSE AND CONTENTS

The purpose of this report is to: (1) describe the Shirley Highway peak period reverse commute routes; (2) analyze and evaluate their operation; (3) determine the factors conducive to the success of reverse commute operations; and (4) identify employment areas within the Shirley Highway Corridor which have high potential as markets for a reverse commute service. Section 2 addresses the first objective, Section 3 the second, Section 4 the third, and Section 5 the fourth objective.

1.3 SUMMARY

In early 1973, two major Shirley Highway Express-Bus-on-Freeway Demonstration Project reverse commute routes, the 19Y and the 27Y, each began service to a newly opened high-rise office building in Northern Virginia. After eleven months, patronage on the 19Y was about 125 on six morning trips and about the same on six evening trips. On the 27Y, patronage was about 65 on four morning trips and 55 on three evening trips.

This reverse commute service was found to provide considerable benefits to its patrons. Responses to an onboard survey taken on these riders in February 1974 revealed that at least 43 percent of them had no means other than bus for getting to work. These riders have been provided with a frequent and reliable means of commuting as a result of the reverse commute service. The service has enabled many of these riders-- who could not have gotten to their jobs if the service did not exist-- to accept jobs that they would otherwise have to forego. Those riders who could have used an automobile to get to work have been provided with an attractive alternative.

The service was also found to be slightly profitable to the bus operator on an incremental cost basis. To estimate the incremental cost of the service, the cost allocation formula that was developed for the evaluation of the Shirley Highway Express-Bus-on-Freeway Demonstration Project was applied. To estimate the incremental revenue, consideration was given to the fares that would have been diverted from the preexisting bus routes had the reverse commute service not been implemented. The cost and revenue estimates showed that the bus operator's margin of income over costs was positive. It was concluded that because the reverse commute service was beneficial to its users and slightly profitable to the bus operator, it has been a successful operation.

Four conditions which were important for the success of the service were found to be important for the success of reverse commute operations, in general. The conditions are as follows:

(1) A given route should serve a concentrated, high employment area in which the working hours of a majority of the employees vary by only a small amount.

(2) The route should be accessible (directly and through single transfers) to people currently working within the employment area and to captive riders who can fill jobs at the employment areas served by the route.

(3) The route should be one in which it is possible to fit most of the reverse commute trips into existing bus schedules.

(4) The route should be one in which it is possible to pair with peak direction trips any trips that cannot be fit into existing bus schedules (and therefore, require additional buses).

A procedure which incorporates these conditions and the techniques used to cost out the present reverse commute service was used to identify employment areas within the Shirley Highway Corridor which have high potential as markets for a reverse commute service. A reverse commute route serving the Shirley Industrial Area in Springfield, Virginia, was found to be promising. It was suggested that a more detailed operational planning study be made prior to implementing this route.

2. CHARACTERISTICS OF THE SHIRLEY HIGHWAY PEAK PERIOD REVERSE COMMUTE SERVICE

This section is divided into two major paragraphs. Paragraph 2.1 examines the bus service provided by the Washington Metropolitan Area Transit Authority (WMATA) reverse commute routes operating in the Shirley Highway Corridor. Paragraph 2.2 examines demographic and travel characteristics of the reverse commute bus users.

2.1 DESCRIPTION OF THE REVERSE COMMUTE SERVICE

There are three Shirley Highway Demonstration Project reverse commute bus routes in operation--the 19Y, the 27Y, and the 17T. The 19Y and 27Y were implemented simultaneously with the opening of the Hoffman Building and Army Material Command (AMC) Building, high-rise Department of Defense offices in southern Alexandria employing 5200 and 2800 people, respectively.[1] The 17T serves the newly opened Northern Virginia Training Center, an institution for mentally retarded children in Fairfax County. Because the scope of the 17T service is small, consisting merely of the expansion of mid-day Route 17 service by the addition of single morning and evening peak period trips, the 17T is not included in this study.

The Route 19Y provides six morning and six evening peak period trips. This 12 mile route has a scheduled travel time of 42 minutes. The 27Y provides four morning and three evening peak period trips. This 11 mile route has a scheduled travel time of 40 minutes. During the morning peak period, the buses on both routes originate at Farragut Square in downtown Washington, D.C. They then proceed south on Shirley Highway to their destinations, the AMC Building for the 27Y, and the Hoffman Building for the 19Y. During the evening peak period, the service on the two routes is in the opposite direction.[2] See Figures 1 and 2 for a detailed description of the routes and schedules of the 19Y and 27Y.

Free transfer to the 19Y and 27Y from other WMATA buses can be made at several locations. Transfers from Washington and Maryland buses can be made at Farragut Square as well as at other stops in downtown Washington. Transfers from Northern Virginia buses can be made at the Pentagon, at Shirlington, and along Duke Street in Alexandria (see map in Figures 1 and 2). Bus fare to the Hoffman Building on the 19Y is 60¢ from downtown Washington and between 40 and 50¢ from Northern Virginia. Bus fare to the AMC Building on the 27Y is 70¢ from downtown Washington and between 40 and 60¢ from Northern Virginia.

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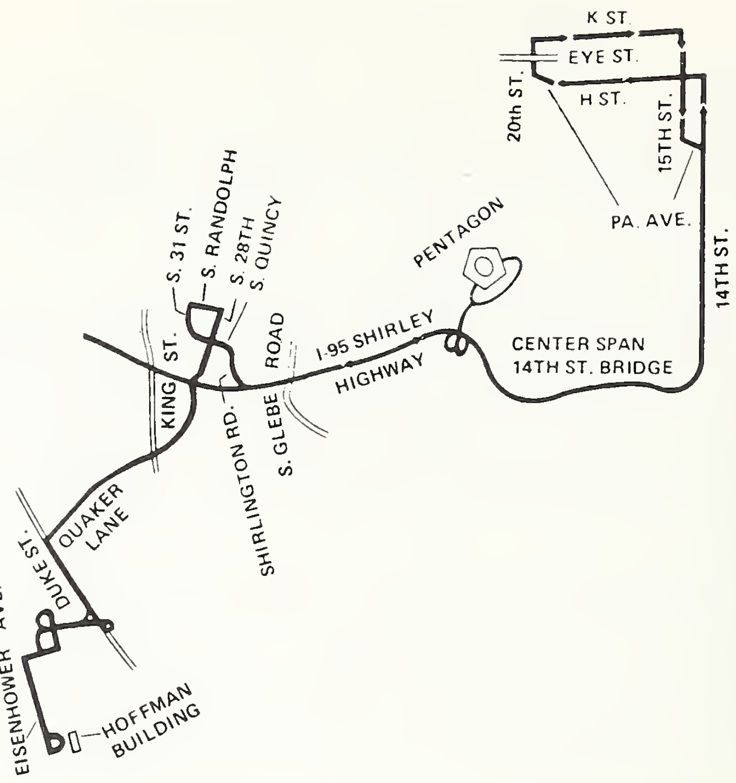
[1] Personal communication from David Erion of the Northern Virginia Transportation Commission (NVTC), November 15, 1973.

[2] The Route B-1, between Carter Barron in Northwest Washington and the Hoffman Building, was begun in April 1973. The buses on this route use the Jefferson Davis Highway, and the route is not a part of the Shirley Highway Demonstration Project.



ROUTE NO. 19Y WEEKDAY SERVICE

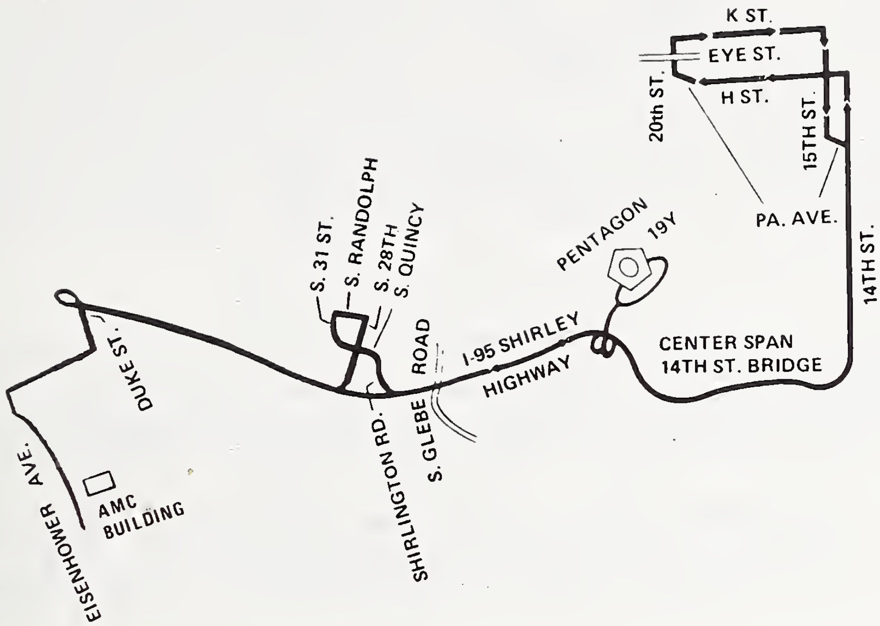
FARRAGUT SQUARE*	14th ST. & CONSTITUTION	PENTAGON	SHIRLINGTON	KING ST. & QUAKER LANE	DUKE ST. & QUAKER LANE	HOFFMAN BUILDING
FROM WASHINGTON A.M.						
6:08	6:17	6:27	6:34	6:38	6:43	6:50
6:22	6:31	6:41	6:48	6:52	6:57	7:04
6:35	6:44	6:54	7:01	7:05	7:10	7:17
6:50	6:59	7:09	7:16	7:20	7:25	7:32
7:06	7:15	7:25	7:32	7:36	7:41	7:48
7:23	7:32	7:42	7:49	7:53	7:58	8:05

*Leave and arrive time at 20th & Eye St. Terminal.

HOFFMAN BUILDING	DUKE ST. & QUAKER LANE	KING ST. & QUAKER LANE	SHIRLINGTON	PENTAGON	14th ST. & CONSTITUTION	FARRAGUT SQUARE*
TO WASHINGTON P.M.						
3:40	3:47	3:52	3:56	4:03	4:13	4:22
3:55	4:02	4:07	4:11	4:18	4:28	4:37
4:10	4:17	4:22	4:26	4:33	4:43	4:52
4:25	4:32	4:37	4:41	4:48	4:58	5:07
4:38	4:45	4:50	4:54	5:01	5:11	5:20
5:00	5:07	5:12	5:16	5:23	5:33	5:42

*Leave and arrive time at 20th & Eye St. terminal.

FIGURE 1. ROUTE AND SCHEDULE OF THE 19Y



ROUTE 27Y WEEKDAY SERVICE

FARRAGUT SQUARE*	14th ST. & CONSTITUTION	PENTAGON (B-1)	SHIRLINGTON	DUKE STREET & VAN DORN ST.	AMC BUILDING
FROM WASHINGTON A.M.					
6:25	6:34	6:44	6:51	6:59	7:05
6:40	6:49	6:59	7:06	7:14	7:20
6:50	6:59	7:09	7:16	7:24	7:30
7:10	7:19	7:29	7:36	7:44	7:50

*Leave and arrive time at 20th & Eye Street Terminal

AMC BUILDING	DUKE STREET & VAN DORN ST.	SHIRLINGTON	PENTAGON (B-4)	14th ST. & CONSTITUTION	FARRAGUT SQUARE*
TO WASHINGTON P.M.					
4:10	4:16	4:24	4:31	4:41	4:50
4:25	4:31	4:39	4:46	4:56	5:05
4:38	4:44	4:52	4:59	5:09	5:18

*Leave and arrive time at 20th & Eye Street Terminal

FIGURE 2. ROUTE AND SCHEDULE OF THE 27Y

The scheduling of the 19Y and 27Y buses coincides with the working hours of the different shifts in the two employment areas. At the Hoffman Building, starting times are from 7:00 to 8:30 A.M. and quitting times are from 3:30 to 5:00 P.M. At the AMC Building, starting times are from 7:30 to 8:00 A.M. and quitting times are from 4:00 to 4:30 P.M.[3] The 19Y, offering headways of 13 to 17 minutes (i.e., six morning buses arriving at the Hoffman Building between 6:50 and 8:05 A.M. and six evening buses departing the Hoffman Building between 3:40 and 5:00 P.M.), can serve all of the shifts at the Hoffman Building. The 27Y, offering headways of 10 to 20 minutes (i.e., four morning buses arriving at the AMC Building between 7:05 and 7:50 A.M. and three evening buses departing the AMC Building between 4:10 and 4:38 P.M.), can serve all of the shifts at the AMC Building.

2.2 CHARACTERISTICS OF THE USERS OF THE REVERSE COMMUTE SERVICE

As of January 1974, about 125 people used the six 19Y buses in the morning, and the same number used the six 19Y buses in the evening. About 65 people used the four 27Y buses in the morning and 55 people used the three 27Y buses in the evening.[4,5] The January 1974 ridership levels are lower than those experienced in early 1973 when the routes were initiated. On the 19Y, ridership is about 10 percent lower, and ridership on the 27Y is about 20 percent lower. Thus, initial ridership on these routes was quite high. This can be attributed to the fact that employees at the Hoffman and AMC Buildings were relocated from various parts of the downtown Washington area, where bus transit service was extensive. The simultaneous implementation of the 19Y and 27Y with the opening of the two office buildings enabled many employees to continue, without interruption, to use bus transit service after their jobs had been moved to the new locations.

To determine the characteristics of the 19Y and 27Y riders, a short onboard survey of these riders was made in February 1974.[6] The survey form used is shown in Figure 3. Survey responses were used to determine the trip origins of the 19Y and 27Y bus riders. The location of the trip origin is important because it affects the number of transfers and both the access and total door-to-door travel times. Of the total bus riders surveyed (140), 87 or 62 percent board the bus in downtown Washington, D.C., and the remainder board the bus in Northern Virginia. Of those who board the bus in Washington, D.C., five live as much as 8 miles from their boarding point. Of the 53 who board the bus in Northern Virginia, three live as much as 7 miles from their boarding point. In

[3]Personal communication from Lawrence Snider of the U.S. Department of Defense, November 28, 1973.

[4]Only about four or five people who use the 19Y and 27Y do not have their starting or end point at the Hoffman Building or AMC Building, respectively (observed during an onboard survey taken in February 1974).

[5]Personal communication from David Erion of NVTC, February 19, 1974.

[6]About 75 percent of the 19Y and 27Y riders were surveyed. The nearly 100 percent response rate yielded a sampling rate of 74 percent.

both groups, it is difficult to tell what percentage live within walking distance of the buses: In answering the survey question, "What is the address where this trip began? (home address if this trip started at home)", a third of the respondents in each group indicated the bus stop at which they board their 19Y or 27Y bus. It is estimated that 65 to 85 percent of the people boarding the buses in both Washington, D.C., and Northern Virginia transfer from other buses (or are driven to the bus stop).

As would be expected, the total door-to-door travel times for those who transfer is considerably more than it is for those who can walk to the bus.[7] Estimates of the distributions of total door-to-door travel times obtained from survey respondents are presented in Table 1.

Form NBS-760A

548

OMB No. 41-R2752
Approval expires 12-31-76

PLEASE RETURN THIS CARD TO THE SURVEY PERSON ON THIS BUS

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

____
Street Number

____
Town (Place) State Zip Code

2. What was the ultimate destination of this trip? (place of work address if work trip)

____
Street Number or Building Name

____
City (Place) State Zip Code

3. When did you begin riding this bus? Month__________ Year__________

4. On the average, how often do you ride this bus?__________ days per week.

5. How many automobiles are owned or operated by members of your household?________

6. Please indicate: AGE ☐ Under 21 ☐ 21-39 ☐ 40-65 ☐ Over 65

SEX ☐ Male ☐ Female

FIGURE 3. FORM USED IN THE SURVEY OF 19Y AND 27Y BUS RIDERS

[7] Total travel time for those who can walk consists of walk time to the bus, wait time for the bus, and in-vehicle time. For those who must transfer from another bus, total travel time also includes the wait time and in-vehicle time for the other bus.

Table 1
Total Door-to-Door Travel Time
Distribution for Survey Respondents

LOCATION AT WHICH REVERSE COMMUTE BUS IS BOARDED	ACCESS MODE TO REVERSE COMMUTE BUS	TOTAL DOOR-TO-DOOR TRAVEL TIME		
		HIGHEST (min)	LOWEST (min)	AVERAGE (min)
Washington	Walk	53	41	48
Northern Virginia	Walk	34	17	27
Washington	Transfer From Another Bus	90*	50*	65
Northern Virginia	Transfer From Another Bus	65*	40*	50

*In-vehicle time on the bus transferred from could be as low as 5 minutes or as high as 35 minutes.

Survey responses were also used to obtain the household auto ownership distrbution of 19Y and 27Y riders. The distribution in Table 2 was derived from the responses to the question, "How many automobiles are owned or operated by members of your household?" The average auto ownership of these bus riders is considerably lower than the average for the Metropolitan area. Average auto ownership for a household in Washington, D.C., is 1.13, and 1.34 for a household in the Shirley Highway Corridor.[8] By contrast, the average auto ownership of the household of a person boarding a 19Y or 27Y in Washington, D.C., is 0.59, and 1.04 autos per household for a person boarding in Virginia.

Table 2
Auto Ownership Distribution for Survey Respondents

AUTOS OWNED PER HOUSEHOLD	PERSONS BOARDING IN	
	WASHINGTON	VIRGINIA
0	49%	33%
1	42	41
2	9	18
3	0	6
4	0	2
Total	100%	100%
Average Household Auto Ownership	0.59	1.04

The auto ownership distributions were used to estimate the percentage of bus riders who are "captive riders" (i.e., riders who have no means other than bus for getting to work). Bus riders who indicated no automobiles in their household are captive bus riders unless the option of riding as a passenger in an auto is available to them. Bus riders who indicated one auto in their household are not captive unless that auto must be used by another household member and the option of riding as a passenger in an auto is not available to them. Those bus riders who indicated more than one auto in their household are most likely not captive. The percentage of riders having zero automobiles in their household was taken as the minimum percentage of bus riders that are captive. With this assumption, at least 49 percent of the bus riders surveyed who board a bus in Washington

[8] James T. McQueen, Richard F. Yates, and Gerald K. Miller, "The Shirley Highway Express-Bus-on-Freeway Demonstration Project/Second Year Results, Interim Report 4" (Report DOT/UMTA 4), Washington, D.C., November 1973, available from NTIS, Springfield, Virginia, COM-74-10875.

and at least 33 percent of those surveyed who board a bus in Virginia are captive riders. Combined, at least 43 percent of all those surveyed are captive riders.

Survey responses also yielded age and sex distributions of the 19Y and 27Y riders, presented here in Table 3. A large percentage of the persons boarding a 19Y or 27Y bus in Washington are females between the age of 40 and 65. About half of the persons boarding in Northern Virginia are male, and while the average age of those boarding in Northern Virginia tends to be lower than it is for those boarding in Washington, a majority of the Northern Virginia riders responding indicated that they are between the age of 40 and 65. These distributions differ markedly from the age and sex distributions of Shirley Highway Corridor riders obtained from unpublished fall 1973 Shirley Highway bus survey data (riders on peak period buses traveling in the direction of the primary flow of peak period traffic). Only 37 percent of these riders are 40 or older and only 43 percent are female.

Table 3
Age and Sex Distribution for Survey Respondents

DEMOGRAPHIC CHARACTERISTICS	PERSONS BOARDING IN	
	WASHINGTON(87)	VIRGINIA(53)
Age		
Under 21	4%	6%
21-39	25	39
40-65	69	53
Over 65	2	2
Total	100%	100%
Sex		
Male	34%	48%
Female	66	52
Total	100%	100%

( ) Number of Respondents

3. EVALUATION OF THE SHIRLEY HIGHWAY PEAK PERIOD REVERSE COMMUTE SERVICE

The analysis in the two following paragraphs will show that the reverse commute service is beneficial to the users of this service and is estimated to be slightly profitable to the bus operator. In Paragraph 3.1, the incremental user benefits are determined by comparing the reverse commute service with the service that would have been available if the reverse commute service had not been provided. The reverse commute service is found to provide substantial benefits to a minimum of 80 captive riders using the service, as well as benefits to the choice riders using the service, and to many peak directional users of the Shirley Express Routes 19G and 27G.

In Paragraph 3.2, the impact of the reverse commute service on the bus operator is examined. To estimate the incremental cost of the service, the cost allocation formula that was developed for the evaluation of the Shirley Highway Express-Bus-on-Freeway Demonstration Project is applied. To estimate the incremental revenue, consideration has to be given to the fares that would have been diverted from the preexisting bus routes had the reverse commute service not been implemented. The cost and revenue estimates show that the bus operator's margin of income over costs is positive. A precise estimate of the size of the margin is impossible because of the uncertainty in determining the number of fares that would have been diverted from the preexisting service.

It can be concluded that because the reverse commute service is beneficial to its users and is slightly profitable to the bus operator, it is (based upon these criteria) a successful operation.

3.1 IMPACTS OF THE REVERSE COMMUTE SERVICE ON THE USERS

Approximately 185 people are using the reverse commute service and, thus, deriving benefits from it. To determine these benefits, the present reverse commute service will be compared with the service that would be available if the reverse commute service had not been provided. Recall that because the reverse commute service was implemented simultaneously with the opening of the Hoffman and AMC Buildings, the alternative service (hereafter referred to as the preexisting service) was probably never used by any of the 185 people using the reverse commute service.

If 19Y and 27Y service were not provided, those who use bus transit to get to the Hoffman and AMC Buildings would be faced with considerably poorer service. For those boarding the 19Y and 27Y buses in downtown Washington, D.C., bus schedules for the preexisting service would still be reasonably matched to working hours of the different shifts at the Hoffman and AMC Buildings. However, headways would be 15 to 25 minutes for buses to Hoffman as opposed to 13 to 17 for 19Y buses, and 25 minutes for buses to AMC as opposed to 10 to 20 minutes for 27Y buses. (For a description of the preexisting service see Appendix A).

For those boarding the 19Y and 27Y in Virginia, preexisting bus service would be extremely poor. From the Pentagon and Shirlington (the main boarding points in Virginia), only one bus would stop near the AMC Building: a Route 7F bus at about 7:05 A.M. From the Pentagon, no buses would stop near the Hoffman Building; from Shirlington, only three Route 6 buses with headways of 20 to 40 minutes would stop near the Hoffman Building. All of the 19Y and 27Y buses stop at the Pentagon and Shirlington, thus providing the same service to people boarding at these points that they provide to people boarding in Washington.

In-vehicle travel times on the preexisting service would be five to ten minutes longer than on the 19Y and 27Y. Most significantly, though, excessive walking distances of three-eights to seven-eights of a mile (with walking times of 8 to 18 minutes) from the preexisting service to the Hoffman and AMC Buildings would be experienced. (One quarter mile is generally acknowledged as the maximum acceptable walk distance to a transit stop.) The 19Y and 27Y buses deliver their passengers directly to the Hoffman and AMC Buildings.

The excessively long walking distances, long in-vehicle times, long wait times, and irregular or nonexistent service for some Virginia passengers, would make use of the preexisting service quite inadequate for many of the current 19Y and 27Y passengers. Therefore, if the 19Y and 27Y were not provided, many of the current 19Y and 27Y passengers would be unable to, or would choose not to use the preexisting service. The rest would be using it at considerable personal hardship. It is apparent that all of the approximately 185 people using the reverse commute service are deriving benefits, especially the captive riders. The reverse commute service provides captive riders with good access to their present jobs. It provides those captive riders who would have used the preexisting service with considerable travel time savings, especially in walk and wait times. It enables those captive riders who could not have used the preexisting service to either (1) retain their present jobs rather than take other, perhaps less desirable, jobs close to public transportation,[9] or (2) avoid finding other means of transportation to get to their present jobs which might compromise their present quality of life, e.g., being forced to buy a car to get to their jobs.

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[9]The present jobs are probably more desirable, i.e., pay more and offer greater chances for advancement than other jobs; otherwise, the job switch would have been made prior to moving to the AMC or Hoffman Building.

The choice riders who use the reverse commute service are not dependent on this service to get to work. Had they been faced with the poor preexisting bus service instead of the reverse commute service, all of these people probably would have chosen auto instead of bus to get to work. The reverse commute service enables them to leave their autos at home, which may result in added convenience for other members of their households. In the long run, the reverse commute service may enable these users to dispose of an auto or avoid buying another auto.

Riders on some peak period buses traveling in the direction of the primary flow of peak period traffic (hereafter referred to as peak direction trips) also appear to benefit from the reverse commute service. The acquisition of additional buses for the reverse commute service (three of the nineteen reverse commute trips could not be fitted into existing schedules and could not use existing buses) has resulted in the addition of three peak direction trips--one morning 19G, one afternoon 19G, and one morning 27G.[10] By supplying much needed additional peak direction capacity, these trips have attracted many new riders, as witnessed by the fact that all of the seats on these buses are taken.[11] These buses have also decreased waiting times for the users of the Route 19G and 27G buses.

In summation, the reverse commute service is providing considerable benefits to both the captive riders and the choice riders using the service. In addition, the reverse commute service provides benefits to some peak directional users. Thus, this service is desirable from the user's point of view.

3.2 IMPACTS OF THE REVERSE COMMUTE SERVICE ON THE BUS OPERATOR

To determine the impacts on the operator, the incremental costs of providing the reverse commute bus service are compared with the incremental income derived from the bus service. To estimate the costs attributable to the service, the cost allocation formula developed for the evaluation of the Shirley Highway Express-Bus-on-Freeway Demonstration Bus Project is used.[12] This formula provides a methodology for allocating all transit operating costs for a specified service in accordance with five variables--platform hours, revenue and non-revenue miles, peak period vehicles, peak period drivers, and passengers.[13] The formula is:

$$C = 5.51H + 0.14M + 13.03V + 26.53D + 0.046P \qquad (1)$$

where C = incremental cost per day (in dollars) for a specified service
H = number of platform hours per day
M = number of revenue and non-revenue miles per day
V = number of peak period vehicles per day
D = number of peak period drivers per day
P = number of passengers per day

The values of the coefficients are mean unit costs derived from 1972 cost data from the Shirley Highway Demonstration Project. The number of platform hours is the number of additional hours required to provide the reverse commute service. This includes the additional hours of service by new buses as well as by buses engaged in the existing peak direction service. The latter includes buses making reverse commute trips which have been fitted into established schedules. The number of miles is the number of additional miles that buses must travel (also includes deadhead miles) to provide reverse commute service. This includes the additional miles traveled by existing buses as well

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[10] See Paragraph 3.2, page 12, for a further discussion of the scheduling of the reverse commute trips.

[11] See Paragraph 3.2, page 13, for a further discussion of peak direction riders attracted by the reverse commute service.

[12] "The Shirley Highway Express-Bus-on-Freeway Second Year Results".

[13] Because new buses have been acquired for the reverse commute service, bus depreciation, which is not accounted for in the cost allocation formula, should be included in the costs. The method for including this capital cost is discussed on page 13.

as the total number of miles traveled by any new buses. Because all of the reverse commute service is peak period service, the number of vehicles and drivers is simply the additional number of buses and drivers needed to provide this service. The number of passengers is the additional patronage attracted by the service. The estimated values of these five variables determine the cost (incremental) of the reverse commute service.

Of the nineteen reverse commute trips, sixteen have been fitted into existing bus schedules and use existing buses, thus eliminating the need for additional buses for these runs. This has been accomplished by fitting these trips onto the beginning of existing bus schedules. In both the morning and evening peak periods, the buses used on these trips make reverse commute runs immediately after leaving the garage. The buses then make the same peak direction trips as they made prior to the initiation of the reverse commute service (i.e., when their first runs upon leaving the garage were the peak direction runs).

The sixteen trips fitted into existing bus schedules are five morning and five evening 19Y runs and three morning and three evening 27Y runs. The total increase in platform time from these runs is:

470 minutes for the 19Y, and

270 minutes for the 27Y

The total increase in total miles is:

130 miles for the 19Y, and

66 miles for the 27Y

See Appendix B for the detailed methodology by which these values are determined.

To operate the three reverse commute trips that could not be fitted into existing bus schedules--one morning 19Y, one morning 27Y, and one evening 19Y--additional buses have had to be placed in service. The two buses making the morning trips have been used on subsequent peak period inbound runs (one 19G and one 27G), and the bus making the evening 19Y trip has been used on a subsequent peak period outbound run (a 19G). Three peak direction trips have thus been added as a result of the implementation of the reverse commute service, and as such, the costs and benefits derived from these trips should be attributed to the reverse commute service.[14]

Based on this assumption, the platform times associated with running the two 19Y trips (including the subsequent 19G trips) and the one 27Y trip (including the subsequent 27G trip) are 249 and 161 minutes, respectively. Total miles traveled by the buses making the two 19Y and one 27Y trip are 74 and 46 miles, respectively. See Appendix B for the detailed methodology by which these values are determined.

The total increase in platform time and miles resulting from providing the reverse commute service is the sum of the values associated with the adding of new buses and the fitting of runs into the existing schedules. For the 19Y, the increase in platform hours is:

$$249 + 470 = 719 \text{ minutes} \simeq 12.0 \text{ hours},$$

and the increase in total miles is

$$74 + 130 = 204 \text{ miles}.$$

[14]It might be argued that the costs and benefits derived from these peak direction trips should be excluded from those derived from the reverse commute service on the grounds that peak direction trips are not part of the reverse commute service. In Appendix C, an investigation is made of the effect of excluding the impacts of the peak direction trips on the determination of impacts of the reverse commute service. To fully understand Appendix C, it is suggested that Paragraph 3.2 first be read in its entirety.

For the 27Y, the increase in platform hours is

$$161 + 270 = 431 \text{ minutes} \simeq 7.2 \text{ hours},$$

and the increase in total miles is

$$46 + 66 = 112 \text{ miles}.$$

The total increase in peak period bus and driver requirements resulting from providing the reverse commute service is the sum of the increases resulting from fitting runs into existing schedules and from adding extra buses. No additional peak period buses or drivers are needed for the runs fitted into existing schedules. For the runs where extra buses have been added, it is apparent that one peak period bus and one peak period driver are needed for the morning and evening peak period 19Y runs (and the subsequent 19G runs); and for the morning 27Y run (and the subsequent 27G run), one bus and one driver are needed for one half day (or one half driver and one half bus for one day).

The total increase in passengers resulting from providing the reverse commute service is the total number of passengers using the 19Y and 27Y plus the increase in the number of passengers on peak direction trips made by buses added for the reverse commute service. The number of passengers on the 19Y and 27Y are known from passenger counts taken by NVTC in January 1974 to be 278 and 120, respectively. The increase in the number of passengers on peak direction service is estimated to be 47 for the morning 19G, 45 for the evening 19G, and 61 for the morning 27G. See Appendix D for the detailed methodology by which these values for peak period passengers are determined. It follows that for the 19Y:

total increase in passengers = total passengers on 19Y

+ passengers on one morning 19G

+ passengers on one evening 19G

= 278 + 47 + 45 = 370.

For the 27Y:

total increase in passengers = total passengers on 27Y

+ passengers on one morning 27G

= 120 + 61 = 181.

The values for all of the factors needed in the cost allocation formula have now been determined. However, because new buses have been acquired for the reverse commute service, bus depreciation, which is not accounted for in the cost allocation formula should be included in the costs. To calculate the bus depreciation cost, values for the capital cost and life of a bus that are applicable to current WMATA operations are used. With values of $45,000 for the capital cost[15] and 12 years for the life of a bus,[16] and an opportunity cost of money of 8% per annum, the depreciation cost of a bus per weekday is calculated to be $23.80. This cost is in addition to the $13.03 per peak period vehicle per weekday used in the cost allocation formula (See Equation 1 on page 11), a cost which reflects only maintenance, garaging, and insurance costs. Using the cost allocation formula and including in it depreciation costs, the average daily costs (C) for the 19Y are:

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[15] K. Bhatt and M. Olson, "Analysis of Supply and Estimates of Resource Costs, Technical Report 2," unpublished working papers, Urban Institute, Washington D.C., November 1973.

[16] "The Economics of Transit Bus Replacement," Metropolitan, November/December 1971, p. 22.

$$C = 5.51(12) + 0.14(204) + (13.03 + 23.80)(1) + 26.53(1) + 0.046(370) = \$174.94.$$

For the 27Y:

$$C = 5.51(7.2) + 0.14(112) + (13.03 + 23.80)(0.5) + 26.53(0.5) + 0.046(181) = \$95.25.$$

The incremental income derived from the bus service is now estimated and compared with the incremental costs to determine the impact of the service on the bus operator (WMATA).

The income consists of the fares paid by both the reverse commute riders and the riders on the peak direction trips made by the buses added to the service. Since fares vary from zone to zone, average fares for the reverse commute riders are based on the origin distribution indicated on the responses of the riders surveyed. Average fares are found to be 54¢ for 19Y riders and 65¢ for 27Y riders. Average fares for riders on peak direction trips made by the buses added to the service are estimated to be 60¢ for the two 19G runs and 70¢ for the one 27G run. Based on these fares, revenues of $205.32 per day are estimated for the 19Y service, and revenues of $120.70 per day are estimated for the 27Y service.

Based on these revenues, the margin of income over expenses for the bus operator is positive on both reverse commute routes. This margin, obtained by subtracting the values obtained for daily incremental costs from those obtained for daily incremental income is for the 19Y:

$$205.32 - 174.94 = \$30.38/\text{day}$$

and, for the 27Y:

$$120.70 - 95.25 = \$25.45/\text{day}.$$

However, not all of these revenues can be considered to have been derived from the reverse commute service. Had the service not been implemented, some of its riders might have used the preexisting service to get to the Hoffman and AMC Buildings. Thus, the reverse commute service may be diverting fares from preexisting bus routes that would have carried some of the reverse commute riders had the present service not been implemented. These diverted fares should be excluded from the income derived from the reverse commute service.

On the other hand, income derived from reverse commute users who transfer from other WMATA buses and do not pay two fares should not be excluded from the income derived from the reverse commute service. The buses that are used to transfer to the reverse commute routes were in service before the reverse commute routes began operation, and prior to that time, did not attract any of the present reverse commute riders. It is the implementation of the reverse commute service that has produced the fares being paid by these transferring reverse commute users. Whether fares are being paid on buses being transferred from, or on reverse commute buses themselves, these fares derive from the addition of the reverse commute service. (Incremental costs associated with carrying the additional passengers on the buses being transferred to and from are quite small and can be ignored.)

Inclusion of the effect of diverted fares obviously will lower the margin of income over expenses and may even result in a negative value for it. However, no direct measurement can be made of the diverted fares. The preexisting service was not used by any of the reverse commute users before the reverse commute service was implemented. To overcome this shortfall, a calculation is made to determine the number of reverse commute users that would have had to have used the preexisting service in order that the margin of income over costs be completely erased. It is then decided whether or not it is realistic to expect that many reverse commute users to have used the preexisting service.

Proceeding in this fashion, it is found that if no more than 27 percent of the reverse commute users would have used the preexisting service, fares generated by the reverse commute service would still be sufficient for the margin of income over costs to be positive. (Incremental costs are only slightly affected by changes in patronage levels.) It is then shown in the detailed analysis in Appendix E that it is unlikely that as many as 27 percent of the users of the reverse commute service would have been diverted from the preexisting service had the present reverse commute service not been implemented. Based on this analysis, it is concluded that the fares generated by the reverse commute service are sufficient for the bus operator's margin of income over costs to be considered as positive.[17]

4. FACTORS CONDUCIVE TO THE SUCCESS OF REVERSE COMMUTE OPERATIONS

A problem of many other reverse commute operations has been their inability to attract riders and operate at an acceptable incremental cost at the same time. For example, five out of six reverse commute routes from downtown Baltimore, Maryland, to three different suburban employment sites in 1971, attracted an average of 26 passengers per bus. However, because of ineffective utilization of buses and operators, these routes needed revenues from 63 passengers per bus to match incremental operating costs.[18] By contrast, the 19Y and 27Y average 19 passengers per bus, but because of low incremental operating costs, need somewhat less than 19 passengers per bus to match these costs.[19]

Paragraph 4.1 of Section 4 discusses some of the reasons for the success achieved by the Shirley Highway Project reverse commute operation. Paragraph 4.2 concludes the section with a general discussion of conditions that would contribute to the success of reverse commuter operations elsewhere.

4.1 EXPLANATION OF THE SUCCESS OF THE SHIRLEY HIGHWAY REVERSE COMMUTE SERVICE

The Shirley Highway Project reverse commute service has been successful for a number of reasons. These reasons are cited in the following discussion:

(1) The 19Y and 27Y each serve a concentrated, high employment area in which the working hours of the employees vary only slightly. This has enabled a relatively small fleet of buses to offer direct service with short headways to an employment area where many people could use such a service.

(2) The routes were implemented simultaneously with the opening of offices whose employees were relocated from various parts of the downtown Washington area. This has enabled employees who had been using bus transit to get to their former work sites to continue, without interruption, to use bus transit after they moved into their new buildings.

(3) The several convenient transfer points along the routes where connections can be made with buses from many locations within the Washington, D. C., metropolitan area have enabled persons from widely scattered origins to connect with the service provided by the 19Y and 27Y. In particular, the extensive connections that can be made with buses serving areas in the center city make the reverse commute service accessible to large numbers of traditionally transit captive

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[17] The reader is reminded that in Appendix C an analysis is made of the effect of excluding the impacts of the peak direction trips added when the reverse commute service was implemented.

[18] Hazel Ellis, "Benefit-Cost Survey: Baltimore Service Development Transportation Project," prepared for Urban Mass Transportation Administration, U. S. Department of Transportation, Washington, D. C., Final Draft, Aug. 1970.

[19] The method used to cost the Baltimore service is comparable to that used to cost the 19Y and 27Y service, and it may actually understate the costs of that service somewhat.

commuters. Even though a transfer is involved, captive riders will generally use a transit service as long as total in-vehicle times are not excessive. Between 65 and 85 percent of the people riding the 19Y and 27Y transfer from other buses.

(4) Sixteen of the nineteen reverse commute trips were fitted onto the beginning of existing schedules in which the first trips were previously peak direction trips. The existing buses used on these reverse commute routes are generating additional revenues at little additional cost. Thus, by efficiently using existing resources, the incremental costs of operating these routes have been kept very low.

(5) The other three reverse commute trips, which require additional buses, were paired with three peak direction trips starting immediately after the reverse commute trips. This pairing of trips has enabled the extra buses to generate revenues from both reverse commute and peak direction trips. These revenues together tend to offset the substantial incremental costs incurred in operating the additional vehicles.

There are also some considerations which might have served to limit the success of the bus service. While the several convenient transfer points along the routes contribute to the success of the service, people who access the reverse commute buses by transferring from other buses have a service that is neither fast nor direct. This is especially true for people living in many parts of Northern Virginia who have to travel north towards Washington to catch the 19Y or 27Y at the Pentagon or Shirlington Circle, and then travel south, away from Washington, to get to work in Alexandria.

The overall quality of the bus service offered on the reverse commute routes is not high enough to offer much incentive to use this bus service if an auto is available. Auto is more convenient, more direct, and faster. Moreover, parking at Hoffman and AMC is fairly cheap and readily available. Parking costs are $10.00 per month at Hoffman and $12.50 per month at AMC. There are 2600 parking spaces at Hoffman and 1725 at AMC, and neither lot is completely filled at the end of the morning peak period.[20]

The analysis of the successful experience with the Shirley Highway Project reverse commute service is now concluded. Using these results and the results of other previous work on reverse commute service,[21] a set of conditions important for the success of future reverse commute services is developed in Paragraph 4.2.

4.2 CONDITIONS IMPORTANT FOR THE SUCCESS OF A REVERSE COMMUTE OPERATION

To have a viable reverse commute operation, it is important that the following conditions be attained:[22]

(1) Concentration of workers in the perspective employment areas. A reverse commute bus route should have as its destination a concentrated high employment area (2500 employees appears to be a minimum) in which the working hours of a majority of the employees vary by only a small amount. (The maximum variation appears to be between 45 and 90 minutes, the allowable spread increasing with the size of the work force.) This will enable a relatively small fleet of buses to offer direct service with relatively low headways to many people in an employment area.

[20] Personal communication from Lawrence Snider of the U.S. Department of Defense, November 28, 1973.

[21] John L. Crain, "The Reverse Commute Experiment: A $7 Million Demonstration Program," prepared for Urban Mass Transportation Administration, U. S. Department of Transportation, Washington, D. C., December 1970. (See also the drafts by John Crain and Hazel Ellis of the individual benefit-cost surveys performed for the cities in the demonstration program.)

[22] While a reverse commute operation that does not totally fulfill one of the conditions may still be viable, one that grossly violates one of the conditions or only marginally fulfills all of the conditions will probably not be a viable operation.

If the working hours in an employment area vary from day to day, or many of the employees often work overtime, a reverse commute service to that area will experience correspondingly lower revenues.

(2) Accessibility of the reverse commute route. The bus route should be accessible to a large segment of the people currently working within the employment area. The route should also be accessible to people who can potentially fill jobs at the employment area but who do not have access to a car or an existing bus service. For the route to be accessible to people from widely scattered origins, there should be several convenient transfer points along the route where connections can be made with buses from surrounding areas.

(3) Availability of non-productive buses and drivers. It should be possible to fit most of the reverse commute trips into existing bus schedules, either by running these trips before the first peak direction bus trips are run, after the last peak direction bus trips are run, or in the deadhead times between consecutive peak direction trips. This will eliminate additional operator and bus requirements, and thus result in low incremental costs for running these trips.

(4) An unmet demand for associated peak direction service. It should be possible to pair any reverse commute trips that cannot be fit into existing bus schedules (and require additional buses) with peak direction trips run immediately before or after the reverse commute trips. This pairing of trips will enable the extra buses to generate revenues from both reverse commute and peak directional trips, tending to offset the costs of additional buses and drivers. A reverse commute route that could fulfill conditions three and four would have to have its end points close to the end points of the peak direction trips.

There are, in addition, certain other situations that would be helpful to the success of a reverse commute service. If the route is implemented simultaneously with the opening of the employment area it serves, higher revenues will be generated immediately. Some potential bus users would be attracted to this service before they developed other travel habits. The size of this initial ridership would be further increased if the employees in the newly opened area have relocated from other employment areas where mass transit has been used extensively. Such a situation would enable many bus users to continue, without interruption, to use bus transit after they moved into their new employment area.

5.0 INVESTIGATION OF ADDITIONAL REVERSE COMMUTE SERVICE WITHIN THE SHIRLEY HIGHWAY CORRIDOR

Section 5, the final section of this report, uses the conditions discussed in Section 4 to identify additional markets for peak period reverse commute service within the Corridor. Only service patterned after the type offered on the present Shirley Highway reverse commute routes (between downtown Washington, D. C. and outlying Northern Virginia areas) is considered. Reverse commute routes emanating from locations other than downtown Washington are not considered. Although the examination of these other routes is important, such a task is considered beyond the scope of this study.

The section is divided into three major paragraphs. Paragraph 5.1 examines the employment concentrations in the Shirley Highway Corridor to determine which employment areas, if any, meet the conditions (presented in Paragraph 4.2) for successful implementation. Paragraph 5.2 discusses expected patronage and cost of potential routes. Paragraph 5.3 concludes the report with recommendations for future study of reverse commute operations.

5.1 IDENTIFICATION OF POTENTIAL MARKETS

A potential reverse commute route should meet the four conditions discussed in Paragraph 4.2 which are important for the success of a reverse commute operation. These conditions are summarized below:

(1) The route should serve a concentrated, high employment area in which the working hours of a majority of the employees vary by only a small amount.

(2) The route should be accessible (directly and through single transfers) to people currently working within the employment area and to captive riders who can fill jobs at the employment area.

(3) The route should be one in which it is possible to fit most of the reverse commute trips into existing bus schedules.

(4) The route should be one in which it is possible to pair with peak direction trips any trips that cannot be fit into existing bus schedules (and therefore, require additional buses).

The staff of the Northern Virginia Transportation Commission has suggested as potential markets the Shirley Industrial Area, located at the northwest corner of the interchange between the Shirley Highway and the Capital Beltway; and the Springfield Mall, located near the southeast corner of the interchange between the Shirley Highway and Franconia Road. Employment data furnished by the Fairfax County Planning Commission has indicated that aside from the Shirley Industrial Park and the Springfield Mall, only the Ravensworth Industrial Park (among employment centers in the Shirley Highway Corridor), located at the southern corner of the intersection between the Shirley Highway and Braddock Road, has over 2000 employees (see Figure 4 for the locations of the three markets). These three areas are examined to determine the extent to which the reverse commute routes that might serve them satisfy the four conditions cited above.

To determine the degree to which the first condition is met, the employment concentrations and working hours of the employees in the three areas are examined. About 4700 people work in industrial establishments in the Shirley Industrial Area and on nearby Cherokee Avenue, and another 1200 people work in commercial establishments in this area.[23] While this employment is spread over nearly a two mile long path, nearly all of the workers could be served along a very compact route. An additional 700 people in commercial establishments on Little River Turnpike adjacent to the Shirley Highway might also be served by a route serving the Shirley Industrial Area[24] (see Figure 4).

Most employees in the industrial establishments that would be served by this route have starting times between 7:00 and 8:30 A.M. and quitting times between 3:30 and 5:15 P.M. (there is little overtime). However, starting and quitting times for employees in commercial enterprises vary widely.[25] A bus route with four bus trips in both the morning and evening peak periods could, with moderate headways (30 minutes), serve a substantial number of the industrial employees but not many of the commercial employees. With only eight runs needed to serve such a large number of employees, a route serving the Shirley Industrial Area appears to meet the first condition.

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[23]Unpublished employment data furnished by the Office of Comprehensive Planning, County of Fairfax, Fairfax, Virginia, November 21, 1973.

[24]Ibid.

[25]Personal communications from the personnel office of several of the large employers in and around the Shirley Industrial Area, Springfield, Virginia, during the week of November 26, 1973.

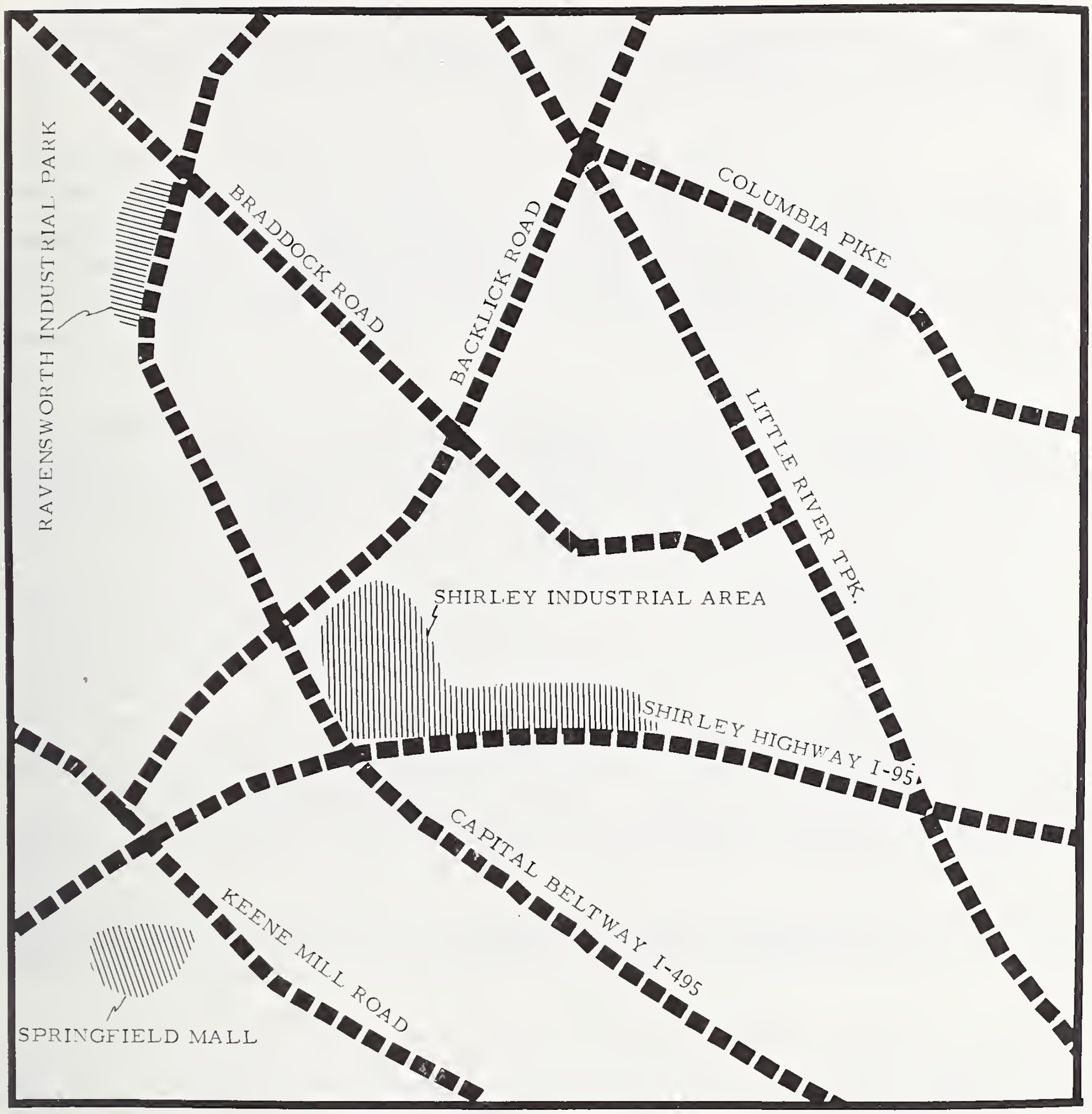

FIGURE 4. LOCATIONS OF MARKETS CONSIDERED FOR REVERSE COMMUTE SERVICE

The second area under consideration, the Springfield Mall, employs approximately 3000 people. This employment, mostly retail, is concentrated in the shopping mall.[26] An additional 700 people in commercial and industrial establishments on Backlick Road and on Old Keene Mill Road could easily be served by a route serving the Springfield Mall[27] (see Figure 4).

Most employees in the retail establishments that would be served by this route have working hours that vary widely throughout the day. For many, working hours vary from day to day and week to week.[28] With such a wide array of working hours, it will be a costly undertaking to serve most of these employees with a reverse commute bus service. At most, a small subset of employees could be served (maybe 20 to 30 percent of the total employment). Because the total employment in the area is about 3700 people, the subset of employees that could be served is too small to justify a reverse commute route. The Springfield Mall area is thus eliminated from further consideration as a potential market to be served by a reverse commute route.

The third area under consideration, the Ravensworth Industrial Park, employs about 2100 people, and adjacent commercial establishments employ about 500 people.[29] This employment is concentrated within a small area. In addition, 700 people in commercial establishments on Little River Turnpike adjacent to the Shirley Highway (the same establishments that could be served by a route to the Shirley Industrial Area) could probably be served by a route serving the Ravensworth Industrial Park (see Figure 4).

The starting and quitting times for most of the 2100 employees in industrial enterprises in Ravensworth Industrial Park vary by about one and a half hours.[30] However, the working hours for the 1200 people in the mainly retail establishments that would also be served by the route vary widely (throughout the day and from day to day), making it a costly operation to serve most of these people. A reverse commute route would basically serve only the 2100 employees at the Ravensworth Industrial Park. A route serving so few employees would be acceptable (with respect to the first condition) only if starting and quitting times for most of these employees varied by only about 30 minutes, as at the AMC Building, where 2800 people are employed. Because starting and quitting times at Ravensworth vary by 90 minutes, Ravensworth does not satisfy the first condition, and is thus eliminated from further consideration as a potential market to be served by a reverse commute route.

Only a route to the Shirley Industrial Area will be given further consideration because it is the only route that appears to have met the first condition. To determine the degree to which this route meets the second condition, the accessibility of this route

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[26]Personal communication from the Springfield Mall Executive Office, Springfield, Virginia, March 29, 1974.

[27]Unpublished employment data furnished by the Office of Comprehensive Planning, County of Fairfax, Fairfax, Virginia, November 21, 1973.

[28]Personal communication from the Springfield Mall Executive Office.

[29]"Economic Development Survey," Fairfax County Industrial Authority, Fairfax, Virginia, Spring, 1971.

[30]Personal communications from the offices of several of the employers in the Ravensworth Industrial Park, Springfield, Virginia, during the week of November 26, 1973.

is examined. The route would follow the same route as the 19Y and 27Y from Farragut Square until past Shirlington Circle, where it would leave the Shirley Highway at Little River Turnpike. (The 19Y leaves the Shirley Highway at Shirlington; the 27Y leaves the Shirley at Duke Street, the same exit as Little River Turnpike, but eastbound instead of westbound.) The transfer points from other buses in downtown Washington, at the Pentagon, and at Shirlington would be the same as those for the 19Y and 27Y.

Because the route would serve basically the same residential areas as are being served by the 19Y and 27Y, it would have to attract most of its riders from people living in Washington, D.C., and Maryland and working in the Shirley Industrial Area. (Recall that while only about one-third of the employees at the Hoffman and AMC Buildings live in Washington, D.C., and Maryland, 62 percent of the 19Y and 27Y riders board the buses in the District, and therefore, live in the District and Maryland.)

To estimate the residential distribution of the people currently working in the Shirley Industrial Area, a detailed accounting of the residences by zip code location of all employees has been furnished by four of the large employers in the industrial park. Responses furnished by these four employees have indicated that out of 2345 employees (about half the total employees in the industrial area), 705, or 30 percent, live in Washington, D.C., or Maryland. This residential distribution is comparable to those at the Hoffman and AMC Buildings. Otherwise, the situation at the Shirley Industrial Area is considerably different from what it was at Hoffman and AMC. Reverse commute service to the Hoffman and AMC Buildings was implemented simultaneously with their opening, and many of the employees had been using bus transit to get to their former work sites. Almost no employees at the Shirley Industrial Area use a bus to get to work: No buses from Washington, D.C., stop within a mile of the Shirley Industrial Area between 7:00 and 8:30 A.M.

Because the route to the Shirley Industrial Area would serve basically the same residential areas as are being served by the 19Y and 27Y, this route would also serve the areas where there are traditionally large numbers of captive riders--people, who at present, could not get to employment at the Shirley Industrial Area even if jobs were available. (Some of the larger employers at the Shirley Industrial Area have indicated that they have sought potential workers who were unable to accept employment because they had no means of transportation to get to the jobs.) A reverse commute route to the Shirley Industrial Area could serve many of these potential riders. This route appears to satisfy the second condition even though none of the present employees at the industrial area currently use a bus to get to work.

To determine the degree to which this route meets the third and fourth conditions, the scheduling requirements for this route are examined. WMATA scheduling data indicate that several Route 18 peak direction buses have their Virginia end point close to the Shirley Industrial Area. These buses have their Washington end point at Farragut Square, an end point of the reverse commute routes. The scheduling data also indicate that many of the reverse commute runs could be added either before a peak direction trip is made, after a peak direction trip is made, or during the deadhead times between consecutive peak direction trips. Where any reverse commute runs could not be fit in, the additional buses that would be needed could easily be scheduled to make Shirley Express peak direction trips that would be paired with the reverse commute trips. There is definitely a need for more peak direction trips. Bus capacity (an average 47 seats per bus) currently constrains patronage on many Shirley Express routes--average patronage per bus on many routes exceeds 50, and on a few routes, exceeds 60. The additional buses needed for reverse commute service could be used on the Route 18 service, where the average patronage per Shirley Express bus was 50.4 in February 1974.[31]

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[31]Unpublished Shirley Highway Express Bus Project Busway Bus and Bus Passenger Counts, taken by the Washington Metropolitan Area Transit Authority, on a normal weekday, mid-February 1974.

Based on the foregoing, the reverse commute route to the Shirley Industrial Area appears to meet the third and fourth conditions which are important for the success of a reverse commute operation. By meeting, to a large extent, all four conditions, this proposed reverse commute route appears to be a potentially viable service.

5.2 EXAMINATION OF REVERSE COMMUTE SERVICE TO THE POTENTIAL MARKETS

A likely route for the proposed service, hereafter referred to as the Route 18Y, would begin at Farragut Square, follow the same route as the 19Y and 27Y past Shirlington Circle, and then continue south on the Shirley Highway until the Little River Turnpike exit. The route would then go west on Little River Turnpike, where it would serve the retail establishments there, and would finally pass through the Shirley Industrial Area (see Figure 5 for the proposed 18Y route between the Little River Turnpike exit of the Shirley Highway and the Shirley Industrial Area). The total distance and travel time of this route would be about 12 miles and 42 minutes, respectively. In keeping with the present zone fare policy, bus fare to the Shirley Industrial Area is assumed to be 70¢ from downtown Washington, D.C., and between 40 and 60¢ from Northern Virginia stops.

A minimum of four buses running at 30 minute headways would be needed in the morning for buses to arrive at the intersection of Industrial and Backlick Roads at 7:00, 7:30, 8:00, and 8:30 A.M. Similarly, a minimum of four buses running at 30 minute headways would be needed in the afternoon for buses to leave Industrial and Backlick Roads at 3:45, 4:15, 4:45, and 5:15 P.M. From an examination of WMATA Route 18 schedule data, it has been determined that either six or seven of these eight 18Y trips could be fitted into existing schedules and use existing peak direction buses. For two morning and two afternoon trips, this could be accomplished by scheduling these trips onto the beginning of existing Route 18 trips (i.e., the buses would leave the garage earlier). One morning trip would be scheduled onto the end of an existing Route 18 trip. This 18Y would deadhead to the garage at the end of its reverse commute trip. One morning, and possibly one afternoon, trip would be scheduled into the deadhead time between consecutive peak direction trips. These 18Y's would not cause any change in existing bus schedules. However, it is not clear whether enough deadhead time exists to fit in the afternoon 18Y. Depending on this, either one or two extra buses that were not previously in service would be needed for afternoon 18Y's. These extra buses would also be used on subsequent peak direction Route 18 trips.

In order to determine the incremental costs of the 18Y bus service, the cost allocation formula and the same techniques employed in costing the 19Y and 27Y will be employed here. Thus, associated incremental increases in platform hours, revenue and non-revenue miles, peak period vehicles, peak period drivers, and passengers have to be determined. Because of the uncertainty over scheduling one of the afternoon 18Y's into the deadhead time between consecutive outbound peak period bus trips, two values for incremental costs will be calculated, a low value where it is assumed that this 18Y can be fitted in and a high value where it is assumed that an extra bus will be needed for this run.

The increase in platform time for each of the two morning and two afternoon 18Y trips scheduled onto the beginning of existing Route 18 trips would be 50 minutes in the morning and 41 minutes in the afternoon. The corresponding increases in total miles traveled would be 14 miles in the morning and 11 miles in the afternoon. For the one morning trip scheduled onto the end of an existing Route 18 trip, the increase in platform time would be 41 minutes and the corresponding increase in total miles traveled would be 11 miles. For the one morning and possibly one afternoon trip scheduled during the deadhead time between peak direction trips, there would be no increase in platform time for either trip because the reverse commute trips would be fitted into existing time in existing schedules, and the corresponding increase in total miles traveled would be 5 miles for each trip.[32]

[32]The 5 miles consist of the distance traveled on the reverse commute route plus the distance from Shirley Industrial Area to the first stop on the 18G minus the deadhead distance between Farragut Square and the first stop on the 18G.

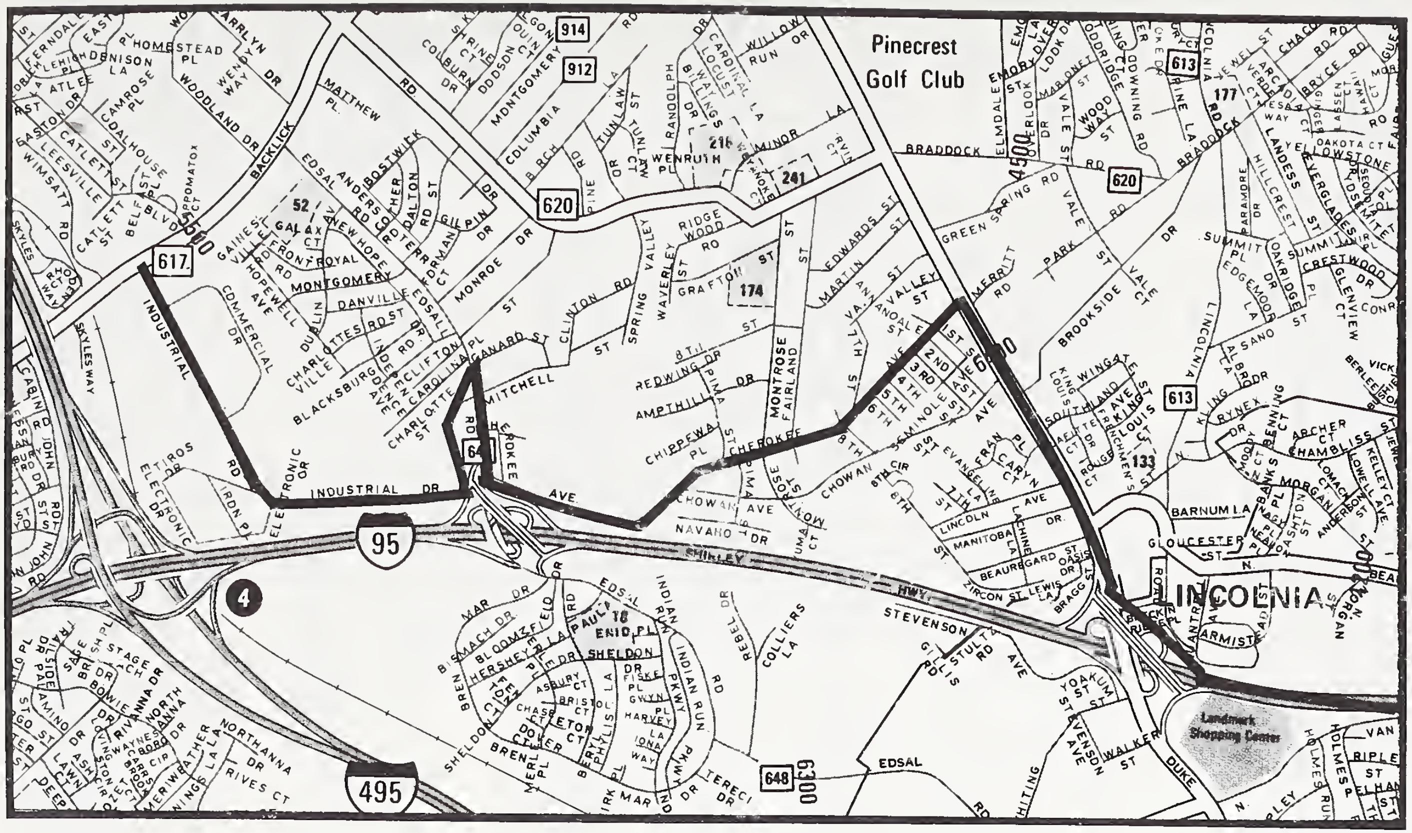

FIGURE 5. ROUTE FOR THE 18Y SOUTH OF THE LITTLE RIVER TURNPIKE AND SHIRLEY HIGHWAY INTERCHANGE

For the one or two afternoon bus trips run with new buses that are then used on peak period outbound trips, the total platform time for each bus, from the time it leaves the garage to the time it returns to the garage (peak and reverse commute operations), would be 151 minutes. The corresponding total miles traveled for each bus would be 44 miles. The total increase in platform hours (or miles traveled) would then be the sum of the increase in platform hours (or miles traveled) for each of the four morning buses plus the sum of the increase in platform hours (or miles traveled) for each of the four afternoon buses:

The low value for the total increase in platform hours is

$$(50 + 50 + 41 + 0) + (41 + 41 + 0 + 151) = 374 \text{ minutes} = 6.23 \text{ hr.}$$

The high value for the total increase in platform hours is

$$(50 + 50 + 41 + 0) + (41 + 41 + 151 + 151) = 525 \text{ minutes} = 8.75 \text{ hr.}$$

The low value for the total increase in miles traveled is

$$(14 + 14 + 11 + 5) + (11 + 11 + 5 + 44) = 115 \text{ miles.}$$

The high value for the total increase in miles traveled is

$$(14 + 14 + 11 + 5) + (11 + 11 + 44 + 44) = 154 \text{ miles.}$$

The increase in peak period vehicles for the low value would be one half bus. (One bus for a single peak period is equivalent to one bus for one half day which is the same as one half bus for one day.) The increase in peak period vehicles for the high value would be one bus (the sum of one bus for one peak period and one bus for another peak period). It is assumed that the one or two buses needed for the 18Y service in the afternoon peak period will be used on other peak period WMATA service. The increase in peak period drivers is assumed to be the same as the increase in buses, one half of one peak period driver for the low value and one peak period driver for the high value, since an extra peak period driver would be needed for each extra peak period bus.

The total increase in passengers resulting from providing the 18Y service would be the number of passengers on the 18Y plus the increase in the number of passengers on peak direction service resulting from trips made by buses added to the service. The number of passengers that would use the 18Y is impossible to predict; however, the number of passengers required for the operator's margin of income over costs to be zero can be estimated.

The required number of passengers will be expressed in terms of an unknown, P. The increase in the number of passengers on peak direction service is estimated to be the number of passengers that would use each peak direction bus trip made by the buses added to the service. This value is assumed to be 50,[33] the present average load on the Route 18 buses using the busway during the evening peak period. With these numbers, the low value for the total increase in passengers would be P + 50. The high value would be P + 50 + 50 = P + 100.

Now using the cost allocation formula (including in it a value for bus depreciation) to cost out the 18Y bus service in terms of the unknown, P, the low value for incremental cost would be \$(83.91 + 0.046P)/day and the high value would be \$(136.73 + 0.046P).

Income is also calculated in terms of the unknown, P. It consists of the fares paid by both the reverse commute riders and the riders on the one or two afternoon peak direction trips made by the bus or buses added to the service. Average fares on the Route 18Y are assumed to be 65¢ and average fares on the peak direction Route 18's are assumed to be 70¢. Based on these values, the low value for income would be

$$0.65P + 0.70(50) = 0.65P + 35.0,$$

[33] See Appendix D for the explanation of the use of the value 50.

and the high value for income would be

$$0.65P + 0.70(100) = 0.65P + 70.0.$$

Setting costs equal to income, the low value of P necessary for the bus operator's margin of income over costs to be zero is 81 passengers per day, and the high value is 110 passengers/day. These statistics represent the total number of passengers that would board the eight 18Y buses (morning and afternoon peak period buses). Because bus service to the Shirley Industrial Area is presently very poor (recall that no buses from Washington, D.C., stop within a mile of the Shirley Industrial Area between 7:00 and 8:30 A.M.), the problem of diverted revenues, considered in the analysis of the 19Y and 27Y service, does not have to be examined here. It is assumed that there would be negligible diversion from existing service to the 18Y.

It must now be determined whether it is reasonable to expect the 18Y to generate a ridership of between 81 and 110 passengers per day. Recall that the 27Y, serving an employment area of 2800 people (as opposed to 4700 at the Shirley Industrial Area), attracts 120 passengers per day (down from an initial patronage of 150). The 27Y began operation under a set of circumstances more conducive to attracting patronage than would exist for the 18Y: the 27Y was implemented simultaneously with the opening of the AMC Building, and many of the employees there had been using bus transit to get to their former work sites. Consider also the 1971 reverse commute route between downtown Washington, D.C., and Tyson's Corner Shopping Center and Fairfax Hospital in McLean, Virginia, which attracted approximately 70 passengers per day on four morning and four evening peak period trips.[34] The Shirley Industrial Area would seem to be a better market to serve than the combination of a large shopping center and large hospital. In view of these facts, it seems reasonable to expect the 18Y to generate a ridership of at least 81 passengers per day.

The results of the foregoing analysis appear promising, and suggest a more detailed operational planning study prior to the proposed 18Y reverse commute service. This would involve obtaining from the schedules section of WMATA an estimate of how the proposed 18Y service would fit into the present bus service. Their judgment would verify the estimates made in the report of the vehicle and operator requirements for such a service. The study would also involve obtaining detailed origin-destination information about the employees at the Shirley Industrial Area from their employers and conducting a survey of these employees to learn about their travel patterns and their attitude toward a reverse commute bus service. This information should allow a better estimate to be made of the expected patronage on the proposed service.

5.3 RECOMMENDATIONS FOR ADDITIONAL REVERSE COMMUTE STUDIES

Other studies of reverse commute service are recommended in addition to the above operational planning study:

(1) The feasibility of offering direct service to the Hoffman Building, AMC Building, and the Shirley Industrial Area from areas outside of Washington, D.C., such as North Arlington or Alexandria, should be investigated. Such service would have to attract most of its patrons from auto. (Recall that only service to these areas from Washington, D.C., was examined in this report.)

(2) A comparison of the occupations of the reverse commuters on the 19Y and 27Y with the employment distributions at the Hoffman and AMC Buildings should be made to determine whether a relationship exists between reverse commute ridership and the types of jobs at the employment centers being served. Such a relationship could be used as a further tool in identifying potential reverse commute routes in the Shirley Highway Corridor and elsewhere.

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[34] John L. Crain, "Benefit-Cost Survey: Washington, D.C., Transportation Demonstration Project," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, Washington, D.C., Review Draft, October 1970.

(3) More exact techniques for determining the scheduling requirements of a planned reverse commute service should be explored. The Run Cutting and Scheduling (RUCUS) computer package, developed by MITRE Corporation, under the sponsorship of the Urban Mass Transportation Administration, could possibly be integrated into an improved procedure.[35] The scheduling requirements for the 18Y in this report were determined by visually inspecting WMATA Route 18 schedule data and deciding where a reverse commute trip could apparently be added. No examination of the Shirley Highway bus system as a whole was made.

[35] Kenneth R. Roberts, "Vehicle Scheduling and Driver Run Cutting: RUCUS Package Overview," prepared for Urban Mass Transportation Administration, U.S. Department of Transportation, Washington, D.C., November 1973, available from NTIS, Springfield, Virginia, PB-222675.

APPENDIX A

APPENDIX A

PREEXISTING SERVICE FOR 19Y AND 27Y RIDERS

The preexisting service consists of the following morning bus trips:

(1) Two Route 11E buses originating at Washington Terminal in downtown Washington stop about three-eights of a mile (about 8 minutes walking time) from the Hoffman Building at 7:25 and 8:00 A.M. The 11E bus that stops near the Hoffman Building at 7:25 also stops about one half mile (about 10 minutes walking time) from the AMC Building at 7:35. Neither of the two 11E buses stop at either the Pentagon or Shirlington, important transfer points in Virginia.

(2) Two Route 6 buses originating at Washington Terminal and a third Route 6 bus originating at Farragut Square stop about seven-eighths of a mile (about 18 minutes walking time) from the Hoffman Building at 7:00, 7:40, and 8:00 A.M., respectively. These buses stop at Shirlington, but not at the Pentagon.

(3) One Route 7F bus originating at Washington Terminal stops about one half mile (about 10 minutes walking time) from the AMC Building at about 7:05 A.M. This bus stops at both Shirlington and the Pentagon.

(4) There is frequent bus service within Alexandria to points along Duke Street about three-eighths of a mile (about 8 minutes walking time) from the Hoffman Building and one half of a mile (about 10 minutes walking time) from the AMC Building.

APPENDIX B

APPENDIX B

DETERMINATION OF PLATFORM TIMES AND TOTAL MILES TRAVELED

Figures 6 and 7 are used to determine the platform time to be charged to the sixteen of nineteen 19Y and 27Y trips fitted into existing bus schedules (without any additional buses or operators). Figure 6 shows the change in the path traversed by these buses during the morning peak period after the reverse commute routes were implemented: once the starting point of the inbound trip is reached, the buses follow the same path they followed before the reverse commute routes were implemented. The increase in platform time (Δtime) for these buses is calculated using Equation 2:

Δtime (morning) = travel time from the garage (in Alexandria) to Farragut Square (the starting point of the reverse commute route)

+ the running time on the reverse commute route

+ the travel time from the end point of the reverse commute route (Hoffman or AMC Building) to the starting point of the inbound route

+ the layover time until the start of the inbound route

- the travel time from the garage to the starting point of the inbound route. (2)

The increase in platform time during the evening peak period is estimated using a similar equation. Figure 7 shows the change in the path traversed in the evening: once Farragut Square (the starting point of the outbound trip) is reached, the buses follow the same path they followed before the reverse commute routes were implemented.

The estimated increase in platform time for each 19Y bus fitted into existing schedules is 65 minutes in the morning and 29 minutes in the evening; the estimated increase for each 27Y is 57 minutes in the morning and 33 minutes in the evening.

Associated with the increase in platform time is an increase in total miles (revenue and non-revenue) traveled. On the 19Y, this amounts to 19 miles in the morning and 7 miles in the evening. On the 27Y, this amounts to 15 miles in the morning and 7 miles in the evening. The increase in total miles traveled is made up of the distance components shown in Figures 6 and 7.

Five morning and five evening 19Y runs and three morning and three evening 27Y runs have been fitted into existing schedules. The total increase in platform time from these runs is:

$$5 \times (65 + 29) = 470 \text{ minutes for the 19Y and}$$

$$3 \times (57 + 33) = 270 \text{ minutes for the 27Y}$$

The total increase in total miles is:

$$5 \times (19 + 7) = 130 \text{ miles for the 19Y and}$$

$$3 \times (15 + 7) = 66 \text{ miles for the 27Y.}$$

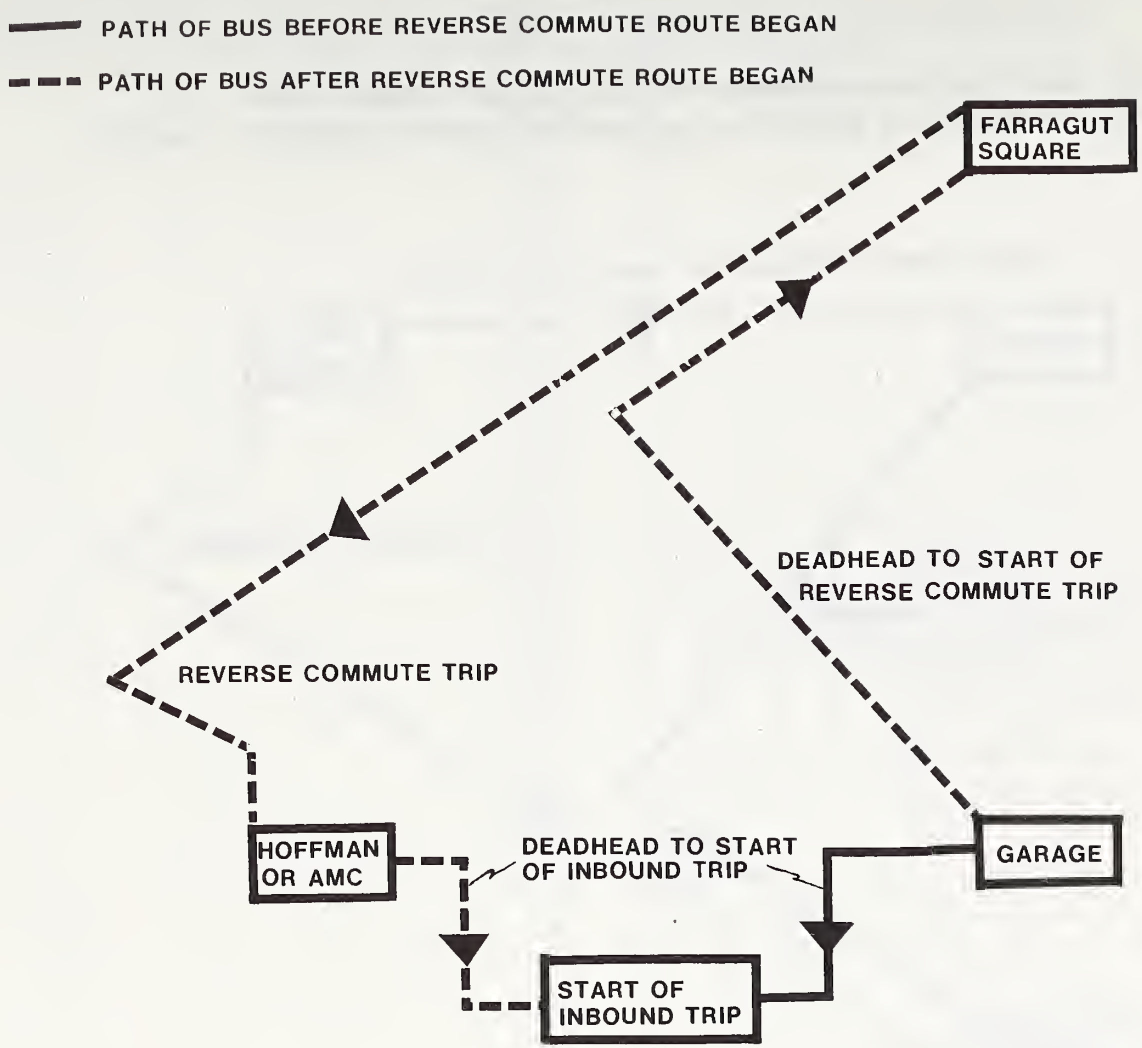

FIGURE 6 . CHANGE IN PATH TRAVERSED BY 19Y AND 27Y BUSES IN THE MORNING PEAK PERIOD AFTER REVERSE COMMUTE ROUTES WERE IMPLEMENTED

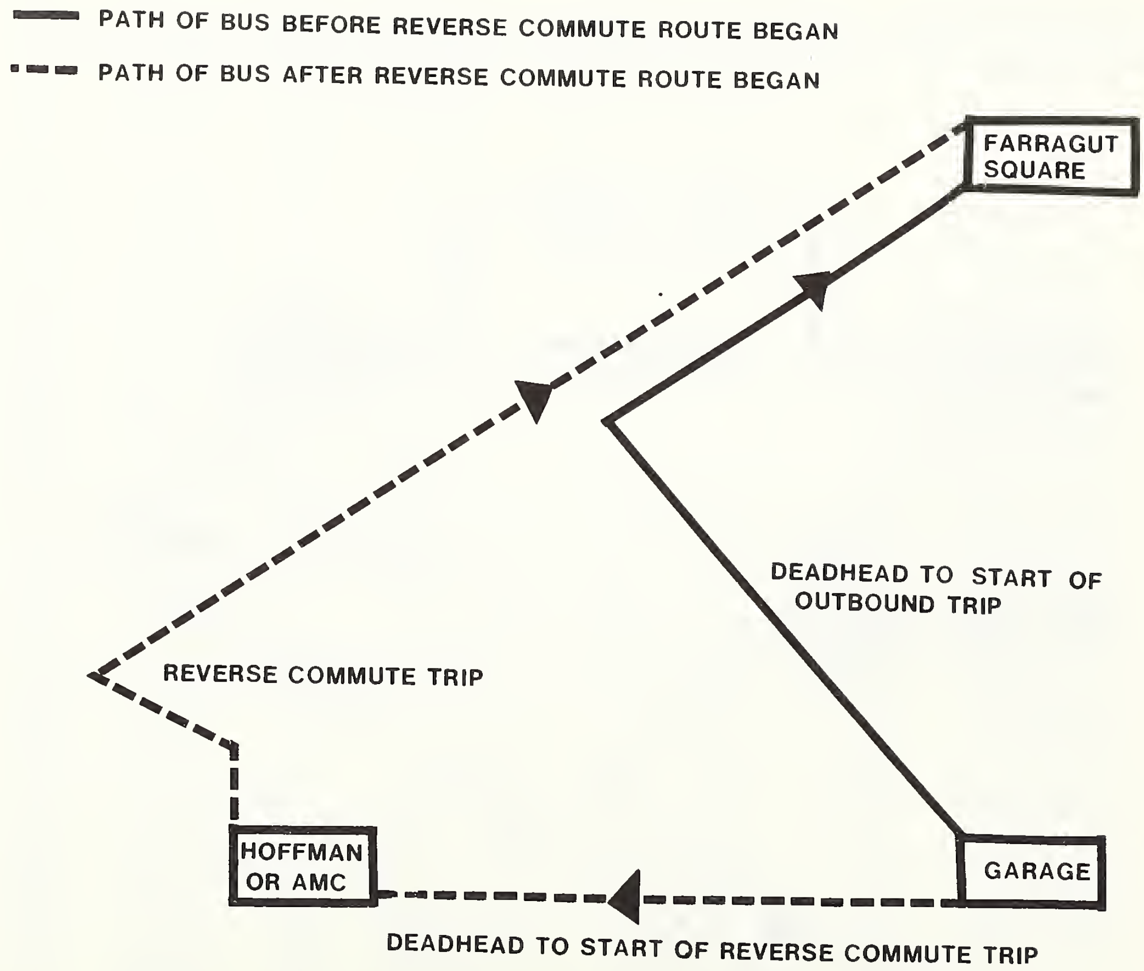

FIGURE 7. CHANGE IN PATH TRAVERSED BY 19YAND 27Y BUSES IN THE EVENING PEAK PERIOD AFTER REVERSE COMMUTE ROUTES WERE IMPLEMENTED

Platform times associated with running the two 19Y trips and the one 27Y trip that could not be fitted into existing bus schedules are calculated using Equation 3:

Δtime (trip not fitted in) = the travel time from the garage to the starting point of the reverse commute route

+ the layover time

+ the running time on the reverse commute route

+ the travel time from the end point of reverse commute route to the start of the peak direction route (in the evening, the end point of the reverse commute route and the start of the peak direction route are the same, Farragut Square)

+ the layover time

+ the running time on the peak direction route

+ the travel time from the end of the peak direction route to the garage. (3)

These platform times are 249 minutes for the two 19Y trips and 161 minutes for the one 27Y trip.

Total miles traveled by the buses making these trips consist of the distance components associated with the travel time components detailed in Equation 3. These distances are 74 miles for the two 19Y trips and 46 miles for the one 27Y trip.

APPENDIX C

APPENDIX C

ANALYSIS OF THE EFFECT OF EXCLUDING THE IMPACTS OF PEAK DIRECTION TRIPS

The exclusion of peak direction trips added when the reverse commute service was implemented affects the user benefits and the costs and income attributable to the reverse commute service. The exclusion of user benefits derived from the peak direction trips does not alter the conclusion that the reverse commute service is appreciably beneficial to the users of the service. However, exclusion of the costs and income derived from these trips might significantly alter the conclusion that the reverse commute service is profitable to the bus operator.

To calculate the decrease in costs charged to the reverse commute service, the decrease in the values of the five cost allocation formula parameters (from Equation 1) are first determined. For each of the three bus runs affected, the layover time, running time on the peak direction trip, and travel time from the end of the peak direction trip to the garage (as shown in Equation 3) are not included in the platform time charged to the reverse commute service. The distance components associated with these travel time components are not included in the distance charged to the reverse commute service. The effect of these exclusions is to decrease platform time and distance charged to the 19Y from 12 hours and 204 miles to 10 hours and 168 miles,and to decrease platform time and distance charged to the 27Y from 7.2 hours and 112 miles to 5.18 hours and 89 miles.

The three bus runs affected make only a reverse commute trip and a return peak direction trip during the peak period. The peak period vehicles and drivers required for these three runs are allocated equally to reverse commute and peak direction service instead of all to the reverse commute service. The effect of these allocations is to reduce the peak period buses and drivers charged to the 19Y from one bus and one driver to one half of a bus and one half of a driver, and to reduce the peak period buses and drivers charged to the 27Y service from one half of a bus and one half of a driver to one quarter of a bus and one quarter of a driver.

The number of passengers charged to the reverse commute service is reduced by the number of passengers charged to the three peak direction trips. Thus, the number of passengers charged to the 19Y is reduced from 370 to 278, and the number of passengers charged to the 27Y is reduced from 181 to 120.

The reduced values for the five parameters are used in the cost allocation formula to determine the reduced costs of the two services. The cost of the 19Y service is reduced from $174.94 to $123.25, and the cost of the 27Y service is reduced from $95.25 to $66.05 per day.

To calculate the decrease in income derived from the reverse commute service, the fares paid by the increased number of passengers attributed to the addition of the three peak direction trips are simply not included in the computation of the income derived from the reverse commute service. The income is thus decreased from $205.32 to $150.12 for the 19Y, and from $120.70 to $78.00 per day for the 27Y.

The decreases in cost and income have the net effect of decreasing the margin of income over costs from $30.38 to $26.87 per day for the 19Y, and from $25.45 to $11.95 per day for the 27Y. Based on these values, if no more than 18 percent of the reverse commute users would have used the preexisting service, fares generated by the reverse commute service would still be sufficient for the margin of income over costs to be positive.

APPENDIX D

APPENDIX D

DETERMINATION OF THE INCREASE IN PASSENGERS ON PEAK PERIOD SERVICE

Estimates for the increase in passengers on peak direction service to be charged to the reverse commute service are based on observations which indicate that the demand for Shirley Express buses entering the Shirley Highway exclusive bus lane (busway) south of Shirlington Circle (19G and 27G buses fall in this category) has been increasing as fast as the supply. Average loads on 19G and 27G buses have changed little since the addition of the two 19G and one 27G trips made by the buses added for the reverse commute service. The increase in the number of passengers on peak direction service resulting from adding the reverse commute service is, therefore, estimated to be the number of passengers on these peak direction trips. These increases in passengers are 47 on the morning 19G, 45 on the evening 19G, and 61 on the morning 27G, which are the average peak direction loads from the February 1974 busway counts.[36]

In a similar fashion, the increase in the number of passengers on peak direction service resulting from providing the proposed 18Y service to the Shirley Industrial Area would be the estimated number of passengers on peak direction trips that would be added. This increase in passengers would be 50 for each Route 18 bus added, which is the average peak direction load from the February 1974 busway counts.[37]

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[36] Unpublished Shirley Highway Express Bus Project Busway Bus and Bus Passenger Counts, by the Washington Metropolitan Area Transit Authority, on a normal weekday, mid-February 1974.

[37] Ibid.

APPENDIX E

APPENDIX E

DETERMINATION OF DIVERSION FROM THE PREEXISTING SERVICE

The available data suggest that diversion from the preexisting service would definitely have been less than 27 percent. Unpublished data from the fall 1973 Shirley Highway bus survey (of peak direction riders only) indicate that only eight percent of the respondents who were "apparently captive" riders had excess travel times of 30 minutes or more.[38] Recall that excess time consists of: walk time to and from the origin and destination bus stops, wait time for the line haul bus, and, where applicable, walk and wait time for buses used for transferring to and from the line haul bus.

As discussed in Paragraph 3.1, excess time with the preexisting service would have been extremely high. On the average, the total excess time would have been about 28 to 38 minutes for those who would have walked to the bus and considerably more for those who would have transferred from another bus (or been driven to the bus). It is estimated that between 15 and 35 percent of the present reverse commute patrons walk to the 19Y and 27Y. If it is assumed that a comparable percentage of bus users would have walked to the preexisting service, then about 95 percent of the present reverse commute users would have been faced with excess times of at least 30 minutes had they used the preexisting service. By comparison, actual total excess times for the 19Y and 27Y users are about 10 to 15 minutes for those who walk to the reverse commute buses, and considerably more, but generally under 30 minutes, for those who do not walk to these buses. The issue of whether the present reverse commute service is profitable reduces to: would more than 27 percent of the present reverse commute riders, at least 43 percent of whom are captive riders, have tolerated excess times greater than 30 minutes had the present reverse commute service not been implemented, where only eight percent of the apparently captive Shirley Highway Corridor bus riders surveyed in fall 1973 indicated greater excess times?

The low percentage of captive Shirley Highway Corridor bus users who had excess times greater than 30 minutes has been, in part, due to the fact that good peak period, peak direction bus service has been available in the Shirley Highway Corridor, reducing the liklihood that captive riders would be faced with excess times greater than 30 minutes. The low percentage also suggests that few captive riders would tolerate such high excess times. Therefore, while 95 percent of the present reverse commute users would have been faced with excess times greater than 30 minutes had they used the preexisting service, it would seem that many of these riders would not have tolerated these high excess times. Moreover, not all of the present reverse commute users are captive riders, and it is unlikely that, with the high excess times, many of the choice reverse commute users would have used the preexisting service. What the data suggest, then, is that while more than eight percent of the reverse commute riders (a high percentage of whom are captives) may have endured such lengthy excess times, it is unlikely that as many as 27 percent of them would have endured these times. Many captive riders faced with these lengthy excess times would quit work, switch jobs to locations where public transportation is better, or be forced to buy a car.

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[38] Respondents who appeared to be captive riders were those who answered the survey question: "Was a car available to you for this trip?", by indicating that a car was not available and bus was the only practical means.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Bus-on-freeway operations generally provide peak period commuter transit service to persons traveling from suburban residences through congested corridors to jobs in the major employment centers of metropolitan areas. In a few cases, peak period reverse commute operations may provide service to persons traveling from residences near the downtown employment centers to jobs in the suburbs. In early 1973, two major Shirley Highway Express-Bus-on-Freeway Demonstration Project reverse commute routes began service to office buildings in Northern Virginia.

An analysis of this reverse commute service revealed that it was a successful operation because it provided considerable benefits to its patrons and was slightly profitable to the bus operator on an incremental cost basis.

Four conditions which were important for the success of the service were found to be important for the success of reverse commute operations, in general. The conditions are as follows: (1) A given route should serve a concentrated, high employment area. (2) The route should be accessible to people currently working within the employment area and to captive riders who can fill jobs there. (3) It should be possible to fit most of the reverse commute trips into existing bus schedules. (4) It should be possible to pair with peak direction trips any trips that cannot be fit into existing bus schedules.

Using a procedure which incorporates these conditions, one employment area within the Shirley Highway Corridor was identified as having potential as a market for a reverse commute service.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Bus-on-freeway operations; choice and captive riders; cost allocation formula; incremental costs and revenues; reverse commute bus service; Shirley Highway; transportation planning

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