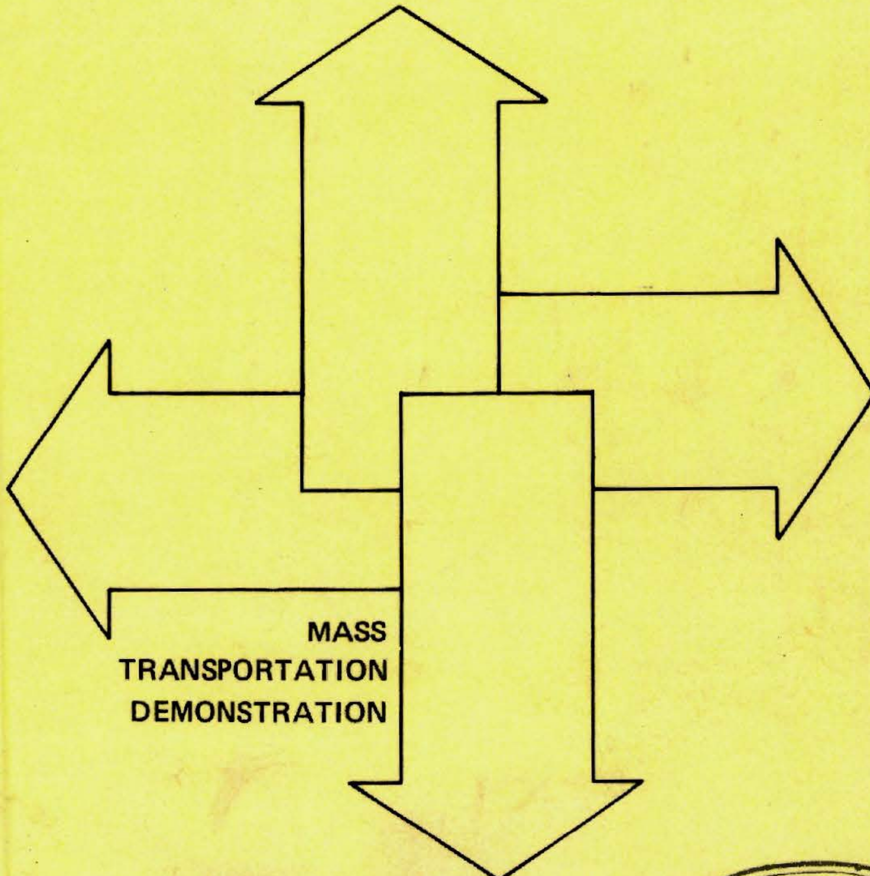

A SYSTEMS ANALYSIS OF TRANSIT ROUTES AND SCHEDULES

**PREPARED FOR
WASHINGTON METROPOLITAN AREA
TRANSIT COMMISSION**

AMV ALAN M. VOORHEES & ASSOCIATES, INC.

A SYSTEMS ANALYSIS OF TRANSIT ROUTES AND SCHEDULES

MASS TRANSPORTATION DEMONSTRATION PROJECT INT-MTD-14

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Prepared for

WASHINGTON METROPOLITAN AREA TRANSIT COMMISSION

By

ALAN M. VOORHEES & ASSOCIATES, INC.
Westgate Research Park
McLean, Virginia 22101

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Study Background and Objectives

The steady decline in bus transit patronage in localities across the United States since World War II has prompted continuous and varied efforts to streamline operations and eliminate inefficiencies. Beyond this, positive steps have been taken to improve passenger speed, comfort, and convenience to retain and attract patrons, such as the institution of express bus lines and the addition of stop shelters and bus air conditioning. However, one area which has remained relatively untouched has been the substantial modification of the systemwide configuration of bus routes to more closely correspond to the travel pattern desires of transit patrons.

An often-cited advantage of buses as a transit mode is their ready flexibility, since they are not confined by permanently installed rails or wires. However, there is a reluctance on the part of transit management to take full advantage of this flexibility in making large-scale route changes. This reluctance often stems in part from a hesitancy to modify long-standing traditional routes, many of which are successors to former streetcar lines. Another reason given is the shortage or absence of a transit planning function resulting, perhaps, from previous economy moves. Yet another is the rescheduling expense, which may be considered to be prohibitively large. Finally, fears have been expressed that the disruption of existing travel habits combined with a poorly conceived plan might cause further patronage losses.

It seems reasonable, however, to assume that systemwide routing changes would be appropriate in many cases. Certainly the urban area itself has changed substantially in recent years. The downtown area, the essential focal point of most route systems, has generally declined in relative importance as many of its employment and shopping activities have moved outward. What is required is a means of adequately evaluating alternative new route systems in advance of actually implementing one.

To this end, the study investigated the feasibility of applying a series of computer programs recently developed by AMV to assist HUD in developing long-range plans for public transit systems.[1/] These programs,

[1/] Urban Mass Transit Planning Project, Technical Report No. 3, Vols. I and II, prepared for the U. S. Department of Housing and Urban Development by Alan M. Voorhees & Associates, Inc., 1967.

hereinafter referred to as the HUD Transit Planning Programs, permit rapid codification of a real or hypothesized transit network in a form that can be readily input into the computer. The computerized representation of the network thus provides the framework for computer simulation and analysis of the transit system. The various computer programs greatly facilitate the system analysis, allowing for the rapid determination of travel paths in any given transit system, the development of patronage estimates for each line and segment of the system, and the generation of a variety of useful quantitative data such as travel speeds, hours, miles of operation, and service frequency requirements.

Some of the detailed system characteristics included in the HUD Transit Planning Programs are the times required for walking and waiting, the differing service frequencies on the various transit lines, the co-existence of multiple transit lines on a single street, the reluctance of transit patrons to transfer between lines, and the reliance of some transit patrons on feeder service by automobiles through park-ride and kiss-ride activities. This level of detail already existing in the HUD Transit Planning Programs, coupled with the computer's inherent calculation capabilities, suggested that these original long-range planning programs might be equally applicable to the short-range transit problem.

One of the primary objectives of this study, therefore, was to investigate this possibility that the simulation of a transit system through computer methods could be effectively used as a tool for short-range transit route planning. Since the system to be studied in this investigation was the D. C. Transit System covering the District of Columbia and nearby suburban Maryland, a further objective was to use this method to devise an improved route and operating plan for that system.

The remaining sections of this Report in Brief present the procedures used and the results achieved in working toward each of these study objectives.

Study Procedures

The early stages of the study consisted of gathering and processing for analysis two basic sets of data. One of these was an accurate description of current travel patterns by patrons of the D. C. Transit System. The source of this data was a passenger origin-destination survey conducted in the Washington area in 1966. The data from this survey, which described inbound trips only, were adjusted to reflect travel in both directions. Further adjustments were made to extract only those trips which used the D. C. Transit System for some or all of their length and to relate traveler origins and destinations to a zone system designed especially for this study.

Ultimately two distinct travel patterns were identified, one relating to the morning peak period of an average day and the other to the midday base period of the average day.

The second basic data set consisted of the current operating characteristics of the D. C. Transit System. These included route locations, bus headways, bus speeds, operating cost data, and field-counted passenger volumes. The first three of these items served as inputs for representing the current D. C. Transit network in the computer format required by the HUD Transit Planning Programs. Using the travel pattern data, this simulated network was then "calibrated," i.e., the various parameters and options in the programs were adjusted until the passenger volumes and other characteristics agreed satisfactorily with known actual conditions. Later, a more simplified network termed the Basic System was similarly prepared which was found to ease the difficulties of analysis substantially with no appreciable loss of accuracy.

In addition to accurately duplicating the performance of the actual network, it was also desired to develop the ability to closely estimate the daily cost of operating the system. Although the cost calculations included in the HUD Transit Planning Programs proved to be inadequate, other data items provided by them proved to be indispensable to an independently developed cost estimating model. This cost model was prepared using actual D. C. Transit cost experience. Application of the model relied on such values produced by the HUD Transit Planning Programs as route miles, running times for each line, and required buses for each line. The model was also satisfactorily calibrated to represent actual results.

The completion of these tasks established that it is indeed possible to accurately simulate the operation of an actual transit system using the HUD Transit Planning Programs. It followed, then, that the effect of modifications to the actual system can likewise be accurately simulated. Each modification is, in effect, an alternate system. The remainder of the project was devoted to postulating and testing several alternatives to select one that provides substantially improved transit service at no increase and, hopefully, a reduction in total operating costs. The steps followed in doing this are briefly discussed in the following paragraphs.

Development and Analysis of System Alternatives

The first step in the evolution of an improved bus routing system is the development of alternative systems. The HUD Transit Planning Programs are useful for analyzing systems, but they cannot by themselves provide a revised bus route structure. To gain full advantage of the systems techniques used, alternative route systems were developed in succession, with each subsequent system building upon the experience gained in the preceding ones. Following this procedure, two different alternative systems were successively developed and analyzed. This led to the development and study of a third and final system, termed the Optimum System.

To assist in alternative development, routes were classified into three basic categories of radial, crosstown, and feeder, and the function of each of these three kinds of routes taken into account. A number of routing and operating criteria were also established which included the provision of route simplicity, the avoidance of large terminal loops on transit lines, and the avoidance of long, complex routes. An important criterion used required the maintenance of existing operating cost levels and hopefully their reduction. The peculiar characteristics of specific subareas and corridors served by D. C. Transit were studied to gain insight into possible route improvements using both the travel pattern data and the system characteristics obtained in the Basic System simulation work. Special attention was given to crosstown travel in recognition of its growing volume and importance. Also the radial routes extending into Maryland were carefully examined, since many of the franchise and regulatory difficulties which had affected the original design of these routes no longer existed.

Each of the alternative systems were processed together with the travel pattern data using the HUD Transit Planning Programs. The cost model was then applied to obtain operating costs for each alternative system. The principal bases for evaluation were comparisons between each alternative and the Basic System of total door-to-door travel times, numbers of transfers, and operating costs. These evaluations led ultimately to the development of the Optimum System for which these comparisons were made in even greater variety and detail.

In addition to overall system comparisons, a feature of the HUD Transit Planning Programs permitted the examination of the effects of the system on individual analysis zones in the served area. Thus it was possible to pinpoint precisely those zones in which transit users would be benefited in terms of travel time or transfers required, those zones in which these characteristics would be essentially unchanged, and those few zones where users would be disadvantaged by the proposed system. Graphical and tabular material illustrating these comparisons may be found in the main body of this report.

Analysis of the Optimum System

The Optimum System incorporated the best elements of all previously considered alternative systems and the Basic System. For all three of the principal bases of evaluation — travel time, transfers required, and operating costs — the Optimum System proved superior to the Basic System. The following summarizes some of the more significant findings in comparing the Optimum System to the Basic System for both the a.m. peak and midday base periods of travel.

- Travel time reduced for 26 percent of peak riders and lengthened for only 9-1/2 percent
- Travel time reduced for 25 percent of midday riders and lengthened for only 8 percent
- Number of peak trips involving transfers reduced 12 percent
- Number of midday trips involving transfers reduced 17 percent
- Number of peak trips involving more than one transfer reduced 37 percent
- Number of midday trips involving more than one transfer reduced 37 percent

Results from application of the cost model indicated that there would be a 1.7 percent decrease in daily operating costs for the Optimum System as contrasted to the Basic System, from $61,312 to $60,251. Thus the goal of reducing operating costs was met. Furthermore, the number of buses required for peak hour operation was reduced 4.7 percent which suggests the possibility of even greater operating cost reductions.

On the basis of these comparative evaluations, the Optimum System is believed to offer the desired significant improvements. Hence it is recommended for adoption and implementation in operating the D. C. Transit System.

Implementation of the Optimum System

In order to implement the Optimum System and to provide a more precise basis for estimating its cost of operation, it will be necessary to prepare a detailed bus schedule. A necessary further step will be the preparation of bus "block summaries" and "run-cutting." The former allocates the scheduled periods of needed bus operation to specific buses and the latter combines them to form "runs" or daily work schedules for individual drivers. This is an intricate and painstaking job requiring not only a thorough understanding of the operating plan, but also of a number of other factors including knowledge of the detailed provisions of the labor contract and the traditions respected by both the transit company management and the drivers' union. Persons with the aptitudes and skills necessary to do this detailed scheduling are becoming increasingly rare as transit companies in general have declined. Also the amount of such work required to change to the Optimum System is expected to be impractical using existing manual scheduling and run-cutting techniques.

Accordingly, an investigation into the feasibility of automating the scheduling and run-cutting function through the application of computer methods was undertaken. Based primarily on past work done in this area, it was concluded that automation of this function is feasible, but that further effort is needed to work out the details. A recommended approach for accomplishing this automation effort is described in the body of this report.

Summary

Completion of this project marks only one step in what must be a continuing research program into methods of providing better local transit operations. In this project, the HUD Transit Planning Computer Programs have demonstrated their utility as a tool for short-range operational transit improvement planning. Using these programs, a revised routing system of D. C. Transit has been devised which would substantially improve service at no increase in operational cost. The next step involves implementation of the new routes and will contribute by its example to the general improvement of transit operational planning.

Chapter I

INTRODUCTION

1.1 Need for Improved Planning Technology

Throughout the country there is a desire for improved local bus service. Transit management in general recognizes a need for improvement, yet management is faced at the same time with increasing labor costs or decreasing transit usage. Of obvious value in this dilemma would be a means for improving service without increasing operating costs.

To suggest that bus service might be improved at no cost implies the existence of operating inefficiencies. At first glance, this seems unlikely. Since World War II, there has been a continuous effort to streamline operations and eliminate frills as patronage has declined. Yet one area of operations has often remained relatively untouched — the transit routes themselves.

The typical systemwide configuration of routes and schedules may be the one major remaining area of potential operating efficiencies. While transit routes in many cities have remained relatively fixed over the years, transit travel patterns may have changed substantially since the decline of usage began. The urban area itself has changed noticeably. Although transit has become more dependent on the downtown travel market, the total number of trips made to downtown has decreased proportionately as the relocation of jobs within each urban area created diverse patterns of daily travel. It would seem logical that traditional transit routes might now be less efficient for serving today's travel needs.

The multiplicity of travel movements within an urban area and the complexity of bus networks in large cities make it difficult to determine how well a transit system really is serving. At the same time, there is a resistance to making significant changes in bus routing and scheduling. This resistance may stem in part from the tradition of fixed route streetcar lines and from the past reduction of transit planning staffs as an economy move. Certainly the expense of rescheduling is an important factor. But it is also understandable that transit management might be reluctant to make changes which might possibly have adverse effects on patronage. Certainly any change in the traditional routes would alter the travel habits of many passengers. A poorly conceived plan might cause further patronage losses.

The first need, then, is a technology which will allow proposals for alternative transit service configurations to be tested in the planning office before they are instituted on the streets. The proposals need to be evaluated against the pattern of travel by transit in a way which will give management the information it requires to fully evaluate routing proposals and to develop recommended changes.

The second need is for a means of scheduling adopted route revisions more quickly and efficiently than is now possible. The flexibility of modern bus transit service may remain largely mythical if the cost and time involved in scheduling new routes cannot be reduced.

1.2 Study Objectives

This Mass Transportation Demonstration Project was designed principally with the need for a transit route planning technology in mind. Work in the area of scheduling was limited to exploratory investigations.

Within the route planning framework, the project has had a dual objective. One objective has been to test and demonstrate the U. S. Department of Housing and Urban Development's transit planning computer program package (HUD programs) for use in developing and analyzing immediate action proposals for transit routing and scheduling improvements. The correlative objective has been to devise in the process substantive improvements to the routing and scheduling of the D. C. Transit bus operation in Washington, D. C. Thus, the project has combined an applied research effort with the specific goal of improving the service and economy of an actual transit operation, that of the D. C. Transit System, Inc.

1.3 HUD Transit Planning Programs

To perceive the use which this project has made of the HUD programs, their general characteristics must be understood. These computer programs were originally designed specifically for use in urban public transit planning, but with the main objective of improving the quality and reducing the cost of long-range planning. The planning tools which resulted, however, appeared to have potential value in the additional application of developing immediate action improvements for an operating bus system.

The HUD programs make it possible to compare the effectiveness of alternative transit systems through the use of simulation, thus comprising what are known to transportation planners as mathematical simulation models. Almost everyone is familiar with physical simulation models. A well-known example is the use of model airplanes in a wind tunnel to study airplane design. Wind pressures on the model and stresses in the structural components are compared for different airplane designs and wind velocities.

Mathematical simulation such as that used in the HUD programs operates in much the same way. Here the design consists of a transit route and service frequency structure and bus passenger travel patterns. The design is described in terms of numerical values for computer processing. Instead of pressures and stresses, the results consist of information on passenger volumes, passenger travel times and transfers, and bus-miles and -hours of operation.

Simulation is an effective tool in circumstances where it is desirable to study changes in a system without having to affect physically the system's current operation. In this case, bus route and service frequency changes have been studied without actual trial operation, attendant operating expense, regulatory requirements, and possible inconvenience to patrons. The results of system changes have been obtained much more quickly and more economically than would have been possible without simulation.

1.4 Work Program

The basic structure of this Mass Transportation Demonstration Project is delineated in the flow chart presented in Figure 1. The numbers below the boxes identify the chapter in this report in which that particular phase of the work is discussed. The chapter references in the following description can be keyed to the flow chart using the numbers.

Figure 1 shows the flow of work as it was actually carried out. Because of the untried nature of the procedures used, many additions, deletions, and modifications were made to the original work plan as the project progressed.

The 1966 Bus Passenger Survey, concluded before the start of this project, was the basic source of travel pattern information. [1/] Since the survey provided an estimate of inbound travel only, one of the early work phases

[1/] "Washington Area 1980 Rail Rapid Transit Patronage Forecast," Chapter II; Alan M. Voorhees & Associates, Inc., for the National Capital Transportation Agency, 1967.

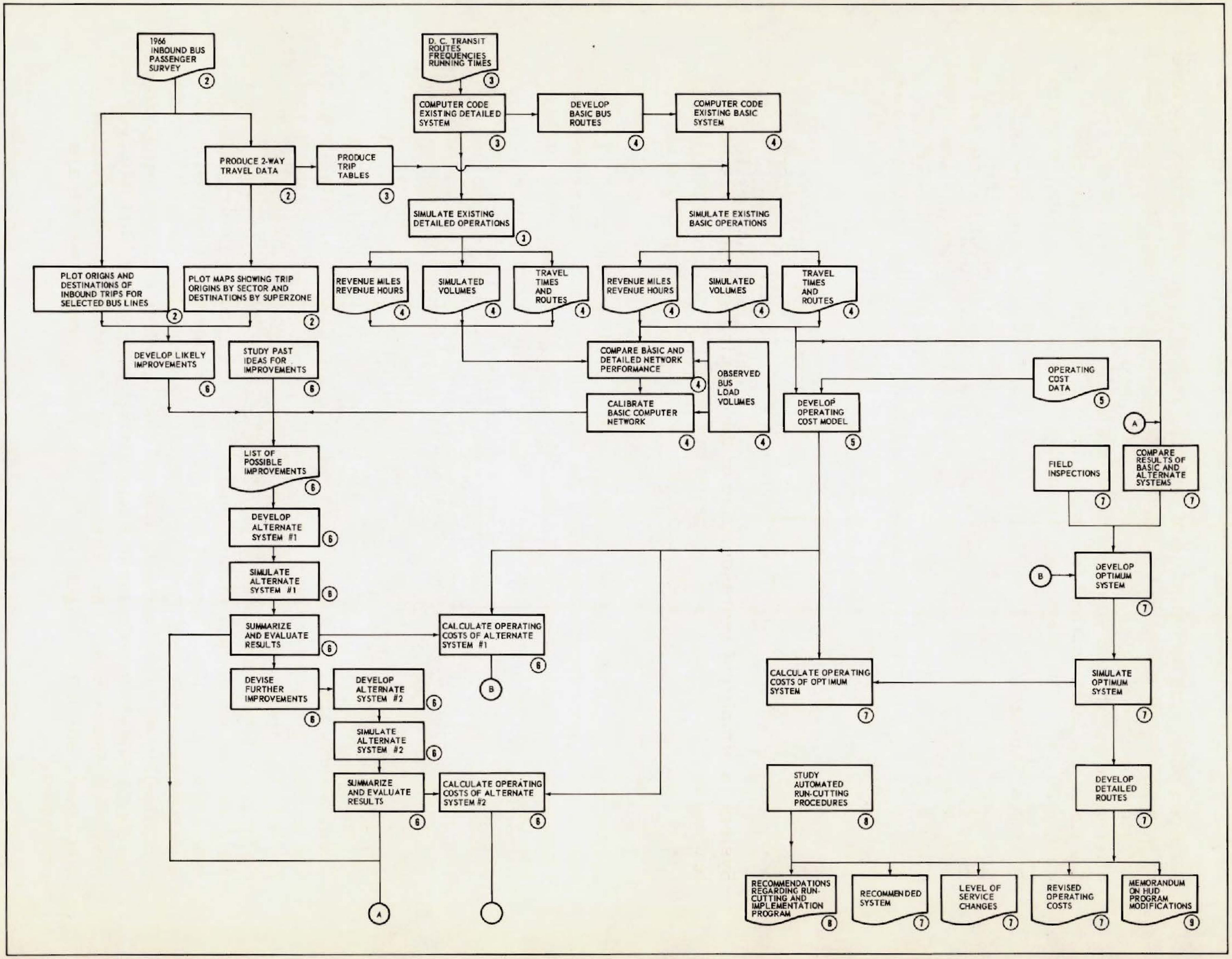

Figure 1 Work Program

involved preparing an estimate of outbound travel to provide a total picture of today's transit travel in the Washington area. The total travel pattern information then had two main uses. Its use as an aid in the design of alternative bus systems is described in Chapter II. Its second use, in the form of a mathematical trip table, was in the simulation process conducted each time a system was tested. The trip table is described in Chapter III.

The first use of the HUD programs was to describe current bus operations. This was done to test the accuracy of the programs for reproducing actual transit system operating characteristics and costs and also to provide summaries of information on the present level of service afforded to bus passengers. Chapters III and IV cover this procedure and also provide a description of the relevant HUD programs used.

The bus network description first prepared for the existing system was very detailed, and while it provided acceptable results, it proved too cumbersome for effective use. The decision was made to code the Basic System, a simplified representation of the existing system. The details leading to this decision are discussed in Chapter IV with a comparison of the two simulations and their accuracy in replicating the existing operations.

A cost model was developed, using operating cost data for D. C. Transit and results from the simulation of the Basic System and is described in Chapter V. This cost model was used to estimate the operating costs and bus requirements of the alternative bus routing systems tested.

The development of the recommended bus routing system was a step-by-step process. Two alternative systems were first developed and analyzed. For each alternative it was then possible to identify portions of the study area where service had been improved or decreased. In most cases it was possible to attribute the service level changes to specific route revisions, thus providing information for design of an Optimum System. These efforts are described in Chapter VI. The Optimum System made use of those portions of the existing and the two alternative systems that proved to be the most effective in providing desirable bus service. The Optimum System was tested to provide an estimate of the service improvement and the effect on operating costs that would accrue from putting it into actual operation. Special service routes were then designed to fit with the basic Optimum System. Chapter VII describes the development and simulation of the Optimum System, and provides comparisons between the Basic System and Optimum System of operating costs and levels of service to the riders. The development of the detailed routes is also discussed, and the highlights of the final recommended system are presented.

As the project progressed, it became apparent that the speed and degree to which the recommended system could be implemented depended to a great extent on the scheduling and run-cutting procedures to be used by D. C. Transit. Thus the investigation of existing automated scheduling procedures proved to be quite important. Chapter VIII covers both the recommendations regarding scheduling and manpower assignment and the suggested implementation program for the recommended bus routes.

An assessment of the utility of the programs along with suggested improvements is provided in a separate memorandum to the Department of Transportation.

It should be noted that this project has not included any estimation of patronage increases which might be brought about by a revised operation. In some areas, the recommended system does provide improved service to persons who cannot now effectively use the bus system. Any resultant increases in patronage are additional gains from the standpoint of this study. The analytical process has been limited to improving service to present riders while attempting to reduce or hold the line on operating costs.

The operating economies which have been made the subject of this study are those which could possibly be realized by changing the pattern of routes and service frequencies. The efficiency with which D. C. Transit operates its present routes to serve the particular volumes now observed on any given route has not been questioned or investigated. The project has concentrated on the thesis that route and service frequency changes can make it possible to serve the existing travel patterns more directly, while at the same time reducing passenger-miles in such a way that bus-miles, bus-hours, and bus units required can also be reduced or at least held constant.

ANALYSIS OF BUS RIDER TRAVEL PATTERNS

2.1 Use of Origin-Destination Information

The use of information as to where and when bus riders travel in the Washington area was a vital element of this study. In 1966, the National Capital Transportation Agency conducted an on-bus postcard survey of all inbound metropolitan area riders. In the current project, after adding estimates of outbound travel, this information was put to two principal uses. First, the indicated travel patterns were plotted on maps and compared to the existing bus routes to identify those trips which were not adequately served and to aid in laying out new services. Second, as discussed in Chapter III, the total movement, when described in mathematical form, was used in the simulation of the present and alternative bus systems. This chapter contains a description of how the origin-destination information was gathered, processed, and used in the design of alternative routes.

2.2 Origin-Destination Survey Procedures

To understand some of the processes involved in preparing the origin-destination survey data for use in this Mass Transportation Demonstration Project, it is necessary to review the conduct of the survey as it was performed for the National Capital Transportation Agency and also the manner in which the survey results were prepared for computer processing.

The survey was conducted on a typical weekday in March 1966 from 5:00 a.m. to 2:00 a.m. the following day. Each inbound adult bus passenger was handed a survey card by his bus driver. On crosstown routes, cards were distributed inbound to a centrally located point. The rider could deposit his completed card in boxes provided aboard the bus or mail it free. The card asked where the rider was boarding and alighting from the bus, where his trip origin and destination were located, what his trip purpose was, what means he used to get to and from the bus, and the number of cars owned in his household. A typical survey card is shown in Figure 2.

By virtue of advance publicity and extensive public interest, an overwhelming response was obtained. Over 48 percent of all survey cards issued were returned — a very high response rate for a postcard survey

TO BUS RIDERS: Please help to plan your future bus and subway systems by telling us ABOUT THE TRIP YOU ARE NOW TAKING. Drop completed card in box at door or hand to driver. If you don't have a pencil now, the card can be mailed free.

1. I got on this bus at ______________________
   (NEAREST STREET CORNER) (CITY OR COMMUNITY)
2. I have come from: ☐home ☐work ☐shopping ☐school ☐other
3. This place I have come from is at ______________________
   (ADDRESS OR NEAREST CORNER)
   ____
   (CITY OR COMMUNITY)
4. I am getting off this bus at ______________________
   (NEAREST STREET CORNER) (CITY OR COMMUNITY)
5. I am now headed for: ☐home ☐work ☐shopping ☐school ☐other
6. This place I am headed for is at ______________________
   (ADDRESS OR NEAREST CORNER)

Nº 465006

____
(CITY OR COMMUNITY)

PLEASE FILL OUT BOTH SIDES

BUDGET BUREAU
NO. 117–6601

UNITED

STATES

GOVERNMENT

NATIONAL

CAPITAL

TRANSPORTATION

AGENCY

PLEASE FILL OUT BOTH SIDES

7. How did you get to this bus:
   ☐Walked ☐Drove and Parked ☐Car Passenger
   ☐Bus ☐Train ☐Taxi or Other
8. How will you get from this bus to where you are headed:
   ☐Walk ☐Bus ______________________
   (Route Number of bus transferred to)
   ☐Car ☐Taxi or Other
9. Check the number of cars in your household:
   ☐None ☐1 Car ☐2 Cars ☐More than two

IF YOU TRANSFER ON THIS TRIP PLEASE DO NOT TAKE ANOTHER CARD

THANK YOU

UNITED STATES GOVERNMENT
NATIONAL CAPITAL
TRANSPORTATION AGENCY
WASHINGTON, D.C. 20432
OFFICIAL BUSINESS

POSTAGE
AND FEES
PAID
N.C.T.A.

NCTA TRANSIT SURVEY
P.O. BOX 9366
WASHINGTON, D.C.
20005

Figure 2 NCTA Bus Survey Card

and a more than adequate sample of travel on a typical weekday by mass transit. A sample of 29 percent of all cards issued was analyzed with the sample being proportioned so as to fulfill requirements for statistical stability on all bus lines, including those which were lightly traveled.

In processing the survey card data, checks were made to ensure that each coded trip was reasonable. Bias control techniques were utilized to keep different survey response rates from influencing the estimates of travel patterns. The survey results were originally checked against 1966 maximum load point passenger counts and were found to compare on the basis of area totals within two percent.

In this project, when the survey trips were used in the simulation of the present operation, the individual bus line volumes obtained from D. C. Transit provided not only a check on the simulation but also a more detailed evaluation of the accuracy of the basic survey data. This check is described in section 4.7.

The fact that the survey is now about three years old is not of major concern except to recognize that the traffic generated by specific apartment or business complexes opened since March 1966 is not reflected. Over a time period of three years, the greater mobility of the population will not significantly affect basic travel patterns. The travel pattern obtained from almost any survey is based on a sample of trips for which specific information was actually received and analyzed. The assumption that new residents have travel patterns similar to trips actually surveyed a short time earlier is comparable to the statistical assumption that the percentage of trips originally not surveyed can be represented by the ones in the sample used.

2.3 Trips Included in the Analysis

The bus rider survey covered trips on each of the four major local bus companies in the Washington area. It was only necessary to include in the analysis those trips which actually used lines of the D. C. Transit Company for at least part of their journey.

All the surveyed trips can be put into one of the following three groups:

1. Those riders who use only D. C. Transit lines
2. Those riders who use only lines of the three suburban carriers
3. Interline passengers who use D. C. Transit as well as suburban company lines

The first group of riders accounts for nearly 80 percent of all metropolitan area trips. They were readily identified in the survey records and were the main subject in the study. The second group of riders did not fall within the scope of the analysis and were set aside. However, trips belonging to the third group were numerous enough to affect D. C. Transit's operations. Interline ticket sales reveal that there are between 8,000 and 10,000 daily riders who start their trips on D. C. Transit and then continue on a suburban company line, with a similar number doing the reverse. Approximately 8,050 inbound interline riders were identified and also included in the analysis.

2.4 Producing A Two-Way Description of Travel

Use of an inbound-only postcard survey for analysis of bus service improvements is quite practical and can produce good results. However, as the project design progressed, it did become apparent that as part of the analysis outbound travel had to be estimated, particularly so that the HUD programs could be adequately tested.

Both directions of travel must be considered at the same time in evaluating the bus service during any given time period of the day. In the peak hours, one direction of travel will predominate on most routes and will set the basic framework within which the total bus service must be fitted. However, reverse trips must be considered at the same time in the context of this basic framework. On crosstown buses where riders classified as "inbound" by the survey become intermingled with "outbound" classified riders, an estimate of all riders is necessary to correctly assess the amount of service required.

A full description of the basic geographic travel pattern was provided by the inbound postcard survey through the use of the "mirror image" concept. This concept assumes that there is an identical return trip for every one-way trip observed. While this is not exactly true, it is a very close approximation in the specific case of travel by transit.

The times at which the outbound trips occurred were estimated using the more comprehensive data on travel time relationships available from the home interview surveys. In such a survey, both inbound and outbound trips are identified by trip purpose, location, and time.

It was determined from home interview survey data, for example, that the average work-to-home trip by transit could be described by adding 9-1/2 hours to the starting time for each home-to-work trip and by reversing the trip's direction. Further details of how the reverse flows were estimated are given in Appendix A.

The home interview survey chosen to provide the requisite travel time relationships was the 1962 Baltimore survey. The choice was made after comparing inbound transit travel time patterns observed in the 1966 postcard survey with the two-way travel time patterns surveyed in various cities, including Washington, D. C. in 1955, and Baltimore in 1962. The home interview surveys for these two cities showed the closest similarity to the 1966 Washington data. The 1962 Baltimore survey was finally chosen as a data source in preference to the older Washington survey because it provided trip purpose breakdowns more directly comparable to those obtained in the 1966 Washington postcard survey.

Figure 3 provides a comparison between the 1966 Washington postcard survey data and the 1962 Baltimore data. Home-to-work and work-to-home inbound transit trip time patterns are shown for D. C. Transit patronage, plotted by one-half hour intervals, and are compared to the Baltimore total inbound and outbound transit work trip time patterns. The very close resemblance in the size of the travel peaks, the time separation of the peaks, and the relative quantity of midday travel can be seen. In the course of the analysis, similar curves were prepared for each of several other trip purposes, as described in Appendix A.

Figure 4 shows the synthesized total inbound and outbound trip time graph for D. C. Transit in comparison with the original total trip curve for Baltimore. Both transit work trips and transit trips for other purposes are included in this display of the final D. C. Transit total trip estimate.

The end product of the two-way travel estimate was a complete description of 1966 adult travel by D. C. Transit buses in terms of trip origins, destinations, and time period of the day. As will be described later, the analyses which involved simulating the transit system or otherwise analyzing the travel pattern in detail were conducted for the 6:00 a.m. to 9:30 a.m. peak time period and the 9:30 a.m. to 3:00 p.m. midday base period.

2.5 Origin-Destination Information Displays

2.5.1 Use of Displays

One of the more important ingredients in designing the alternative bus routes has been the knowledge of existing travel desires gained from the 1966 bus rider survey. For the route designer to successfully use the survey information, it had to be displayed in relevant and readily comprehensible forms. To this end, two types of displays were used.

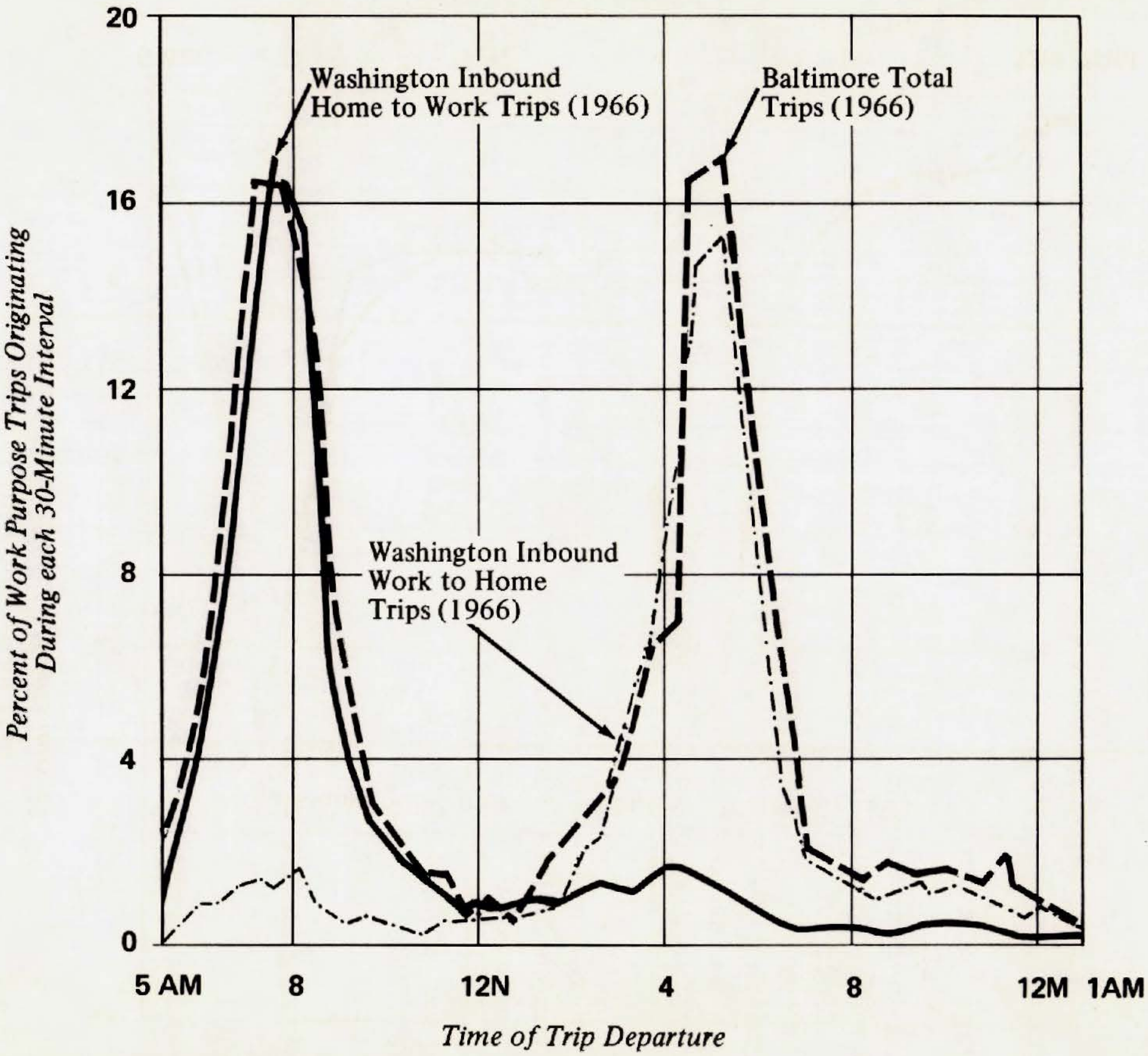

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Figure 3 Washington and Baltimore Work Trip Variations by Time of Day

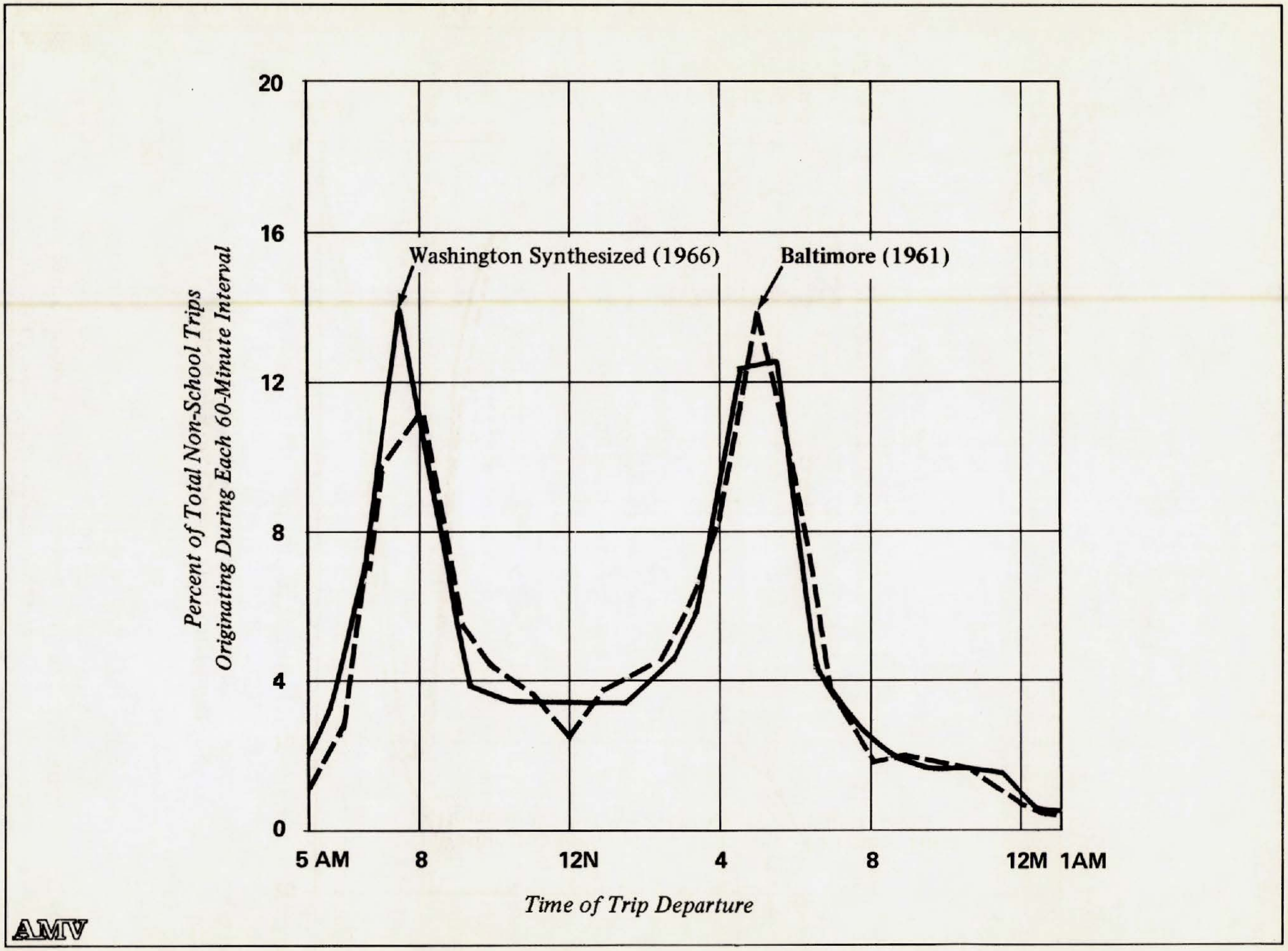

Figure 4 Total Two Way Trip Curves for Baltimore and Washington

The first type of display was oriented to the study of individual bus lines, while the second type concentrated on the total pattern of movement, one corridor at a time.

Early in the study, it became apparent that analysis of travel patterns at the bus line level of detail did not go far enough in providing the type of information needed in alternative route planning. The study of travel desires at a corridor level did provide the basic information necessary to make comprehensive revisions to the existing bus route structure. Both types of display are described here and are evaluated in respect to their use for route design purposes.

2.5.2 Trip Data Analysis for Selected Lines

The Demonstration Project design originally contemplated that for each D. C. Transit bus line rider origins and destinations would be plotted separately for each of four time periods. After further study, it became apparent that there were basic disadvantages to producing and depending on map plots of this type.

One prime disadvantage was the immense volume of data which would have been produced. Origin and destination plots for all lines, for just two time periods, could have resulted in about 600 maps. The intelligent, integrated study and comparison of this number of maps by a route designer would be impossible.

It should be remembered, of course, that the basic purpose of the alternative route design was not to isolate minor route realignments or extensions that should be made. The primary objective was to make an overall evaluation of travel patterns and system performance, leading to possible major system changes for the overall benefit of the average patron.

The use of the line plot maps had other shortcomings. Since some of the maps dealt with a very limited number of trips, it was difficult to discern travel patterns which might imply possible routing improvements. The ends of individual trips, once mapped, could not feasibly be keyed, thus giving no feel for the length of trips using a line. It was also found impossible to include in the analysis of a given line, trips which did not begin on that line.

For these reasons, the survey trip data analysis on a line-by-line basis was limited to certain selected routes. A sample line analysis map is shown in Figure 5. The lines chosen were selected because of particular problems suspected. In certain instances, the information did prove useful. For instance, the analysis for present bus routes A2, A4, A6,

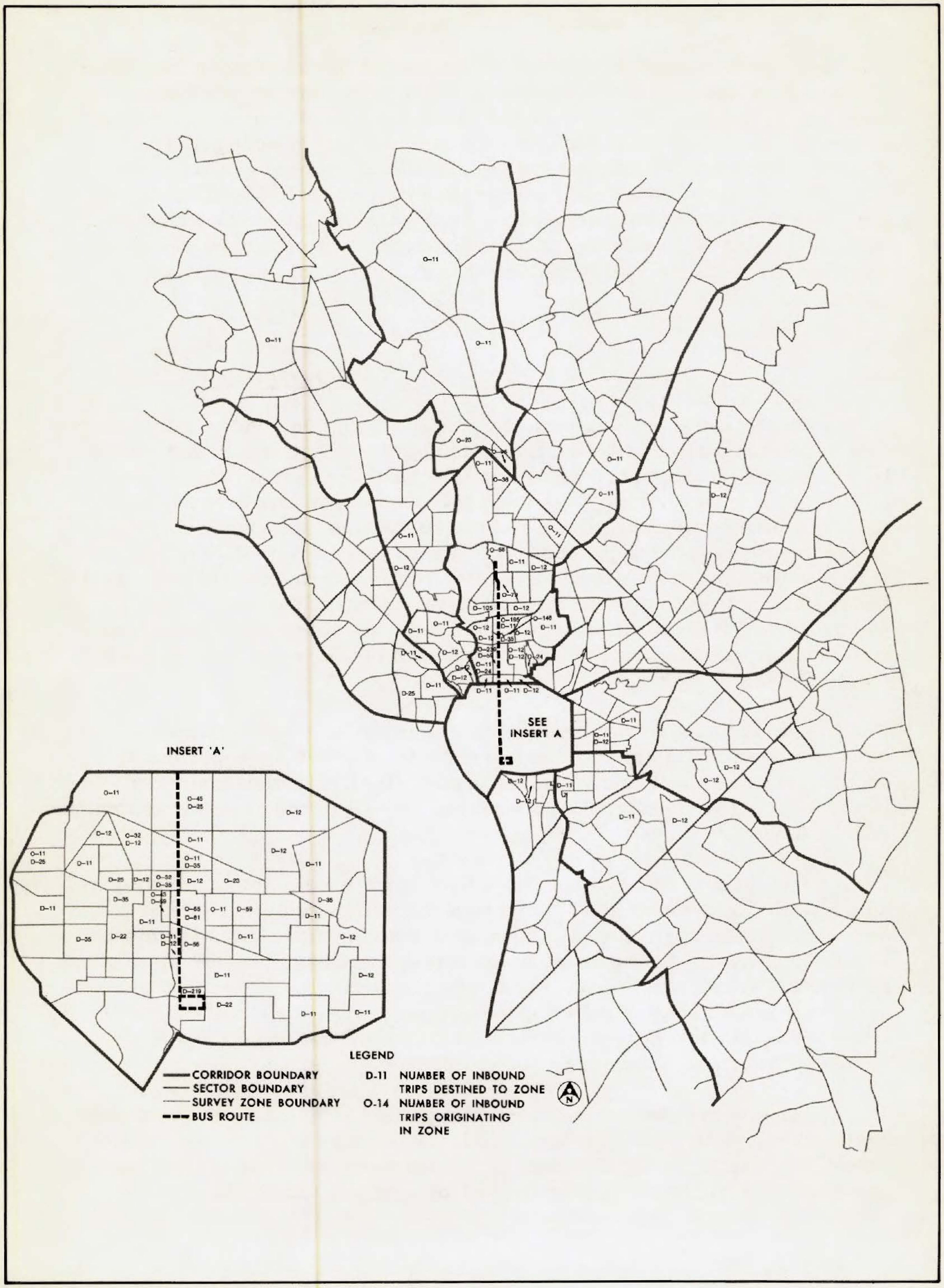

Figure 5 Sample Line Travel Analysis Map

A8, and A9 indicated that at least 25 percent of the total riders on these lines could eliminate one or more transfers if the lines were extended from the present Archives terminal (three blocks from downtown) into the center of downtown. Similar analyses of northwest Washington lines N2, N4, and L2 indicated there were significant numbers of trips headed east of the present downtown route terminals. In the case of route 54, the density of trip destinations along the Pennsylvania Avenue alignment west of Capital Hill indicated that the present route should be retained even though there were alternatives that at first glance appeared promising.

2.5.3 Trip Data Analysis for Corridors and Superzones

The corridor and superzone trip data analysis was devised to allow study of outbound as well as inbound trips, to key the origin and destination of trips, and to provide more definitive information in terms of the number of trips ending in each analysis zone. The corridor analysis was specifically designed to identify those areas in which bus service is not well oriented with respect to present trip patterns. Of interest here is not only how well individual routes serve the trip pattern, but also how well the system of routes works together to serve travel desires. With poorly served travel interchanges identified, the alternative bus systems could be designed to provide improvements in the areas where they are most needed.

For the corridor analysis, the area was divided into seven basic corridors as shown in Figure 6. The corridor boundaries were chosen in consideration of topography and the present D. C. Transit route configurations. The boundaries were placed so as to cross a minimum number of radial bus lines.

Each corridor was then subdivided into sectors to take into account non-homogeneity of the corridors, to match crosstown route service areas, and to provide recognition of the fact that many radial routes terminate at the D. C. line. Sector boundaries follow the D. C. line for most of its length. Additional boundaries inside the District of Columbia were drawn to divide areas of different socio-economic characteristics which might exhibit different transit travel patterns. Topographic barriers, such as rivers and parks, were used wherever possible.

The sectors were used to define trip origins. To facilitate study of the destination end of trips, the study area was divided into 119 superzones. These smaller units were chosen to allow a more detailed analysis of major attractors, such as employment or commercial areas.

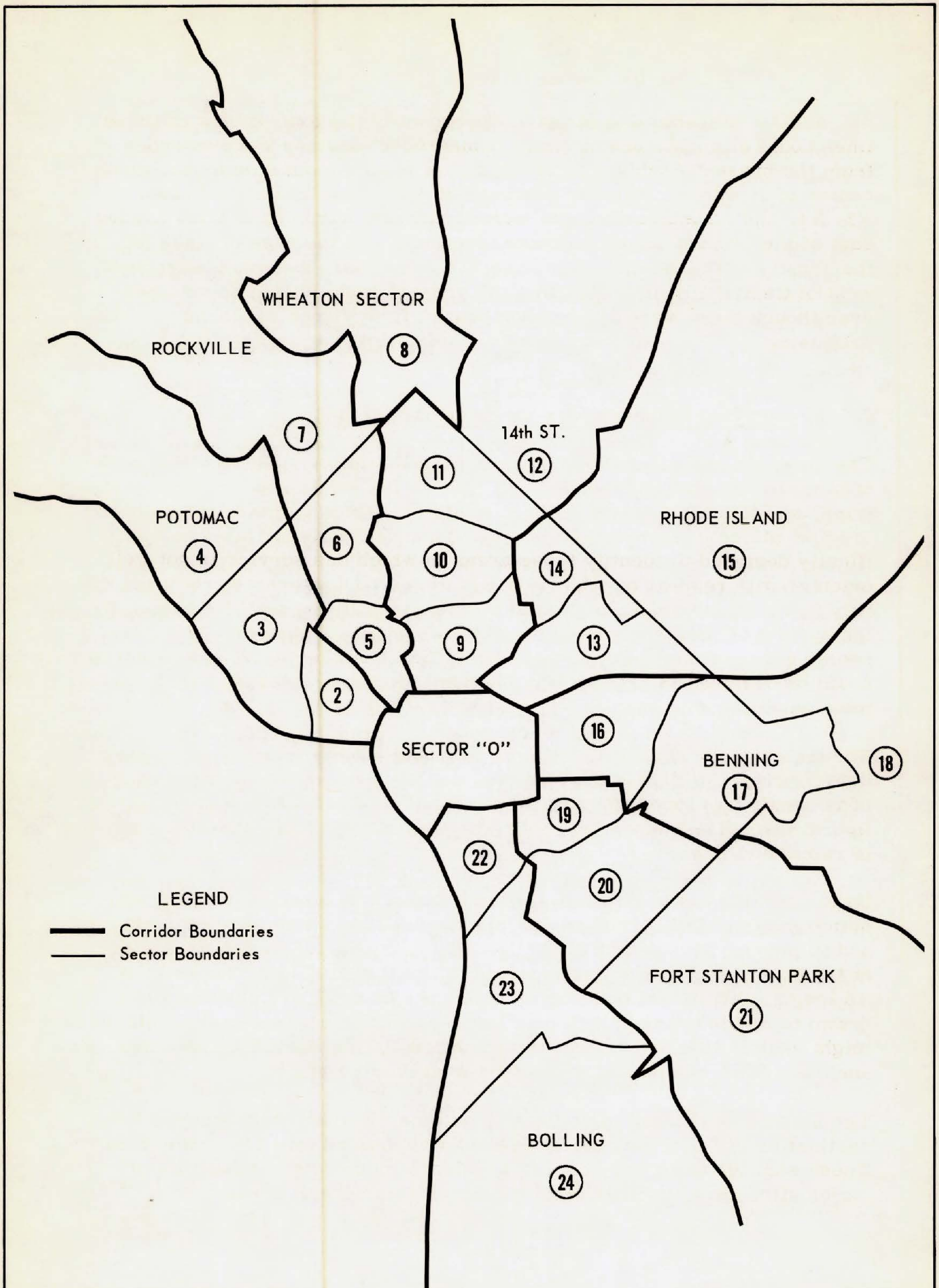

Figure 6 Corridors and Sectors for Trip Data Analysis

The corridor analysis maps show existing bus lines in the corridor, differentiating between trunk lines and lightly serviced lines. In addition, certain important connector routes were shown to help identify heavy transfer points.

On each map, the destinations of all inbound and outbound trips which originated in the given corridor were plotted. The number of trips destined to each superzone was accumulated and indicated on the map. This number was broken down and keyed according to the particular sector in the corridor from which the trips had originated. A sample map is shown as Figure 7.

A total of 16 maps were prepared, eight each for the a.m. peak and mid-day base periods. The eighth map for each time period shows the trips originating in Sector O[1/] and the Wheaton sector which did not fit into the seven primary corridors used.

The corridor analysis revealed some very important characteristics of trip-making by mass transit within the study area. It highlighted two basic and distinct movements of D. C. Transit patrons. As expected, the first is the movement between all areas and downtown. This constituted 66 percent of all trips during the morning peak period. The second movement is a very distinct flow between the southern and eastern sections of the District of Columbia and the northern and western areas. This second movement does not have the high concentration of destinations which characterizes the downtown movement, but rather has a dispersed pattern of both origins and destinations. The travel flow is highly directional, being from south and east to north and west in the morning peak period with no appreciable counterflow. An illustration of the origins of non-downtown movements is provided in Figure 8.

From the two corridors west of Rock Creek, 77 percent of all trips are destined to Sector O. In contrast, the two sectors constituting the D. C. portion of the Benning corridor have only 51 percent of their trips destined to Sector O. Most of the remaining 49 percent is made up of crosstown trips forming part of the second basic movement.

[1/] The area in downtown D. C. traditionally used in transportation studies to define the central business district (CBD). This area is bounded on the north by S Street, N.W., and Florida Avenue, N.W.-N.E.; on the east by 4th Street, N.E.-S.E.; on the south by North Carolina Avenue and I-95, and on the west by the Potomac River, Rock Creek, P Street, and Florida Avenue.

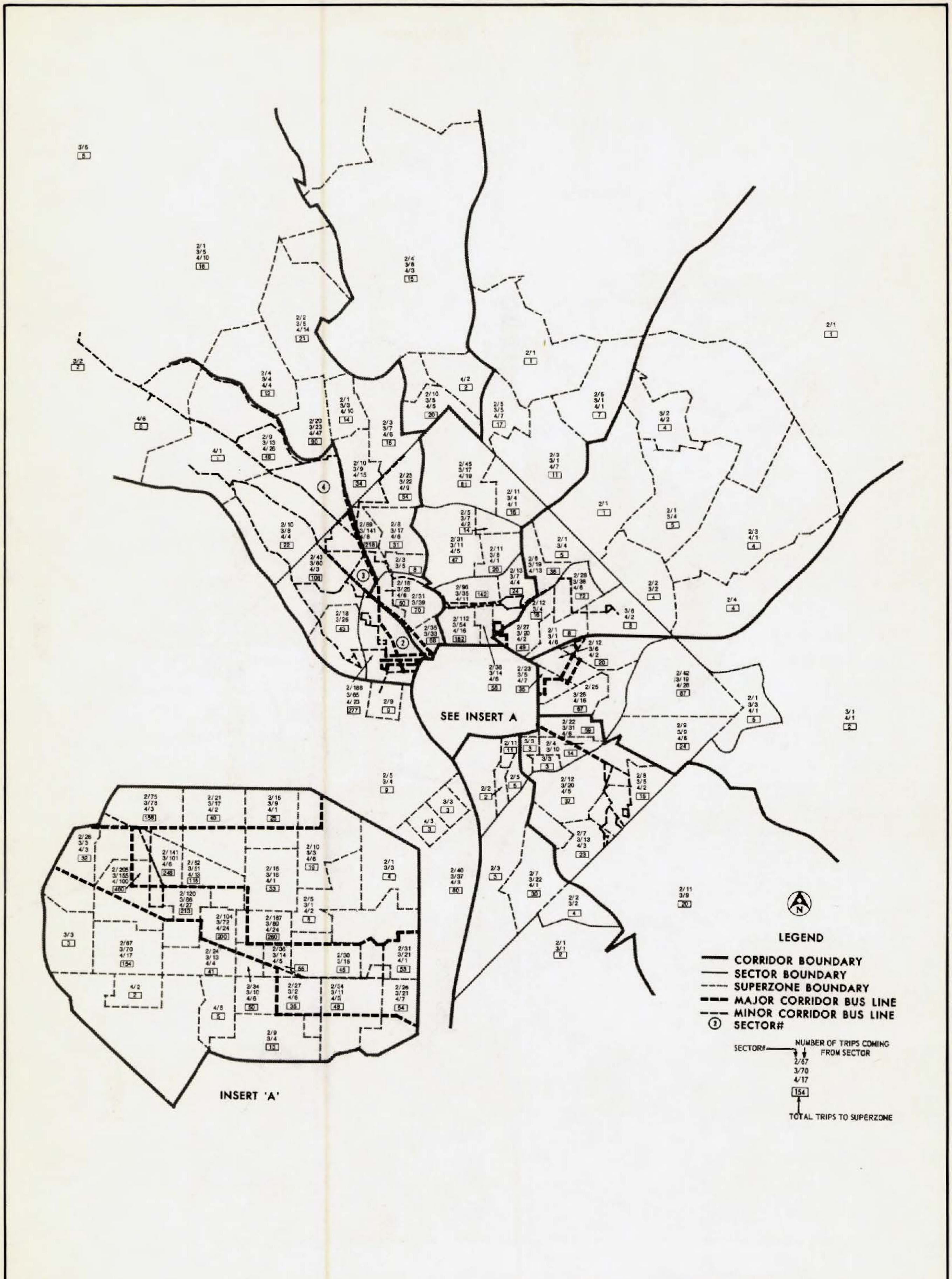

Figure 7 Sample Corridor Travel Analysis Map

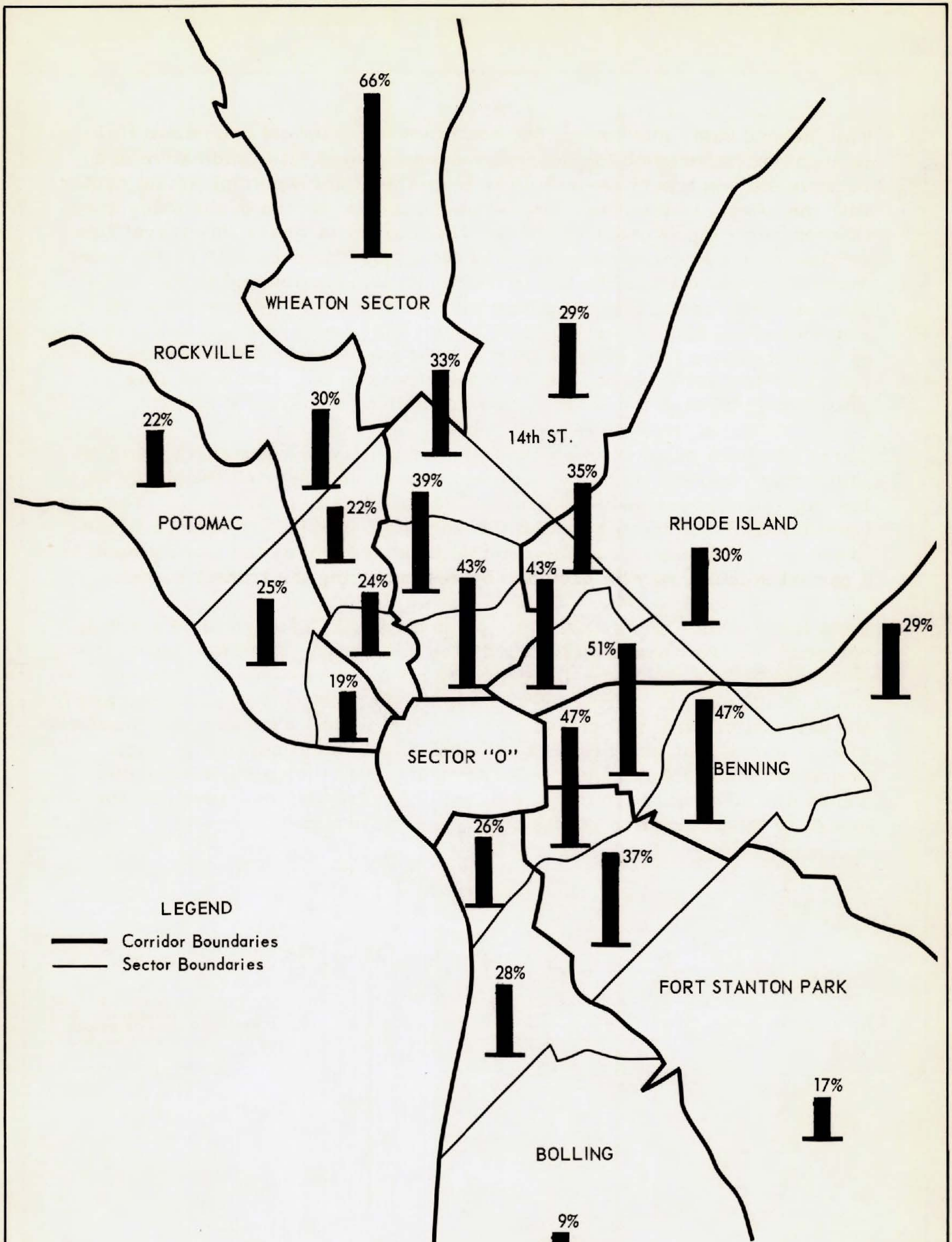

Figure 8 Proportion of Transit Travel with Destinations Outside of Downtown by Sector of Origin

This second basic movement, the southeast to northwest crosstown flow, is of major importance for several reasons. First, it is indicative of a relative shift in travel desires away from the downtown employment center with the effect, in this case, concentrated in one portion of the study area. Of even more significance is the fact that the areas where this travel flow originates are lower income areas of the city. The necessity of the lower income groups to travel by bus to northwest Washington and to the Maryland suburbs seeking employment involves a long journey to work. For these long and dispersed trips, which are at best difficult to serve by transit, there is at present only limited express service and very few direct no-transfer routes. Many of the riders in this crosstown flow must travel through the heart of downtown along F, G, or H Streets.

There has been much discussion of the possibility that bus service to the lower income areas might be inferior, even though service frequency and loading standard measures might not indicate this to be the case. The corridor analyses have indicated that the basic problem of service to the lower income areas lies in the orientation of the travel and that at least a partial solution may be provided by restructuring the transit routes.

Thus the corridor and sector plots pointed up what appears to be a strong potential for improvement in the existing crosstown bus route structure. Additional areas also showed potential for route revisions, particularly in the peak periods. These areas included the west side of downtown and the new Southwest Employment Area. In the midday base period it was also observed that many trips did not have convenient service through downtown, or in many cases, even across to the other side of downtown. These are some of the more significant factors which contributed to the design of the alternative routes discussed in Chapter VI.

Chapter III

COMPUTER REPRESENTATION OF THE BUS SYSTEM

3.1 Purpose and Basic Procedures

The bus service and cost analyses conducted in this study have been highly dependent on the use of computer networks to represent the bus systems being examined. A computer network is a mathematical description of a transit system in terms that can be interpreted and processed by use of computer programs designed for this purpose such as the HUD programs used in this study. The networks are employed in conjunction with other mathematically represented information such as trip table representations of bus rider travel patterns.

The first network used in this project was designed to represent in detail the existing bus system. It was prepared to determine how accurately bus operations could be simulated with the HUD programs and to allow experimentation in finding how best to use the program options in achieving satisfactory results. It was also prepared to develop the passenger service characteristics of the present bus system for comparison with alternative systems. This function was later transferred to a second network, the Basic System, described in Chapter IV.

The detailed coding of the existing bus system involved two main tasks. The first was the selection of a traffic analysis zone system used to designate the points at which people begin and end their trips. The second task was the gathering and computer coding of relevant information pertaining to the present bus route locations, speeds, frequencies, and service characteristics. These two efforts are typical of computer network preparation, except that the zone system is developed only once for any given study.

This chapter describes the selection of traffic zones and coding of the present bus routes. The development of trip tables to represent mathematically the bus rider travel patterns is also discussed. Descriptions of the HUD programs themselves are provided in Appendix B, and the results of the existing network simulation are presented in Chapter IV.

3.2 Traffic Zone System

A traffic zone can be defined as a small part of the metropolitan area used to describe the geographic location of travel volumes and related demographic characteristics. Travel volumes to, from, or between zones are represented as totals. The networks are keyed to the traffic zones, so that the trips between zones can be loaded onto the networks using the HUD programs to obtain bus line passenger volumes and related information.

The traffic zone system should be consistent with the objectives of the study, the survey data base, and the transit system. The special needs of this short-range operational planning project required the zone system to be designed in more detail than is frequently used and with some special uses of the zoning concept. The traffic analysis zones were assembled from the subzones to which the 1966 bus rider survey had been coded. They were shaped as much as possible to divide groups of riders observed in the survey into different basic travel routes.

Three types of traffic zones were used in order to describe fully the travel patterns of D. C. Transit riders. The first and most important, designated transit zones, cover the entire D. C. Transit service area. The trips beginning or ending in these zones were those where the rider walked to or from his D. C. Transit bus stop. To facilitate the design of these transit zones, computer tabulations were obtained which showed summaries of trips originating within each survey subzone and identified by the individual bus routes used. When there was a major difference in use of routes between subzones of a given zone, the zone was split to create two or more transit zones. This process resulted in 104 of the original survey zones being split, making a total of 488 transit zones.

Foreign zones were a second category of traffic zones used to cover areas outside that served by D. C. Transit. These were necessary to facilitate description of trips made partially on D. C. Transit and partially on other area bus companies. Nine foreign zones were created: four for WMA riders; one each for WV&M and AB&W riders; plus three additional Virginia zones to specifically identify Rosslyn, the Navy Annex, and the Pentagon.

Auto connector zones were established as the third traffic zone category to allow separate consideration of park 'n' ride and kiss 'n' ride trips. These are the trips which start out in a private auto and then continue by public transit, with the auto either being parked at the transit stop or driven away by a second party. Park 'n' ride and kiss 'n' ride patrons received separate treatment because of their very special characteristics. These auto access trips are not affected by the quality of transit service in the immediate area of trip origin. They have a considerable degree of flexibility in choice of transit routes. On the other hand, park 'n' ride trips are affected by the availability of parking at transit stops.

The 1966 Bus Rider Survey showed that almost 10 percent of all inbound bus passengers come to the bus stop by auto. In suburban areas, this percentage is much higher, exceeding 50 percent in some instances.

To allow design of auto connector zones which would reflect auto access trip patterns, computer summaries were prepared linking trip origins with the place of first boarding. This allowed the identification of the major bus loading points and their areas of influence. These areas of influence were then delineated into 20 auto connector zones. These zones overlapped regular transit zones, since from most areas there are both people who walk to bus service and people who use an auto to reach the bus.

In addition, 12 spare zones were established. These were used for the accumulation of transit trips which did not use D. C. Transit, but had to be included to obtain error check totals. These and the 517 transit, foreign, and auto connector zones comprised a total traffic zone system adapted to the particular needs of this Mass Transportation Demonstration Project.

3.3 Preparing Trip Tables

With the traffic zone system established, it was possible to proceed with network preparation described in the following section and to prepare the trip table representations of the bus rider travel patterns. Trip tables were prepared for the a.m. peak period and the midday base period.

A trip table is a matrix similar to the mileage chart often found on highway maps. The figures in the rows and columns give, instead of mileage, the number of trips between each pair of traffic zones. Unlike a mileage table, the number of trips must be separately specified for each direction of travel. The rows and columns are identified by the traffic zones of trip origin and destination.

In the case of this study, the traffic zones defined a trip table format with 529 possible origins and 529 possible destinations — or about 280,000 possible trip orientations which could be described. The number of trips in each interchange was obtained from the 1966 Bus Rider Survey and from the outbound trip estimate described in Chapter II. The result was a set of travel descriptions for the a.m. and midday time periods for use in the network analysis.

3.4 Preparing the Bus Network Description

The detailed network description of the present bus operation was based on source data provided by D. C. Transit. These data included route maps, supervisors' run guides (schedules), route mileage sheets, and running time sheets. Information on the other bus companies was obtained from public schedules and route maps.

Using the source data, coding maps were prepared of the system. These are graphic representations which facilitate and serve as a record of the translation of the bus system into numerical values.

On the coding maps and in the mathematical description, the bus system characteristics are represented by centroids, nodes, links, and lines. These components perform the following functions:

- Nodes — These are the points where links are terminated and joined. Transfer points are always represented by nodes, as are the points used to represent where people board and alight transit services.

- Centroids — These are the points in the network which represent the individual traffic analysis zones. The bus passenger trips are loaded onto and taken from the network at the centroids. Centroids are a special type of node, and are placed within the zone to which they refer, in relation to the center of gravity of the population of that zone.

- Links — These are the segments of bus routes or access routes that define the shape and speed of the network. A link is identified by the node numbers at each end and carries a distance value and a speed or travel time value for movement between the two nodes via that link.

In the networks used in this project, several different kinds of links were employed. They fall in one of two major categories, the first being transit links. Transit links describe the movement of transit vehicles and can be given one or more mode codes. This study has used a link mode code of "4" for local service transit lines, "5" for express transit lines, and "6" for the suburban company bus lines which connected with the foreign zones.

The second major category of links consisted of walk and auto access links. Two types of walk links were used. The first type of walk link connected zone centroids to nearby bus stops. The second type of walk links made up a "sidewalk network," used principally in the CBD for transferring between buses or reaching a centroid slightly removed from the bus line used. Auto connector access links connected the centroids of the auto connector zones to the most frequently used park 'n ride and kiss 'n ride bus boarding points. "Dummy" links were used in connection with the other access links to enforce boarding and alighting restrictions.

Because of the nature of the HUD programs, the definition of a network "line" is somewhat different than a bus company's definition of a route. The computer network line can have only one beginning and one ending point, and must have a constant service frequency or headway. Thus a bus company route that branches near its end or has "turn back" points, or a route that has different headways in different directions, must be broken down into several lines for network purposes.

The first network was coded to include all but the most insignificant of the lines operated by D. C. Transit. This Detailed System included a network description of 242 local service D. C. Transit lines, 73 D. C. Transit limited service lines, and 20 trunk lines representing the service of the suburban companies in the area of interchange with D. C. Transit. Chapter IV will describe how it was possible to reduce the network size by coding only the Basic System of D. C. Transit routes.

3.5 Building the Bus Network

Once the bus system had been coded, the first HUD program, AVNET, was used to assemble the network for further processing. As part of its operation, this program produces reports locating errors in the network coding and provides other summaries as outlined in Appendix B. The transit line summary thus produced was used as an aid in the subsequent operating cost calculations for the existing and alternative systems.

Checks were performed on line length and running times as printed out in the summaries to see if they conformed to the actual. Once it was established that the overall running times and route mileages were correct, it was possible to have confidence that the specific link information was accurate. This information was of importance in the calculation of operating costs for the Alternative Systems.

Further and more revealing checks were performed on the network representation as part of the calibration procedure described in the next chapter.

Chapter IV

CALIBRATION RESULTS AND NETWORK MODIFICATIONS

4.1 Objective

The purpose of the calibration phase of the project was threefold. First priority was to complete a simulation of the present bus service by using the detailed network described in Chapter III, thus making an initial determination of how accurately the bus system could be represented. The second task was to determine what possible modifications of HUD program applications would give the best simulation results. Finally, the calibration phase involved revising the representation of the present bus system on the basis of the modified techniques. This revision ultimately took the form of preparing a new network which has been called the Basic System.

4.2 Calibration Procedures

The accuracy checks on the present bus system simulation and the development of technique modifications were actually conducted nearly in parallel. The calibration was an iterative process. The process terminated when it was judged that the accuracy being obtained was consistent with the objectives of the project and that further effort would not yield any significant improvement.

In the course of calibration, three principal simulations of the present bus system were conducted. The first two used the detailed network initially prepared, but with differing penalties being employed to represent the inconvenience to a passenger of waiting for his bus or making a transfer. The third used the Basic System simplified network representation.

The first of the series of checks on simulation accuracy was that of bus route running time and mileage. This was completed when the detailed network was first assembled for computer analysis and has already been described.

The next check was to trace individual zone-to-zone passenger travel paths as produced by the HUD programs and to check them for logic. Finally, the most important check carried out was to load the trips from the trip tables onto the networks and compare the simulated bus route loadings against actual passenger counts provided by D. C. Transit. As an adjunct to this latter check, it was possible to make other comparisons, such as comparing the percentage of trips involving transfers against data obtained directly from the 1966 survey questionnaires.

4.3 Travel Path Checks

The checking for logic of individual zone-to-zone travel paths required use of HUD program AVPATH. This is the program which determines all travel paths through the network. Individual sets of paths were printed out and traced in color on the network maps. These paths were then reviewed using the analyst's judgment to discover any illogical traces. Obviously errant paths were normally the result of simple coding mistakes. More subtle problems such as the occasional incidence of an abnormal number of transfers were traceable to the techniques of using the programs.

It is appropriate here to describe the criteria used by AVPATH in establishing the travel path between any pair of traffic analysis zones. The program algorithm is designed to choose the minimum adjusted door-to-door travel time path. Adjustment of true time is provided for to recognize that a person's actual choice of route for a given trip is not contingent entirely upon pure travel time. It is recognized that riders may travel several extra minutes to avoid a transfer or to get off at a stop closer to their destination. In the process of calibration, a set of time penalties and constraints were developed to take into account some of these considerations. These were the time adjustments allowed for by the parameters of the AVPATH program. For example, a set amount of time may be added to the true travel time for each transfer required.

Initial trials at setting the time penalties were undertaken during travel path checking. When all network errors were corrected, the calibration moved to the trip table assignment phase.

4.4 Load Count and Transfer Checks

In preparation for loading trips onto the network, all minimum time paths through the computer network were built. This provided a description of the shortest adjusted time paths from each zone of the study area to every other zone through the bus system. The surveyed trips, described in the trip tables, were then loaded onto these minimum time paths and accumulated to provide an estimate of the passenger volume on each segment of the bus system. This was accomplished by use of the assignment programs of the HUD package, AVLOAD and AVPRAS.

The computer-assigned volumes were then compared with actual volumes as counted in the field at bus route maximum load points by D. C. Transit

Company personnel. The degree of closeness in such comparisons is contingent upon several factors, including:

- Extent to which the one-day count made by the bus company is truly representative of the average daily loading on that line

- Accuracy of the trip table, which in turn depends on the quality of the bus survey, the survey expansion factoring process, and the estimation of outbound trips

- The ability of the computer network and related HUD programs to represent the bus operation, given the constraints of the traffic analysis zone configuration and the line coding techniques used

Two assignments were done using detailed networks. In the first assignment, all waiting times at bus stops were weighted by a penalty factor of 2.5 which had been derived from previous studies of travel mode choice. For example, if a bus line operates at a six-minute frequency and the average passenger waits three minutes, an adjusted time of 7.5 (3 x 2.5) minutes was employed as the waiting time of passengers using this line.

The assignment using this technique produced an excessive number of simulated transfers on certain types of routes and showed up several localized coding problems. With this information, another network was built which incorporated the indicated coding corrections and other improvements. For this run, an additive transfer penalty of three minutes was used in lieu of the 2.5 factor on waiting time.

The results of the second network assignment showed a closer match with actual passenger counts in most of the analysis corridors, with a simulated systemwide total of maximum load point count volumes within two percent of the bus company counts. The number of transfers also appeared more reasonable when compared to the original survey response.

In spite of improved results from the second assignment, the remaining variations between the simulation results and actual counts for individual routes were sufficient to indicate that the detail of the network was out of scale with the accuracy being obtained. It was at this point that the project work plan was modified (as shown in Figure 1) to provide for development of the Basic System.

4.5 Reasons for the Basic System

Three basic problems became apparent in analyzing the detailed network application of the HUD programs to short-range operational planning. These can be summarized as follows:

- The exacting detail of the computer network made its development and use time-consuming and expensive.
- The results obtained were not commensurate with the detail and would have required grouping of individual data for meaningful analysis.
- The complexity of the network and the corresponding quantity of passenger volume data produced tended to obscure the central objective which was to determine how the total bus system operated and how it could be improved.

To resolve this dilemma, an approach to development of the network was sought which would concentrate on the basics of the system and yet allow analysis in as much detail as the procedures were capable of producing satisfactorily. A solution was found when in restudying the present bus operation it became apparent that there does exist a basic route structure which can be described by fairly constant headways, speeds, distances, route termini, and equipment requirements. Variations among the different hours of the day and among the days of the week will occur, but without serious differences in system structure.

Overlaid on this basic route structure, most notably during the peak hours, are certain special routes. These routes serve particular passenger travel needs that, in contrast to the major traffic flows, are limited in time and geographic extent. Since the HUD programs represent transit service as a continuous function, these special-purpose routes cannot be well described. As an extreme example, even a single bus trip over its own unique route must be shown at some specified continuous frequency of operation. If the headway is specified at the true average for the time period under study, the service appears very poor and no one is shown to ride it. By using a more frequent but false headway, riders can be attracted to such a line in the computer representation, but they will include passengers who cannot in reality use the service actually offered. There may be a middle ground, however, but the amount of manipulating necessary to achieve it makes the computer representation of such routes impractical. In light of this, it was decided to divide the D. C. Transit routes into two categories — those comprising a basic route structure and those which are special-purpose routes. The Basic System was then coded which excluded those routes in the second category. Since a full detailed network had already been analyzed, it provided a base for comparison.

4.6 Method and Criteria of Basic System Design

In order to translate the broad principles established for the Basic System into actual practice, it was necessary to develop a line classification system. Accordingly, all the lines originally contained in the Detailed Network were allocated into one of the following groups:

1. Lines which operate basically unchanged through the day

2. Peak period supplementary lines which serve significant numbers of trips not adequately served by the all-day lines

3. Peak period routes which are extensions of all-day routes

4. Cutbacks on basic lines where the headway of the cutback service is approximately four times the route headway or greater

5. Branches of all-day lines with headways of greater than 15 minutes which serve traffic analysis zones already served by other principal routes

6. Peak period supplementary services where the origins and destinations of bus passengers are adequately served by other major lines

7. Specialty services consisting of one or two trips

8. Short feeder lines operating primarily within one traffic zone

9. Multi-terminal lines

In general, lines in groups 1-3 were always used in the Basic System. Lines in groups 4-8 were either eliminated or combined with other lines that were retained. Lines in group 9 were, for the most past, modified for analysis purposes by using simplified representations.

In preparing the Basic System for processing, it was possible to utilize much of the work done on the Detailed Network. For clarity, a new set of line maps were prepared. The same node numbers and links were maintained with only the line descriptions being changed where necessary. Travel paths were determined using the three-minute additive penalty on all transfers.

4.7 Comparison of Basic and Detailed Systems

The Basic System proved more convenient and economical to use than the Detailed Networks while providing a comparable representation of the existing bus operations.

For comparison, statistics from four networks are presented in Table 1. The differences shown between the two detailed networks are those resulting from changes made to lines and frequencies after analyzing Detailed Network 1 and from the changed time penalties used in determining travel paths. The time penalties adopted for Detailed Network 2 were retained in use for all subsequent networks. In terms of computer processing characteristics, the Basic System employed the same link set as the detailed networks. However, only 45 percent as many lines were used. To illustrate fully the computer processing benefits obtained by using basic network concepts, measures pertaining to the Optimum System network are also presented. This network represented complete conversion to basic network concepts in that the link set was also completely revised. The number of links was reduced by 14 percent compared with the detailed networks, and the computer core requirements of AVPATH were cut by 16 percent. AVPATH, the longest running program, took 30 percent less computer time to complete. In respect to the capability of the Basic System to satisfactorily represent the bus operations, the last four measures in Table 1 show the low degree of difference as compared to the second detailed network. The vehicle-hour figures show only a six percent decrease, indicating the overwhelming importance of the basic route structure in the total system. The number of transfers was increased by only 1.2 percent in the Basic System representation, the number of bus-passenger-hours by 1.0 percent, and the bus-passenger-miles by less than 0.5 percent.

A summary comparison of the assigned peak load point volumes with actual counts is provided in Table 2. The results show that the Basic System was as close or closer than the detailed networks in matching bus company counts. An examination of the passenger load information at the individual bus route level of detail showed that the Basic System improved simulated volumes in several instances. Two of the corridors remained overassigned in all the present system simulation — a problem that apparently could not be eliminated within the constraints of the analysis. To minimize this type of error, all final estimates of revised

TABLE 1: SUMMARY OF ACCURACY AND COMPUTER EFFICIENCY MEASURES FOR DETAILED, BASIC, AND OPTIMUM SYSTEMS

Item	Detailed Network 1	Detailed Network 2	Basic System	Optimum System
Number of Lines	354	349	162	155
Number of Links	5,681	5,667	5,681	4,882
Revenue Vehicle-Miles -- One Hour Average for A.M. Peak Period	8,072	7,727	7,302	7,689
Bus-Passenger-Miles	558,412	557,916	560,615	547,934
Bus-Passenger-Hours	55,272	53,540	54,096	50,481
Unadjusted Number of Transfers[1/]	100,176	82,529	83,514	68,822

[1/] These figures have not been adjusted to compensate for riders who use the "sidewalk net" for their entire trip, and therefore differ from the final values in Table IV.

TABLE 2: NETWORK PEAK LOAD POINT COUNT COMPARISONS WITH BUS COMPANY COUNTS -- A.M. PEAK PERIODS

Corridor	Detailed Network 1 Percent	Detailed Network 2 Percent	Basic System Percent
Bolling - Fort Stanton Park[1/]	+20	+17	+20
Benning	- 8	- 8	- 7
Rhode Island	+29	+27	+26
14th Street	- 6	- 9	- 5
Rockville	+ 8	+ 7	+ 7
Potomac	-18	+ 1	+ 1
Screen Line (all corridors)	+ 3	+ 2	+ 4

[1/] These two corridors have been combined since routes from both pass through load points in the same area.

bus system volumes made subsequently in the study were obtained by observing shifts in simulated ridership rather than by using unadjusted values directly from the computer program results.

From the point of view of the Demonstration Project, perhaps the most significant accomplishment in the calibration phase was finding that the primary interactions between the riders and the bus system could be described in a simplified form without loss of accuracy. This made it easier to avoid "not seeing the forest for the trees." Use of the Basic System concept focused attention on the major bus lines where improvements will help the greatest number of riders. Those needs that remained unaccounted for after design of an optimum basic route structure were then met in the recommended system by adding a revised set of special-purpose routes.

All the revised systems subsequently tested were comprised of lines which met the Basic System criteria. The comparisons of service and costs with the existing system were made on this basis.

Chapter V

OPERATING COST MODEL

5.1 Need for Cost Model

It would be a simple matter to improve drastically the level of transit service provided to the riders if cost were no object. However, the goal of this project was to achieve service improvements while at the same time reducing, or at least holding the line on operating costs. For this reason and also because it was desired to evaluate the cost-estimating tools provided by the HUD programs, determination of operating costs was an essential element of this Mass Transportation Demonstration Project.

D. C. Transit can now estimate precisely costs for its operations by manually developing a complete schedule and assigning the manpower and vehicles to operate it. However, this is a lengthy and expensive process, and it is not suited to testing three alternative bus systems as has been done in this study. There is an obvious need for a quicker method of cost analysis which would still have an acceptable degree of accuracy.

Procedures were developed in this study which, in lieu of actually building the schedule, used reliable indicators of those operating costs which could be expected to change in the revised systems. The operating cost calibration involved the development and testing, on the Basic System, of a model which could be applied with confidence to estimate the costs of Alternative Systems proposed as improvements to the Basic System.

The operating cost-estimating procedures used dealt only with variable operating costs. These are the costs which depend directly on the amount of service provided such as drivers' wages, fuel, and vehicle maintenance. It was not expected that the overall size of the D. C. Transit operations would be affected in such a manner that changes in the size of the administrative staff would need to be made. However, the peak vehicle requirement was specifically estimated to allow evaluation of possible savings on that score.

5.2 Evaluation of HUD Program Cost Calculations

The computer program AVNET provides, for each line represented in the bus network simulation, a calculation of route-miles, route running time, required number of vehicles, vehicle-miles, vehicle-hours, layover time, percentage inefficiency of the schedule, and operating cost. The calculation can be obtained for up to four time periods, each representing a period of continuous frequency operation. In addition, systemwide totals are provided for each transit mode identified in the network and for each company. These computer calculations and summaries, in themselves, proved to be inadequate as a cost model for this project. The programmed cost formulas did not provide the required level of accuracy or consistency for the following reasons:

- No estimates of nonrevenue operations involved in deadheading equipment are provided.
- Operating efficiencies which can be gained from interlining (scheduling two or more lines as a single unit) are not considered.
- Two-way bus lines are treated as two one-way lines, automatically assuming a layover at each end of the line.
- No iteration is performed to reevaluate the stated frequency of inefficient lines.

Consider the following example: Two-way Line A has a running time of 20 minutes in each direction and operates at a sixty-minute frequency. In performing the operating cost calculations program AVNET would, however, break Line A up into two one-way lines and show that each of these lines had a 20-minute running time, a 40-minute layover, and an efficiency of 33 percent. In other words, the program would calculate that it would take two buses to operate this one two-way line. In actual practice, D. C. Transit would at a minimum schedule such a line with one bus, a 20-minute layover at one end and a round-trip time of 40 minutes. Or, for further efficiency, Line A might well be interlined with another route whose terminal was close to one end of Line A. In general, D. C. Transit uses a minimum layover time of 10 percent of the round-trip running time. This would be four minutes for Line A in the hypothetical example. The schedule-maker would strive to devise a means for cutting the layover as close to this four minutes as possible.

Although the cost calculations of AVNET could not be used directly, components of the calculations were very useful. In particular, the programmed computations of route-miles and running time for each line saved considerable effort over previously available estimating techniques. The computed values could be used directly in the independently developed cost model.

5.3 Cost Model Development

The basic cost model developed to meet the needs of the project provided estimates of total revenue and nonrevenue vehicle-hours and vehicle-miles. To obtain dollar cost estimates, the appropriate D. C. Transit average operating costs per vehicle-hour and vehicle-mile were applied. Only those cost elements which would be significantly affected by the modified systems tested were included.

A manual vehicle-hour and vehicle-mile estimation procedure was developed with five principal steps, as follows:

- Estimation of total revenue and nonrevenue vehicle-hours required to operate the service represented in the Basic System a. m. peak and midday base computer networks
- Adjustment of this estimate to reflect the actual a. m. peak and midday base vehicle-hours of a complete operating system
- Expansion of the a. m. peak and midday base vehicle-hour estimates to represent the total average weekday vehicle-hours with subtotals for each of five time periods
- Preliminary estimation of daily vehicle-miles through use of average speeds obtained from the networks
- Adjustment of the preliminary vehicle-mile estimate to provide a final forecast of systemwide average weekday vehicle-miles

The calibration of the model involved carrying out these five steps for the existing system and making comparisons with actual service records at appropriate points.

Knowing that the operating cost model could be used to reproduce present vehicle-miles and vehicle-hours with satisfactory accuracy and having developed the required adjustment factors, the same procedures could then be used with confidence to estimate the operating costs of the Alternative Systems as described at the end of this chapter. Further details on the calibration phase of the model and checks with D. C. Transit operating data are provided in Appendix C.

5.4 Unit Operating Costs

The unit operating costs shown in Table 3 were used in the model. These were based on D. C. Transit data for July, 1967. The unit cost per vehicle-hour was set equal to the average operator cost per platform hour. The unit cost per vehicle-mile was constructed of several mileage related components as outlined in the latter part of Table 3.

The unit cost figures applied were thus $4.27 per vehicle-hour and 18.33 cents per vehicle-mile. Since the comparisons of alternative systems made using the cost model are all relative, changes in costs since July 1967 are not of particular concern in the analysis.

5.5 Alternative System Cost Estimation

The operating cost estimates for the Alternative Systems were handled in a manner similar to the technique used in the model calibration.

Route structure was again a function of the system. Except in those cases where headway was arbitrarily set, line frequencies were determined by using present loading standards and applying them to passenger volume estimates derived from the Alternative System simulations. Revenue mileage and running times were obtained from AVNET results.

The five steps of the cost model were applied but they consisted only of applying the adjustments or expansion factors already derived.

After multiplying the Alternative System vehicle-hour and vehicle-mile estimates for a typical twenty-four hour weekday by the appropriate unit operating costs, the twenty-four hour variable cost estimates were completed. These could then be compared directly with the value derived for the present operation. The results of these comparisons are discussed in subsequent chapters and are also given in Table C-1.

TABLE 3: CHARACTERISTICS OF EXISTING D.C. TRANSIT OPERATIONS

A.M. Peak Vehicles on Road	1,022
P.M. Peak Vehicles on Road	1,027
Base Period Vehicles	362
Number of Scheduled Platform Hours	10,006
Number of Miles Operated	101,425
Miles per Vehicle-Hour	10.13
Fleet Size	1,192
Number of Runs (including trippers)	1,491
Average Operator Cost per Scheduled Platform Hour	$4.27
Operating Expense Directly Related to Bus-Miles Driver (Cents):	
Bus Body Maintenance	2.18
Bus Chassis Maintenance	6.66
Tires and Tubes	1.34
Fuel for Revenue Vehicles	3.12
Lubricants for Revenue Vehicles	.25
Garage Supplies and Expenses	.45
Injuries and Damages	3.93
Insurance	.19
Bus License Taxes	.23
Total	18.33

Note: Data represent a typical weekday in July, 1967.

DEVELOPMENT AND TESTING OF ALTERNATIVE SYSTEMS

The HUD transit planning programs do not provide the capability to produce by themselves a revised bus route structure. The actual route design must be accomplished outside the programs by the transit analyst. The various program outputs do, however, provide much useful information.

As each alternative to the present D. C. Transit operation was designed, its computer representation was prepared using the same criteria and techniques as described previously for the Basic System. One of the most important purposes of the networks was to provide valid comparisons of service levels among the Alternative Systems and the existing system. For this reason, throughout the Alternative System tests, constant attention was given to the need for uniformity of the assumptions and techniques used in the simulations. The basic purpose of the simulations was to provide valid comparisons, and the major technical effort was directed to this end.

To gain full advantage of the systems techniques used, alternative bus systems were developed in succession, each alternative building upon what was learned in the preceding trial. Alternative 1, being the first trial, made use of what had been learned from the investigation of current origin and destination desires as compared to the existing transit service. Alternative 1 incorporated an application of certain principles of bus routing and, to some extent, intuitive reasoning. In the design of Alternative 2, it was possible to apply, in addition, what had been learned in Alternative 1. Further, since Alternatives 1 and 2 were really design tools and not even tentative recommendations, several idealistic bus routing structures were tested.

This chapter deals with the development of the two initial alternatives and gives the results of some of the comparisons that were made. The principles outlined in this chapter, of course, carried over into the design of the Optimum System discussed in Chapter VII.

6.1 Route Classification

The major principles used in alternative system route design, outside the general objective to best serve travel desires, can be grouped either in the category of route classification or in the category of operating criteria.

The route classification system will be described first.

The definition prepared for each classification of route was a working definition, containing a description of just what each type of route is meant to do and how it should ideally be designed to accomplish this purpose. Three basic classifications were covered: radial, crosstown, and feeder.

6.1.1 Radial Routes

The basic purpose of the radial route is to allow direct, no-transfer travel from various parts of the area to the central business district. To be completely effective, radial routes should penetrate the downtown area in such a manner that most of the major points of attraction are well served. This is, of course, much easier to do in small, compact central business districts than it is in downtown Washington, which is spread out and has a number of major attractors.

By the very nature of city structure, the further the distance from the central area, the more a radial route's territory is enlarged. For this reason, it is common practice to create branches from radial lines at various points to better cover the entire area. These branches perform a viable function up to a certain limit. This limit is defined by the minimum desirable frequency at which the branch service should be performed.

As the number of branches increases, the frequency of service must, of course, decrease. As an example, if a line leaves the central area at a frequency of twelve buses per hour and then splits into two equal branches, both will have a frequency of only six buses per hour. If each of these two branches splits into two more, then the new branches can average only three buses per hour. In a branching type system, therefore, the inner areas are served more frequently than those further removed from the downtown. Up to the point where the frequency falls below the desirable minimum, the decrease does not present a problem, since the inner areas of most major cities in this country are areas of high residential density and lower incomes. Thus those areas which will naturally produce the most transit riding are provided with the higher service levels.

6.1.2 Crosstown Services

A crosstown line is a transit route operating at right angles to major radial routes. It generally does not have a service area of its own, but performs the function of connecting radial corridors and also major outlying generators and attractors. In fulfilling these functions, it eliminates the need for some transit passengers to travel through the downtown area in order to travel from one peripheral point to another.

Crosstown lines, by their very nature, require transferring; thus, to be effective, they must operate at high frequencies. The transfer passenger, in contrast to one who is boarding the initial bus of a trip, has no control over his arrival time at the bus stop. If a person arriving on one bus at a transfer point misses his next bus by five minutes and if the line to which he is transferring has a thirty-minute headway, he must wait an additional twenty-five minutes. If, however, that line had a ten-minute headway, he would only have to wait an additional five minutes. It follows that any line serving a purely crosstown function must have good service frequencies.

6.1.3 Feeder Lines

A feeder line, just as the name implies, feeds passengers to higher volume radial lines and, in some instances, crosstown lines. After transferring, the passengers continue to their destinations. In an ideal system, from the passenger point of view, there would be no feeder lines, since it would be more convenient for the passenger to make his entire trip on one bus, if at all possible. However, the exigencies of schedule preparation and the limitation in the number of branches a major trunk line can support make the provision of feeder lines necessary in some cases.

A feeder line differs from a crosstown line in that it has its own area of service, and its basic purpose is to take passengers from that area of service to connections with high-frequency radial and crosstown services. Feeder lines are generally of low frequency since if they were capable of supporting a higher frequency they would be portions of trunk lines. For this study, feeder lines have been divided into three types: central business district distributors, District of Columbia residential collectors, and Maryland suburban shuttles. The central business district distributors operate through downtown by connecting the various radial lines with points of attraction they do not directly serve. The District of Columbia residential collectors are the classical type of feeder as first described.

The Maryland suburban shuttles are in a slightly different classification. They not only provide connection to major radial lines, but also provide a subcenter distribution system serving local activity centers such as Wheaton and Silver Spring. Because of this added function, they are somewhat more useful than the typical feeder which merely serves as a connector.

6.2 Operating Criteria

Buses operating on any of the three types of routes previously described should meet other standards described below.

6.2.1 Simplicity

Individual bus routes should be kept as simple as possible and easy to understand by a person traveling for the first time. In addition, the entire route structure should be simple so as to minimize confusion and make it possible for a person to easily choose the best route to his destination. The principles of the radial and crosstown arrangement lend themselves well to a simple system configuration. Another element that helps to enhance the simplicity of the system is to have basic routes that operate the same way throughout the rush hours and the base period, performing a fairly regular service throughout the operational day. These can always be augmented in the peak hours by additional buses which may vary to some degree in routing and type of service provided.

6.2.2 Avoidance of Loops

The use of large one-way loops at terminal points of transit lines is generally not good practice. Large loops have the effect of causing people to wait through layovers, sometimes fairly time-consuming, before reaching their final destination. They also preclude the extension of lines at some future time into areas of new development.

The major reason for the existence of large loops on many lines is one of superficial economy. It is easy and cheap to loop a line around to serve a large residential area near the terminus of the line instead of providing two lines for the same area. As the economic fortunes of many bus companies have declined, loops have often been created from the tail ends of two previous lines to reduce the total number of miles spent in providing service. It has been easier to do it this way than to go through a more extensive rerouting which might accomplish the same purpose without the necessity of the loop. This study has attempted to reroute service in such a way as to preclude the need for any large one-way loops.

6.2.3 Maintenance of Existing Cost Structure

As pointed out in Chapter I, one objective of this entire project has been to accomplish service improvements while decreasing or holding the line on operating costs. Thus one of the operating criteria has been to stay within the limitations of existing facilities and expenditures.

6.2.4 Avoidance of Long, Complex Routes

Very long bus routes, particularly if they have several branches, are hard to operate at a satisfactory level of schedule adherence. From the operating point of view, it was deemed desirable to keep routes as short as possible and to limit the number of branches on longer routes. This criteria is, of course, in conflict with the aim of providing the maximum number of through rides for passengers, and in many instances, compromise was necessary.

Many D. C. Transit lines are, because of the area served, quite long, extending to points as far away, for example, as Rockville, Maryland. If such a line as the Rockville Route were extended through downtown for some distance, there would be many opportunities when buses could become late, thus causing irregular service. In the many cases where routing through downtown has been proposed, the longest lines have been avoided. In addition, attempts were made to link long lines on one side of town with short lines on the other side to keep the overall length of all routes at a reasonable level.

6.3 Analysis of Specific Areas

The overall objectives and criteria for alternative bus system design discussed earlier in this chapter can fit together perfectly only in an ideal situation. Some of the objectives are inherently in conflict and require compromise. Many of them must be modified in real system design where lack of homogeneity in the area, variations in land use, demographic characteristics, topography, and the available street system preclude the development of an ideal system.

The following discussion, then, provides examples from the alternative system designs of how the objectives and criteria were handled in different parts of the D. C. Transit service territory. Other influences on system design peculiar to the areas covered are also discussed.

6.3.1 Area East of the Anacostia River

The area east of the Anacostia River received special attention due to its geographic position and socio-economic characteristics. It is separated from the rest of the District of Columbia by the Anacostia River which is crossed by only a limited number of bridges. The northern part of the area has a higher-than-average percentage of nondowntown-oriented trips. Many long transit rides across town to Northwest Washington and beyond are involved. Since the area contains many of the lower income residents of the District of Columbia, there is a great reliance on public transport. To improve service for the residents, extensive network changes were tested for both peak and base service.

At present, the area is linked to the rest of the District of Columbia in terms of all-day service by three radial trunk lines and two crosstown lines. The radial lines are of relatively high frequency near the Anacostia River. Service near the Maryland line is less frequent, because of the great number of branches presently operated. In addition to the basic routes, there are several high frequency, peak-period, limited service lines to specific areas of downtown.

In the alternative system tests, the three existing radial trunk lines were extended through downtown by linking them with existing lines to Northwest Washington. Different combinations were tried in each alternative. The through routing served three primary purposes. First, a number of destinations in Northwest Washington could be directly served from east of the Anacostia River. Second, direct service to points on the far side of downtown was provided without duplication of routes in the downtown area. Third, transfer to other radial routes was facilitated since in crossing downtown almost all principal radials were intercepted, and many cases where double transfers had been required before were eliminated.

In addition to the three existing radial trunks, two new ones were added via the East Capitol Street and South Capitol Street Bridges. The buses required for these new routes were taken from the three existing trunks which were each of such high frequency that the loss did not seriously impair their service characteristics. Again, three objectives were accomplished. Direct routings to downtown were provided. Costs were reduced without loss of frequency by consolidating the new routes with existing lines which presently terminate short of the Anacostia River. Finally, because consolidation with the shorter lines allowed some overall increase in buses crossing the Anacostia River, the tails of the five resultant trunk lines could be adjusted and several short feeder lines could be converted to through service.

The area east of the Anacostia River provides an existing example of a crosstown route which performs mixed functions. Attempts were made to rationalize this service in the alternatives. Crosstown routes 92 and 94 provide a radial type of collector service east of the Anacostia River. This is to the disadvantage of the majority of originating riders in the a.m. peak period who would be better served by a true downtown radial than by a crosstown route.

The tests showed, however, that it was not a good solution to shorten the crosstown route and to make the tail part of a downtown radial. Too many riders — a bit over half in the off-peak period — were actually seeking the crosstown service. A compromise solution was developed which left the eastern portion of lines 92 and 94 relatively unaltered in the off-peak period. However, in the a.m. peak period, their frequency south of the Anacostia River was reduced. The vehicles thus released were used to provide direct express service via the southwest freeway into downtown and into the Southwest Mall employment area.

The Benning portion of the area east of the Anacostia River received special attention as the origin of a peak period "super" crosstown service. This will be discussed later under crosstown services.

6.3.2 Rhode Island Corridor

In direct contrast to the area east of the Anacostia River, the Rhode Island corridor provides an example of an area where most of the existing services appear to be best left as they presently operate. In initially studying the four major trunk lines in this corridor (E2, F2, 80, and 82), it appeared that operational improvements could be made. These major routes make a seemingly inordinate number of turns and cross each other at frequent intervals.

The alternative systems tested two different patterns which involved straightening these lines and reducing the number of turns and crossings. However, the final results showed that service levels would be lowered by such revisions, and most of the service in this corridor was left as is in developing the Optimum system. One can hypothesize that the advantages of straightening out the lines were more than outweighed by the loss of direct service to travel which over the years had oriented itself to the existing routes. It is pertinent here that the Rhode Island corridor, with relatively slow turnover in population, has been one of the more stable areas of the city. Crosstown service changes made in the vicinity of the Rhode Island corridor proved more successful.

6.3.3 Crosstown Services

Crosstown services received constant attention in the Alternative System tests, with particular attention to finding ways of better serving the daily flow of traffic from the east side of the District of Columbia to Northwest

Washington and Montgomery County. Some quite innovative routes were tried as well as more traditional revamping of crosstown services in accordance with the principles outlined earlier.

The one particularly successful innovative crosstown route tested in the simulations connected the Benning corridor with Northwest Washington and Bethesda. This limited-stop "super" crosstown service is designated on the map in Figure 23 (page 82) as X3. From east of the Anacostia River in the Benning corridor, all existing routes presently terminate in some part of downtown. Yet approximately half of the people from this corridor are traveling to Northwest Washington and to points as far away as Bethesda and Potomac in Maryland. To better serve these long trips, existing line X3 was totally revised to provide a frequent, one-way, limited stop, express service from Benning to Northwest Washington and Bethesda in the a. m. period and to Benning from this area in the p. m. peak period. The main purpose of new line X3 was to collect people east of the Anacostia River and deliver them to transfer points at the major radial lines running north and northwest from downtown. The line which avoids downtown also services a significant number of destinations directly. The results of simulating this line indicated a peak load of close to 2,500 people in the a. m. peak period, justifying a six-minute headway through the maximum load point. As well as serving riders from the Benning area, this line would also provide convenient connections to Northwest Washington for about 800 other riders from the lower 14th Street corridor.

In revising X3, an important consideration from an operations standpoint was the interlining of buses once they reach their Northwest terminals. In studying the time variations of travel, it was observed that the peak load occurs about one-half hour earlier on inbound lines from the Benning area than on the inbound Northwest Washington buses. Thus it would be possible to interline a part of the X3 service with inbound trips from the Bethesda area, thus avoiding the operating inefficiency which might otherwise be expected from such a long one-way line.

No other such highly specialized crosstown services were developed, but the existing crosstown routes were reworked — some extensively, to better meet crosstown service standards. Existing line B2 provides the most notable example. This line presently runs in a radial direction in its northerly portions along Bladensburg Road. Then from Florida Avenue, it follows a zigzag pattern south to Anacostia, connecting with the terminals of several radial lines, providing feeder service to those lines, and also giving local access to specific attractors, such as D. C. General Hospital.

In revamping this line, it was observed from the Basic System simulation that the majority of southbound passengers on Bladensburg Road transfer to downtown routes, and it was found possible to make this portion of the route into a downtown radial service. It was found that the zigzag pattern between Florida Avenue and Anacostia could be eliminated by extending existing lines 40 and 42 a few blocks east with a branch serving D. C. General Hospital.

In the first alternative, the straightened portion of line B2 was consolidated end to end with crosstown route T8, forming a longer route to accommodate crosstown trip design from Anacostia to Friendship Heights.

The results obtained from Alternative 1 revealed that service levels were improved. In fact, the revised crosstown route, designated T8, developed sufficient patronage to justify a higher frequency.

A slightly different pattern was tested in Alternative 2. However, results did not yield as satisfactory a service level as that of the first arrangement tested, which was then made a part of the Optimum System.

Other crosstown route revisions included a modification to the west end of this same route T8 where, at present, lines T8 and T6 deviate from their circumferential pattern and swing north through Bethesda to provide radial service. In this case, it proved more desirable to have the crosstown routes continue in a circumferential pattern, intersecting the radial bus routes destined to the Potomac corridor. The present Bethesda services were linked with true radial routes.

One scheduling problem of interest was found with existing crosstown routes 92 and 94. In the midday base period, bus trips that start at either end are turned back before reaching the other end. Thus, although there is some overlap, it requires a transfer to go from one end of the route to the other end. A significant number of riders desire to do so. Beneficial results were obtained in the alternative system tests by designing this service to run straight through. This line was also extended to the west to meet additional major radial routes not now intersected.

It should be noted that in the simulations each of the crosstown improvements attracted riders away from the downtown area. This allowed the number of buses crossing through downtown to be reduced and contributed to the favorable operating cost results of the Alternative System tests.

6.3.4 Downtown Access and Distribution

The more outstanding benefits to transit riders destined to the downtown area were achieved in the Alternative System tests by the through routing of radial services already discussed. This provided both more possibilities for no-transfer rides and better distribution for those who still had to transfer. A new closed-loop distributor line (route 90) proved to add further to the quality of the distribution system and was shown to be heavily used in the simulation.

All areas of downtown gained from the through routing and related all-day route improvements, but the West Potomac Park and Southwest Employment Area were least benefited because of their positions off to one side. In the cast of West Potomac Park, branching of certain all-day lines into the area was tested without particularly favorable results. This was a case in point where the frequencies provided by the branches were not sufficient to provide a tangible service improvement. The best results were obtained from modification of the special service lines already penetrating the area to give them somewhat greater coverage.

The Southwest Employment Area was of special concern as it is presently the most rapidly developing employment area in the District of Columbia. It lies south of Independence Avenue, between 2nd and 14th Streets, S. W. Since the 1966 Bus Rider Survey was taken, the employment in this area is estimated to have doubled. It is felt, however, that updated trip data would not significantly change the results of this analysis.

Despite the large number of trips into the area, many cannot efficiently and directly be served by basic trunk lines because the origins are widely dispersed. At present, D. C. Transit is satisfying the increasing demand in the Southwest Employment Area by extending many of its peak-period limited service bus trips into the area. One new express line (designated W3) proved beneficial, as did routing a number of local lines across South Capitol Street Bridge through the area. It would appear, however, that the rest of the trips to the Southwest would best be served by existing lines and the recent extensions of special service into the area.

6.3.5 Maryland Services

Analysis of D. C. Transit service to Maryland concentrated on the radial routes lying in those specific areas where ridership is well established at present. These routes provide an example of how changing conditions may negate the original reasons for a particular route structure.

As highlighted by the origin-destination survey analysis, the vast majority of riders on the Maryland services are in fact destined to the District of Columbia. This is despite the fact that a large portion of the Maryland service, particularly in the off-peak period, consists of shuttle operations which take riders to terminals at the D. C. -Maryland boundary line.

The development of the District Line transfer terminals has been more a political and historical phenomenon than anything else. Until recently, there had been several conditions which encouraged the retention of these terminals. Many of the Maryland routes were once operated by independent companies. Until the formation of the Washington Metropolitan Area Transit Commission, there were different regulatory bodies for transit service in Maryland and the District of Columbia. Licensing regulations until recently occasioned duplicating payment of fees for buses in interstate service. Lastly, many of the present bus terminals are the former terminals of fixed-route street car lines.

These conditions having changed, the Alternative System tests gave extensive attention to the improvement potentials of through service. The most efficient patterns were determined for each terminal and then used in the Optimum System tests.

In Alternative 1, through service was first examined by extending the Wisconsin Avenue and Connecticut Avenue services across the District line. The test verified that most of the Maryland riders were destined to downtown Washington. The service improvements were particularly of note in the off-peak period when the number of transfers by Maryland passengers dropped drastically. An all-day express modification of the Wisconsin Avenue service with limited stops within the District of Columbia was adopted for the Optimum System.

In Alternative 2, similar improvements were tested on Georgia Avenue at the Silver Spring terminal. In addition to decreasing the number of transfers required in the Silver Spring area, better distribution into the Silver Spring business district was provided. Although there was not enough volume attracted in the simulation to justify the through routing to downtown of all the Silver Spring community lines, the through routing of the higher volume lines was retained for the Optimum System tests.

6.4 Summary

The preceding examples have covered only some of the areas studied and route improvements devised in the Alternative Systems test. They serve to illustrate, however, not only how service improvements can be designed but also the utility in evaluating potential service revisions of the simulations provided by the HUD programs. Using these computer programs in an intensive analysis such as this provides a facility for evaluating transit properties which has not previously existed.

The most encouraging statistics in the alternative system tests were the reductions in travel times and transfers for specific trips. The overall system comparisons showed only modest improvements, for the significant benefits were averaged in with other changes which proved less successful.

The operating cost calculations indicated that Alternative 1 would involve a small increase in operating cost. However, Alternative 2 showed significant reductions in operating cost and vehicle requirements. Both systems showed higher average speeds than at present because of the decreased number of buses operating through the central business district. Some operating cost statistics are presented in Table C-1.

The test results presented in this chapter for the alternative systems do not represent the final benefits to be gained by route revisions. They serve in the analysis only to guide the design of a final recommended system. The testing of the two alternative systems proved quite worthwhile in providing a better understanding of the existing routes and the potentials for specific improvements.

Chapter VII

OPTIMUM SYSTEM

The Optimum System is the name that has been given the final alternative routing system that was tested. Though not necessarily optimum in the strictest sense of the word, the Optimum System was in fact designed to contain the best of the existing system and the previously tested Alternatives 1 and 2.

As indicated in the examples provided in the preceding chapter, certain route structures were found to provide better levels of service than others in the different portions of the study area. Using the network evaluations of the Basic and Alternative Systems, the best route structures were selected for the Optimum System. The various parts then had to be worked together into a full system, resulting in some limited number of arrangements that were peculiar to the Optimum System itself. One important policy followed in designing the Optimum System that had not previously been of concern was to choose, when other considerations were equal, those configurations requiring the least change from the present established route structure.

The same methodology as has been described for the other systems was used in the network coding and computer analysis of the Optimum System. The network simulation used the same criteria as the Basic System. Thus the Basic System representation of the present D. C. Transit operation and the Optimum System can be directly compared to obtain evaluations of cost and service changes.

7.1 Systemwide Comparison of Systems

As with Alternatives 1 and 2, the principal comparisons made between the Optimum System and the Basic System were of total door-to-door travel times, numbers of transfers, and operating costs. The comparisons were made in greater detail and variety, however, to fully describe and document the Optimum System characteristics.

The Optimum System proved superior to the present operation on all three counts: travel time, transfers required, and costs. The comparisons developed are set forth in Figures 9 through 16 and in Tables 4 through 8. These illustrations and tables, largely self-explanatory, should be reviewed in detail to gain a full understanding of the improvements in transit travel that the Optimum System revisions would produce.

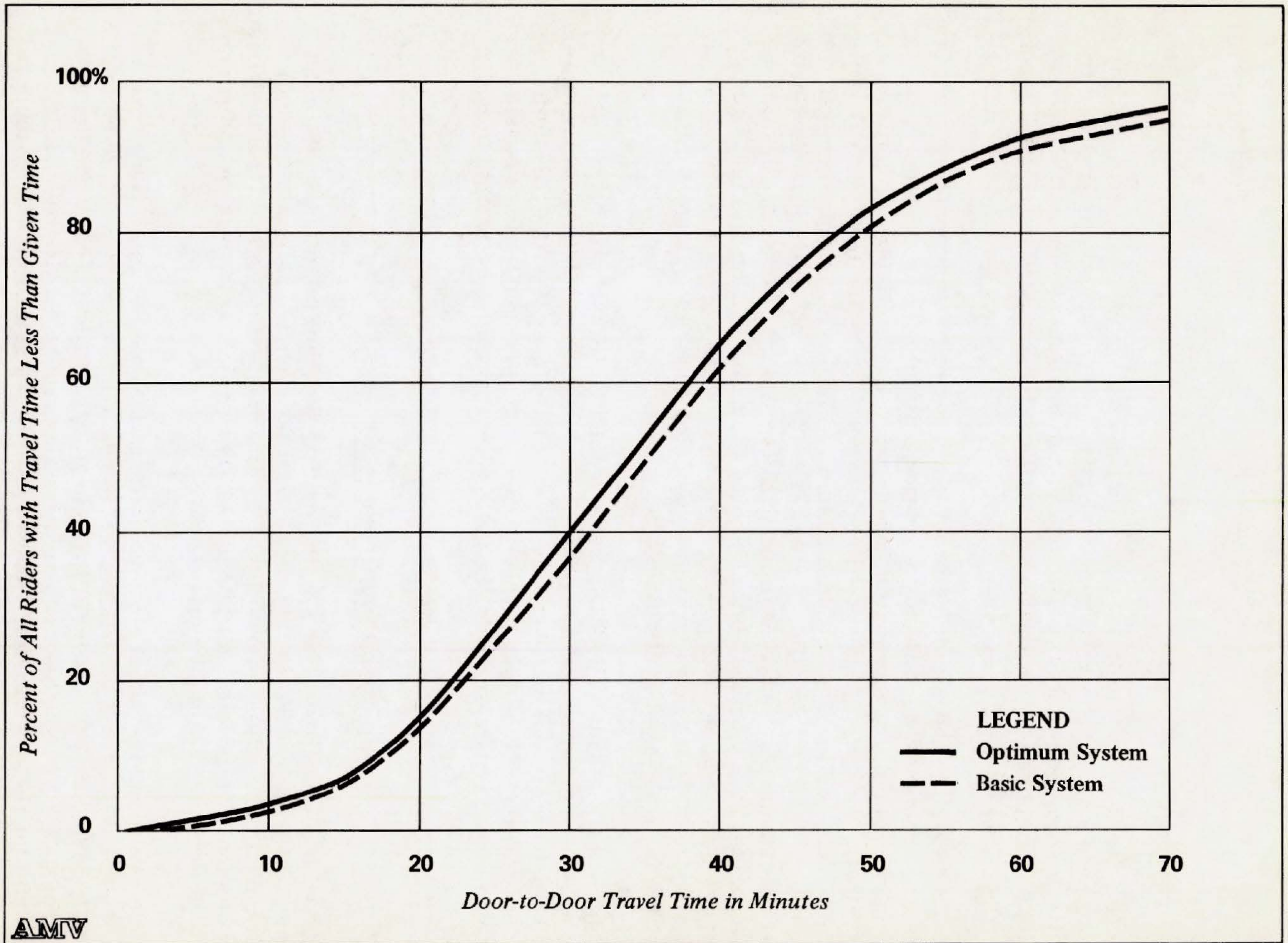

Figure 9 A.M. Peak Period Travel Time Cumulative Frequency Distributions

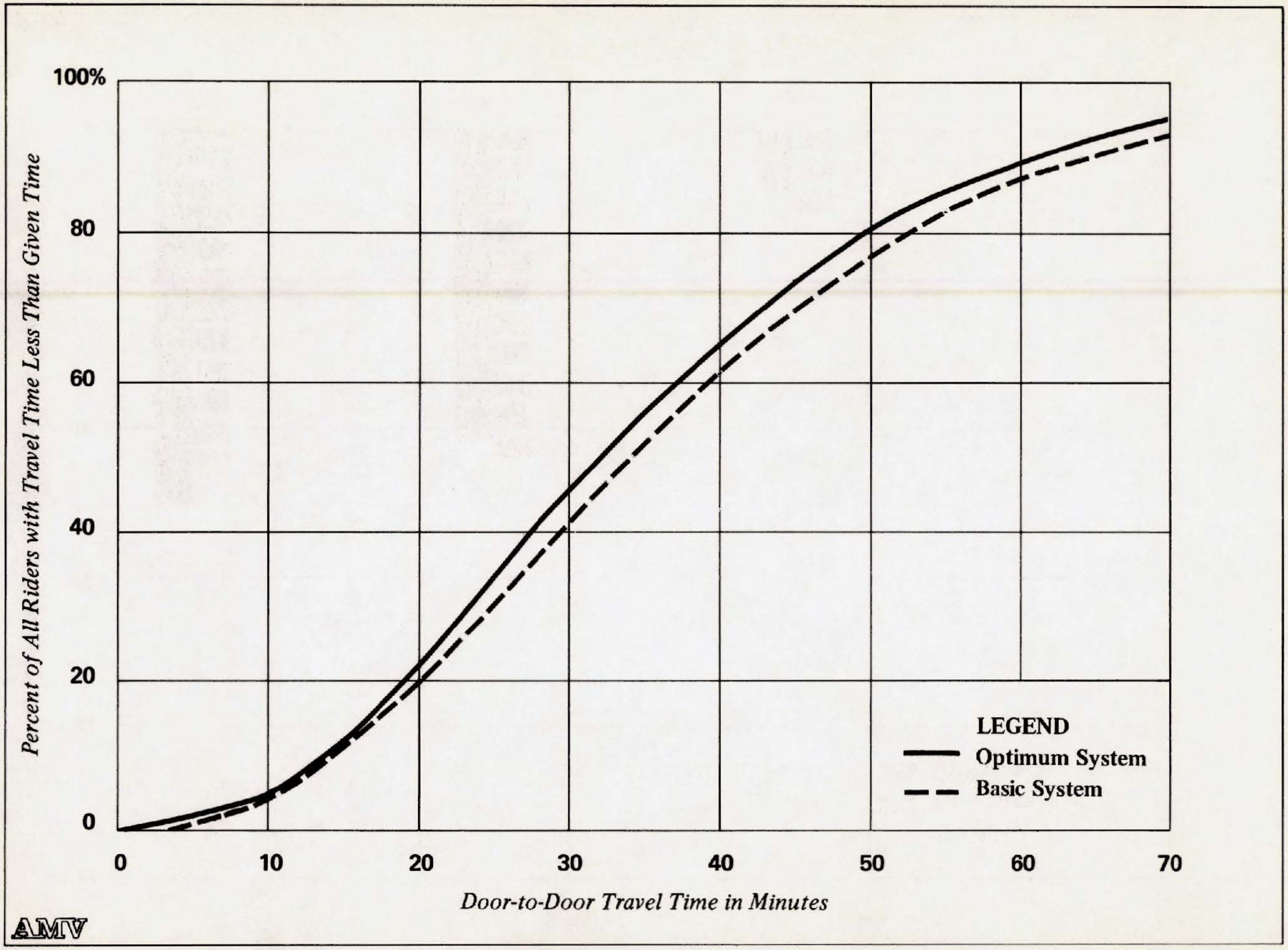

Figure 10 Mid-Day Base Period Travel Time Cumulative Frequency Distributions

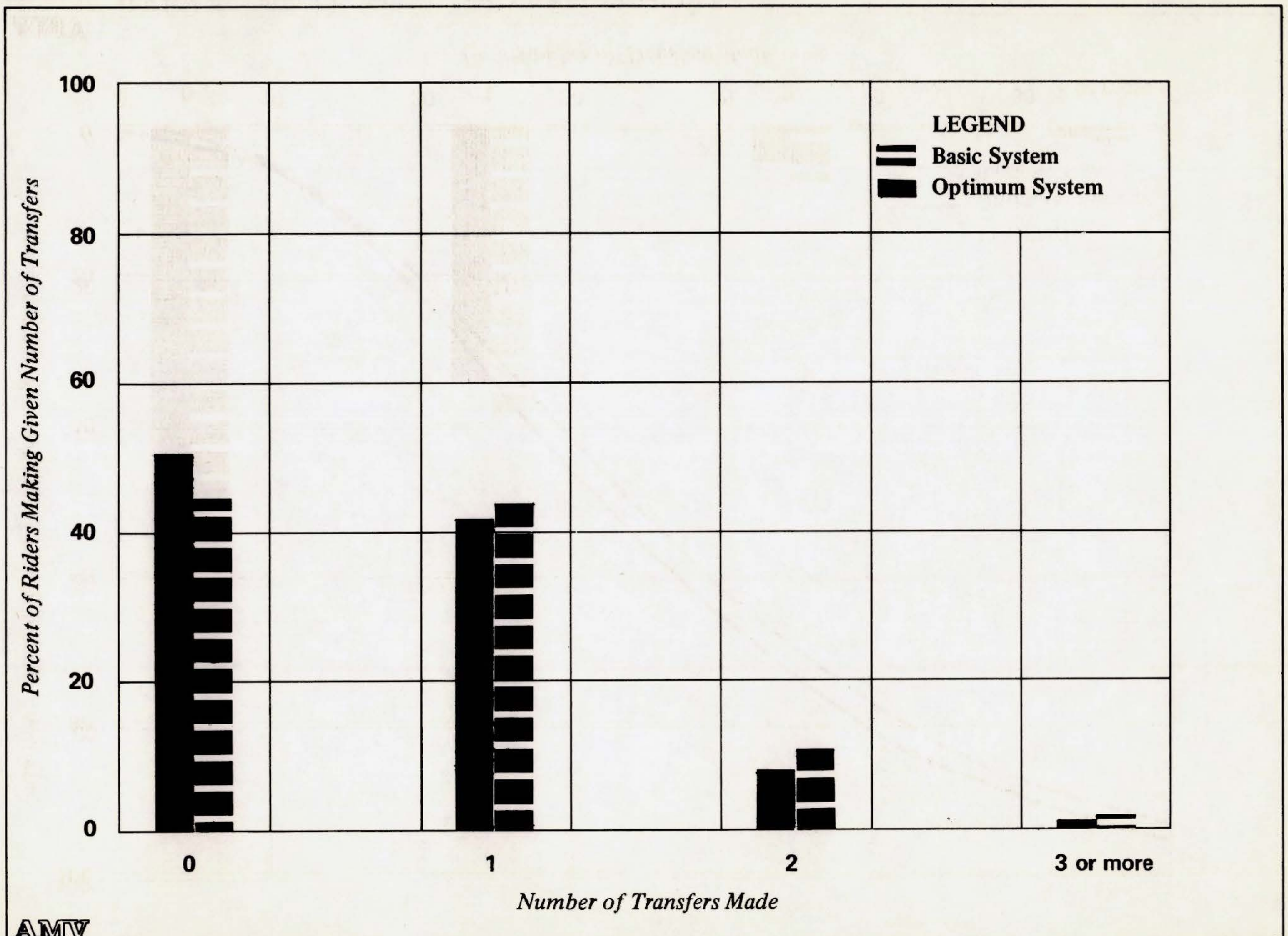

Figure 11 A.M. Peak Period Comparison of Transfer Distributions

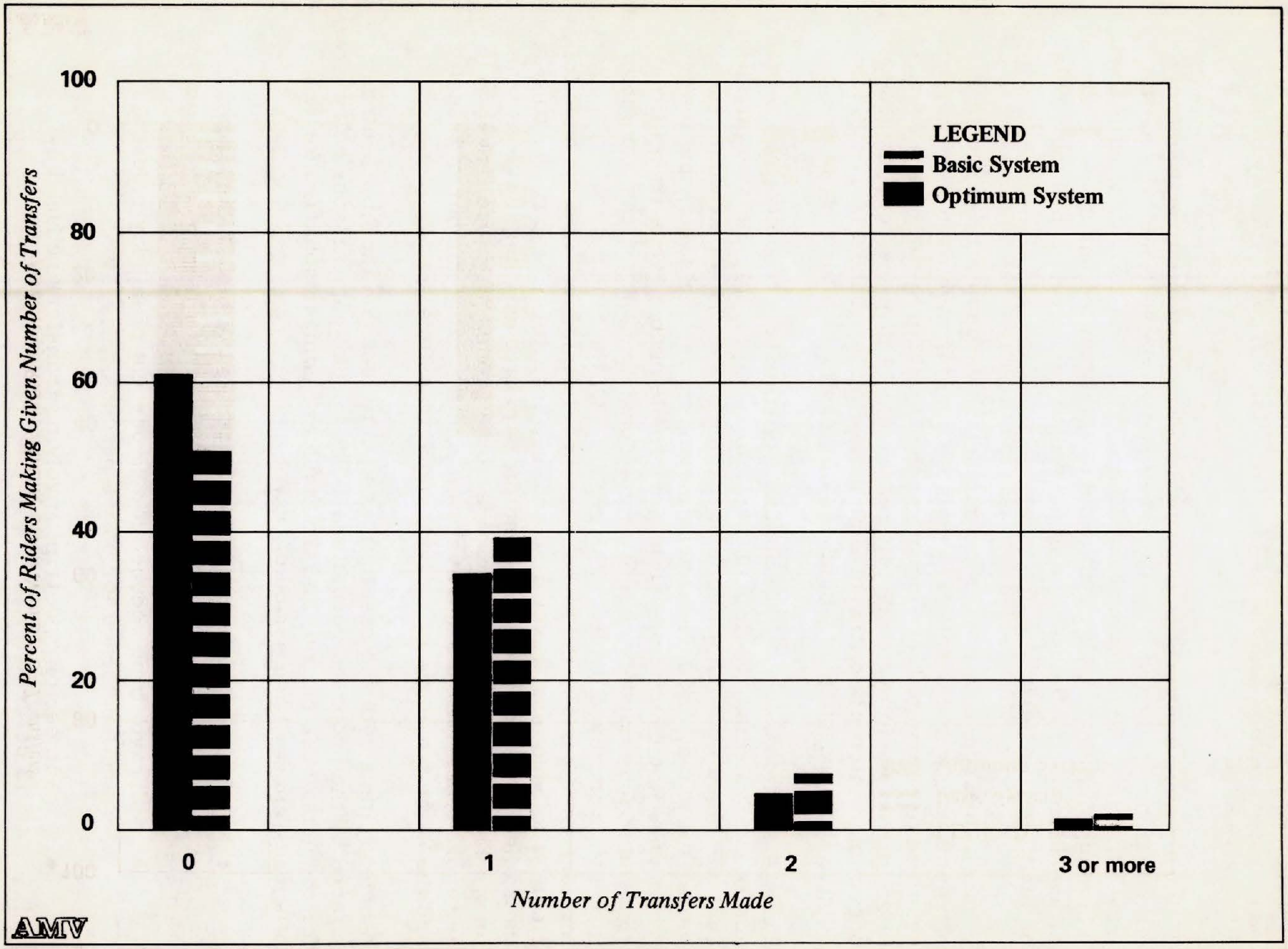

Figure 12 Mid-Day Base Period Comparison of Transfer Distributions

The figures are presented in pairs, the first of each pair covering a. m. peak system results and the second covering off-peak, midday base system results.

Figures 9 and 10 present passenger travel time cumulative frequency distributions, comparing the Optimum and Basic Systems. Like all travel time comparisons presented here, full door-to-door time is used, including even the average walk time to and from the bus stop. Figures 11 and 12 compare the number of passengers involved in making single or multiple transfers.

Figures 13 through 16 go further into detail and depict the percentage of riders who would specifically gain or lose in travel time or transfers required to complete their journey if the Optimum System were substituted for the Basic System. Figures 13 and 14 give the percentages by one-minute intervals of travel time gained or lost, and Figures 15 and 16 give the percentages by numbers of transfers avoided or imposed.

Table 4 summarizes the total numbers of transfers made on the Optimum and Basic Systems. Table 5 presents what is possibly the most significant summary — a comparison of the number of trips that would require more, the same, and less travel time and more, the same, and fewer transfers if the Optimum System were implemented. Only travel time changes of four minutes or more were considered significant for inclusion in the time increase or decrease groups. Of the nine categories presented for each time period, the three most clearly improved are the ones for riders who have less travel time and less transfers, less travel time and the same number of transfers, and the same travel time, but less transfers. The disadvantaged riders are in the groups for more travel time and more transfers, more travel time and the same number of transfers, and the same travel time, but with more transfers.

A brief summary of the results may help to focus on the improvements offered by the proposed reroutings. The "peak" comparisons below are for the a. m. peak period, and the "midday" comparisons are for the off-peak, midday base period of travel:

- Travel time reduced for 26 percent of peak riders and lengthened for only 9. 5 percent

- Travel time reduced for 25 percent of midday riders and lengthened for only 8 percent

- Number of peak trips involving transfers reduced by 12 percent

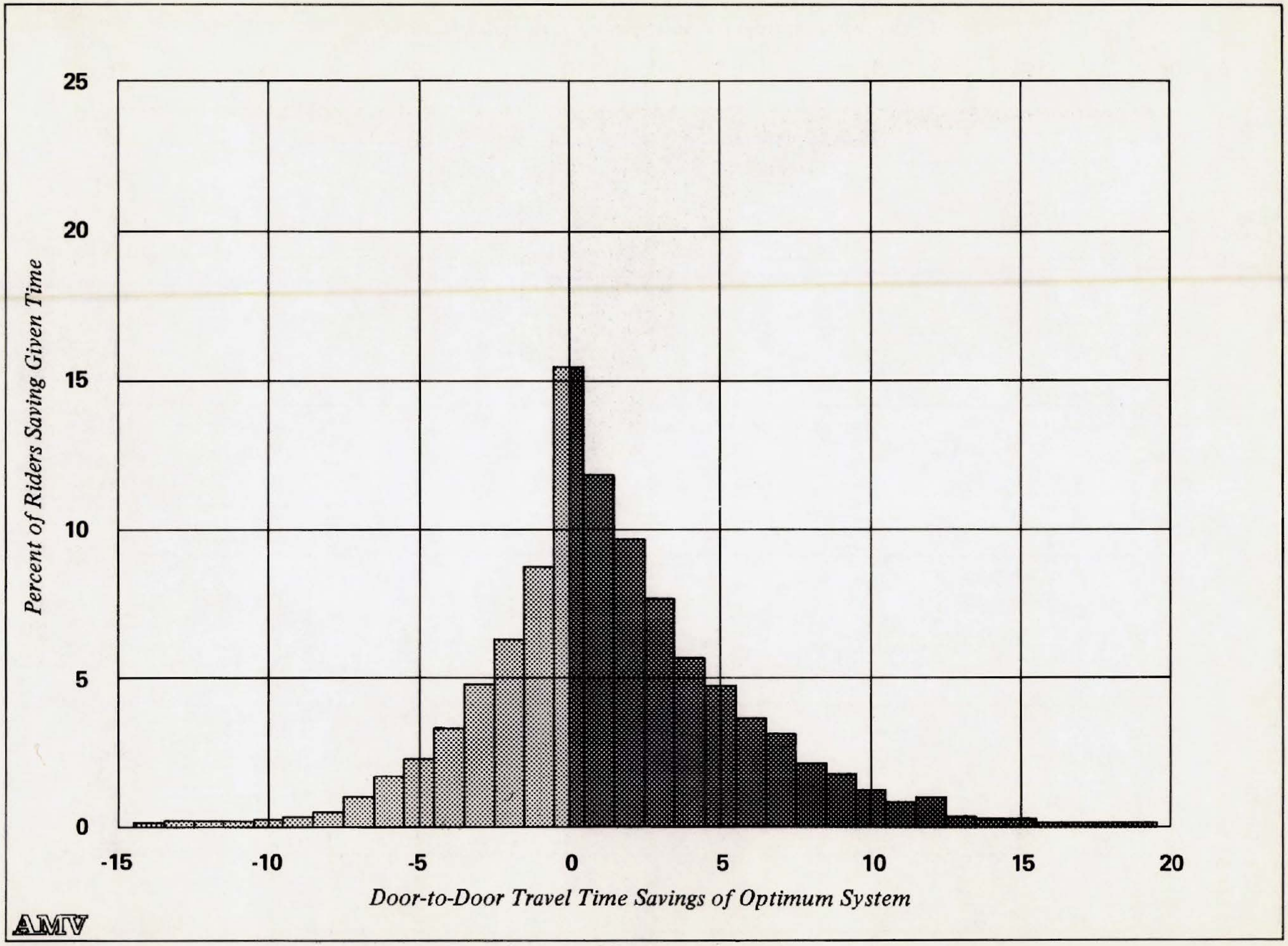

Figure 13 Frequency Distribution of Travel Time Savings of Optimum System, A.M. Peak Period

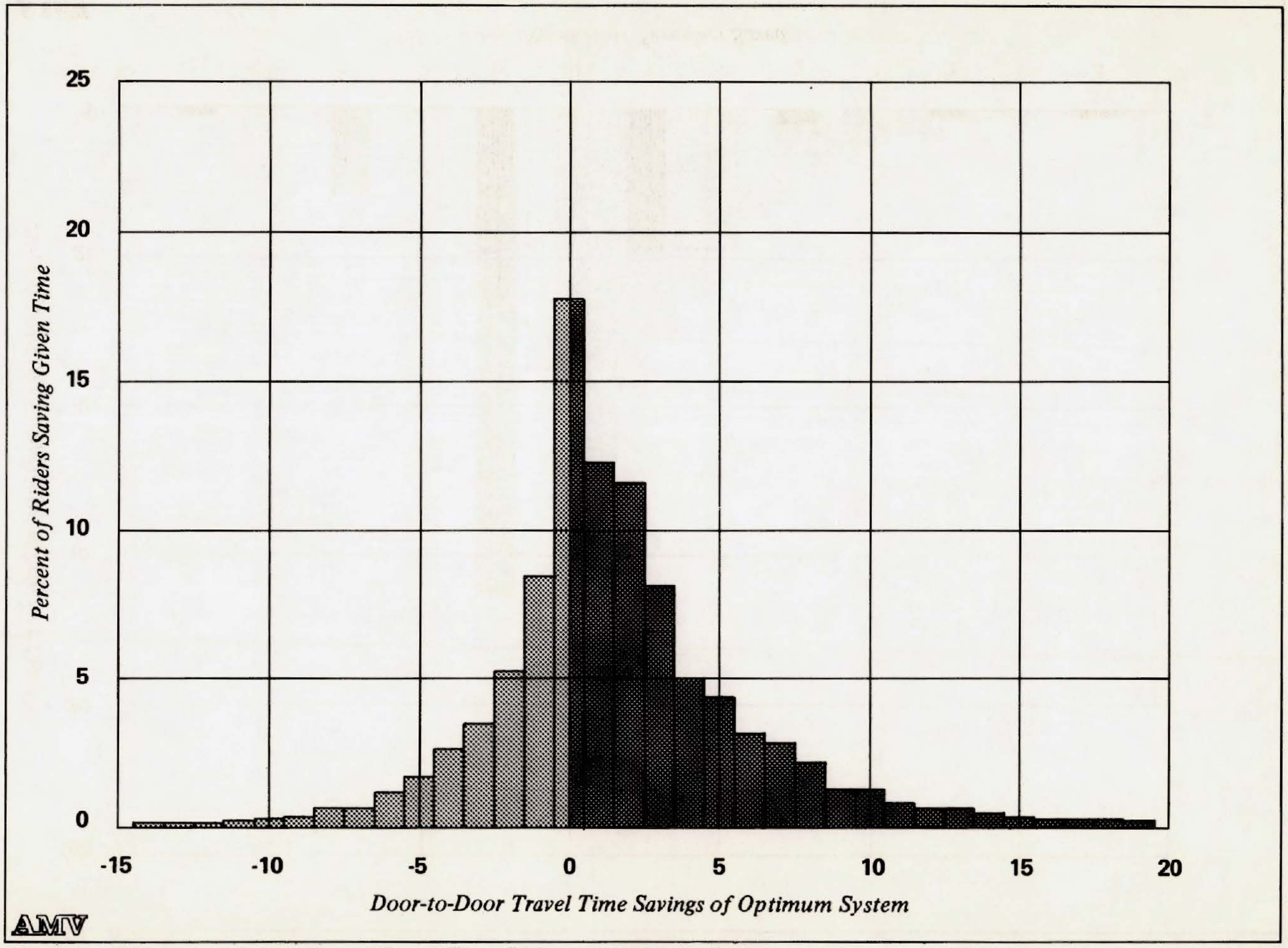

Figure 14 Frequency Distribution of Travel Time Savings of Optimum System, Mid-Day Base Period

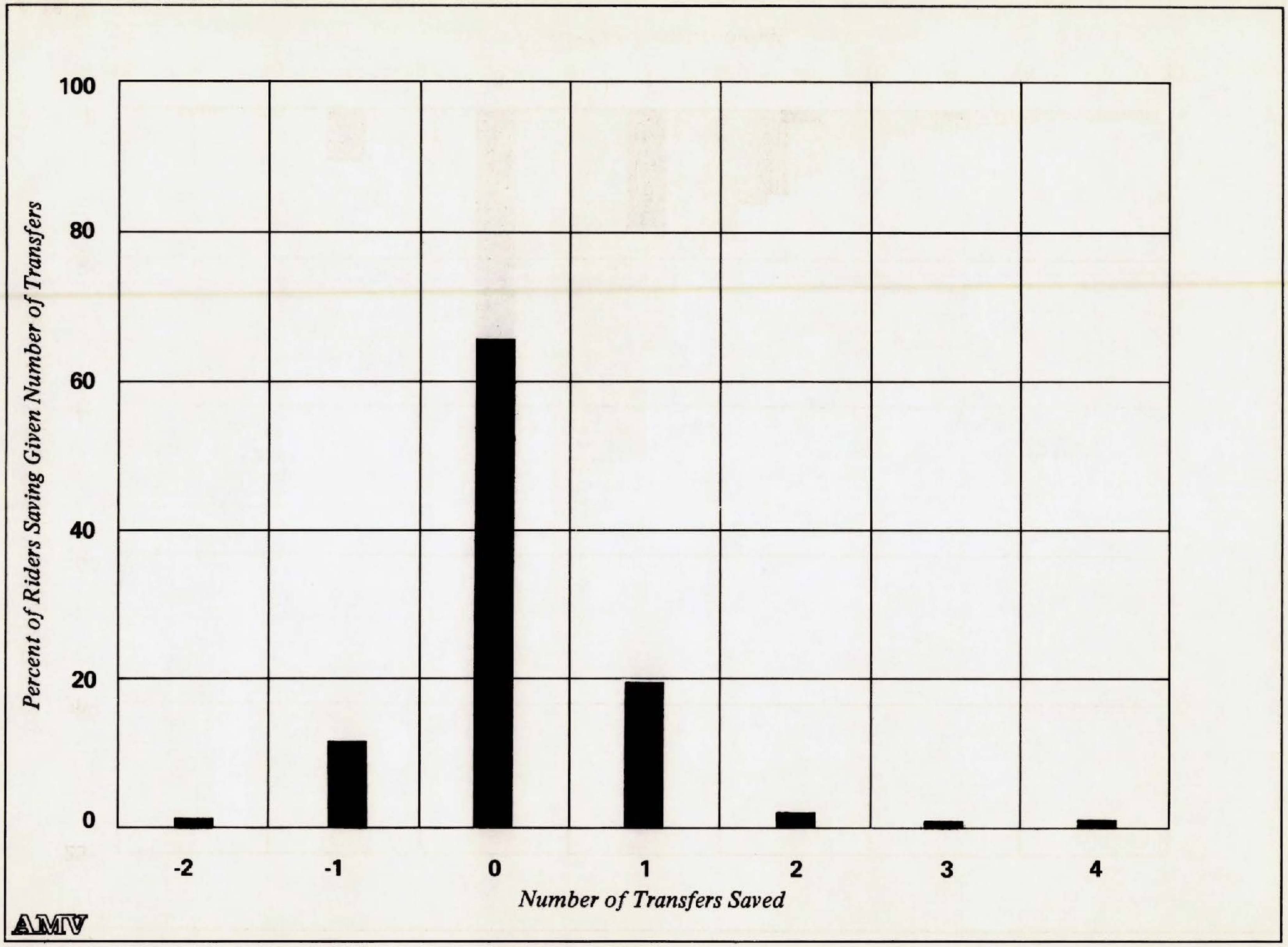

Figure 15 Distribution of Transfer Reductions of Optimum System, A.M. Peak Period

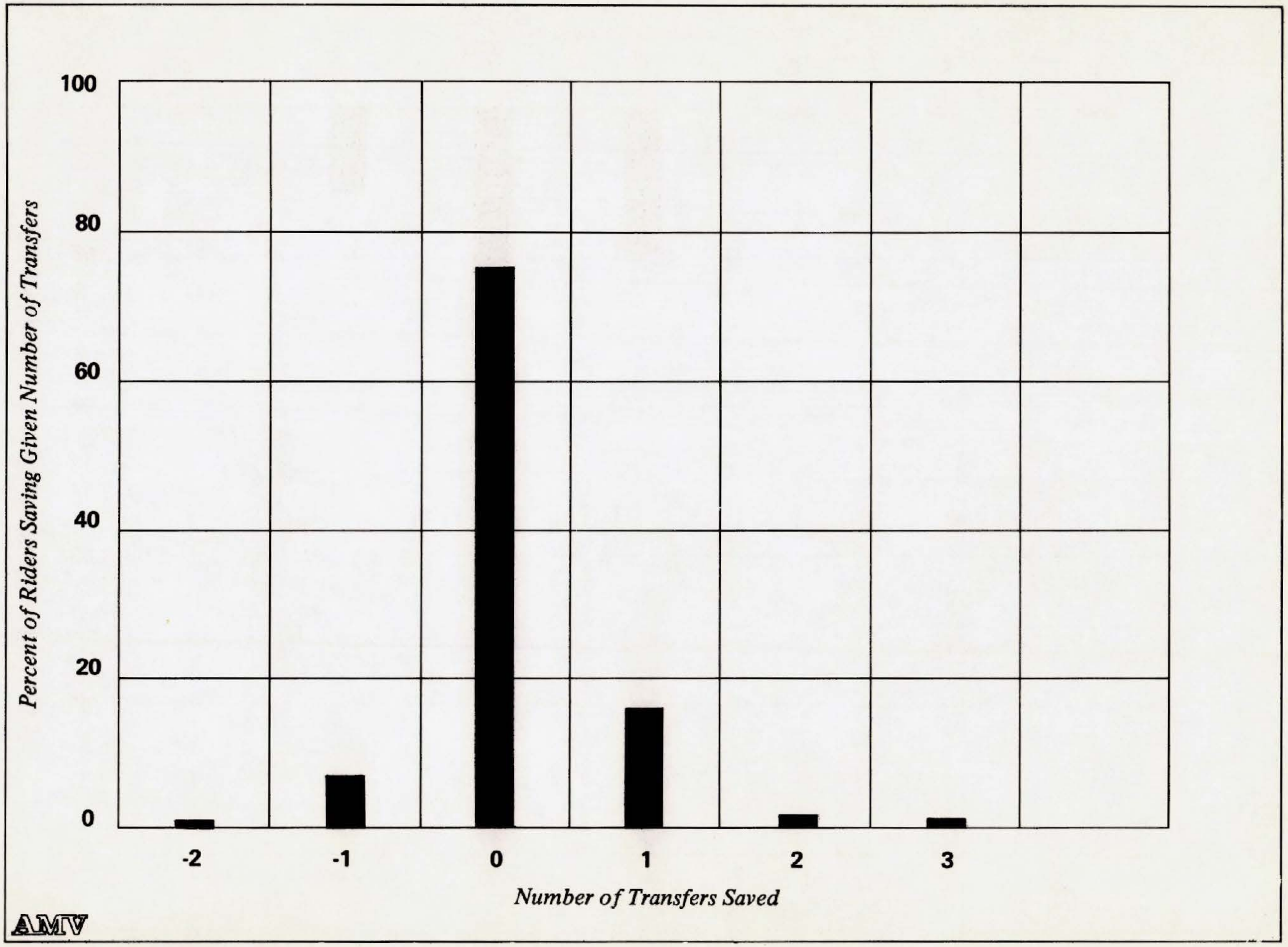

Figure 16 Distribution of Transfer Reductions of Optimum System, Mid-Day Base Period

TABLE 4: TOTAL NUMBER OF TRANSFERS MADE

	Basic System	Optimum System	Percent Reduction
A. M. Peak Period	84, 765	70, 275	17. 1%
Midday Base Period	42, 707	33, 923	20. 6%
Total	127, 472	104, 198	18. 3%

TABLE 5: INTERACTION OF TRAVEL TIME AND TRANSFER REDUCTIONS OF OPTIMUM SYSTEM OVER BASIC SYSTEM

A. M. PEAK PERIOD TRIPS

	Less Transfers	Same Number of Transfers	More Transfers	Totals
Less Travel Time	10,182 8.3%	15,219 12.5%	6,391 5.2%	31,793 26.0%
Same[1/] Travel Time	13,411 11.0	58,654 48.0	6,560 5.4	78,625 64.4
More Travel Time	3,272 2.7	6,664 5.4	1,815 1.5	11,751 9.6
	26,866 22.0	80,537 65.9	14,766 12.1	122,169 100.0

MIDDAY BASE PERIOD TRIPS

Less Travel Time	5,850 7.6	11,134 14.5	2,252 2.9	19,236 25.0
Same[1/] Travel Time	5,871 7.7	43,520 56.7	2,125 2.8	51,516 67.2
More Travel Time	1,432 1.9	3,609 4.7	926 1.2	5,967 7.8
	13,153 17.2	58,263 75.9	5,303 6.9	76,719 100.0%

[1/] Trips with less than a four minute change in travel time are included in "Same Travel Time."

- Number of midday trips involving transfers reduced by 17 percent

- Number of peak trips involving multiple transfers (more than one transfer required) reduced by 36 percent

- Number of midday trips involving multiple transfers reduced by 37 percent

It is practically inevitable when revising a system that some riders will not be as well off as they were, no matter how many other bus patrons are helped. Of course, some people who have longer trips as measured in the Optimum System simulation may make fewer transfers and vice versa. In particular, some riders might make an additional transfer as a matter of choice to take advantage of a new express route offering a faster ride.

As has already been indicated, Table 5 provides a summary of the trips falling in each category. A few highlights are listed below. In these tabulations, unlike the others, change in travel time of a trip is not counted unless the difference is at least four minutes.

- Significant reduction in travel time and transfers for 8.3 percent of peak trips versus only 1.5 percent increased on both counts

- Significant reduction in travel time and transfers for 7.6 percent of midday trips versus 1.2 percent increased on both counts

- Significant reduction in travel time and/or transfers with neither increased for 31.8 percent of peak trips versus 12.3 percent in the opposing categories

- Significant reduction in travel time and/or transfers with neither increased for 29.8 percent of midday trips versus 8.7 percent in the opposing categories

These comparisons are all for trips which are already being made via the present D. C. Transit bus system. The percentage of travelers using transit service as compared to auto users will, on the average, be lower where the service is now least good. It can therefore be safely assumed that if the Optimum System versus the Basic System comparisons were rerun for potential transit riders, as compared to actual transit riders, the Optimum System would compare even more favorably. The possible attractiveness of an improved transit system to persons not presently riding transit is an aspect to be carefully considered, as even a modest increase in ridership could have a very salutary effect on the economics of transit operation in the metropolitan area.

7.2 Comparison of Systems by Specific Area

The comparisons just presented contrasting the Optimum System with the Basic System each described the effect the revised routes would have on the riders of D. C. Transit as a whole. To make it feasible to study the effect on riders from particular areas, measures of percentage of change in average trip minutes and percentage of change in average number of transfers were developed for each traffic analysis zone of the D. C. Transit service area and were plotted on maps for evaluation. These maps are presented as Figures 17 through 22.

A simplified example may serve to explain the concept of these measures. Assume that traffic zone A today has five transit trips leaving it in the a.m. peak period. They go in diverse directions, but in this example, each requires a 50-minute door-to-door travel time. The travel time involved for the five trips leaving the zone thus totals 250 minutes and averages 50 minutes each. If the average travel time has been shortened from 50 minutes to 45 minutes, then there has been a ten-percent reduction in average travel time for trips leaving traffic zone A. This is the type of measure employed in Figures 17 through 22.

Specifically, Figure 17 illustrates the ratio of change in average trip minutes for trips leaving each traffic analysis zone in the a.m. peak period, providing, in essence, a measure of service to the different residential areas of the city. Figure 19 shows the same for trips arriving at each zone, thus providing a measure of service to the employment areas. Figure 21 concerns trips in the midday base period and shows the ratio of change in average trip minutes for the sum of trips both leaving and arriving in each zone.

Figures 18, 20, and 22 show the corresponding changes in the number of transfers for the trips involved with each traffic analysis zone. For any given type of trip, the trip minute and transfer change maps must be looked at together to gain a complete picture of the service changes.

The most notable effect illustrated is the reduction in transfers for trips going to and from most parts of the area. This improvement is attributable to four basic actions taken in the design of the Optimum System:

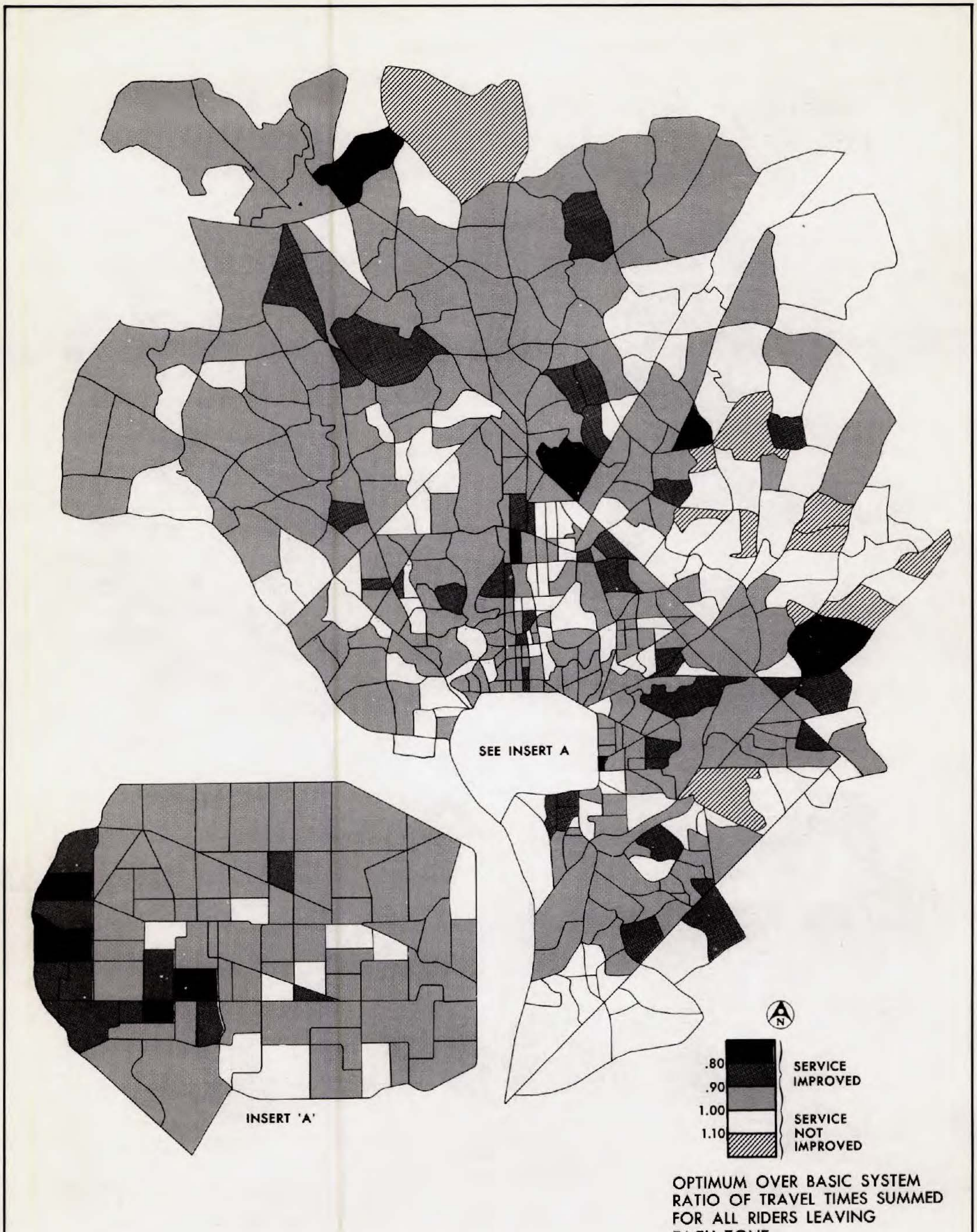

Figure 17 A.M. Peak Period Travel Time Comparison For Riders Leaving Each Zone Optimum System Vs. Basic System

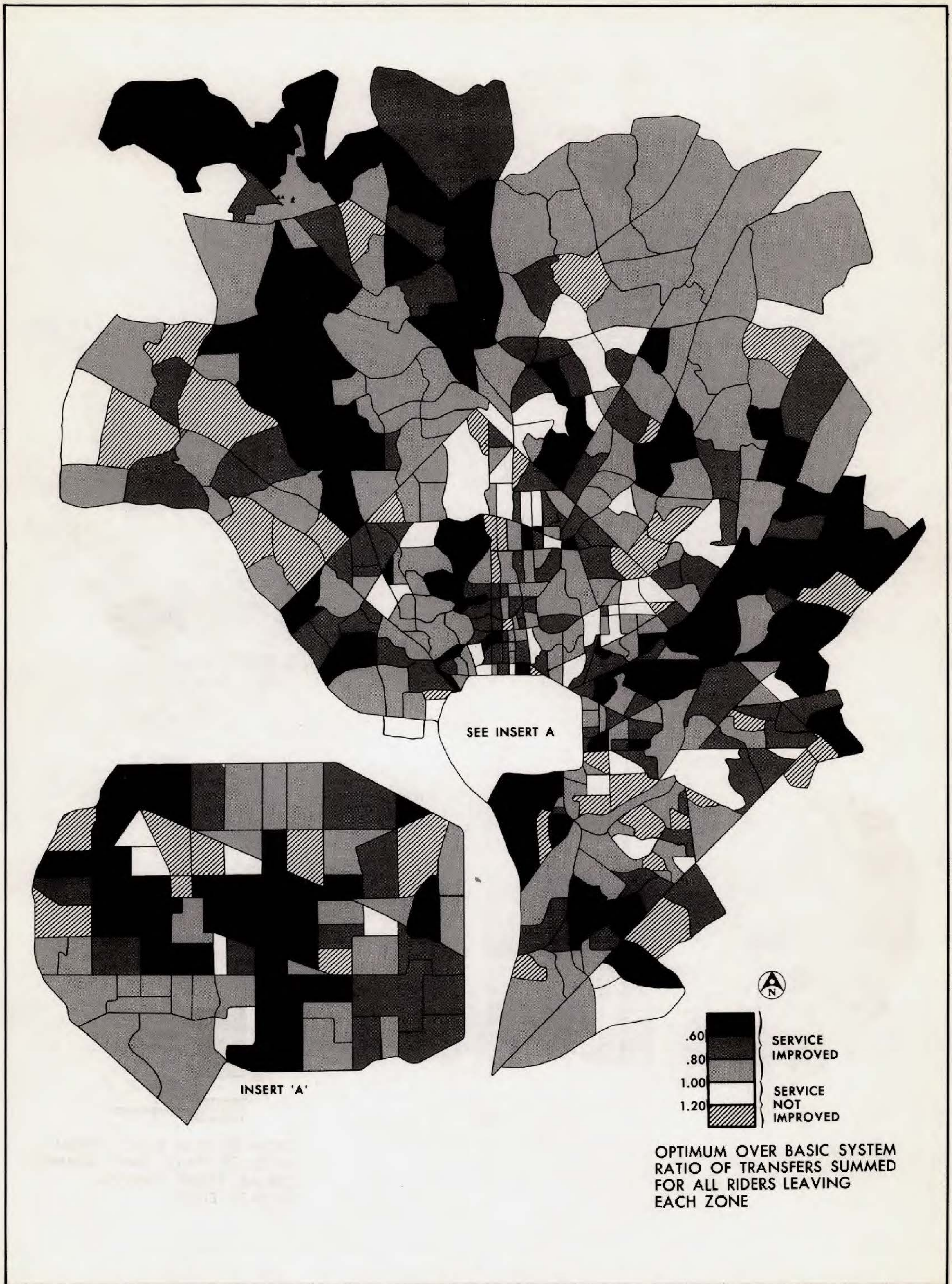

Figure 18 A.M. Peak Period Transfer Comparison For Riders Leaving Each Zone Optimum System Vs. Basic System

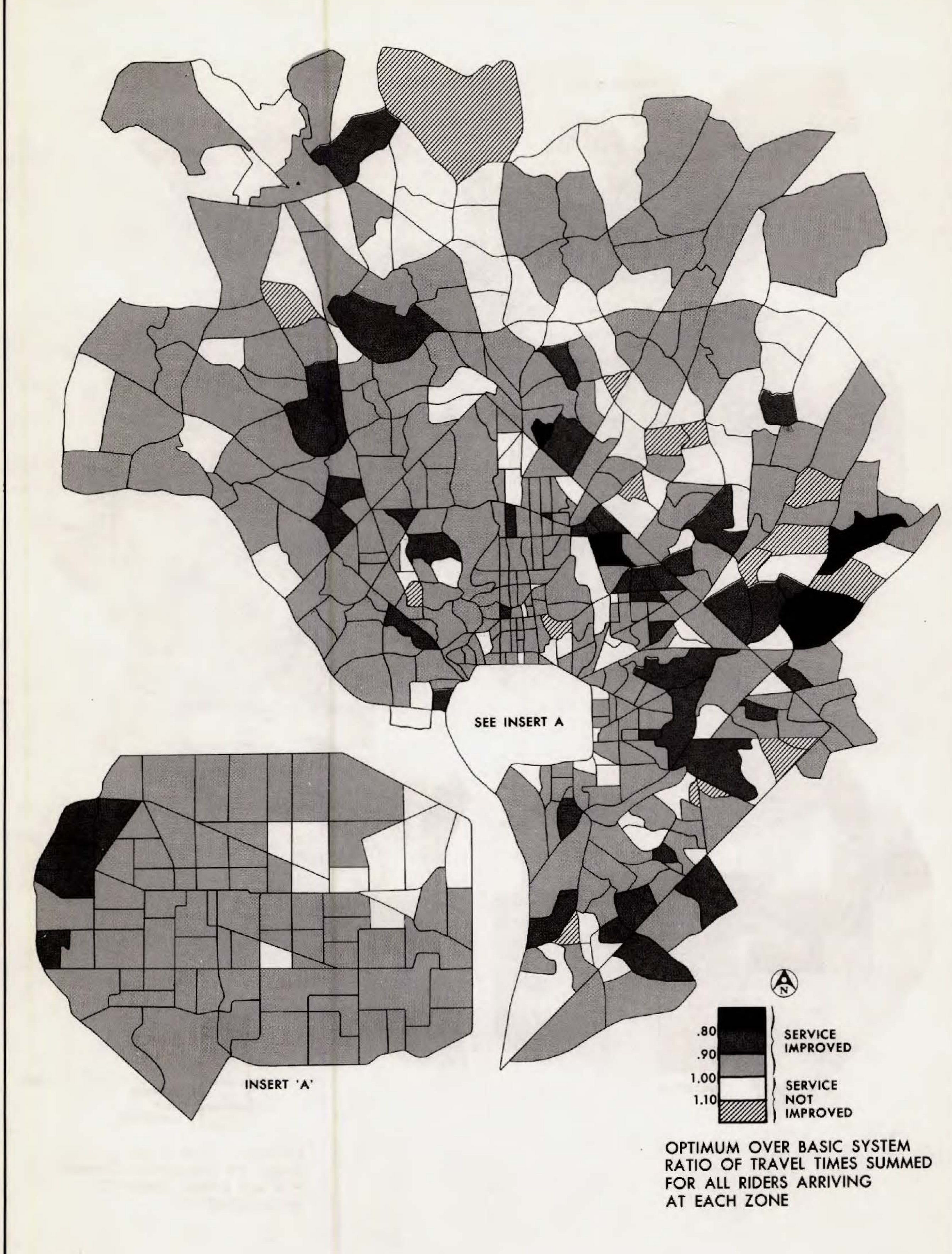

Figure 19 A.M. Peak Period Travel Time Comparison For Riders Arriving at Each Zone Optimum System Vs. Basic System

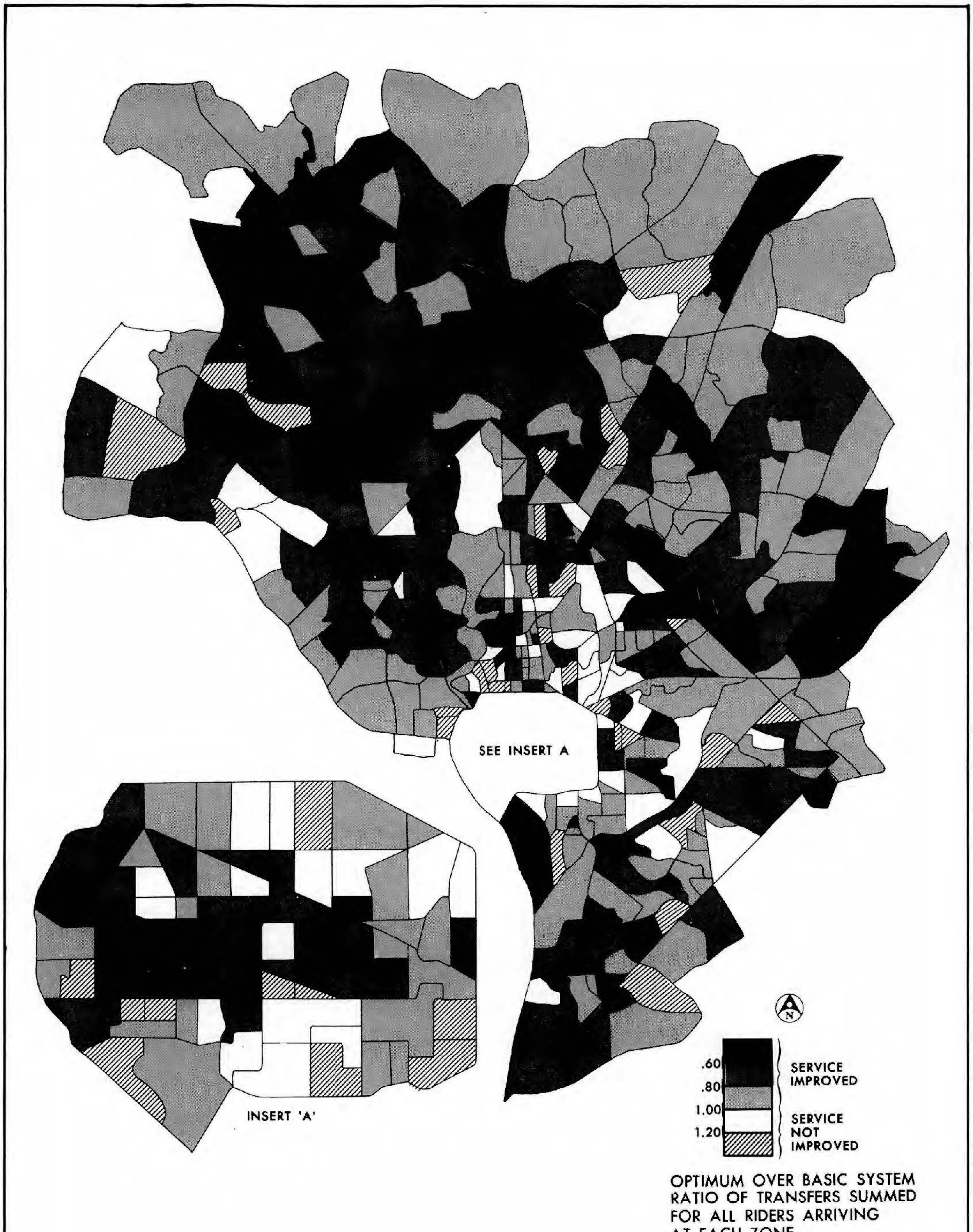

Figure 20 A.M. Peak Period Transfer Comparison For Riders Arriving at each Zone Optimum System Vs. Basic System

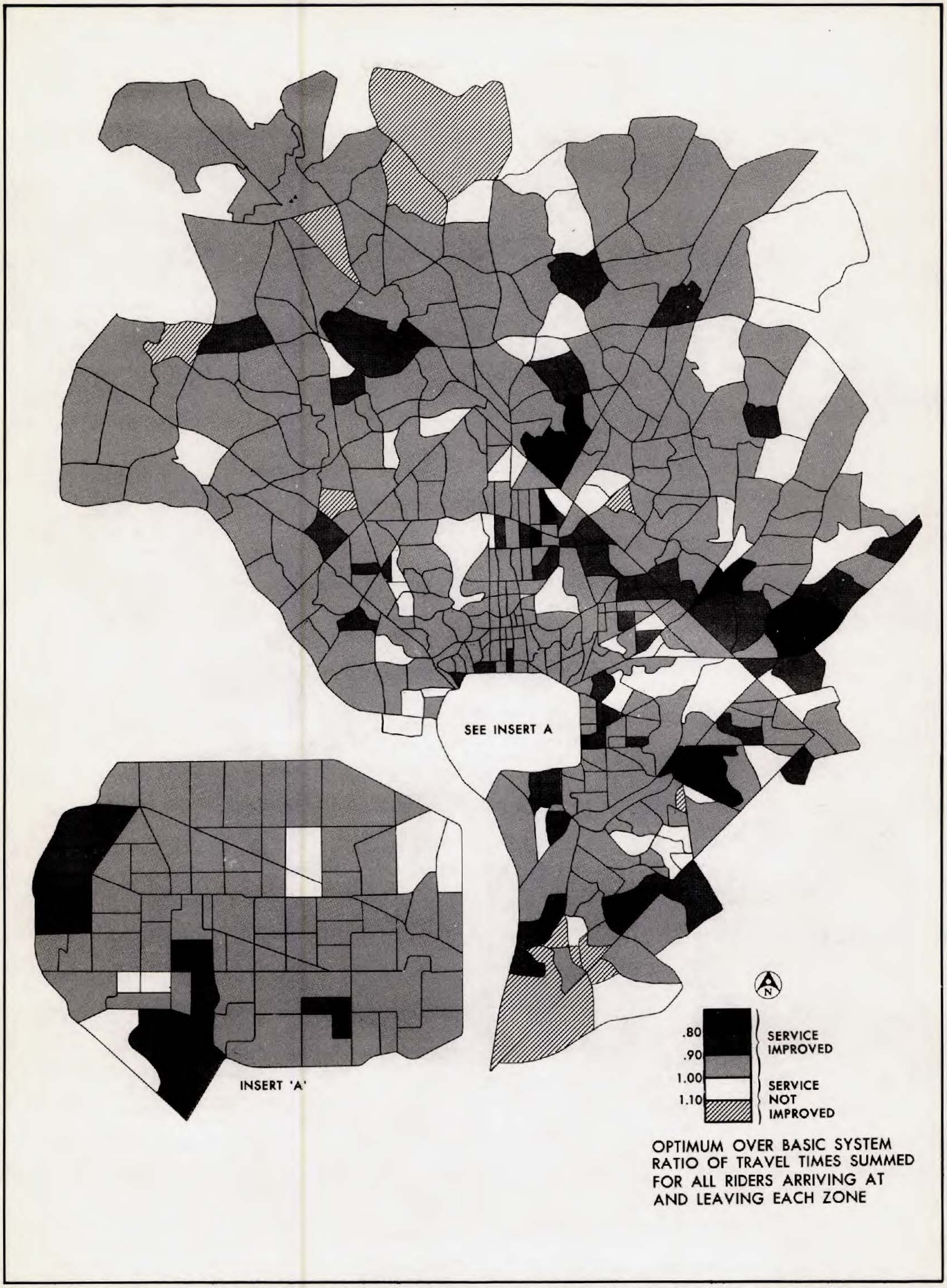

Figure 21 Mid-Day Base Period Travel Time Comparison For Riders Arriving at and Leaving Each Zone Optimum System Vs. Basic System

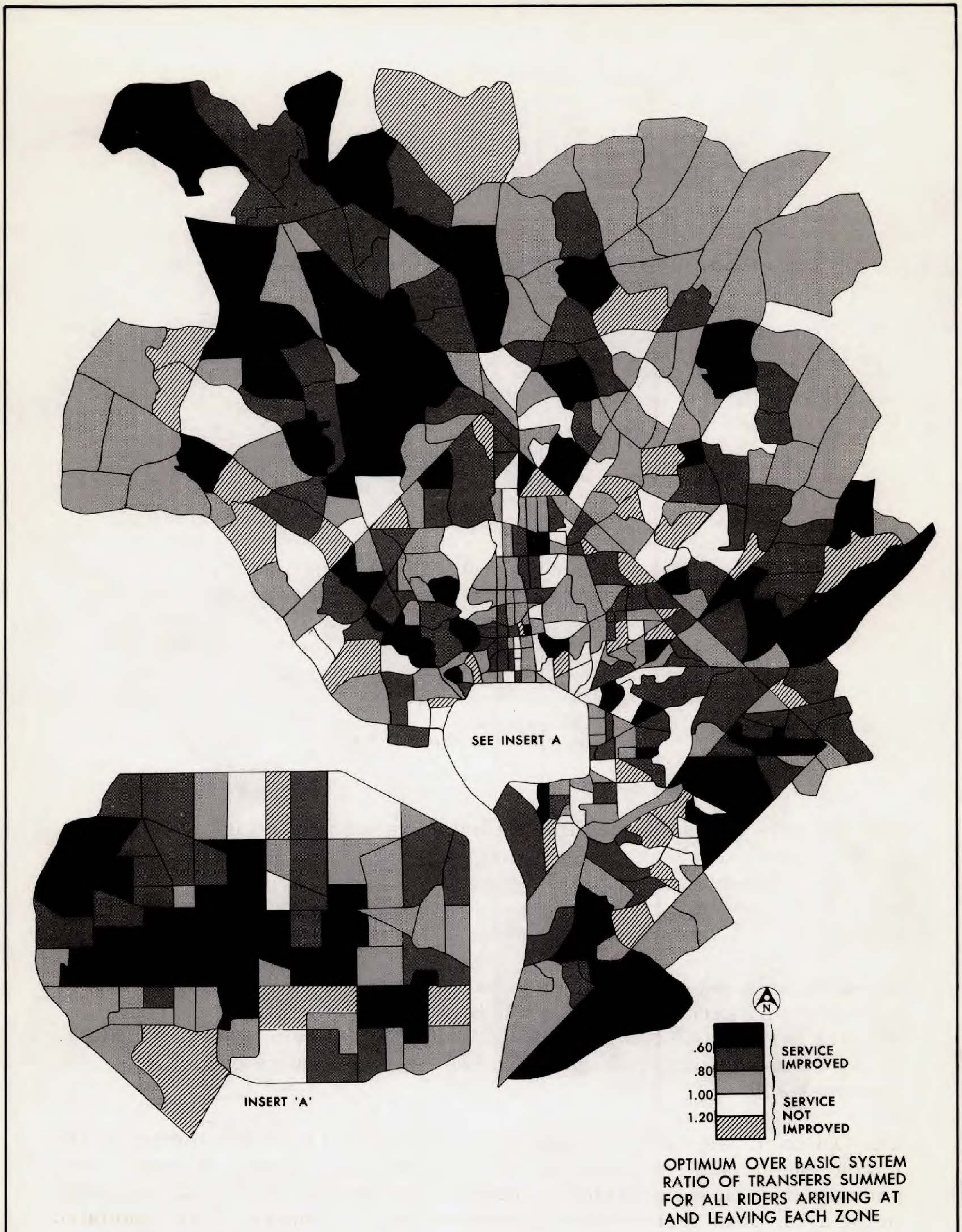

Figure 22 Mid-Day Base Period Transfer Comparison For Riders Arriving at and Leaving Each Zone Optimum System Vs. Basic System

- Through routing of radial bus lines across the central business district
- Extension of radial trunk lines across the District of Columbia-Maryland line
- Replacement of short feeder routes with extensions or branches of radial trunk lines
- Modification of existing crosstown services into a circumferential pattern and provision of additional crosstown routes

Table 6 is presented to indicate the magnitude of some of the travel time and transfer savings provided individual trips by certain of the specific route changes tested.

For example, a savings of 18 minutes in the a.m. peak period from Grant and Division Streets to Bethesda has been made possible by the route X3 revision. The 13-minute travel time reduction and the elimination of one transfer in midday from Grant and Division Streets to Sibley Hospital is attributable to the extension of route X2 from Lafayette Square over the present route of line D2. The off-peak travel time and transfer savings from Bethesda to downtown result from the extension of routes O4 and O6 as express lines into the District of Columbia.

7.3 Optimum System Operating Costs

The net differences between the Optimum System and the Basic System in those items that make up operating costs are estimated to be so small as to be relatively insignificant. The estimates do indicate, however, that the operation of the Optimum System should not cost more than the present operation. Yet, as previously shown, a better service would be provided.

The estimates indicate that the typical weekday 24-hour operating cost, including only variable costs, would be reduced by 1.7 percent from $61,312 in the Basic System to $60,251 in the Optimum System. Table 7 shows the more important operating cost characteristics of the two systems.

The Optimum System operations are characterized by more service in the midday period and reduced vehicular requirements in the a.m. peak period. It is most important to note that the number of vehicles required in the a.m. peak period would be reduced by 4.7 percent. It is postulated by several authorities that total system operating costs are directly

TABLE 6: SYSTEM TRAVEL COMPARISONS FOR SPECIFIC TRIPS

Origin	Destination	A. M. Peak Travel Time 1/		A. M. Peak Transfers		Midday Base Travel Time 1/		Midday Base Transfers		
		Optimum	Basic	Optimum	Basic	Optimum	Basic	Optimum	Basic	New Lines Used
Division & Grant, N. E.	Downtown Bethesda	81	99	0	2	93	112	1	2	X3 O4
Division & Grant, N. E.	Sibley Hospital	78	86	0	1	82	95	0	1	X2
Division & Grant N. E.	Silver Spring Terminal	74	86	0	1	78	94	0	1	W4
Division & Grant, N. E.	State Dept.	53	59	0	1	57	63	0	1	X2
Division & Grant, N. E.	Stanton Rd. & Alabama, S. E.	43	56	0	3	47	78	0	1	W4
Nichols & S. Capitol	State Dept.	44	48	0	1	57	58	1	1	A9
Nichols & S. Capitol	American University	75	76	1	2	82	87	1	2	S2 N2
Nichols & S. Capitol	Downtown Bethesda	86	95	1	2	93	106	1	2	O4
Stanton Rd. & Alabama, S. E.	S. W. Mall	36	41	1	1	48	53	0	1	32 W3
Stanton Rd. & Alabama, S. E.	State Dept.	43	52	0	2	67	72	0	1	W1
Downtown Bethesda	Farragut Square	39	45	0	1	43	62	0	1	O4
Wheaton Plaza	S. W. Mall	73	71	1	1	83	87	0	1	76 78
Silver Spring Terminal	Sibley Hospital	63	69	1	2	69	79	1	2	T4

1/ This is the door-to-door travel time which includes time spent walking to and from and waiting for buses

TABLE 7: OPERATING COMPARISON OF BASIC AND OPTIMUM SYSTEMS

Item	Optimum System	Basic System
A. M. Peak Period Average Vehicles	742	780
A. M. Peak Period Vehicle-Miles	27,921	28,295
A. M. Peak Period Vehicle Speed (mph)	10.58	10.20
Midday Base Period Average Vehicles	365	362
Midday Base Period Vehicle-Miles	21,558	21,054
Midday Base Period Vehicle Speed (mph)	9.79	9.64
Typical Weekday 24-Hour Vehicle-Hours	9,750	10,006
Typical Weekday 24-Hour Vehicle-Miles	101,574	101,425
Typical Weekday 24-Hour Vehicle Speed (mph)	10.42	10.14
Typical Weekday 24-Hour Variable Operating Costs	$60,251	$61,312
Approximate Peak Vehicle Requirement (A. M. Peak Period)	968	1,018

proportional to peak vehicle requirements. If this is so, then the savings afforded by the Optimum System might be even more than 1.7 percent.

The increased service in the midday period is partly attributable to the extra crosstown services provided. On these crosstown lines, it is not expected that the buses will be near capacity. Nevertheless, it is recommended that the headways specified for these routes be kept as a policy for service reasons covered in detail in Chapter VI.

The reduction in peak vehicle requirements can be attributed to several causes. First, there is an increase in the amount of express service provided which enables buses to do the same job in less time. Second, there is a more efficient deployment of buses in that the revised crosstown services are more closely parallel the travel desire lines for non-downtown-oriented riders. Finally, the improved crosstown services have enabled many riders to avoid crossing through downtown. Thus fewer buses are necessary in the congested downtown where running times are relatively slow. Table 8 compares peak load point volumes on several lines for the Basic and Optimum Systems.

While the methods used for determining Optimum System operating costs are valid for a planning study, the intricacies of bus interlining, the importance of layover time at various terminals, necessary pull-out and pull-in times from the terminals and other vagaries of the schedule-making process dictate that a precise cost estimate cannot be had until the final scheduling is followed through to completion. The magnitude of this task is discussed in some detail in Chapter VIII. The cost analysis makes it evident, however, that one of the basic objectives of the study has been obtained — that of providing systemwide service improvements without the necessity of increased operating cost.

7.4 Optimum System Routing Characteristics

The objectives and criteria — and the study processes — that contributed to the design of the Optimum System have already been discussed, particularly in Chapter VI. The details of the Optimum System bus routings can be studied by reviewing the maps presented in Figures 23 and 24. It is perhaps appropriate, however, to briefly review at this point the major characteristics of this system which these studies show would improve the transit service provided for each operating cost dollar.

The Optimum System, as planned, has a modified radial and ring configuration. In a true radial and ring system, trunk lines emanate from the central business district like spokes in a wheel and are crossed at

TABLE 8: COMPARISON OF ASSIGNED INBOUND AND OUTBOUND RADIAL PEAK LOAD POINT VOLUMES BY CORRIDOR

Number of Trips in Corridor at Peak Load Points

	A. M. Peak Period				Midday Base Period			
	Inbound		Outbound		Inbound		Outbound	
	Optimum	Basic	Optimum	Basic	Optimum	Basic	Optimum	Basic
Potomac-Rockville	18,895	19,813	5,956	9,540	7,840	7,935	7,301	7,630
14th Street	26,837	26,430	5,377	7,238	9,295	9,604	7,756	8,168
Rhode Island	9,058	12,038	1,794	2,322	2,866	3,721	2,115	2,857
Benning	14,264 [1/]	15,663 [1/]	3,523	2,630	5,680	6,046	4,499	4,675
Ft. Stanton Park - Bolling	15,000	14,225	3,821	2,822	5,119	5,230	3,856	4,013
Total	84,054	88,169	20,471	24,552	30,800	32,536	25,527	27,343
Change from Basic to Optimum System	-4,115		-4,081		-1,736		-1,816	
Percentage Change	-4.7		-16.6		-5.3		-6.6	

[1/] X3 is included as an inbound radial line from the Benning Corridor

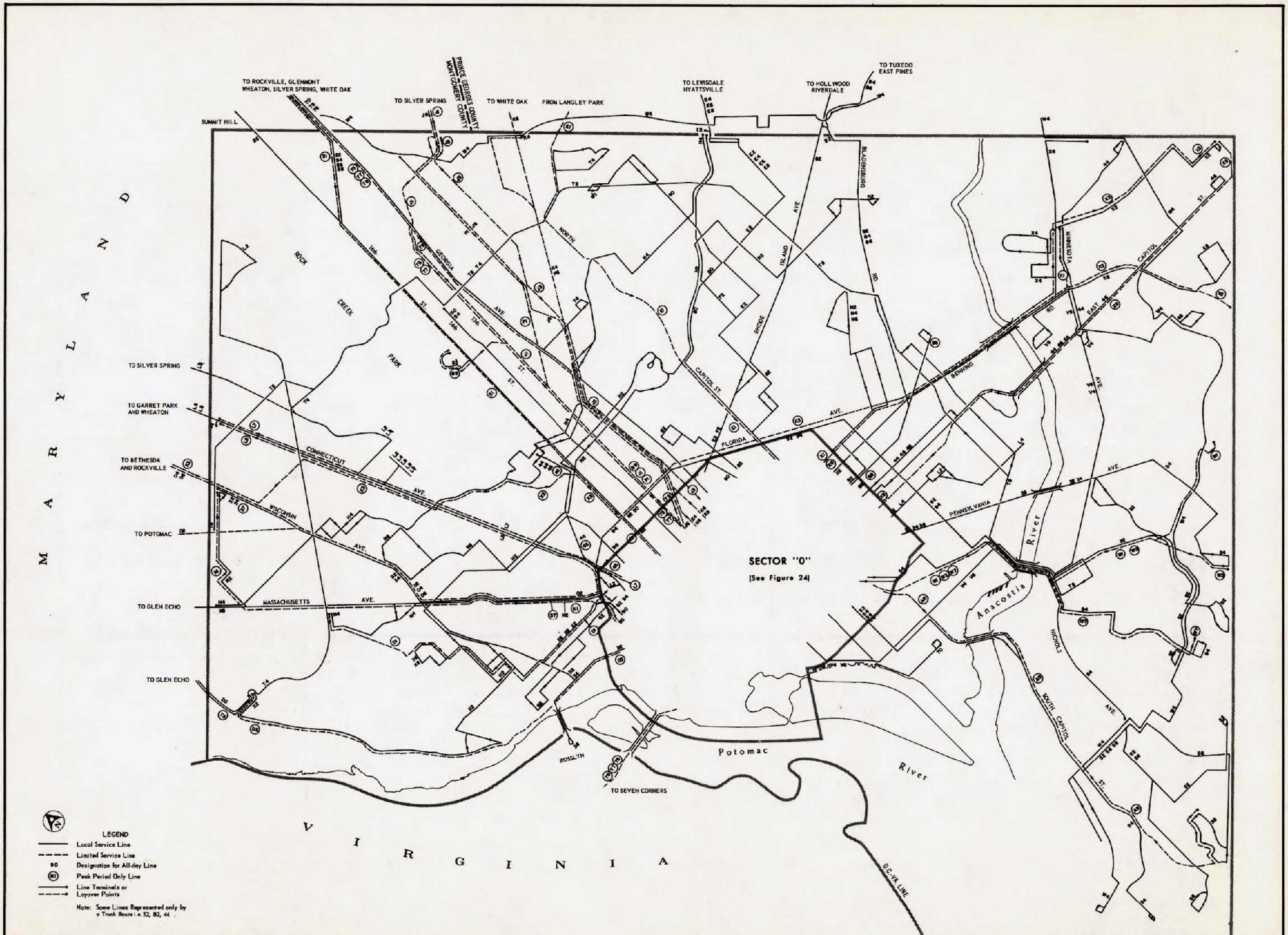

Figure 23 Recommended System in District Of Columbia

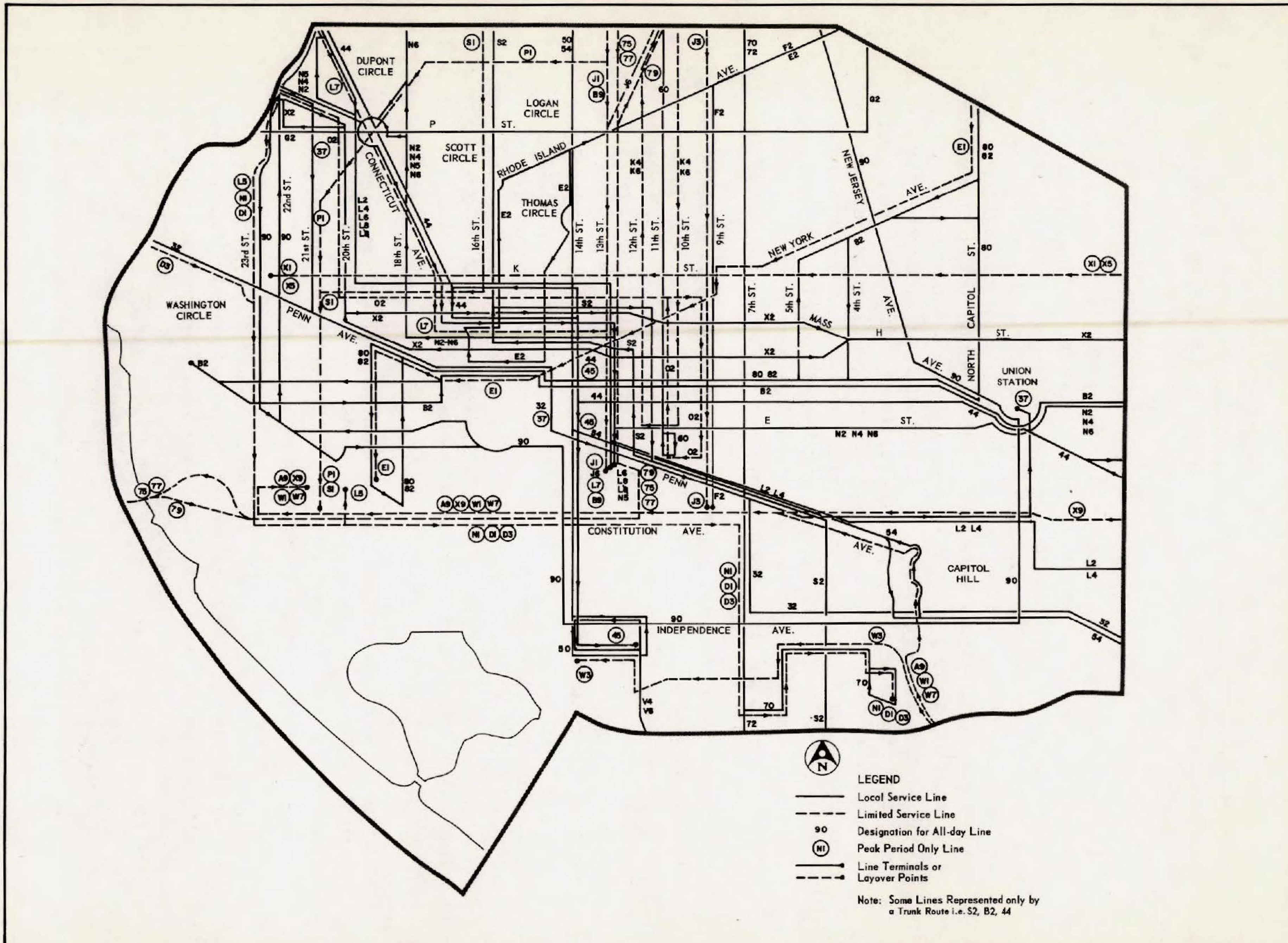

Figure 24 Recommended System In Sector "O"

intervals by circumferential lines connecting the city's various corridors. This basic concept has been modified where appropriate to match particular travel demands, to maintain some continuity with historical routing, and to provide for easier implementation by stages.

A basic requirement of a successful radial and ring type operation is a framework of good, strong lines, both radial and circumferential, which maintain quite frequent service throughout the day. This is particularly true with reference to the circumferential crosstown lines because of the need to minimize transfer waits. In the District of Columbia, the Optimum System crosstown frequencies have been maintained at a maximum of 15 minutes in the midday base period, keeping the average wait for transferring passengers at the 7-1/2-minute level or lower. Many of the crosstown lines in the peak period operations would be more frequent. The circumferential crosstown lines are quite important because they shorten the length of trip for many passengers and make it unnecessary for them to travel into the central business district to effect a transfer to their final destination. As a side effect, this permits a reduction in the number of buses passing through downtown, as previously discussed.

The circumferential routes can be traced on the system maps (Figures 23 and 24) as routes 90, 92, 94, G2, H2, H4, T4, T8, V4, V6, and W4. Route 90 is perhaps the most novel, serving as a central business district distributor by operating in a complete circle through the fringe areas of downtown. This one route serves the place of four present-day downtown shuttles. The radial trunk routes of the Optimum System typically are through-routed across downtown. This increases the accessibility of all areas of downtown for transit riders, provides more possibilities for crosstown through rides, and improves downtown transfer connections. It should also tend to reduce traffic congestion. Fewer downtown terminals would mean fewer turns to be made by buses, and overlapping of lines in the downtown area could be eliminated.

Examples of through-routing that can be identified on the maps include the Trinidad to Massachusetts Avenue corridor services (the "N" routes), the Benning to Georgetown services (the "X" routes), and the East Capitol Street to Connecticut Avenue services (the "L" routes).

The radial trunk routes are branched and in some cases are extended across the District Line to minimize the number of shuttles required and to thus provide the maximum amount of through service to downtown and crosstown connections. Examples of branching and extensions can be seen following around the periphery of Figure 23 at the west end of the "L" routes, the north end of the "70's" routes, the east end of the "40" and "X" routes, and the south end of the "S" routes. Note that for operational simplicity the branching occurs, as much as possible, at one end of each trunk route only.

The basic framework of the Optimum System is in operation continuously throughout the peak and off-peak periods. Furthermore, the through-routing of radial trunk lines has been accomplished in such a way that the off-peak traffic loads should balance on opposite sides of downtown, allowing a simple off-peak schedule with no turnback of individual buses in the central area. These basic schedules are continued as much as possible through the peak, with additional trips being superimposed on one or both ends of the line as required by peak loads. These additional trips can be set up to operate through town, to turn back at some point in the central business district, or to connect directly with special employment centers in the downtown area as required.

Finally, the Optimum System is characterized by an expanded system of high frequency peak period express routes. These all serve the downtown area except for the "super" crosstown line (route X3), already described in Chapter VI.

7.5 Route Checks and Detailing

All the proposed routings in the Optimum System were discussed with D. C. Transit personnel to determine the suitability of the streets, terminals, layover points, and turnbacks that are suggested. Where required, on-site physical inspections were conducted.

The final step in preparing a recommended system was to reintroduce into the bus network those special service lines omitted from the Basic and Optimum System studies. As was explained in Chapter IV, the Basic System was created by setting aside from consideration certain routes and portions of routes considered least important in the systems analysis. The Optimum System was designed to a comparable level of detail. Therefore, to make the Optimum System into a complete detailed network describing all the various routes that would be operated in a revised system, the special service lines or a new equivalent had to be, with some exceptions, reinserted. The following methodology was used to perform this reinsertion.

Each local peak-period specialty service was reanalyzed to see if any new Optimum System routes were meeting the original purpose of the service. If not, the route was reinserted. All peak periods supplementary express lines were reinserted unless a new Optimum System express line fulfilled the same function. Existing feeder services were reinserted if their service areas were not adequately covered by Optimum System lines. Low frequency branches were restored to their present frequency unless the Optimum System trunk line had increased service, in which case it was possible to increase the branch frequency.

The percentage of turnback trips on any given line was generally taken to be in the same proportion as currently exists. The resultant full detailing of the Optimum System described an operation comparable in detail to the present one. The fully detailed system is not of sufficient general interest to be described here, but has been furnished to the parties directly concerned.

7.6 Conclusions

The indicated benefits to be gained through the operation of the Optimum System revised routes are of sufficient magnitude as to suggest their prompt adoption and the institution of a program of implementation. Because of the complexity and extent of the work involved, this implementation program cannot be accomplished overnight. It will take considerable time, effort, man hours, and money. However, the benefits to be accrued — not only in the Washington area but also as a demonstration of what might be accomplished in other major cities throughout the country — make the effort well worth the expenditure. Chapter VIII spells out the methodology that might be followed in a program of implementation.

Chapter VIII

SCHEDULING AND RUN–CUTTING INVESTIGATIONS

Any proposal for improved bus routing is valueless if the necessary implementation techniques are not available or are not equal to the task. One major task of implementation is scheduling the new services and assigning operators. It is in recognition of this fact that an investigation of possible benefits accruing from computerization of the route scheduling and run-cutting process has been included as one phase of this Mass Transportation Demonstration Project.

This chapter outlines the investigations made and the recommendations developed concerning scheduling techniques as they apply to the D. C. Transit operation. The recommendations were prepared based on a re-review of current scheduling practices, studies of recent efforts at automation, and AMV's knowledge and experience in these areas.

As will be discussed, it has been concluded that the speed, efficiency, and flexibility of D. C. Transit's scheduling capabilities can be improved by using presently available technology. A program is outlined to accomplish these improvements using the preparation of schedules for the proposed D. C. Transit route revisions as the subject of a further research and development effort.

8.1 Scheduling Process

The purpose of this section is to describe the basic elements of the scheduling process in a format suitable for understanding the recommendations which follow. A flow chart of the scheduling process is illustrated in Figure 25.

The first main step in the scheduling process is to assemble the basic information required such as passenger loadings, running times, route structure, and scheduling standards. These must be determined for each of the various time periods of the day.

For an existing bus route, maximum load point counts or boarding and alighting counts are made to find the passenger loadings. For a new route, the loads must be estimated as well as possible. In the case of the route revisions proposed in this project, the estimation of traffic loads for the principal time periods has already been carried out, although minor adjustments might be advisable to reflect any conditions that have

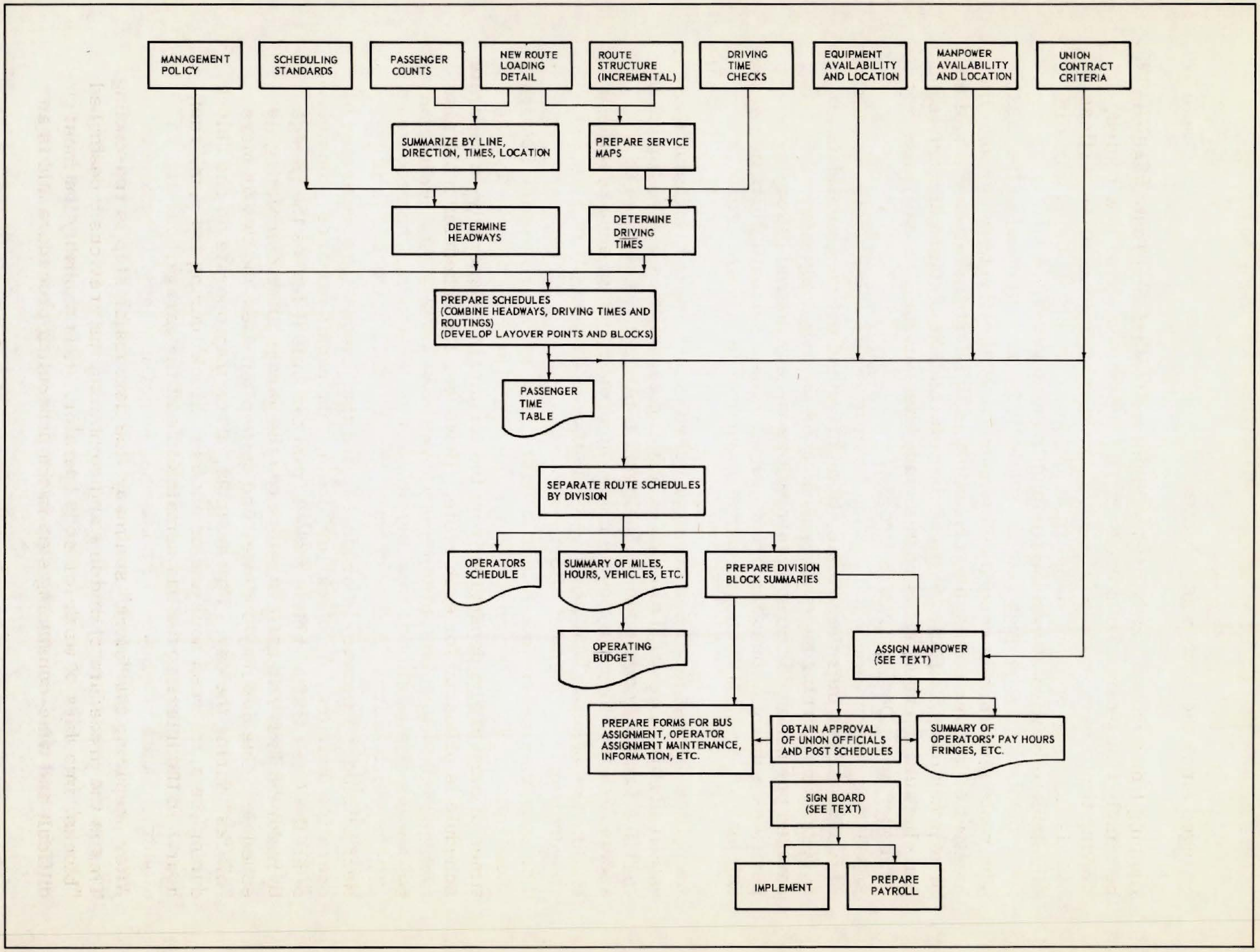

Figure 25 Flow Chart of Present Transit Scheduling Process

changed since the study was initiated.

Running times have already been determined for existing routes and can be simply transferred from one schedule to the next. For new routes, driving times have to be developed from experience on similar portions of existing lines or from actual field checks, possibly by using a bus in simulated operation at various times of the day.

The route structure is described by identifying the streets to be used; the location of layover points and turnback points; the rules for local, limited, or express operation; the length of the line; and the distance and driving time between garages and points of entry into service.

Scheduling standards consist of load warrants and headway policies which in the local case either are set by WMATC or reflect the practice of D. C. Transit. Loading standards define how many passengers may be carried per bus under peak or off-peak travel conditions. Headway policies define minimum service frequencies for application in those cases where the loading standards should not govern.

Using this information, the second step is to calculate the required headway at one or more points along the line. This is done for each period of the day, in this instance by using periods generally in increments of twenty or thirty minutes. Headways are calculated according to the bus loading and headway standards applicable in each period.

The schedule-maker determines at what times buses are to pass through these points, which terminals on the line the buses are to use, and the times of arrival and departure from the terminals. Generally, a separate schedule is prepared for each route. However, the scheduler must also take into consideration interlining, whereby one vehicle may operate on two or more lines.

Next a "block" summary is produced, and the "blocks" are separated by operating division. A "block" or "train," in transit parlance, consists of all the trips that a vehicle makes from the time it leaves the garage to make its first trip until it returns to the garage after completing its schedule. One bus may operate, and quite often does, on two or more "blocks" during the day. For example, a bus may operate on one "block" during the a. m. rush hour and on another "block" during the p. m. rush hour. In the interim, the bus remains idle at the garage.

After preparing the "block" summary, the next major step is run-cutting. This is the procedure of dividing and combining the previously described "blocks" into days of work for each operator. It is probably the most difficult and time-consuming step in the scheduling procedure and is an area where considerable money can be saved or lost. A critical element in manpower assignment is the union contract where many of the provisions, penalties, and constraints governing the run-cutting procedure are spelled out. Aside from the contract, there are usually a number of tacit understandings between the company and the union as to what can and cannot be done in the matter of run-cutting.

Once the runs have been cut, they must be reviewed by a union committee, as specified in the contract. This review can take up to two days. It usually involves, more than anything else, some negotiation between the schedule-makers and the union representatives.

Once a new schedule has been developed, the manpower assignments detailed, and the union review completed, "posting" takes place. The runs for each operating division, along with the individual schedules that will be operated, are posted for that division's operators to inspect. Following the posting there are, in the case of D. C. Transit, 17 days allowed for the selection of runs by the operators. Each operator is called in the order of seniority to choose, from among those runs they are entitled to pick, the one which they desire.

Once the selection is completed, the schedules can go into effect. At D. C. Transit there are three general selections required during the year; thus there are three occasions annually where major scheduling changes can best be implemented.

8.2 Need for Automation

Transit systems throughout the country have by and large experienced a downward trend of ridership since World War II. As a result, the efforts of the schedule and planning departments of most transit companies have been directed toward patching schedules — making minor revisions instead of rescheduling routes in their entirety. This patching has mostly involved deleting trips and making occasional route extensions or contractions. Rarely has a major bus company attempted to completely, or even partially, reroute an existing system.

Since scheduling is considered to be an overhead item, it is unfortunate but usually true that when the axe of economy falls, one of the first places to be hit in any transit company is the schedule department. Thus as a result of the transit-riding decline, few people have been learning the schedule-making trade over the past two decades.

It takes a period of several years to train a good schedule-maker. Furthermore, the work requires a person who has a good head for figures and a certain amount of imagination, and yet is not afraid of the constant tedium of schedule preparation. This type of individual is hard to find. For these reasons, good schedule men have become much in demand. Over the past year or so, D. C. Transit has lost at least three key schedulers to other agencies.

With few exceptions, all transit companies in this country, including D. C. Transit, perform by hand all the tasks related to route changes and schedule revisions. It has been stated that it might take a full year or more to completely reschedule the D. C. Transit System using existing techniques. In the face of these difficulties, there is an increasing need for comprehensive rescheduling capabilities. The route revisions recommended in this report would require these capabilities.

In the Washington area, the need for rescheduling flexibility will become even more apparent as the date approaches for opening of the Metro rail rapid transit operation. It is anticipated that the first stages of this rail system will be in operation by late 1972. With the commencement of service and with the opening of each new section of this system, the area bus operators will of necessity have to prepare major route and schedule revisions.

Using existing methods to prepare for such changes, the schedule department capabilities of any transit company would be severely taxed. In fact, the schedule and planning departments of most transit companies in this country have suffered such attrition over the years that in many cases there is no longer enough staff to do the work necessary to make a major revision.

What is needed is a scheduling procedure that will allow major route revisions to be prepared by using existing or further reduced scheduling staffs; at the same time, transit management should be provided with the flexibility to examine a wider range of options when implementing new schedules. All of this points to the need of automating the schedule-making process.

8.3 Existing Examples of Automation

There have been a few attempts to develop automated methods of preparing schedules and accomplishing related tasks. The automated process that has been developed at Baltimore Transit Company is probably the most advanced in regular use at this time. In Baltimore, a computer is used, to the company's satisfaction, to perform a number of scheduling and manpower assignment tasks.

The more significant advantages gained by Baltimore Transit Company through automation are the speed with which new schedules can be prepared and the accuracy with which they are produced. In addition, the automated procedures have replaced many time-consuming computations, thus allowing reduction of the schedule and planning department staff.

It should be emphasized that the scheduling process in Baltimore is only partially automated. Only the more obvious functions are being performed, using an obsolescent computer which does not allow carrying the process to its logical conclusion. In particular, the run-cutting procedure used is not an optimization process. It is not known how favorably the runs cut would compare to an optimum set of runs. On the other hand, the results have proved acceptable to management. It should also be noted that even at the Baltimore Transit Company a major change of routes and schedules would be difficult since its staff is presently only large enough to handle the minor patching required on a day-by-day basis. Nevertheless, these various limitations should not obscure the advantages demonstrated by the Baltimore Transit Company through its early attempts at automated scheduling.

It would appear that it is practical to automate every step of the schedule-making procedure and to carry out the process in one long train without intervening steps. This is the approach that is being advanced by Dr. Samy E. G. Elias of West Virginia University.

Dr. Elias' first investigations concerned the run-cutting process. After several partial successes, he now has developed an algorithm that has shown considerable promise in limited tests. He has also worked on the initial data collection phase of scheduling using an on-board machine to take bus passenger counts which then are summarized for specific stops.

8.4 Application of Automated Scheduling

Recognizing that certain automated processes would be developed more slowly than others, the long-range application would probably lead to a scheduling and planning process something like this:

1. Throughout the year, passenger load counts would be made by automated on-bus equipment. The output of this equipment would be in the form of punched tapes to be fed to data processing equipment at regular intervals, providing fully summarized passenger load information and related data, such as schedule adherence. These data would be inspected by an expert scheduler and adjusted to remove anomalies.

2. An ongoing program of running time checks would be carried out. The checks would be performed by speed-and-delay study methods, with new running times being prepared to meet current conditions.

3. Concurrently with these operations, the planning department would be developing new routes to serve various areas of growth, to take advantage of new and improved highways, or eventually to serve the Metro as it is developed.

   Running times and headways for these new and changed routes would be developed from experience and from analyses such as have been performed in this project.

4. All passenger data, running times, route structures, and scheduling standards would be processed by the computer programs, and basic schedules would be prepared. Upon completion, these basic schedules would be inspected by trained schedule personnel, again to remove anomalies. With the adjustments completed, operator schedules and passenger time tables would be automatically printed out.

5. "Block" summaries would be produced by the scheduling program and examined by the run-cutter, with the aim of identifying and adjusting conditions that might make run-cutting difficult. When adjusted, the "block" summaries would be input to the run-cutting program, and the entire process of run-cutting would be carried out. Miles and hours would be determined, and work weeks would be developed as part of the process.

6. Finally, the union review would be carried out. Necessary adjustments brought about by the review would be done by hand; the board would be reprocessed by computer and posted, and finally, operation of the revised schedules would take place.

In addition to the operating schedules and runs, various other information would be available as by-products from any automated process. Included would be summaries of miles, total hours, operating speeds, platform hours, fringe hours, operator requirements, and equipment use.

8.5 Recommended Program

As a result of the investigations made, the consultant has concluded that it is feasible and desirable to develop an automated schedule-making and run-cutting procedure applicable to the D. C. Transit operation. Furthermore, the D. C. Transit rerouting, if it is to be implemented, would provide an excellent laboratory for the development of automated scheduling procedures which would have wide application throughout the transit industry. It is recommended that development be carried out through use of an implementation program such as that described in the next several paragraphs. A flow chart of the implementation program is illustrated in Figure 26.

The initial step of an implementation program would involve developing a pilot project in which the first phase of the route revisions would take place. The suggested route implementation phases are given in Appendix D. The scheduling and run-cutting for the first routes would be done manually, presumably by the D. C. Transit schedule department. At the same time, a public relations and information program would be developed to acquaint the public with the new routes and to convince them of the potential benefits.

While the pilot project was being carried out, a detailed analysis would be made of schedule-making and related functions at D. C. Transit preparatory to actual automated system design. Included would be the preparation of cost estimates in terms of elapsed time, man hours and dollars, for continuing with existing techniques, and for converting to an automated procedure. These estimates would allow detailed budgets and time-phasing to be prepared.

Subevaluations would be carried out for the data collection process, summarization process, schedule preparation, run-cutting, and the actual sign-up of operators. A study of public information processes would also be made, including the costs for using the various types of communications media and for preparation of maps and schedules. A determination would then be made of the degree of schedule automation that should be attempted in each of the successive phases of route implementation. In any given phase, the data collection process may be either manual, semi-automated, or fully automated. The summarization of these data might be done by hand or by computer, and schedule preparation and run-cutting might be by hand, computer assisted, or completely computerized.

An important part of the scheduling evaluation would be a study of the union contract to determine all the provisions that must be met in the scheduling process with the objective of ensuring that the end product

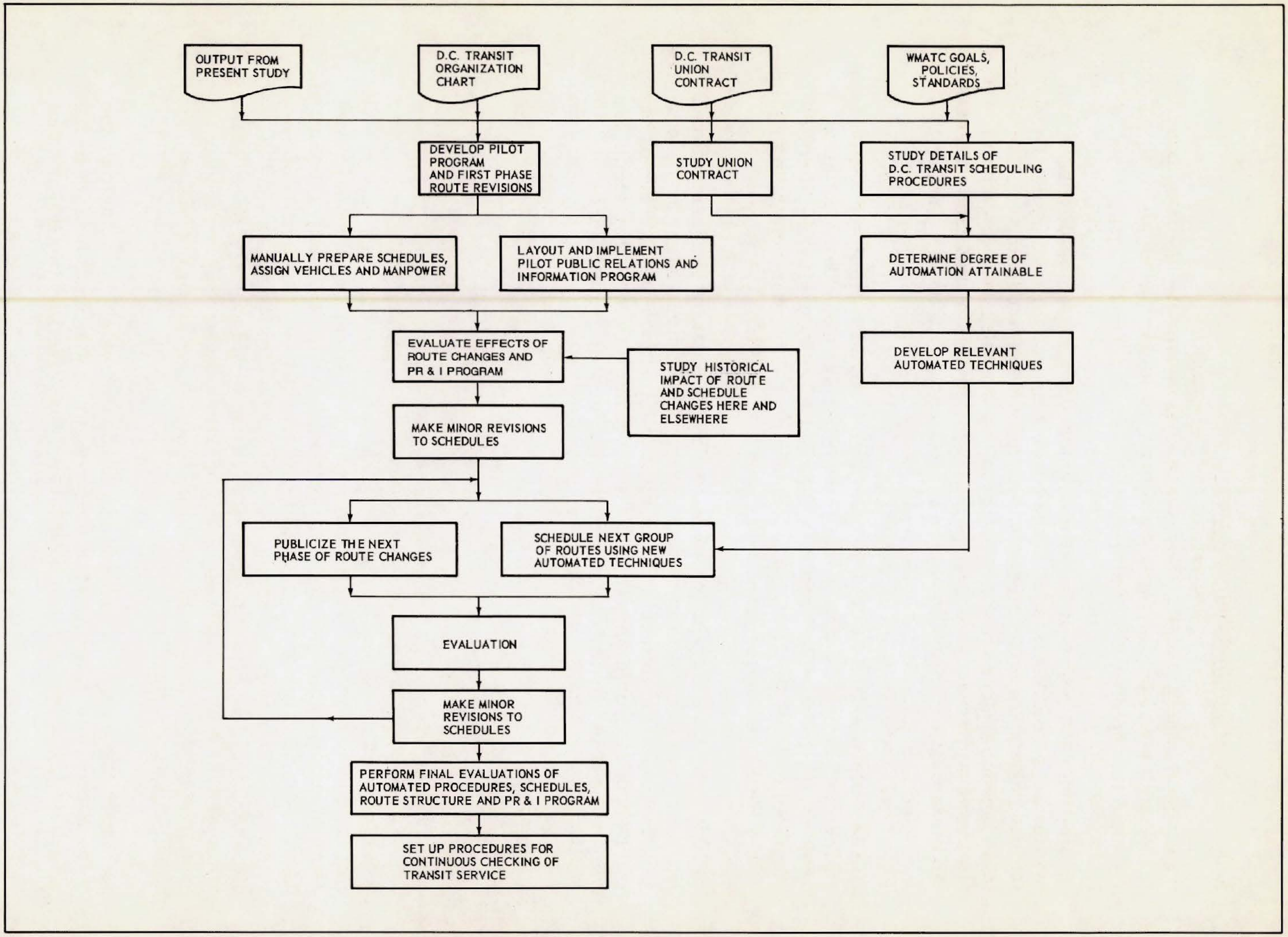

Figure 26 Flow Chart of Implementation Program

would be acceptable to union personnel.

Once the analysis described above was complete, the development of automated subsystems could begin. The first of these subsystems would be used in implementing the second phase of route changes.

Following each phase of route implementation, a series of checks and evaluations would be made. Passenger load counts and driving time surveys would be conducted. With allowance of adequate time for ridership buildup, successive minor revisions of schedules would be undertaken as necessary to match actual patronage. Studies of the public relations and information efforts would be made to evaluate their effect on ridership and public acceptance.

All these evaluations would be used to improve the implementation techniques for each following group of route revisions. The evaluation procedures themselves would be rated and revised with the intent of developing and establishing a productive yet economic continuing evaluation procedure for the transit service.

With completion of the current Mass Transportation Demonstration Project, the next step must be a series of decisions regarding the degree and method of implementation of the recommended D. C. Transit route revisions. It would appear that the opportunity is here for significant improvements in bus transit service and scheduling techniques.

Chapter IX

CONCLUSIONS AND IMPLICATIONS

9.1 General Conclusions

The project demonstrated that it is possible and advantageous to use the HUD Transit Planning Programs for short-range transit operations studies. A new route structure for the D. C. Transit Company operations in Metropolitan Washington has been developed and, through the aid of the programs, found to be a significant improvement over existing operations. Thus the primary objectives of the Demonstration Project have been met, namely, the testing and demonstration of the HUD programs for developing and analyzing immediate action proposals for transit route and schedule improvements and the design of substantive improvements to the routing and scheduling of the D. C. Transit system.

In this final summary, attention will be directed first to a review of findings in respect to the utility of the HUD programs, and secondly, to a recap of the transit planning and operations implications of the project. The findings in respect to the advantages of the revised D. C. Transit route system that has been developed are presented fully in Chapter VI.

9.2 Evaluation of the HUD Programs

The HUD programs have proved to be an effective aid in estimating quickly and efficiently the consequences of short-range transit system revisions. The benefits from extensive systemwide changes have been evaluated for specific areas as well as for the total population of existing transit riders. Although not a phase of this study, the information provided by the programs can be used to identify the extent to which the level of service improvements could generate additional transit patronage.

The HUD programs used in this study were:

AVNET	Build Computer Network
AVPATH	Determine Minimum Paths
AVLOAD	Load Trips on Network
AVPRAS	Summarize Loaded Trips
AVPSUM	Sum Travel Times
AVFMTR	Format Trip Tables
AVTCON	Convert Data Formats
AVMDSP	Interchange Modal Split

Brief outlines of the functions of these programs are given in Appendix B.

The HUD programs, along with other complementary transportation planning programs, form a well-integrated package to enable the comprehensive and rigorous study of urban transit operations. Because of the common data formats employed by the programs, information can be passed directly from one program to another without special manipulations.

The network representations of actual transit operations are easier to prepare and interpret than any preexisting technique available — in large measure because the graphic representation of the coded network is constructed like a detailed, number-coded transit map. The earlier techniques invariably resulted in representations that bore close resemblance to an electronic wiring diagram.

The HUD programs with complementary transportation planning programs provide meaningful and relevant information summaries. For example, program AVPRAS provides estimated ridership volumes in essentially the same format as a traditional boarding and alighting count summary, giving at major points the number of passengers boarding, alighting, and traveling along each line. As discussed in Chapter V, the operating cost calculations provided by the programs proved too oversimplified for use in an operations study, but the related information, such as route travel time and mileages, proved quite useful.

Special mention should be made of the utility of program AVPSUM. This program totals the separate elements of travel time, by category, along each minimum path through a simulated transit system. These summaries have formed the basis of the travel time and transfer comparisons presented in Chapter VII. In essence, the program allows the transit system to be studied from the point of view of the bus riders. Before the development of the HUD programs, it was simply not possible to do much of what is required in such an analysis. One could not, for example, systematically study the number of transfers involved in transit travel or to analyze any individual components of travel time.

The programs can be quite flexible in their application, the prime example in this study being program AVMDSP. Originally intended as a basic program for use in estimating relative transit usage, the program can actually be employed in any number of applications involving traffic zone or trip interchange data. In this study, the program was used to categorize transit riders as to how their level of service would change if the Optimum System were substituted for the Basic System of transit routes and schedules. The values given in Table 5 of Chapter VII were obtained through use of program AVMDSP.

One problem area in the use of the HUD programs for transit operational planning is the approximation which employs a single minimum path to represent how transit riders will travel from one traffic analysis zone to another. Transit riders moving from one zone to another in real life often take several different paths. Sometimes this will be because one rider evaluates the convenience of a given route differently than the next rider. In other cases, it will be because the riders on one side of a traffic analysis zone are nearest to one particular bus line and the riders on the other side are nearest to another.

The principal difficulty caused by the single-path approximation is over-assignment of travel to some bus routes, with corresponding under-assignment of travel to parallel routes. This makes the job of estimating bus route service frequency requirements more difficult, and the analyst using the HUD programs must be prepared to make manual shifts in line volume estimates based on judgment or to use an incremental charge approach such as was followed in this study.

This project has undertaken the first use of the HUD programs for operational studies, and it is to be expected that much would be learned about the program capabilities themselves. As part of the project, a separate memorandum is being furnished to the U. S. Department of Transportation suggesting ways in which the programs might be made even more useful by modifying or expanding the present programs. The need for investigation and development of multiple path transit assignment techniques or some other means of resolving the passenger load estimate difficulties encountered is covered along with numerous suggestions for small modifications that would make the analyst's job easier.

It can be fairly said that the HUD Transit Planning Programs successfully allowed this study to focus on the basic transit passenger movements and needs in the Washington area with productive results. Instead of having to study each bus line out of context to the system, it was possible to observe the important shifts in ridership as new routes were tried out. Once the basic network link data had been prepared, systems could be tested at a rate of about one a month.

Because of the complexity of transportation problems, simulation tools such as the HUD programs are very valuable to the transit planner. The use of these programs provides a learning device. They enable one to determine the importance of the various parts of a transit system, to understand how the system is functioning, and to see the effectiveness of changes in the operation.

9.3 Implications of the Study

More than simply testing or demonstrating the HUD programs, this demonstration project has validated the concept of applying modern transportation planning and systems analysis techniques to the problem of improving urban bus service. As described in Chapter VII, a revised operating plan was developed for the D. C. Transit Company which would reduce transfers and/or significantly reduce travel time for about one third of the system's riders; improving the service to approximately three people for every one disadvantaged. It is estimated that the plan would not increase operating expenses and might enable a reduction.

This study required many inputs other than just the computer programs, including detailed schedule and route information, a viable description of present transit travel in the study area, policy and service standards for public transit in Washington, and cooperation and encouragement from local public officials. These four ingredients are essential for the transit planning process to be effective.

The study has defined certain areas where the transit planning process can be improved. Further research into transit travel characteristics is needed, particularly as it pertains to a rider's choice of route. The results of such investigations could be used to improve the simulation afforded by the transit planning programs and could also contribute directly to understanding what the average patron most desires from his transit service. Also, some modifications to the HUD programs would serve to provide added flexibility, convenience, and analytical capabilities.

Bus systems by nature are supposedly highly flexible; they are not tied to fixed routes by tracks or wires and can supposedly be adjusted easily in response to changes in demand. This project has highlighted the fact that this is not completely true at our present level of planning and scheduling effort and technology. The amount of work inherent in the physical implementation of route changes tends to discourage the undertaking.

The investigation of scheduling and run-cutting techniques has led to a recommended program for developing computerized procedures in order to break the scheduling bottleneck. A suggested implementation phasing has been presented for the revision of D. C. Transit bus routes and the development and implementation of automatic scheduling on the D. C. Transit property, and eventually, other transit systems around the country. The need has been identified for a concurrent public relations program to inform the public of route changes, generate acceptance of them, and monitor the public reaction to them.

Hopefully, this project will serve as the starting point for a successful initiation of improvements to the D. C. Transit bus service in the Washington area, and thus contribute by example to the general improvement of transit operational planning.

Appendix A

ESTIMATION OF OUTBOUND TRIPS

This Appendix outlines the techniques used to develop the synthesized two-way travel data used in this study on the basis of travel time relationships observed in the Baltimore 1962 Home Interview Survey.

The Baltimore survey was chosen after preparing graphs showing the time of occurrence of transit travel in Dalls, Fort Worth, Seattle, Chicago, Detroit, Pittsburgh, San Francisco, Washington, D. C. (1955), and Baltimore (1962). The graphs from all these cities were similar in shape and showed a high level of transit usage during the morning and evening rush hours and considerably lower usage at other times of the day.

The curves from the 1962 home interview travel survey in Baltimore and the 1955 survey in Washington most closely resembled the 1966 Washington postcard survey data in terms of the relative size of the travel peaks and the time separation of the peaks. Since the 1955 Washington survey used trip purpose breakdowns which were not readily comparable to the 1966 postcard survey, the Baltimore data were chosen.

Graphs similar to that shown for home-to-work and work-to-home trips in Figure 3 of the text were plotted and compared for the following additional trip purposes:

- home to shopping
- shopping to home
- home to other
- other to home
- nonhome based

Examination of the graphs indicated that the 1966 Washington inbound transit trip data and the Baltimore two-way travel data could best be matched if the following assumptions were made:

- For each surveyed Washington trip, another trip takes place in the opposite direction

- Persons going to work from home return 9-1/2 hours later

- Persons going shopping from home return three hours later

- Other trips starting from home also return three hours later

- For nonhome based trips before 11:00 a.m., the reverse direction trip takes place two hours later

- For nonhome based trips between 11:00 a.m. and 11:00 p.m., one-half of the component of the reverse direction trip takes place two hours earlier and the other half two hours later

- For nonhome based trips after 11:00 p.m., the reverse direction trip takes place two hours earlier

The final comparison of the two-way travel time curve plotted for the Washington area using the 1966 postcard survey data and preceding assumptions showed the final simulated two-way D. C. Transit work curve to be very close to the Baltimore work trip curve. The synthesized curves for shopping, other, and nonhome based trips had the same general shapes as the Baltimore curves.

Using the stated assumptions, the next task was to translate them into factors that could be used in creating a two-way trip table description of travel for use in studying travel origins and destinations and for assignment to the networks. These factors defined which of the four basic time periods the reverse direction of a set of trips was assumed to take place in, and in what proportion. The four basic time periods used are as follows:

• A.M. Peak	6:00 a.m. to 9:30 a.m.
• Midday Base	9:30 a.m. to 3:00 p.m.
• P.M. Peak	3:00 p.m. to 7:00 p.m.
• Evening Base	7:00 p.m. to 12:00 midnight

These periods were chosen for consistency with the periods used by the Washington Metropolitan Area Transit Commission for varying bus loading standards.

A set of special computer programs were written to reverse the direction of the surveyed trips and distribute them into the four time periods through use of the factors. A total of 140 separate factors were required. The end result was a set of four estimates of two-way travel via bus, one for each time period. Trip tables were constructed from the first two for use in the analysis.

Appendix B

DESCRIPTION OF COMPUTER PROGRAMS USED IN STUDY

1. AVNET — Edits the line and link description of the transit system prepared by the analyst, writes a binary representation of the transit system for use by other computer programs, and produces reports describing and summarizing the network characteristics.

Each link is described by its length and the time required to traverse it. It is also possible to substitute the speed of travel for the time. Each transit line is described by the nodes through which it is routed and its frequency of service in up to four time periods. The start and end points of all transit trips are represented by centroids (see Chapter II). Access to the bus routes is described with walk or auto connector links to nodes along the bus lines.

One of the reports produced includes a transit line summary which gives for each line the route miles, running time, estimated standing time, required vehicles, vehicle-miles, vehicle-hours, and daily costs.

2. AVPATH — Determines and describes minimum time paths between all traffic analysis zones. This can be done using true times or using factored times, thus allowing the inconvenience of certain activities such as walking or transferring to affect the travel paths.

3. AVLOAD — Assigns passenger trips, input in trip table (matrix) form to the minimum time paths and produces a summary of systemwide mode-to-mode transfers and one of the following:

   a. A summary of the loadings on all nontransit links
   b. An output tape with transit line loadings to be read by AVPRAS

4. AVPRAS — Accepts the tape output by AVLOAD and produces a link-by-link equivalent of a boarding, alighting, and load count for each line. A summary lists the total number of passenger-hours, passenger-miles, the peak load, the coded headway, and an estimated revised headway for each line.

5. AVPSUM — Produces zone-to-zone matrices of times from the minimum time paths, with a breakdown possible between times by each travel mode, initial wait time, and transfer time. The number of transfers can also be accumulated.

6. AVMDSP — This program is more generally used in longer range comprehensive transportation planning studies. It accepts the variables used in determining the proportion of trips by each mode and a relationship between these variables, usually expressed as an equation. The output is interzonal trip tables by mode, i. e., highway or transit. Because of certain logical capabilities, this program was used in this study to categorize the trips as to their level of service changes (see Chapter VII).

7. AVFMTR — The purpose of this program is to read up to six tables which contain either zone-to-zone trips or zone-to-zone travel characteristics. Elements are printed for selected origin-destination pairs in juxtaposition.

8. AVTCON — This program performs data set conversions among the following three groups of programs:

a. U. S. Bureau of Public Roads transportation planning programs

b. The IBM 7090/94 HUD transit planning programs

c. The IBM 360 HUD transit planning programs

In this way, compatibility among all existing and future computer programs is maintained.

DETAILS OF COST MODEL CALIBRATION

The initial work in the manual procedures involved combining into groups all lines from the basic network representation of the existing system which could be conveniently interlined. For each group, the total vehicle-hours and vehicle-miles were obtained by multiplying the round-trip running times and route miles by the frequency of the vehicles in the group. Where part of the round trip involved nonrevenue operation, the running time for this segment was computed by assuming the systemwide nonrevenue average speed of fourteen miles per hour.

Any line which ran with the same frequency in each direction was in a group by itself. There were some line groups consisting of only one line for which each vehicle made only one one-way revenue trip during the a.m. peak period and then returned to the garage. The round-trip calculation for this line used two times the one-way route mileage for the route miles, and the one-way running time plus the deadhead driving time for the round-trip running time. The inherent assumption is that the deadhead time and miles calculated are equivalent to the run-on and run-off time and miles. The manual procedures provided estimates of the number of vehicle-hours in an average hour for the a.m. peak and midday base periods. The respective values of 780 and 362 obtained can also be interpreted as the average number of vehicles on the road in each time period. The measures were then compared with similar estimates from D. C. Transit operating data.

The data from D. C. Transit provided the actual number of buses on the road at intervals of 15 minutes. These data were broken down to obtain the number of vehicle-hours for 24 hours (10,367 vehicle-hours), and the average number of buses on the road in each of the following five time periods:

Period	Time	Type
A.M. Peak	6:00 to 9:30 a.m.	Peak
Midday Base	9:30 to 3:00 p.m.	Off-Peak
P.M. Peak	3:00 to 7:00 p.m.	Peak
Evening Base	7:00 to 12:00 a.m.	Off-Peak
Night	12:00 to 6:00 a.m.	Off-Peak

A factor of 3.556 was then calculated as the ratio of the true total a.m. peak period vehicle-hours to the one-hour average estimated in the manual tabulations. This factor was used on Alternative Systems to obtain the full system a. m. peak period vehicle-hours from the one-hour Basic System estimate provided by the manual tabulations. , A similar factor was developed for the midday base period. To obtain vehicle-hour estimates for the other three time periods, it was assumed that the peak period results and the off-peak period results would change in direct proportion to one another.

Each link in the network was coded by using times from the longer trips for the major lines using that link. Although this is not true for trips made across that link at other times of the day, it did provide a built-in layover time factor. The manual procedures yielded speeds of 10. 2 miles per hour in the a. m. peak and 9. 64 miles per hour in the midday base periods, respectively. The higher a. m. peak speeds resulted from more deadheading and express operations in that period. The D. C. Transit twenty-four hour average operating speed for July 1967 was 10. 13 miles per hour. It should be pointed out that for consistency all schedule data were taken from the summer schedules for 1967 and the cost data from July 1967.

For each period, an estimate of the vehicle-miles was obtained by multiplying the vehicle-hours by the appropriate peak speed of 10. 2 miles per hour or off-peak speed of 9. 64 miles per hour. The resultant twenty-four hour total was 99, 780 which could be compared to the actual figure of 101, 425 vehicle-miles supplied by D. C. Transit. Thus a factor of 101, 425 ÷ 99, 780 = 1. 017 was used in computing correct estimates of the twenty-four hour vehicle-mile totals for all systems.

Two other values from the D. C. Transit schedule summaries are also of interest at this point. They are the peak number of vehicles required in the a. m. and the number of base period vehicles. The peak number of a. m. vehicles for July 1967 was 1, 018. As the networks have been prepared to simulate travel for a three-and-one-half hour a. m. peak period, the headways used have been average headways. Thus the peak vehicle requirements are not estimated directly either in the networks or the hand tabulations, but are averages over a three-and-one-half hour period. For the Alternative Systems, a rough idea of the peak vehicle requirements in the a. m. was estimated by applying a factor of 1, 018 ÷ 780 = 1. 305 to the a. m. peak period average vehicles.

The number of base vehicles required by D. C. Transit for July 1967 was 362, which corresponds to the value obtained from the manual tabulations. It should be noted, however, that the average number of vehicles actually required over the whole period from 9:30 a. m. until 3:00 p. m. is 397.

As already mentioned, the AVNET program computes a value for the average number of vehicles required to operate the schedule for each time period coded. The value for the a. m. peak period in the Basic System as computed by AVNET was 781. This compares well with the value of 780 calculated using the manual tabulations. However, it should be pointed out again that these values are computed by using different concepts. When AVNET was run for the Optimum System, the a. m. peak period value computed was 785 vehicles. However, when the manual tabulations were carried out, the resultant figure was 742 vehicles, thus showing the necessity for manual adjustment based on logic.

TABLE C-1: OPERATIONS COMPARISONS OF BASIC AND ALL TEST SYSTEMS

	Optimum Network	Detailed Network 2	Detailed Network 1	Basic Network
A.M. Peak Period Average Vehicles	742	686	779	780
A.M. Peak Period Vehicle-Miles	27,921	26,341	29,750	28,295
A.M. Peak Period Vehicle-Speed (mph)	10.58	10.80	10.74	10.20
Midday Base Period Average-Vehicles	365	334	363	362
Midday Base Period Vehicle-Miles	21,558	20,432	21,353	21,054
Midday Base Period Vehicle-Speed (mph)	9.79	10.14	9.75	9.64
Total Weekday 24-Hour Vehicle-Hours	9,750	8,974	10,009	10,006
Total Weekday 24-Hour Vehicle-Miles	101,574	96,007	105,177	101,425
Typical Weekday 24-Hour Vehicle Speed (mph)	10.42	10.70	10.51	10.14
Typical Weekday 24-Hour Variable Operating Costs	$60,251	$55,917	$62,017	$61,312
Approximate Number of Vehicles Required in A.M. Peak	968	895	1,017	1,018

Appendix D

IMPLEMENTATION PHASES

Table D-1 presents a list of the suggested actions to be taken to various routes in each phase. All the present and recommended new routes are listed in the table.

Several criteria were used in grouping the routes to be changed in each phase. Two of these criteria were to keep each group as small as possible, but also to have as few groups as possible. To meet these criteria and provide flexibility for the implementation program, the five primary phases have been subdivided into smaller groups of routes. In most cases, each of these smaller groups could be implemented independent of the other groups. The chief exception is in Phase 2, where if the smaller groups are used, the Military Road Lines (T5, T5, T6, and T8) would have to undergo changes each time — first, west of Rock Creek Park, second, in the upper 14th Street Corridor, and finally, south of the present terminal of Ivy City.

Two criteria have been used in arriving at the ordering of the phases — importance of the routes and convenience. Line X3 has been included in Phase I(a) as it is estimated to have the greatest impact. It will serve a large number of riders, cut travel times for some of the longer trips by up to 20 minutes, and serve a group of lower income riders who are most dependent on the bus system.

Convenience and continuation of service have affected other group choices. For example, new lines W1, W3, and W7 cannot be instituted after A1 is withdrawn; L2, M6, and M8 should not be removed from Calvert Street, N.W. before N6 and H2 have been instituted through this area.

The Recommended System consists of those basic routes studied in the computer networks as well as the detailed routes as described in Section VII. Three existing detailed route designations have been used for new basic-type routes in the Recommended System and thus do not have asterisks. These are B5, B9, and E1.

TABLE D-1: RECOMMENDED SYSTEM IMPLEMENTATION PHASES

PHASE	DROP EXISTING	REVISE EXISTING	POSSIBLE RESCHEDULE	LOWER FREQUENCY	INSTITUTE NEW SERVICE
1. (a)		X3	37, L3, L7, N1, T7*, T9*	U2, U4, U6, U8, X2	
(b)	P4*	B9, J1, J3, J6, P1, P3*		50, 72, SØ	
2. (a)	30, 36,*D5*,*J7*, T6, T7*, T9	32, 34, 38, D6***, *T1, T2*(02), J4, O4, O5*, O6, T5*, T8	33*, 39, K3**, K9, O8**	37, L3, L7	O7* (Alta Vista), T4
(b)	K8	72, K4, K6, (T4)			
(c)	X5, R6	B2, B4, B8, T8, V4, V6 W4, W5			B5
3. (a)	S9*, X4, Y6, Y8, Z4	70, 72, 74, S7*	71*, Y2, Y4, YØ (Y8), Z1 Z2, Z3, Z6, Z8		75, 76, 77, 78, 79 (Counter flow express) W1, W3, W7
(b)	39, R4	90, 92, 94, H2, H4	D1, D3, H1*, N1, N3*	G2	W1, W3, W7
(c)		E1	E2, E6, G4 (E8)	E4, F9	
4. (a)	A1, A2, A3*, A4, A5*, A6* A8, P9*, R5, R8, V8	54, 60, A9, S2, S3*, S4, S5, S6	50, 52**, 53**, S1		S8
5. (a)	40, 42, D2*, D4*, M4*, M6, M8*, N3*, U2, U4, U6, U8	D3, D6***, J5 (N5), L2, L4, L6, LØ, L8, N2, N4, X1, X2 (X4), XØ, X7**, X9, V4	45, 49*, D1, L1, L3, L5, L7, L9*, Q5*	N1	44, 46, 48, N6, X5, X6, X8

Unchanged Routes (including those just rescheduled)—15**, 17**, 19**, 20, 21*, 33*, 45, 49*, 52**, 53**, 80, 82, 87*, 91*, A7*, B3**, B7*, C1*, C7*, D7*, D8*, E2, E6, F1*, F2, F4*, G4 (E8), G5**, G6, G7*, G8*, G9*, H1*, J8, K3**, K6, K9*, L1*, L5, L9*, O8**, Q1*, Q3*, Q5*, Q7*, Q9*, S1, S3*, T3, U3*, U5**, Y2, Y3*, Y4, Y9*, Z1, Z2, Z3, Z6, Z8

* Detailed Route not included in Optimum System tests.

** Recent D. C. Transit Additional Services

*** Southern portion of D6 Cutback at Sears Store in Phase 2, Rerouted in Phase 5 to complement L2

Note: Designations in brackets are suggested for the existing line immediately preceding.

Appendix E

IMPLEMENTATION INFORMATION

This appendix presents information about the suggested operational revisions of the D. C. Transit System routes in accordance with the conclusions of this study. The tables shown here specify details of the manner in which individual routes should be modified.

Table E-1 gives the line descriptions and schedules for routes on which changes are recommended. The "revenue trips" shown are trips on which revenue passengers are carried as opposed to "deadhead" trips. The trip numbers shown are the number of revenue trips leaving each terminal during the entire period indicated. Thus, for line 30, seventeen trips leave Barney Circle during the three-and-one-half hour a. m. peak period (approximately 12. 5-minute headways), and seven trips leave Washington Circle during the same three and one-half hours (30-minute headways). During the five-and-one-half hour midday base period, eleven trips leave these two terminals (30-minute headways). The "Comments" shown usually refer to routing or type of service.

Table E-2 shows the revenue trips for Connecticut Avenue local service lines in a manner similar to Table E-1.

Table E-3 similarly shows revenue trips for local service on the 16th Street-Anacostia line.

Table E-4 lists the recommendations regarding boarding and alighting restrictions. For lines on which restriction changes are recommended, the locations at which restrictions would be in effect and the points where the lines would stop are given.

TABLE E-1: RECOMMENDED SYSTEM DETAILED LINE DESCRIPTIONS[1/]

Line	Terminal "A" to	Terminal "B"	Revenue Trips: A.M. Peak[2/] From "A"	Revenue Trips: A.M. Peak[2/] From "B"	Revenue Trips: Midday Base[2/] From "A"	Revenue Trips: Midday Base[2/] From "B"	Comments
30	Barney Circle	Washington Circle	17	7	11	11	
32	Friendship Heights	15th P. & Alabama SE	14	22	17	17	
33	Friendship Heights	Southwest Mall	7	-	-	-	
34	Friendship Heights	Naylor & Southern	14	23	16	16	
37	Friendship Heights	Union Station	9	-	-	-	
38	Rosslyn	Barney Circle	18	18	22	22	
40	Mount Pleasant	Union Station	-	-	18	18	
42	Mount Pleasant	18th & D, NE	2	2	-	-	
44	Mount Pleasant	Sheriff & Eastern	16	16	17	17	
45	Mount Pleasant	Bureau of Engraving	11	-	-	-	
45̸	18th & Columbia Road	Bureau of Engraving	2	-	-	-	
46	Mount Pleasant	60th & Blaine	12	12	17	17	
48	Mount Pleasant	46th & Hilltop SE	12	12	11	11	
49	Mount Pleasant	West Potomac Park	7	-	-	-	
50	14th & Colorado	Bureau of Engraving	19	19	33	33	
50̸	14th & Decatur	Bureau of Engraving	23	23	-	-	
52	14th & Colorado	Southern & 6th Streets, SE	10	10	11	11	Via Penn. Ave.; Via Wheeler Road
54	14th & Colorado	Southern & 6th Streets, SE	11	11	11	11	Via M St. SW; Via 4th St. SE
52̸	14th & Colorado	Nichols & Portland, SE	4	4	6	6	Via Penn. Ave.
54̸	14th & Colorado	Nichols & Portland SE	3	3	5	5	Via M St. SW
60	11th & Monroe	Archives	21	31	24	24	
70	Montgomery J.C.	SW Mall	-	-	11	11	
72	Takoma	Wharves (Buzzard Pt.)	3	10	11	11	Operates via Kansas Ave. and 3rd St. SW
74	U.S. Soldiers Home	8th & Market	14	14	17	17	
76	Glenmont	SW Mall	9	9	11	11	
76	8th & Market	Glenmont	10	-	-	-	
73	Four Corners	W. Potomac Park (7 Cor)	4	-	-	-	Revised Silver Rocket in D.C. & Maryland

1/ The following lines should operate with no changes in their schedule, routing, or boarding/alighting restrictions: 20, 21, 82, 87, A7, B7, C7, D7, C1, G6, G8, K7, K9, L1, L3, L5, L7, L9, P9, Q1, Q3, Q5, Q9, R7, S1, S1̸, S3, U5, X7, Y3, Y9, Z1, Z2, Z3, Z6, Z8.

2/ A.M. Peak period: 6:00 - 9:30 a.m.; Midday Base period: 9:30 a.m. - 3:00 p.m.

TABLE E-1: RECOMMENDED SYSTEM DETAILED LINE DESCRIPTIONS (page two)

Line	Terminal "A" to	Terminal "B"	Revenue Trips: A.M. Peak[2] From "A"	Revenue Trips: A.M. Peak[2] From "B"	Revenue Trips: Midday Base[2] From "A"	Revenue Trips: Midday Base[2] From "B"	Comments
75	Gaithersburg	W. Potomac Park (7 Cor.)	1	-	-	-	
75	Rockville	W. Potomac Park (7 Cor.)	8	-	-	-	Revised Silver Rocket in D.C.
75	Montgomery J.C.	W. Potomac Park (7 Cor.)	3	-	-	-	And Maryland. 79 operates
77	Glenmont	W. Potomac Park (7 Cor.)	11	-	-	-	Counterflow
79	W. Potomac Park (7 Cor.)	Rockville	8	-	-	-	
79	W. Potomac Park (7 Cor.)	Montgomery J.C.	4	-	-	-	
80							Frequency unchanged, routing altered
90	23rd & P, NW	23 & P, NW	21	21	33	33	Two-way circumferential
92	23rd & P, NW	Shipley Terrace	7	7	11	11	
92	23rd & P, NW	Navy Yard	7	7	11	11	
94	23rd & P, NW	Stanton Road	7	7	11	11	
A9	Livingston	W. Potomac Park	13	-	-	-	Limited Service
A0	Livingston	Archives	13	-	-	-	
B2	Mount Rainier	Virginia & N. Hampshire	14	14	22	22	
B4	East Pines	Virginia & N. Hampshire	7	7	5	5	
B5	21st Place & M, NE	Virginia & N. Hampshire	7	7	-	-	
B6	Tuxedo	Virginia & N. Hampshire	7	7	6	6	
B9	Carter Barron	13th & Penn. NW	18	-	-	-	Express
D1	Ward Circle	SW Mall	16	-	-	-	Limited Service
D3	Sibley Hospital	SW Mall	6	-	-	-	Limited Service
E1	Langley Park	W. Potomac Park	14	-	-	-	Express, Uses Riggs Road in Maryland
E2	Avondale	Lafayette Square	14	14	6	6	Three inbound morning trips to 14th and Constitution Avenue
E4	University City		5	5	6	6	
E6	Lewisdale		5	5	6	6	
E8	Hyattsville		5	5	6	6	Formerly G4
F2	29th & Randolph NE	9th & Constitution	13	9	13	13	
F4	Avondale	9th & Constitution	15	12	13	13	
F5	Avondale	14th & Constitution	2	-	-	-	
F9	University City	21st & Virginia	3	-	-	-	Express
G5	Highview	Bureau of Engraving	1	-	-	-	Express
G7	9th & Constitution	Highview	1	-	-	-	Express
G9	Highview	21st & Virginia NW	5	-	-	-	Express
G2	Howard University	Georgetown University	28	21	28	28	
G2	New Jersey & P, NW	Wisconsin & P, NW	6	-	-	-	

TABLE E-1: RECOMMENDED SYSTEM DETAILED LINE DESCRIPTIONS (page three)

Line	Terminal "A" to	Terminal "B"	Revenue Trips: A.M. Peak[2/] From "A"	A.M. Peak[2/] From "B"	Midday Base[2/] From "A"	Midday Base[2/] From "B"	Comments
H1	Catholic University	McLean Gardens	1	-	-	-	Express
H2	31st & Douglas NE	Georgetown University	20	20	22	22	
H2̸	Catholic University	Georgetown University	5	-	-	-	
H4	Avondale	Westmoreland Circle	14	14	22	22	
H4̸	Taylor & 13th NE	Tenley Circle	4	-	-	-	
J1	Silver Spring	13th & Pa. NW	12	-	-	-	Limited stop, follows J6 rt. in Maryland
J1̸	Takoma	13th & Pa. NW	10	-	-	-	Limited stop
J1̸	Georgia & Piney Branch	13th & Pa. NW	27	-	-	-	Limited stop
J3	Takoma	8th & Market	13	-	-	-	Limited stop
J4	Wilson Lane & River Road	Beltway Plaza	4	4	5	5	
J6	13th & Penn.	Silver Spring	9	-	11	11	Limited stop
J6̸	13th & Penn.	Takoma	11	-	27	27	Limited stop
J6̸	Petworth	13 & Penn.	11	-	-	-	Limited stop
J8	Wheaton Plaza	Beltway Plaza	3	-	6	-	
K3	N. Hampshire & Eastern	Southwest Mall	2	-	-	-	Limited stop
K4	N. Hampshire & Eastern	12th & F St.	26	4	16	16	Limited stop
K6	White Oak	12th & F St.	11	11	17	17	Limited stop
K6̸	12th & F	14th & Merrimac	6	-	-	-	
N1	Friendship Heights	Southwest Mall	13	-	-	-	
N2	Friendship Heights	Trinidad	14	14	15	15	
N4	Ward Circle	Federal Triangle	14	14	11	11	
N5	Glen Echo	Federal Triangle	7	7	11	11	Formerly J5, should operate local service in off-peak
N6	Macomb & Wisconsin	Ivy City	17	17	22	22	Via 29th Street
N8	Macomb & Wisconsin	Ivy City	17	17	22	22	Via Cleveland Avenue
O2	Rockville	10th & E, NW	7	7	5	5	Same schedule and routing as present
O2̸	Normandy Farm	Tenley Circle	7	7	5	5	T2, south of Tenley Circle follows
O2̸	Cong. C.C.		7	7	5	5	route of O5
O3	10th and E, NW	Montrose & Rockville Pike	2	-	-	-	
O4	Friendship Heights	Rockville	3	-	-	-	Express in D.C., local service in Md.
O4	10th & E, NW	Rockville	2	-	5	-	In Md., follows existing routing of O4
O4	Rockville	10th & E, NW	5	-	5	-	and O6, uses routings of T5, T6, and 78
O4̸	NIH	10th & E	3	-	-	-	to serve Alta Vista, NIH, and Naval
O5	Rockville	Southwest Mall	2	-	-	-	Medical
O6	Montrose & Rockville Pike	10th & E, NW	2	-	-	-	

TABLE E-1: RECOMMENDED SYSTEM DETAILED LINE DESCRIPTIONS (page four)

Line	Terminal "A"	to	Terminal "B"	Revenue Trips: A.M. Peak 2/ From "A"	Revenue Trips: A.M. Peak 2/ From "B"	Revenue Trips: Midday Base 2/ From "A"	Revenue Trips: Midday Base 2/ From "B"	Comments
O6	Rockville		10th & E, NW	3	-	6	-	Express in D.C., local service to Md. In Md., follows existing routing of O4 and O6, uses routings of T5, T6, and 78 to serv Alta Vista, NIH, and Naval Medical
O6	10th & E		Rockville	2	-	6	-	
O6	Friendship Heights		Rockville	5	-	-	-	
O6	Naval Medical		10th & E	3	-	-	-	
O7	10th & E		Alta Vista	2	5	-	-	
P1	5th & Dahlia		W. Potomac Park	16	-	-	-	Limited stop
P3	5th & Dahlia		Lafayette Square	7	-	-	-	Limited stop
S2								For 16th St. local service see Table E-3
S5				-	-	-	-	P.M. only
S7	Wheaton		Federal Triangle	5	-	-	-	Boarding & alighting restrictions unchanged
T1	Leland & Wisconsin		Congressional C.C.	9	9	-	-	Follows present route; no service south of Wisconsin Avenue and Bradley Boulevard
T1	Friendship Heights		Congressional C.C.	-	-	5	5	
T4	Sibley Hospital		Chillum Pl. & 11th NE	7	7	11	11	
T5	Map Service		Chillum Pl & 11th NE	4	4	-	-	Follows existing D5 in Maryland
T8	River Road & Western		Anacostia	7	7	22	22	
T8	Friendship Heights		Anacostia	7	7	-	-	
T6	Friendship Heights		Navy Yard	7	7	-	-	
V4	Bureau of Engraving		Minnesota & E. Capitol	7	7	11	11	
V6	Bureau of Engraving		Anacostia & Blaine NE	14	14	11	11	
W1	Fairfax Village		W. Potomac Park	28	-	-	-	Express
W3	Naylor & Southern		Southwest Mall	21	-	-	-	Express
W4 W5	Anacostia		Silver Spring	14	14	11	11	Between Mt. Rainier & N. Hampshire Ave., it follows present routing of B4
W7	Alabama & Stanton Road		W. Potomac Park	35	-	-	-	Express
X1	Kenilworth & Deane		23rd & K	10	-	-	-	Express
X2	63rd & Dix		Sibley Hospital	21	14	22	22	
X3	63rd & Dix		NIH-Alta Vista	13	-	-	-	Crosstown Express follows O4 or O6 routings in Maryland
X3	63rd & Dix		Friendship Heights	11	-	-	-	" " "
X3	Kenilworth & Deane		Friendship Heights	13	-	-	-	" " "
X4	Mayfair Terrace		Farragut Square	7	7	11	11	
X5	Benning & Southern		23rd & K	10	10	-	-	Express
X6	Eastern & Division NE		Glover Park	11	13	14	14	
X6	Eastern & Division NE		11th & NY	4	-	-	-	

TABLE E-1: RECOMMENDED SYSTEM DETAILED LINE DESCRIPTIONS (page five)

Line	Terminal "A" to	Terminal "B"	Revenue Trips: A.M. Peak[2/] From "A"	Revenue Trips: A.M. Peak[2/] From "B"	Revenue Trips: Midday Base[2/] From "A"	Revenue Trips: Midday Base[2/] From "B"	Comments
X8	54th & C, SE	Glover Park	10	10	11	11	
X8̸	54th & C, SE	11th & NY	2	2	-	-	
X9	63rd & Dix	21st & C, NW	20	20	-	-	Limited stop
Y2	Kensington	Southwest Mall	6	6	-	-	
Y2̸	Kensington	Silver Spring	-	-	9	9	
Y4	Kensington	Silver Spring	6	6	9	9	
Y8	Montgomery Mall	Silver Spring	4	4	5	5	

TABLE E-2: RECOMMENDED SYSTEM

REVENUE TRIPS ON CONNECTICUT AVENUE LOCAL SERVICE

Terminal	Revenue Trips			
	A. M. Peak 1/		Midday Base 1/	
	Northbound Arrivals	Southbound Departures	Northbound Arrivals	Southbound Departures
Garrett Park (L6)	7	7	5	5
Wheaton Plaza (L8)	7	7	6	6
Silver Spring (LØ)	10	8	11	11
Chevy Chase (L4)	-	17	33	33
Oregon & Dogwood (L2)	7	11	-	-
Western & Chestnut (L2)	-	-	11	11
	Southbound /Westbound Arrivals	Northbound /Eastbound Departures	Southbound /Westbound Arrivals	Northbound /Eastbound Departures
Federal Triangle (L6, 8, Ø)	29	2	22	22
Lincoln Square (L2)	-	8	22	22
D. C. General Hospital (L4)	21	21	22	22

1/ A. M. Peak period; 6:00-9:30 A. M.; Midday Base period; 9:30 A. M. - 3:00 P. M.

TABLE E-3: RECOMMENDED SYSTEM

REVENUE TRIPS ON 16th STREET - ANACOSTIA LOCAL SERVICE

Terminal	Revenue Trips			
	A. M. Peak 1/		Midday Base 1/	
	Northbound Arrivals	Southbound Departures	Northbound Arrivals	Southbound Departures
Silver Spring (S2 via Alaska)	35	35	8	8
Georgia & Eastern (S2 via Alaska)	1	5	-	-
Carter Barron				
16th & Euclid	-	10	-	-
16th & Shepherd				
Silver Spring (S4 via 16th St. and Eastern Avenue)	8	8	2	2
Summit Hill (S6)	9	9	2	2
	Southbound Arrivals	Northbound Departures	Southbound Arrivals	Northbound Departures
Federal Triangle (S2)	32	9	6	6
Comp Simms - Cafritz Hosp (S2)	13	18	2	2
Bellevue (S4)	11	11	2	2
Nichols & Joliet (S6)	11	13	2	2

1/ A. M. Peak period 6:00-9:30 A. M.; Midday Base period 9:30 A. M. - 3:00 P. M.

TABLE E-4: RECOMMENDED SYSTEM— BOARDING AND ALIGHTING RESTRICTIONS

The following existing lines should operate with no changes in their boarding and alighting restrictions:

A7, B7, C7, D1, D3, D7, F1, F9, G5, G7, G9, K9, L1, L3, L5, L7, L9, N1, Q1, Q3, Q5, Q7, Q9, S1, S3, S5, S7, X7, X9, 15, 17, 19, 87.

The following lines, listed by their proposed revised designations should operate as follows in the A. M. Peak and Midday Base Periods.

A9—Inbound boarding only from southern terminal to S. Capitol and Eye. Alighting only from Independence and 1st Street SW to West Potomac Park.

B9—Inbound stops for boarding and alighting only at the following stops:

Carter Barron Parking Lot
16th and Decatur NW
14th and Decatur NW
13th and Park NW
13th and Columbia NW
13th and U NW
Logan Circle
All stops south of Massachusetts Avenue

E1—Inbound local service except no stops from North Capitol and Hawaii to Mount Vernon Square.

J1—Inbound local service from Silver Spring to Takoma Terminal. Then stops only (for boarding and alighting) at the following stops:

5th and Butternut NW
Georgia and Piney Branch
13th and Kennedy NW
13th and Park NW
13th and U NW
Logan Circle
All stops south of Massachusetts Avenue

J3—Inbound local service from Takoma Terminal to New Hampshire and Upshur NW. Hence, stops for alighting passengers only at:

Georgia and New Hampshire
Sherman and Columbia
9th and U NW
9th and G NW
Local service south of Massachusetts Avenue

TABLE E-4 (continued)

J6—Local service in both directions north of Upshur and New Hampshire and south of Massachusetts Avenue. Inbound stops for alighting and outbound for boarding only at:

New Hampshire and Georgia
Sherman and Columbia NW
Vermont and U NW
Logan Circle

K3, K4, K6—Local service north of New Hampshire and Upshur. Remainder of service unchanged.

N5—(Formerly J5) could possibly operate local service in off-peak, unchanged in peak.

O2—Operates all day in local service from Tenley Circle to northern terminals. South of Tenley Circle bus stops only (for boarding and alighting) at:

Wisconsin and Massachusetts
All stops east of Florida and Massachusetts

O3, O4, O5, O6, O7—Operate all day in both directions. Local service in Maryland. Stops in D. C. for boarding and alighting only at:

Tenley Circle
Massachusetts and Wisconsin
All stops east of Florida and Massachusetts

P1, P3—Inbound local service from northern terminals to Sherman Circle. Hence, stops for boarding and alighting passengers at:

13th and Park NW
13th and Columbia NW
13th and U NW
All stops from 14th and R to Downtown Terminals

W1, W3, W7—Inbound boarding only south of Navy Yard. No boarding permitted west of Navy Yard.

X1, 5—Inbound local service with a non-stop express portion from Bladensburg and 15th NE to Mount Vernon Square.

X3—Super Crosstown. Westbound in a. m. peak, eastbound in p. m. peak. Stops for boarding and alighting passengers at:

All stops east of Benning Bridge
Bladensburg and H NE
Montello and Florida NE

TABLE E-4(continued)

N. Capitol and Florida NW
Rhode Island and Florida NW
7th and Florida NW
10th and U NW
14th and U NW
16th and Harvard NW
Connecticut and Porter NW
All stops hence to Friendship Heights and NIH

X9—Inbound same as existing. No boarding along Constitution Avenue.

73, 75, 77—Inbound in a.m., outbound in p.m. Local service north of Georgia and Piney Branch. Hence makes some stops as J1 to Federal Triangle. 75 and 77 run local service to West Potomac Park.

79—Counterflow express. Local service from West Potomac Park to 13th and Massachusetts Avenue. Hence stops for boarding and alighting only at:

Logan Circle
Vermont and U
Irving and Sherman NW
Georgia and New Hampshire
Georgia and Kennedy
All stops from Georgia and Piney Branch to Rockville

ALAN M. VOORHEES & ASSOCIATES, INC.

Thomas B. Deen, Vice President in Charge
Richard H. Pratt
Joel A. Miller
Michael D. Shields
David J. Hensing