A PROCEDURAL METHOD FOR EXPRESS BUS-FRINGE PARKING TRANSIT PLANNING

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

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ABSTRACT

The report illustrates a procedural method for planning express bus-fringe parking transit services — a method built upon the findings from previous research, including disaggregate travel choice models and planning guidelines. The methodology addresses the tasks of site selection, demand analysis, and site evaluation. The appropriateness of this subarea planning process is demonstrated in an application to Southside Richmond. The case study is documented so that transportation planners can use it as a guide for employing the procedure.

PREFACE

This report is one of two which record the implementation portion of a three-phased study concerning planning procedures for express bus-fringe parking subarea transit. The first two phases concerned the analysis of the application of existing techniques and the development of design guidelines and choice models, respectively.

The implementation of logit choice models in the demand analysis stage of a complete planning process which focuses on site selection and site evaluation is described here. A jointly published report shows the mechanics of computations with logit choice models, both manual and computerized. The companion document is titled "Applications Manual for Logit Models of Express Bus-Fringe Parking Behavior."

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INTRODUCTION

Recent research conducted by the Virginia Highway and Transportation Research Council produced a theoretical framework for studying express bus-fringe parking lot operations. This research included an analysis of general tripmaker comments and aggregate travel behavior and a set of planning guidelines.[1,2] Mathematical models of the demand for the service as a function of the accessibility of the lot to residential areas, tripmaker characteristics, and the dimensions of alternative travel choices were also developed.[3]

The purpose of this report is to present the findings from the previous research in a format that can easily be followed by transportation planners to develop express bus-fringe parking transit services.

SCOPE

A basic approach to planning express bus-fringe parking transit consists of (1) a feasibility study to determine the appropriateness of this transit service for a specific urban area, (2) the designation of potential fringe parking lot sites, (3) an analysis of the demand for the service expected from each potential fringe parking lot site, (4) a comprehensive evaluation and comparison of the potential lot sites, (5) the development of transit services, and (6) the marketing of the new operation. This report organizes these steps into a generalized planning methodology which uses the following tools and criteria.

1. Characteristics of successful express bus-fringe parking services.

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2. Criteria for locating fringe parking lot sites.
3. Procedures for estimating the auto-transit split and the access mode choice for transit users.
4. Criteria for establishing the transit service.

METHODOLOGY

In the methodology recommended for planning express bus-fringe parking transit the primary tasks include the selection of potential sites, demand analysis, and evaluation of the potential alternative sites. The specification of the appropriate level of transit service for each alternative site must also be considered. The procedural method for developing express bus transit services is shown in Figure 1 and is subsequently demonstrated in an application to alternative sites for three corridors in the Southside Richmond area.

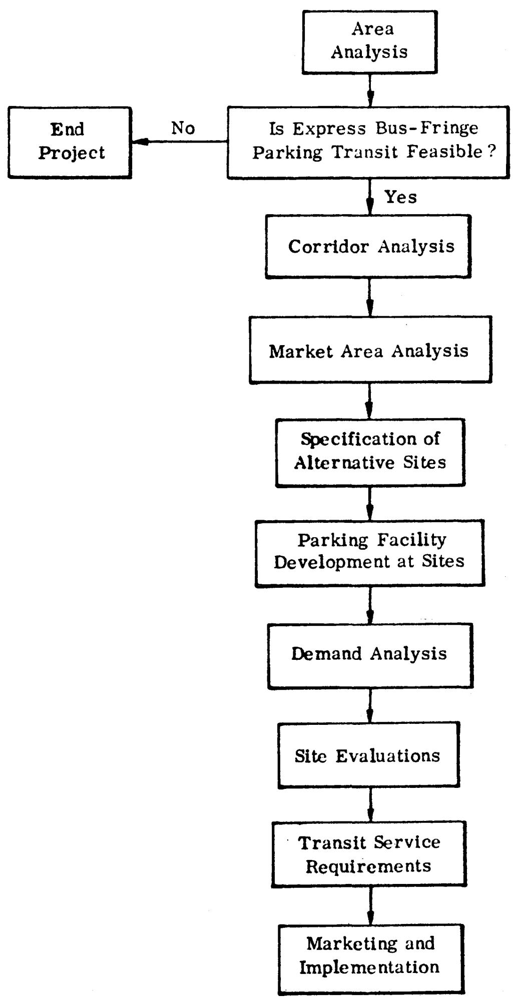

Figure 1. Fringe parking-express bus transit planning process.

Area and Site Analysis

Service Area Analysis

The Study Area

The development of an express bus-fringe parking operation requires an initial investigation to determine its appropriateness for a specific urban area. Studies of previous park-and-ride operations indicate that the success of the operation depends upon the presence of the following transportation conditions within an urban area.

1. Limited Parking Facilities — The demand for parking within the central business district (CBD) exceeds the supply of parking. Such a situation results in high parking costs and in parkers walking significant distances from their autos to their final destinations.

2. Congested Roadways — A significant level of congestion exists on roadways connecting trip endpoints. The high level of congestion would be equivalent to the levels of service D, E, or F as defined in the Highway Capacity Manual.[4]

3. Excessive Trip Making Costs — An excessive cost is incurred by tripmakers between trip endpoints due to high parking fees, high roadway tolls, and any other similar cost penalties acquired during the course of the trip.[5]

The Corridor

Once it has been determined that the urban area transportation conditions potentially support express bus-fringe parking transit, it is necessary to analyze the surrounding area to determine those corridors affording the greatest improvement (e.g., reduction in vehicle miles of travel) to the transportation system by the implementation of the transit service. Corridor is used to define a potential subarea to be serviced by an express bus-fringe parking lot operation. It is defined as a set of opportunities located along and at extreme points of a major transportation link. Areas whose development is influenced by the existence of corridor-related opportunities and/or transportation facilities are also included within this areal specification.[2]

The Market Area

The market area for an express bus-fringe parking operation is defined as the geographic location whose residents are potential users of the service. Market areas should generate a significant number of work trips which are attracted to the destination point. Studies have indicated that express bus-fringe parking operations realize their greatest patronage among people making work trips during the peak hours.[5,6,7]

Home-to-work trips can be estimated for market areas through the use of census tract data. The total number of work trips within a market area can be determined and defined with respect to their destinations. Areas generating a significant number of work trips applicable to the new transit service are candidates for express bus-fringe parking lot operations.[8]

Previous urban area transportation studies can also be used for securing estimates of home-to-work trips attracted from market areas to specific destinations. Since federal law requires that transportation studies within urban areas be continuous and comprehensive, information from this source should be more reliable than census data.

Site Analysis

Lot Location

Fringe parking lots should be located along established travel corridors on which significant numbers of home-to-work trips generated by the market areas can be intercepted. It is desirable for a lot to be situated prior to those points where road congestion begins in order that the transportation system realize a reduction in vehicle miles of travel. If possible, the lot should be placed at a point where access to several destinations is provided by roadway facilities that can accommodate express bus service (i.e., busways, preferential lanes, etc.).[5,6,7]

Lot Accessibility

Wherever the fringe parking lot is located, it is important for it to be highly accessible by the local arterial system. It should provide minimal delays in entry and egress for both buses and automobiles. The ideal location of a park-and-ride facility is at the intersection of a major arterial and a freeway. Such a location provides express buses good freeway access, which is important to minimize bus travel in slow moving arterial traffic and therefore maximize the amount of travel in the faster moving freeway traffic. In considering potential fringe parking lot sites located at points where a number of travel corridors access the CBD and/or major activity center served, travel time studies are required to determine the route with the least time of travel. It is also important that the bus route be free of congestion, and that measures be taken to eliminate any delays.[2,5,7,9,10]

Consideration should be given to locating the fringe parking lot to the right side of the corridor of travel leading into the CBD and/or major activity center, so as to enable a large percentage of the patrons to make right turns when entering it.[7]

Local Transit Demand

A possible indicator of desirable fringe lot locations is on-street parking areas used by commuters in the vicinity of transit stops. Therefore, existing local bus service within a market area should be analyzed to determine if such locations exist. More than likely, an express bus-fringe parking lot operation would draw patronage from the existing local service. The local transit service could be used to supplement the express bus-fringe parking lot operation during off peak hours.[7]

Impact on Adjacent areas

The park-and-ride lot should be placed within an area in which it would be compatible with surrounding land uses, and it should have a minimal environmental impact.

Visibility of Lot

The fringe lot should be visible from the freeway or the major arterial that it is near. Such visibility would enable commuters to observe the system and possibly influence them to use it. Law enforcement officials would be able to observe the lot and prevent vandalism, thus making it a safe place for commuters to leave their cars.[2,11]

Parking Facility Development

An attractive feature of the express bus-fringe parking lot concept is that it can be implemented at a low capital cost through the utilization of existing parking facilities. However, the potential demand for the proposed operation has to be determined to assure that existing facilities will be adequate.

Joint Use Parking Facilities

The objective of the express bus-fringe parking operation is to minimize the capital cost involved in improving transportation facilities. Therefore, the parking lot should be so located as to minimize capital and operational outlays. Accordingly, initial consideration should be given to the joint use of existing parking facilities. Joint use sites should be evaluated with respect to potential for conflict between park-and-ride patrons and other users, local environmental concerns, and existing traffic and travel hazards.

Potential joint use parking facilities are listed below.

Primary Choice Sites

1 — Shopping Plazas or Malls

2 — Movie or Drive-in Theaters

3 — Church or Other Religious Properties

4 — Non-school Municipal or Transit Owned Real Estate

Secondary Choice Sites

1 — Schools

2 — Apartment and/or Townhouse Complexes

3 — Parks and Recreational Facilities

4 — Nightclubs, Restaurants, Motels

Constructed Fringe Parking Lots

Studies of successful park-and-ride operations have identified criteria relating to the design of the parking lot that play an important role in attracting patrons. These criteria are discussed with reference to the list of design considerations given in Table 1.[2,11]

Safe, rapid parking and related movements should be provided to all patrons by the layout of the parking lot. Enough space should be provided to enable park-and-ride and kiss-and-ride functions to be conducted separately. This can be accomplished by making separate lanes available near transit boarding points for discharging and picking up kiss-and-ride patrons. Raised sidewalks should be provided near transit boarding points for pedestrians and patrons waiting to board the bus. A margin of safety is provided by segregating pedestrian and vehicle movements.

Table 1

Fringe Parking Lot Design Considerations

A. Parking Lot Design Considerations
   1. Drainage
   2. Lighting
   3. Aesthetics (Landscaping)
   4. Pavement
   5. Delineated Parking Spaces
   6. Bikeways
   7. Walkways (Pedestrian Access Ways)

B. Traffic Flow
   1. Access Facilities
   2. Egress Facilities
   3. Delineation of Traffic Movements
   4. Direct Links to High Speed Roads
   5. Drop Off Lane for Kiss-and-Ride Patrons

C. Amenities
   1. Shelters
   2. Benches
   3. Newspaper Stands
   4. Telephones
   5. Bicycle Racks

D. Boarding Station
   1. Locate where patrons required to walk a maximum of 1,000 feet (Preferably center of parking lot)
   2. Walking distance greater than 1,000 feet should provide feeder bus service
   3. Kiss-and-ride drop off areas should be located near boarding points
   4. Raised sidewalk should be provided at boarding points

E. Miscellaneous Considerations
   1. Automatic Fare Collection Equipment
   2. Security

Direct links connecting fringe parking lots with high speed roads are sometimes necessary to ensure that neighboring residential areas are not saturated with traffic entering and leaving the lot. The ingress and egress facilities of the lot should be designed to meet the traffic conditions of the peak periods.

Rainfall data should be utilized to estimate runoff so that adequate drainage can be provided to ensure unimpaired use of the lot and protection for adjacent properties. The lots should be paved and the parking spaces marked so that the area can be used to its full potential. Lighting should be adequate for security, but should not affect neighboring land uses. Amenities such as bus shelters, benches, telephones, and newspaper stands enhance the operation. Bicycle racks, access ways for pedestrians, and feeder bus service attract nondrivers.

Lots requiring a fee should have automatic fare collection equipment as part of the effort to keep operating costs at a minimum.

In large lots, the transit boarding points should be located near the center so patrons will not have to walk more than 1,000 feet (305 metres) from their cars. It might be necessary to provide multiple boarding points, multilevel parking, or internal people-mover systems where there is a very large parking demand.

Demand Analysis

Disaggregate Behavioral Models

Kavak and Demetsky have developed disaggregate behavioral models to be used in predicting the demand for a potential express bus-fringe parking operation.[3] These models are disaggregate because the individual is the primary unit of decision, and they are behavioral in character because they are based on theories of individual behavior. These models predict the probabilities of mode choice.[3]

Two demand estimating models were developed from two urbanized areas in Virginia for this planning process; namely the Parham Road model and the Princess Anne Plaza model. The Parham Road express bus-fringe parking lot model was developed from a high income area ($12,000 per family and greater) with the fringe parking lot located 10 miles (16 km) or less from the CBD. The cost of parking within the CBD was relatively high and the frequency of bus service was 15 minutes or less. Use of this model would be restricted to areas having the same characteristics as the Parham Road area.[3]

The Princess Anne Plaza model was developed from a low income market area with the fringe lot located 10 miles (16 km) or more from the CBD and/or major activity center. The cost of parking in the CBD was low (75.9% paid less than 50 cents per day) and the frequency of bus service was 30 minutes or more.(3)

Model Application Procedure

The following process is recommended to be used in applying the travel choice models to each potential site.

1. Establish an approximate market area to be serviced.

2. Delineate the market area into three hypothetical rings as follows:

    Ring 1 consists of traffic zones or census tracts adjacent to the zone or tract containing the potential fringe parking lot.

    Ring 2 consists of zones or census tracts whose minimum travel path to the CBD passes close to the lot and/or the travel time via the fringe parking lot to the CBD is reasonably close to the minimum direct travel time.

    Ring 3 consists of zones or census tracts touching the first and/or second ring but not included in either category.

3. Determine the socioeconomic data listed in Table 2 for the respective market areas by traffic zone or census tract.

4. Determine the transportation data listed in Table 3.

5. Select the appropriate model meeting the criteria of the area under study.*

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*The Parham Road model includes three forecasting models, because of the three hypothetical rings defined earlier for each respective market area. There is an individual model to apply to each respective accessibility group. The Princess Anne Plaza model includes only one model.

(1) Parham Road Model

$$P_b = \frac{e^{G(X)}}{1 + e^{G(X)}}$$

where:

P_b = The probability of choosing the express bus

$G(X)$= A linear function of explanatory variables

The model coefficients vary according to accessibility level as follows.

Accessibility Group 1

$$G(X) = -1.3416\ X_1 + 1.1430\ X_2 + 2.353\ X_3 + 4.2932\ X_4 + 3.3990\ X_5 + 2.3732$$

Accessibility Group 2

$$G(X) = -1.3092\ X_1 - 3.9319\ X_3 + 10.8990\ X_4 + 4.1533\ X_5 + 4.3230$$

Accessibility Group 3

$$G(X) = 1.4384\ X_2 - 4.7517\ X_3 + 8.5377\ X_4 + 4.7783\ X_5$$

(2) Princess Anne Plaza Model

$$P_b = \frac{e^{G(X)}}{1 + e^{G(X)}}$$

$$G(X) = -3.2961\ X_3 + 2.8514\ X_4 + 2.0156\ X_5 + 1.2444$$

6. Determine the potential bus ridership by each accessibility group with respect to sex and age as defined by the independent variables listed in Table 4. This can be accomplished with a hand calculator. Once the probability is determined with respect to the accessibility group, age, and sex the auto-transit split can be obtained by multiplying the percentage of population within the respective group times the total number of home-to-work trips for each zone or census tract. Tables 5 and 6 will assist the planner in accomplishing this step.

7. Determine the potential number of autos to be parked at the potential fringe parking lot utilizing the following submodal split model. Computations are assisted with Table 7.

<u>Submodal Split Model</u>

$$P_b = \frac{e^{G(X)}}{1 + e^{G(X)}}$$

$$G(X) = -5.7146\ X_3 + 3.4796$$

The application of this procedure to each potential lot site provides an estimate of demand for the operation that allows planners to locate lots so as to optimize patronage and best satisfy the planning objectives. It is important to emphasize the part the level of transit service plays in the level of demand expressed for the operation; the better the service, the greater the demand.

The steps of the generalized forecasting procedure for work trips originating at a given zone are summarized in Figure 2.

Table 2

Socioeconomic Data

Data	Source
No. of zonal work trips terminating at destination zone of service (e.g., no. of CBD work trips)	Census or gravity model output
Estimates of captivity to either mode	Preliminary survey
Zonal or census tract sex distribution for home-to-work trips	Census or survey
Zonal or census tract age distribution for home-to-work trips	Census or survey
Zonal or census tract automobile ownership	Census or survey
Zonal or census tract licensed drivers	Census or survey

Table 3

Transportation System Data

Average Cost Per Trip via Each Alternative Mode

- Tolls
- Operating cost of auto (dollars per mile)
- Transit Fare

Average Total Travel Time Per Trip via Each Alternative

- Highway travel times
- Transit running time
- Excess times

Table 4

Independent Variables

X_1 = Sex 0 = Female 1 = Male

X_2 = Age 0 = 25-44 1 = Otherwise

$$X_3 = \frac{\text{Number of Household Autos}}{\text{Number of Licensed Drivers}}$$

$$X_4 = \frac{T_a - T_b}{(T_a + T_b)/2}$$

T_a = Travel Time via Auto

T_b = Travel Time via Bus

$$X_5 = \frac{C_a - C_b}{(C_a + C_b)/2}$$

C_a = Cost of Using Auto

C_b = Cost of Using Bus

Table 5

Potential Fringe Parking Lot Site Variables

Potential Fringe Parking Lot Site	Auto Cost C_a	Transit Cost C_b	Auto Travel Time T_a	Transit Travel Time T_b	X_4 $\frac{T_a - T_b}{(T_a + T_b)/2}$	X_5 $\frac{C_a - C_b}{(C_a + C_b)/2}$

Table 6

Potential Express Bus Ridership

Potential Fringe Parking Lot Site	Accessibility Group	Modal Split (Bus Ridership)				CBD Work Trips (Minus Captive Trips)				Potential Express Bus Ridership				Total Express Bus Ridership (Includes Captive Trips)
		Male		Female		Male		Female		Male		Female		
		25-44	Other	25-44	Other	25-44	Other	25-44	Other	25-44	Other	25-44	Other	

Table 7

Potential Fringe Parkers

Potential Fringe Parking Lot Site	Potential Express Bus Ridership	Submodal Split		Potential Fringe Parkers
		Kiss n'Ride	Park n'Ride	

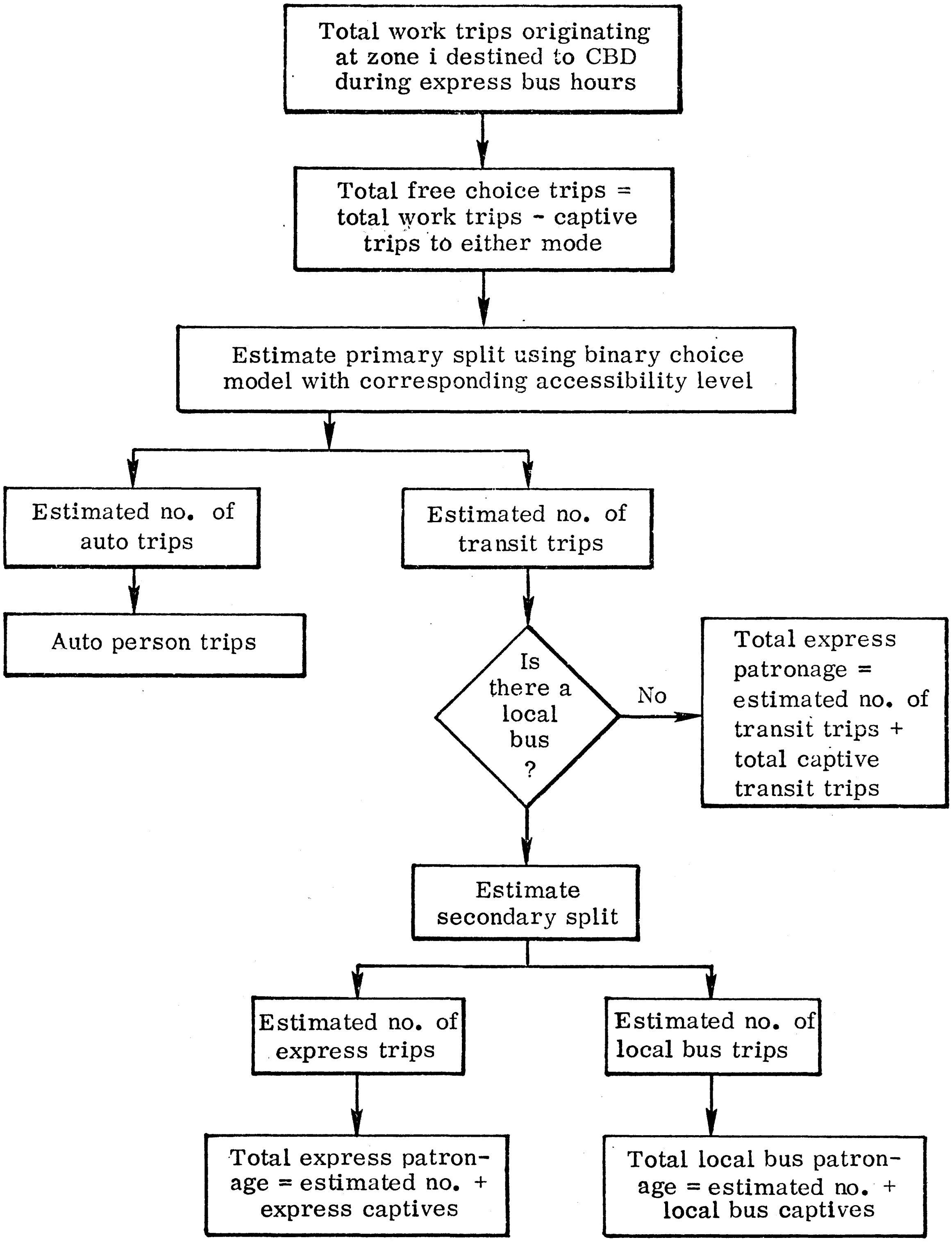

Figure 2. Generalized demand forecasting procedure.

Site Evaluation

The potential sites are next evaluated to compare their ability to support express bus-fringe parking transit services. Specific measures derived from studies of successful express bus-fringe parking lot operations are used here for evaluating potential fringe parking lots. The first four measures cited are required for the implementation of any potential fringe parking lot. Using these measures for a preliminary evaluation, sites unlikely to succeed can be eliminated. Table 8 will assist planners in this preliminary round of evaluation.

Once the preliminary investigation is completed, the remaining potential sites can be evaluated using the measures listed below. Application of table 9 will give each potential site an evaluation rating. Sites can be placed in numerical order with the "best" site having the highest numerical rating.

1. Bus ridership potential

   Utilizing the results obtained in the demand analysis, compare the estimated demand of each site to those of the other sites.

2. Accessibility to major corridor or expressway

   Evaluate each site's accessibility to a major corridor or expressway (having a minimum of traffic impedances) leading into the CBD destination served.

3. Accessibility of autos and buses to potential sites

   Each site should be evaluated with respect to the access and egress of autos and buses.

4. Compatibility with surrounding land use

   The compatibility of each site with surrounding land uses should be reviewed.

5. Modifications of site

   The modifications to be made at the proposed site depend upon whether the lot is to be jointly used or constructed. Reference should be made to the checklist of design criteria found in Table 1.

Table 8

Preliminary Evaluation

Potential Fringe Parking Lot Sites																		
Potential Bus Ridership																		
Accessibility to Major Corridor or Expressway Leading to Destination																		
Accessibility of Autos and Buses to Site																		
Compatibility with Surrounding Land Use																		

Table 9

Evaluation Rating Table

Potential Fringe Parking Lot Sites	Potential Bus Ridership	Access to Major Corridor or Expressway	Access of Autos and Buses to Site	Compatibility with Surrounding Land Use	Observed Fringe Parking Needs	Expansion Potential of Site	Availability of Parking Spaces	Current Status of Site	Size of Site	Modifications of Site	Estimated Cost of Construction	Access to Existing Bus Routes	Requires Major Policy Decision	Total Evaluation Rating
	2 High 1 Medium 0 Low	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Observed 1 Maybe 0 None	2 Yes 1 Maybe 0 None	2 ≥ 100 1 50-100 0 ≤ 50	2 Empty Lot 1 Utilized Lot 0 Vacant Land	2 ≥6 Acres 1 4-6 Acres 0 ≤ 4 Acres	2 None 1 Minor 0 Major	2 0 - $10,000 1 $10,000 - 250,000 0 ≥ $250,000	2 Good 1 Fair 0 Poor	2 No 1 Maybe 0 Yes	

Source: Reference 8.

6. Current status of the site

Potential sites should be reviewed in regard to their current use (empty parking lot, partially filled lot, or vacant land). It is more feasible to utilize an empty parking lot than one that is being used.

7. Size of the site

Each site should be evaluated to assure that adequate space is provided for the movement of buses and cars and the estimated demand.

8. Availability of parking spaces

The utilization of a joint use parking facility requires that it be reviewed with respect to available parking spaces and the estimated demand.

9. Observed fringe parking needs

The demonstrated demand of each site should be compared to that of the other sites.

10. Potential of site expansion

Consideration should be given to future expansion of the site.

11. Accessibility to existing bus routes

An efficient express bus-fringe parking lot operation can be established if there is potential of services being provided by local bus routes during the off peak hours.

12. Estimated cost of construction

The evaluation of each site includes the development of an estimate of capital costs.

13. Required major policy decisions

Major policy decisions should be made early in the planning process so that no major delays occur in the implementation of an express bus-fringe parking lot operation.

Transit Services

Once potential sites for fringe parking lots have been evaluated and the most feasible sites selected, transit services can be developed. The transit service, being a critical part of the express bus-fringe parking operation, warrants a careful analysis with respect to the criteria discussed under the following subheadings.

Transit Service Hours

The express bus-fringe parking operation is particularly appropriate for serving work trips. Accordingly, peak periods should be analyzed to determine the starting and quitting times of the workers to be served so that service can be provided during the full range of hours.

A study conducted by the Institute of Traffic Engineers found most park-and-ride operations providing service in the off peak hours. Transit service should be provided on a limited scale during off peak hours for those people going to or leaving work early or those desiring to use the service for shopping and nonwork trips. Local transit operations should be reviewed to see if their services can be coordinated with the express bus-fringe parking lot operation. Off peak hour services could be provided by local transit.(12)

Peak Hour Headway

The frequency of trips is an important aspect of transit service. The demand for this type of operation will depend greatly upon the headways between vehicles. The shorter the headway, the greater the demand. The following criteria should be referred to when determining the headways required to provide a high level of service.

1. Potential estimated ridership,
2. bus capacity,
3. trip end travel times, and
4. starting and stopping work time range.

Peak hour headways for buses serving the fringe parking lots should be no more than 20 minutes. Studies of such operations have found utilization to decrease rapidly with peak hour headways greater than 20 minutes. Excellent service is provided with headways ranging from 5 to 10 minutes. A 1-hour headway is recommended during the off peak period.(12)

Transit Service Within the Area Served

The express bus-fringe parking lot operation provides bus service to a specific destination. Due to this ideal situation, a high level of service should be provided at the destination. Development of good service requires an analysis of the destination area to determine the relationship between major entry points, street patterns, and employment locations.

Transit service should terminate within a suitable walking distance of major employment locations. It is recommended that bus stops be located at distances ranging from 600 to 800 feet (183 to 244 metres) from major employment destinations. A high level of service requires that waiting times at downtown bus stops not exceed 5 minutes.(13)

Transit Fare

The cost incurred by patrons of the express bus-fringe parking lot operation is a factor in the patronage of the system. The transit fare combined with the cost of parking at the fringe lot (if there is a charge to park) should be less than the cost of using an automobile, i.e., the cost to drive, tolls, downtown parking.(12)

Costs for utilizing the fringe parking lot operation will have to be determined within each metropolitan area. Local governmental agencies and transit companies should develop transit fares that have considered operational costs, governmental subsidies, and the benefits to be realized by implementation of such an operation. Most express bus-fringe parking lot operations have a 5 to 10 cent premium charge for the high level of service they will provide.(12)

Transit Vehicle Requirements

The standard sized bus (8.5 reet wide (2.4 m), 40 feet long (12.2 m), 9.8 feet high (3.0 m) seating 40 to 50 persons should be utilized in providing the transit service. Each bus must have air conditioning and new or refurbished interiors and exteriors, and be capable of good mobility and high speeds. They should be maintained in the best operating order and be kept clean inside and outside. It is recommended that the buses for this special service be delineated from local buses by exterior markings.[13,14]

Marketing

Promotional activities should be provided to educate the public and to stimulate interest in and awareness of the transit service. It is recommended that a minimum of 2% of the revenues taken in be expended for marketing. Marketing functions should be organized and carried on by the transit company providing the service. Promotional activities would include newspaper, radio, and television coverage, logo and color schemes to distinguish the service from local services, the development of simple coded system maps with schedule information on route origin and destination times, and the development of responsive telephone inquiry services.[13]

APPLICATION TO SOUTHSIDE RICHMOND

The study area is located south of the James River and comprises Chesterfield County and a portion of the city of Richmond. The example application of the planning methodology concerns the southwestern quadrant of the Richmond Metropolitan area ,shown in Figure 3. This area is primarily residential in character with some commercial and light industrial establishments. A number of major and minor arterial routes along with one interstate highway traverse the area. Yet a significant amount of traffic congestion exists on all of these major roadways. During the peak hours of the day the major transportation corridors within this area operate at low levels of service. The problem scenario addresses the feasibility of express bus-fringe parking operations for Southside Richmond and the location of suitable lot sites..

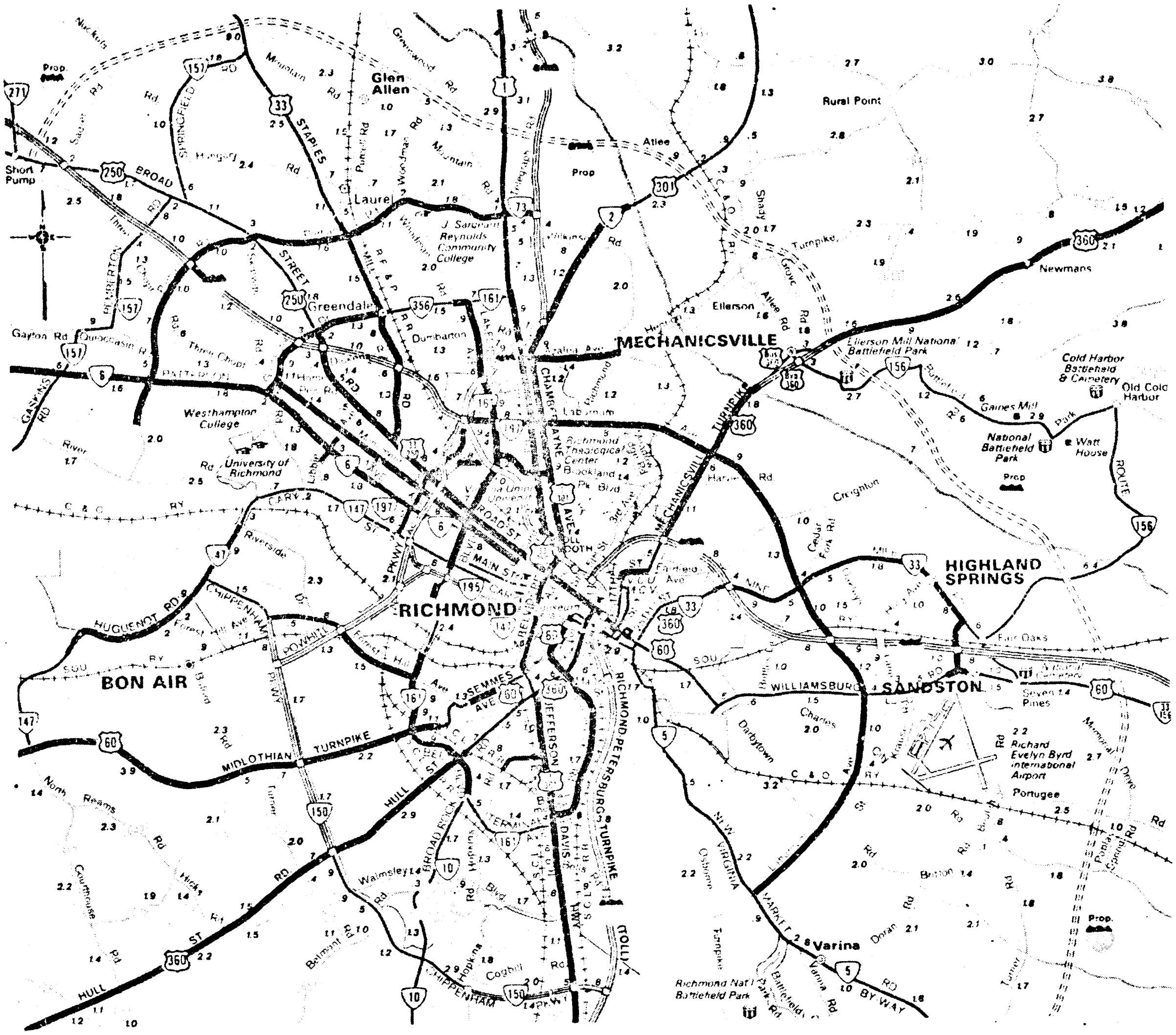

Figure 3. The Richmond Metropolitan area.

Site Selection

Service Area Analysis

The Study Area

The study area is examined to determine whether it can support express bus-fringe parking transit.

Parking Analysis. As of 1972 approximately 20,209 off-street parking spaces were available within the Richmond CBD.(15) According to 1970 census data, approximately 37,157 people worked within the Richmond CBD. It is most likely this figure would have increased by 1972. Therefore, comparing the available parking spaces to the working population, it can be seen that the demand for parking places exceeds the supply. Even with an auto occupancy rate of 1.6 persons per auto, the demand would still be greater than the supply (23,223 autos with 1.6 persons per auto).

High parking costs result from the demand exceeding the supply. A survey of parking costs within the Richmond CBD showed costs ranging from $1.25 per day to $4.00 per day.

Roadway Analysis. The majority of major roadways from Southside Richmond to the CBD operate at level of service D or below during peak hours. Table 10 shows the traffic conditions on the major corridors of travel and estimates of their respective levels of service. Traffic counts were secured from the urban traffic counts for the Richmond Metropolitan Area published annually by the Traffic and Safety Division of the Virginia Department of Highways and Transportation.

Tripmaking Costs. At the present time there are tolls on the Powhite Expressway, the Richmond-Petersburg Turnpike, and the Nickel Bridge which connects Westover Hills Boulevard with Pump House Drive. All three roadways link Southside Richmond with the Richmond CBD. The cost of accessing downtown Richmond via the Powhite and Downtown Expressway is 35 cents. Presently this is the only major corridor operating at a level of service greater than D. The cost of utilizing the Richmond-Petersburg Turnpike and the Nickel Bridge is 10 cents.

The above conditions are favorable to the implementation of an express bus-fringe parking lot operation somewhere in Southside Richmond.

Table 10

Roadway Traffic Conditions

Route	Street Name	Between	24-Hour Traffic Volume	Peak-Hour Traffic Volume	Estimated Level of Service
147	Huguenot Road	Robious Road & Route 60	9,580	960	C
147	Huguenot Road	Robious & Buford Roads	16,130	1,610	D
147	Huguenot Road	Cherokee Road & Chippenham Parkway	21,820	2,180	C
147	Huguenot Road	James River Bridge & Kanawha Drive	26,760	2,680	D
147	River Road	Three Chopt Road & Hampton Hill	22,800	2,280	D
147	Cary Street	Maxwell Road & Lock Lane	12,710	1,270	D
60	Midlothian Turnpike	Huguenot Road & Route 868	13,380	1,340	B
60	Midlothian Turnpike	Huguenot & Robious Roads	14,360	1,440	B
60	Midlothian Turnpike	Buford & Turner Roads	31,660	3,170	D
60	Midlothian Turnpike	Chippenham Parkway & Warwick Road	34,010	3,400	D
60	Midlothian Turnpike	German School & Covington Roads	30,900	3,090	D
60	Midlothian Turnpike	Roanoke & Darden Streets	20,030	2,000	D
60	Roanoke Street	Northrop Avenue & Crutchfield Street	8,190	820	C
60	Forest Hill Avenue	Brookside & Carson Streets	13,140	1,315	D
60	Semmes Avenue	22nd & 24th Streets	20,120	2,000	D
60	Manchester Bridge	N. End of Bridge & Byrd Street	25,170	2,520	D

Table 10 (Continued)

Route	Street Name	Between	24-Hour Traffic Volume	Peak-Hour Traffic Volume	Estimated Level of Service
150	Chippenham Parkway	Routes 95, 1 & 301	10,580	1,060	D
150	Chippenham Parkway	Routes 1, 301 & Hopkins Road	14,170	1,420	D
150	Chippenham Parkway	Hopkins Road & Iron Bridge Road	16,690	1,670	D
150	Chippenham Parkway	Iron Bridge & Belmont Roads	18,390	1,840	D
150	Chippenham Parkway	Walmsley Boulevard & Hull Street	22,970	2,300	D
150	Chippenham Parkway	Hull Street & Midlothian Turnpike	31,670	3,170	C
150	Chippenham Parkway	Midlothian Turnpike & Jahnke Road	38,590	3,860	C
150	Chippenham Parkway	Jahnke Road & Powhite Parkway	32,410	3,240	C
150	Chippenham Parkway	Forest Hill Avenue & Huguenot Road	12,380	1,240	C
360	Hull Street Road	Turner & Elkhardt Roads	23,540	2,350	D
360	Hull Street Road	Route 150 & Warwick Road	22,630	2,260	D
360	Hull Street	Shelby & Woodhaven Drives	24,750	2,480	D
360	Hull Street	34th & 33rd Streets	15,690	1,570	D
360	Hull Street	30th & Playn Streets	14,560	1,460	D
360	Hull Street	24th Street & Pilkington Avenue	21,880	2,190	D

Table 10 (Continued)

Route	Street Name	Between	24-Hour Traffic Volume	Peak-Hour Traffic Volume	Estimated Level of Service
360	Hull Street	12th & 13th Streets	14,120	1,410	D
360	Hull Street	Mayo's Bridge & Dock Street	18,980	1,900	D
95	Richmond-Petersburg Tnpk.	Falling Creek Toll Plaza	35,230	3,520	C
1-301	Jefferson Davis Highway	Curtis Street & Route 613	15,620	1,560	C
1-301	Jefferson Davis Highway	Kingsland Road & Route 613	18,920	1,890	C
1-301	Jefferson Davis Highway	Kingsland & Beulah Roads	20,390	2,040	C
1-301	Jefferson Davis Highway	Watkins & Falling Creek Avenues	27,720	2,770	C
	Bellemeade Road	Lynhaven Avenue & Krouse Street	12,590	1,260	C
	Forest Hill AVenue	31st Street & Broad Rock Road	6,560	660	D
	Forest Hill Avenue	Roanoke & 41st Streets	13,070	1,300	D
	Forest Hill Avenue	Jahnke Road & Westover Hills Blvd.	17,150	1,715	D
	Forest Hill Avenue	Dorchester & Liecester Roads	16,540	1,650	D
	Forest Hill Avenue	Old Westham Road & Melbourne Drive	19,100	1,910	D
	Forest Hill Avenue	Cherokee Road & Chippenham Parkway	18,200	1,820	D
	Forest Hill Avenue	Grantwood Road & Chippenham Parkway	15,490	1,550	D

The Corridor

When an urban area exhibits transportation conditions that warrant the implementation of express bus-fringe parking transit, a corridor study is conducted to determine those corridors which would benefit most with the development of the service.

The Bon Air Corridor. The Bon Air corridor is shown in Figure 4. This area of development runs along Huguenot Road-Cary Street (Route 147), Forest Hills Avenue-Semmes Avenue and the Downtown-Powhite Expressway (Route 195) into Chesterfield County. The portion of the corridor located north of the James River is predominantly a mixture of industrial and commercial areas with the rest of the corridor radiating south of the James River primarily consisting of single family residential units with a scattering of apartment buildings and small shopping areas. Access to the Richmond downtown area is provided by the above noted highway links. During the peak periods of the day these streets are heavily congested, with the exception of the Downtown-Powhite Expressway. The 35-cent toll is the most likely factor in the limited use of the Downtown-Powhite Expressway.

The Route 60 Corridor. The Route 60 corridor, shown in Figure 5, extends approximately 5 miles from the Cloverleaf Mall area into Downtown Richmond. It consists of the Midlothian Turnpike (Route 60) and Hull Street (Route 360). The portion located within the Richmond city limits is predominantly a mixture of industrial and commercial areas with a scattering of residential areas. Land use in Chesterfield County is predominantly residential, with apartment and single family units and some scattered shopping centers.

The Route 1 Corridor. The Route 1 corridor is shown in Figure 6. This spine of development runs along the Jefferson Davis Highway (Route 1-301) and the Richmond-Petersburg Turnpike (Interstate 95). That portion located within the Richmond city limits consists of a mixture of industrial, commercial and residential areas. The part of the corridor in Chesterfield County is primarily residential with a scattering of shopping centers. Access to downtown Richmond is provided by the Jefferson Davis Highway (Route 1-301), the Richmond-Petersburg Turnpike (Interstate 95) and Commerce Road.

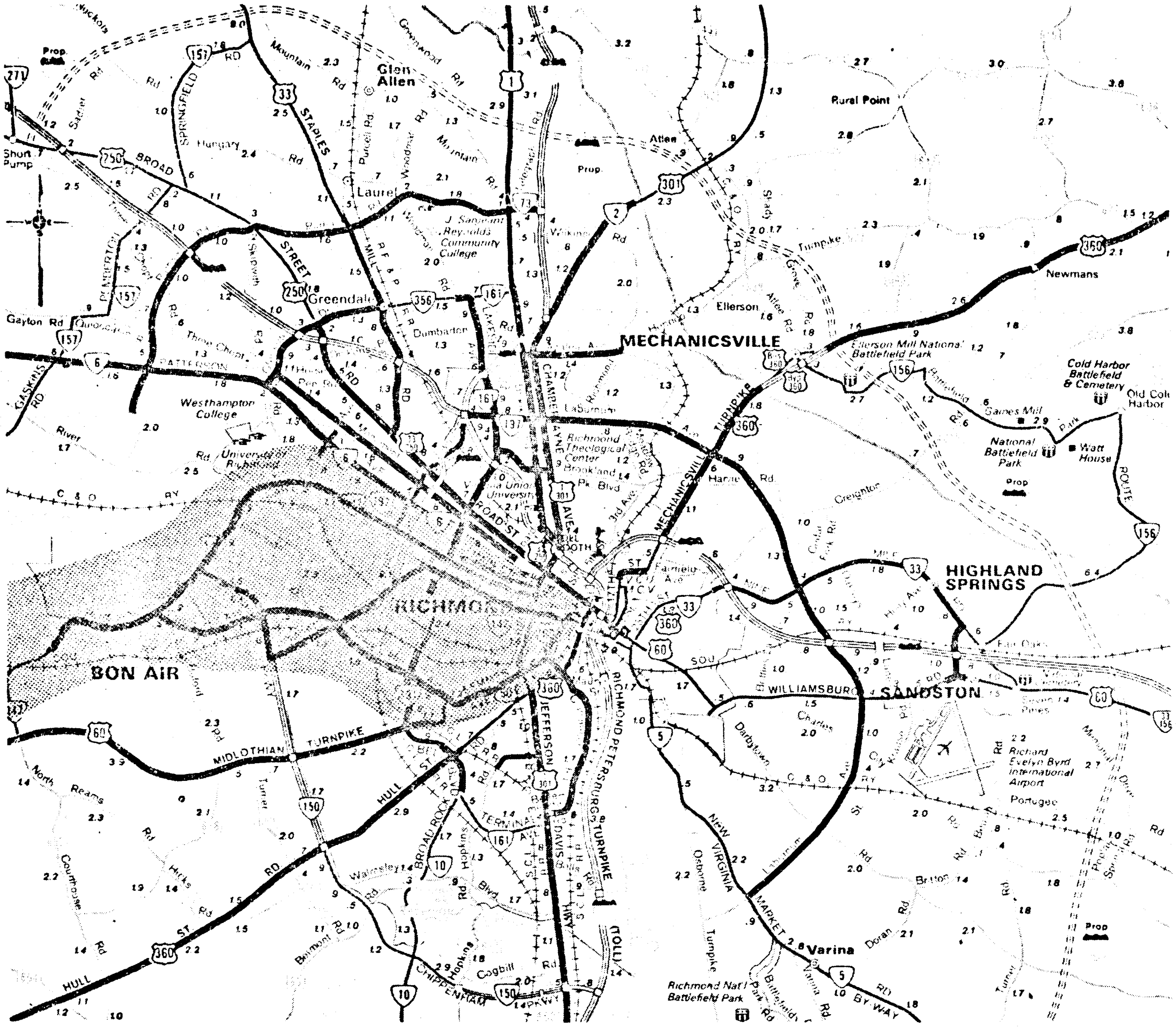

Figure 4. The Bon Air corridor.

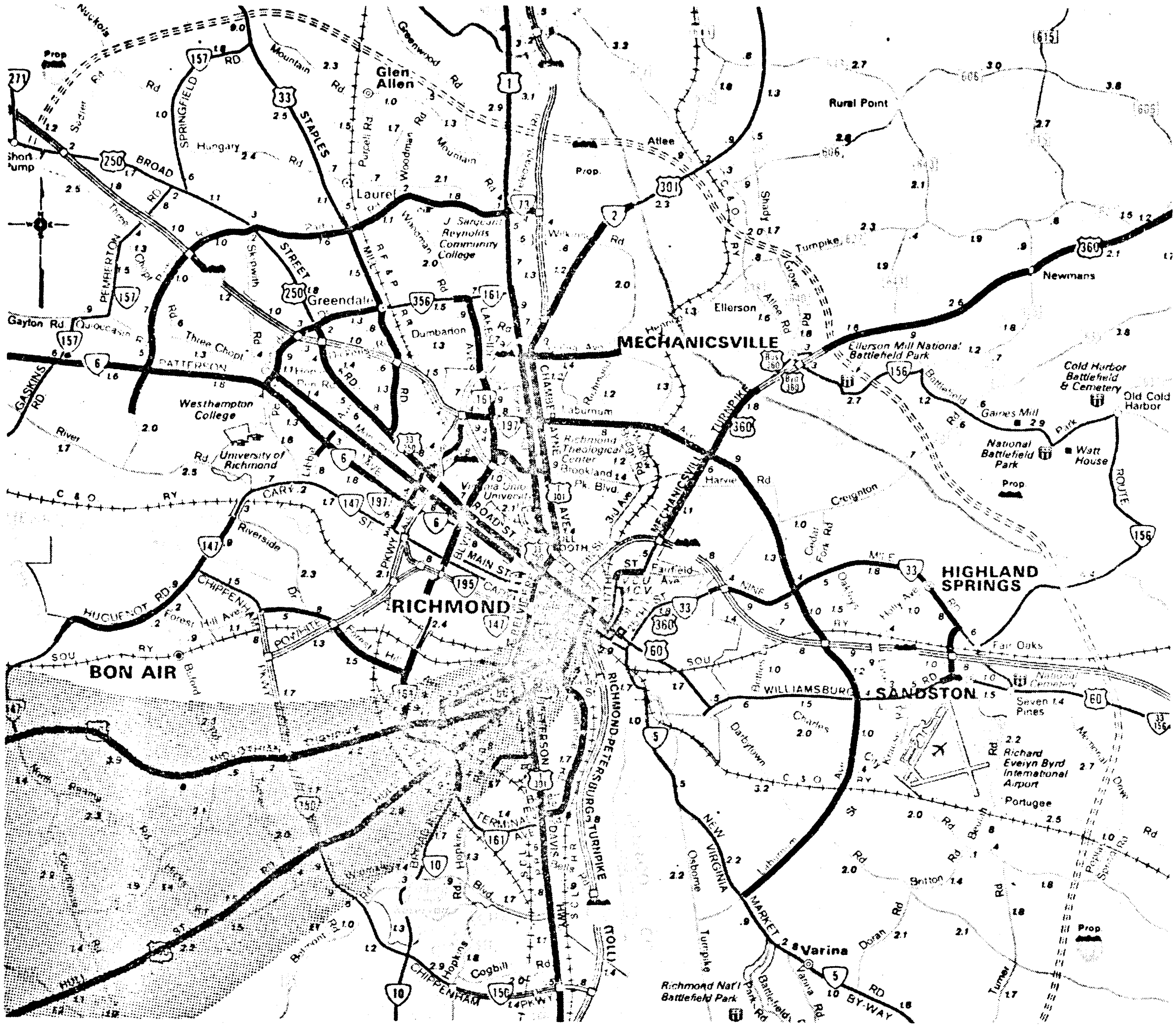

Figure 5. The Route 60 corridor.

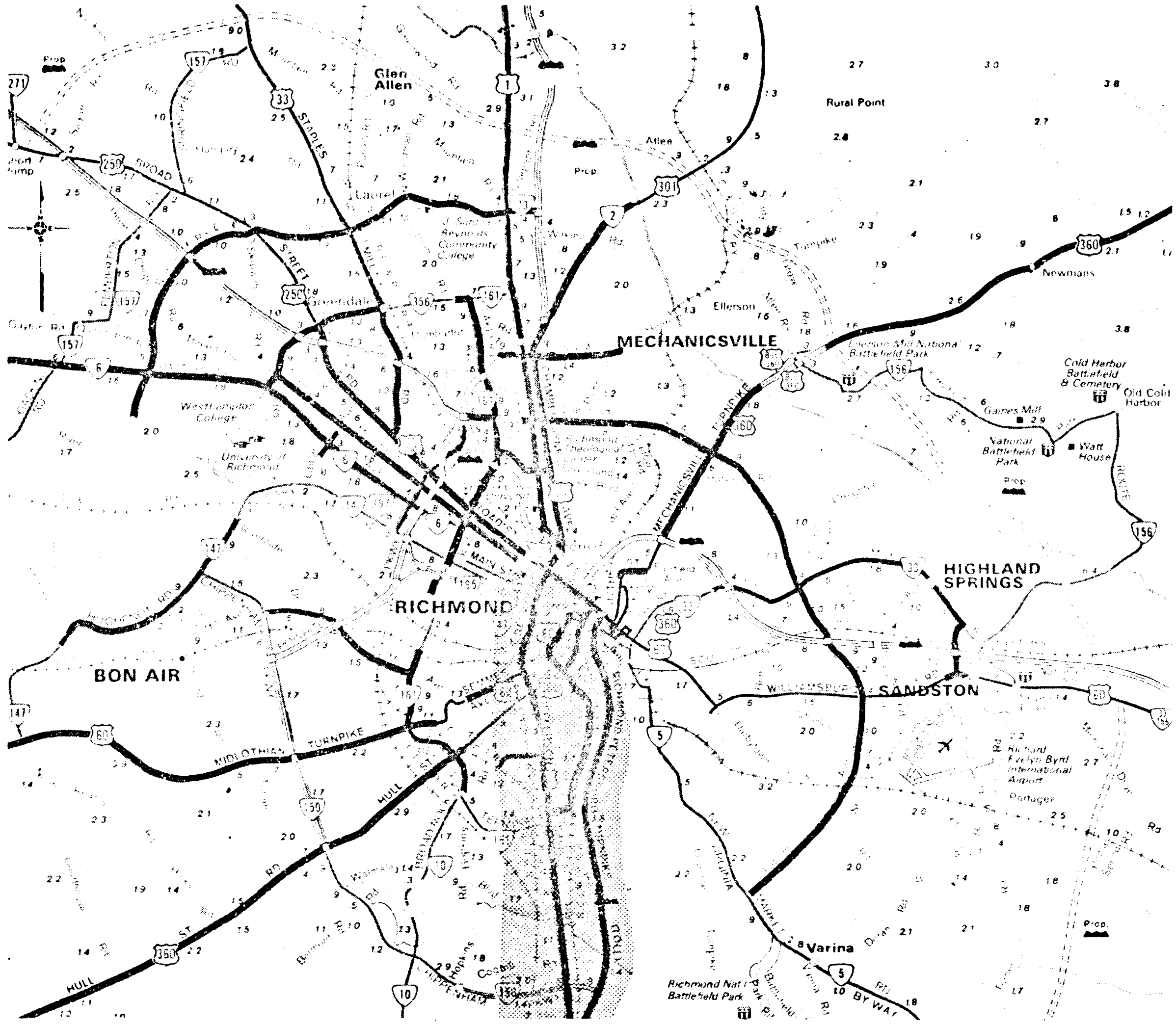

Figure 6. The Route 1 corridor.

The Market Area

Utilizing census data, subareas of the respective corridors are analyzed to determine if a substantial number of home-to-work trips destined to the Richmond CBD exist to warrant the implementation of an express bus-fringe parking lot operation. Figures 7 through 11 show the respective subareas and the census tracts. Tables 11 through 13 list the census tracts and their respective numbers of home-to-work trips destined to the Richmond CBD by individual subarea.

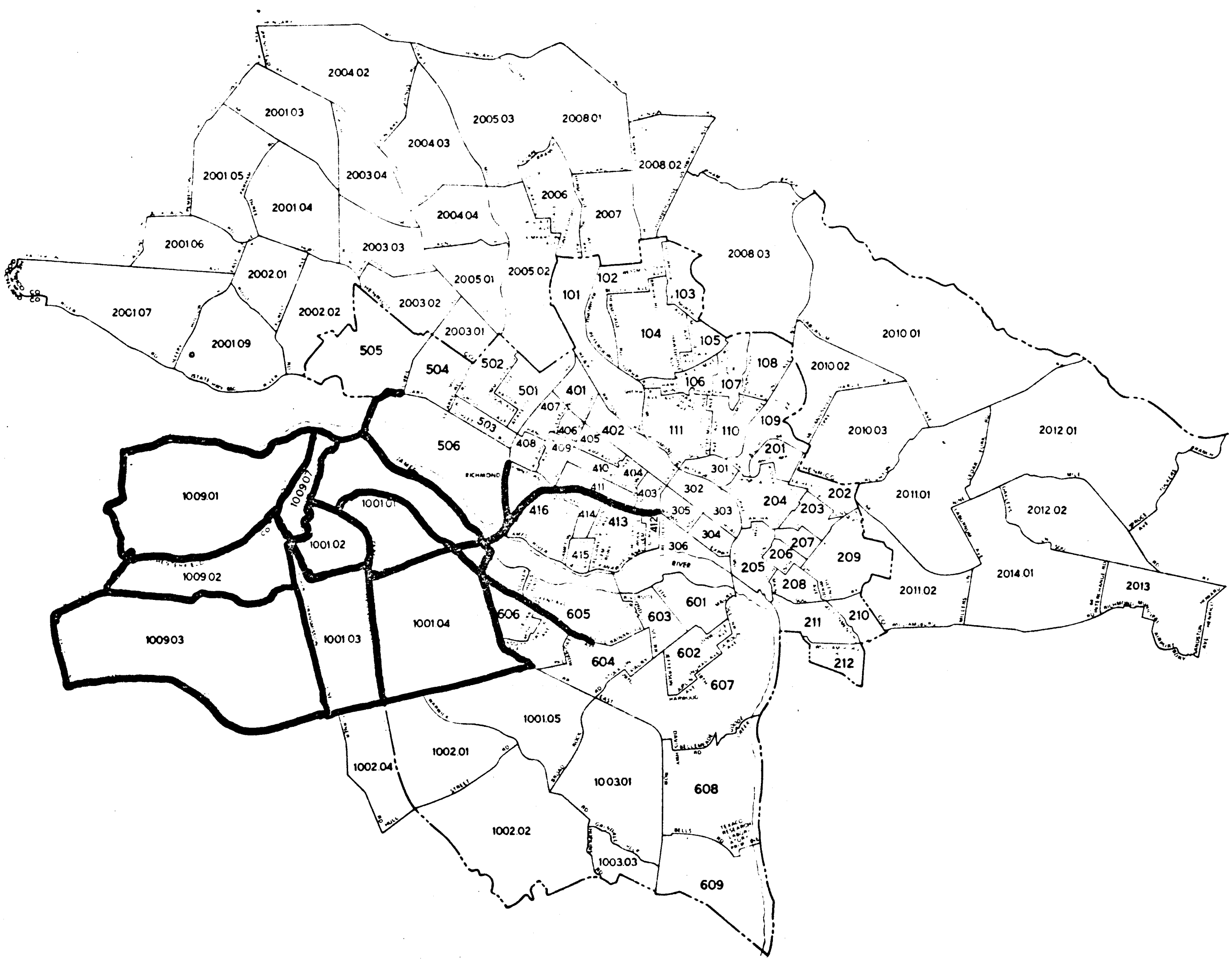

Figure 7. The Bon Air corridor market area.

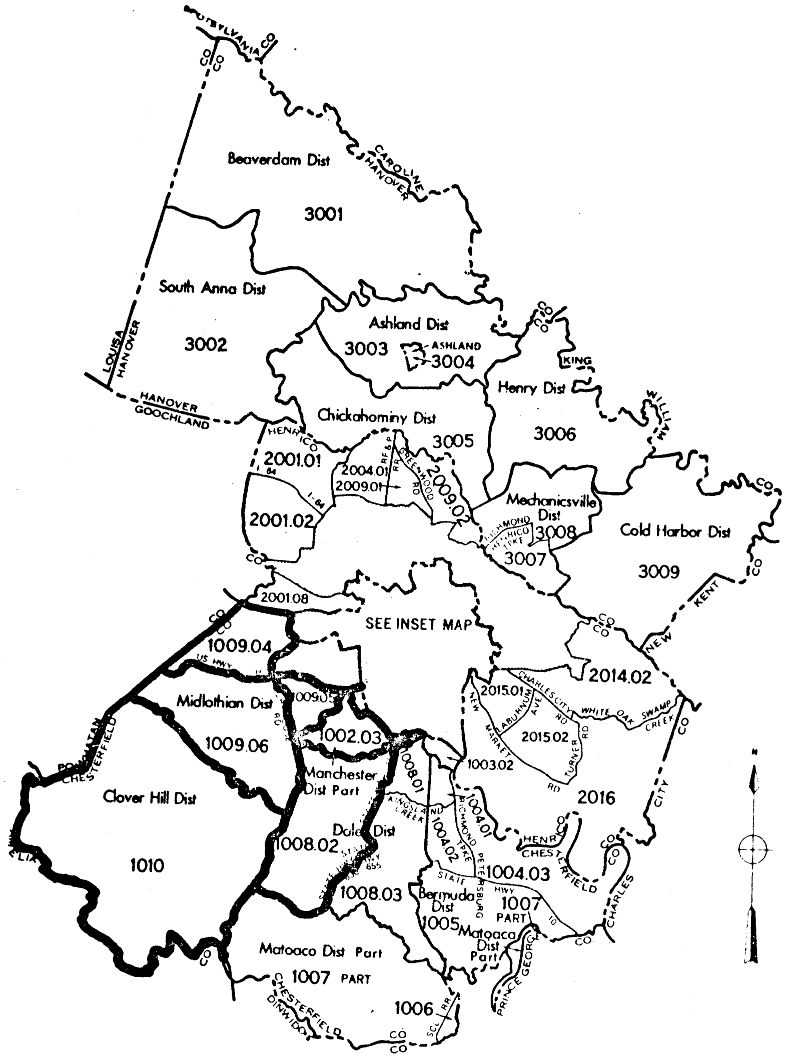

Figure 8. The Route 60 corridor market area.

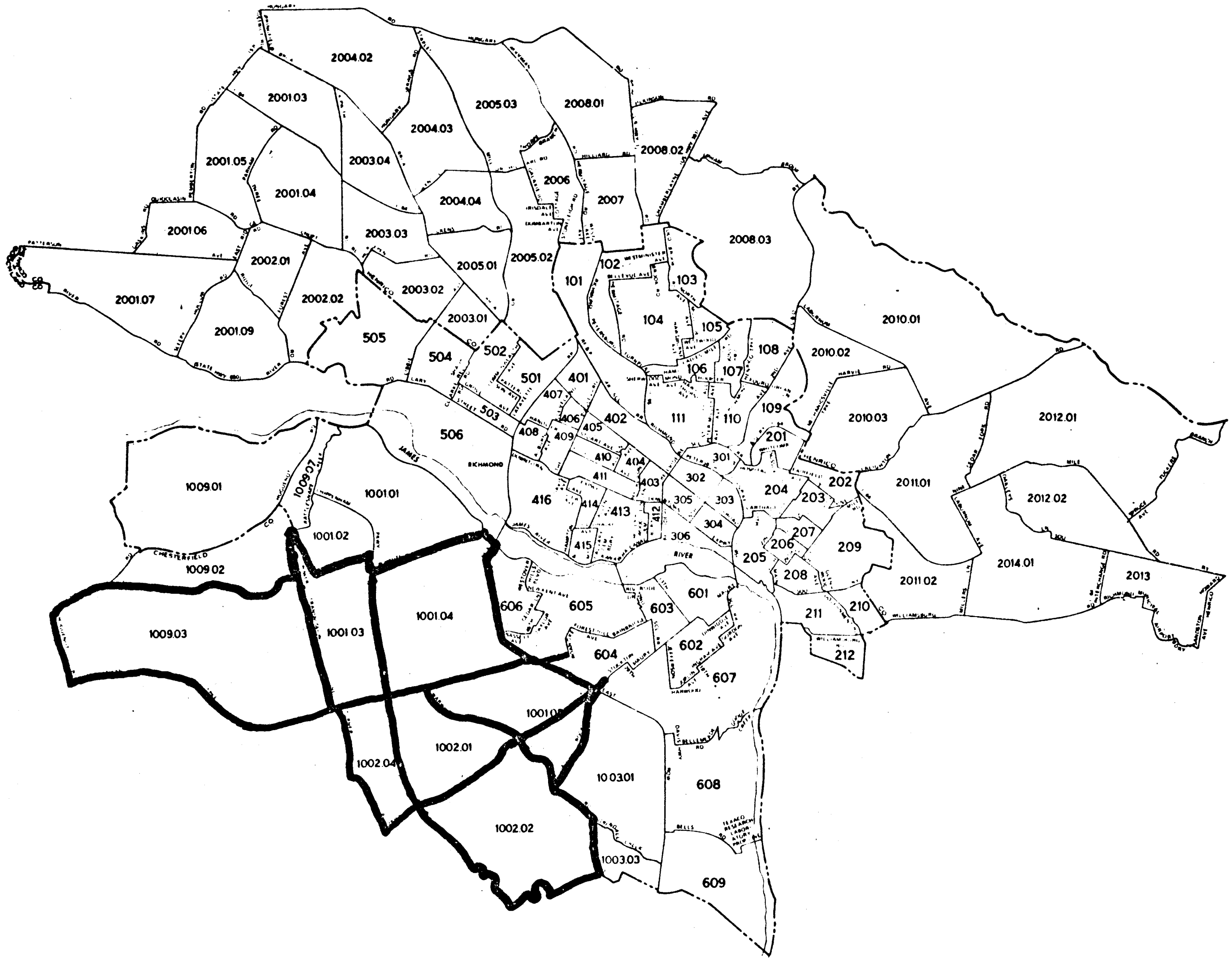

Figure 9. The Route 60 corridor market area.

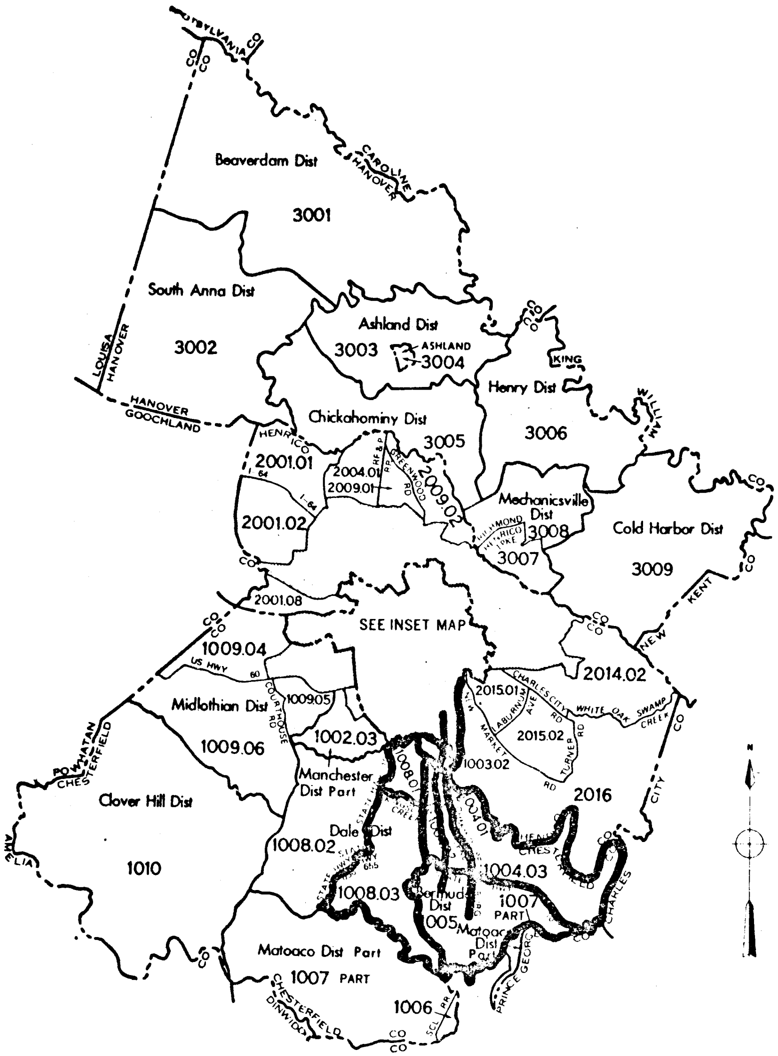

Figure 10. The Route 1 corridor market area.

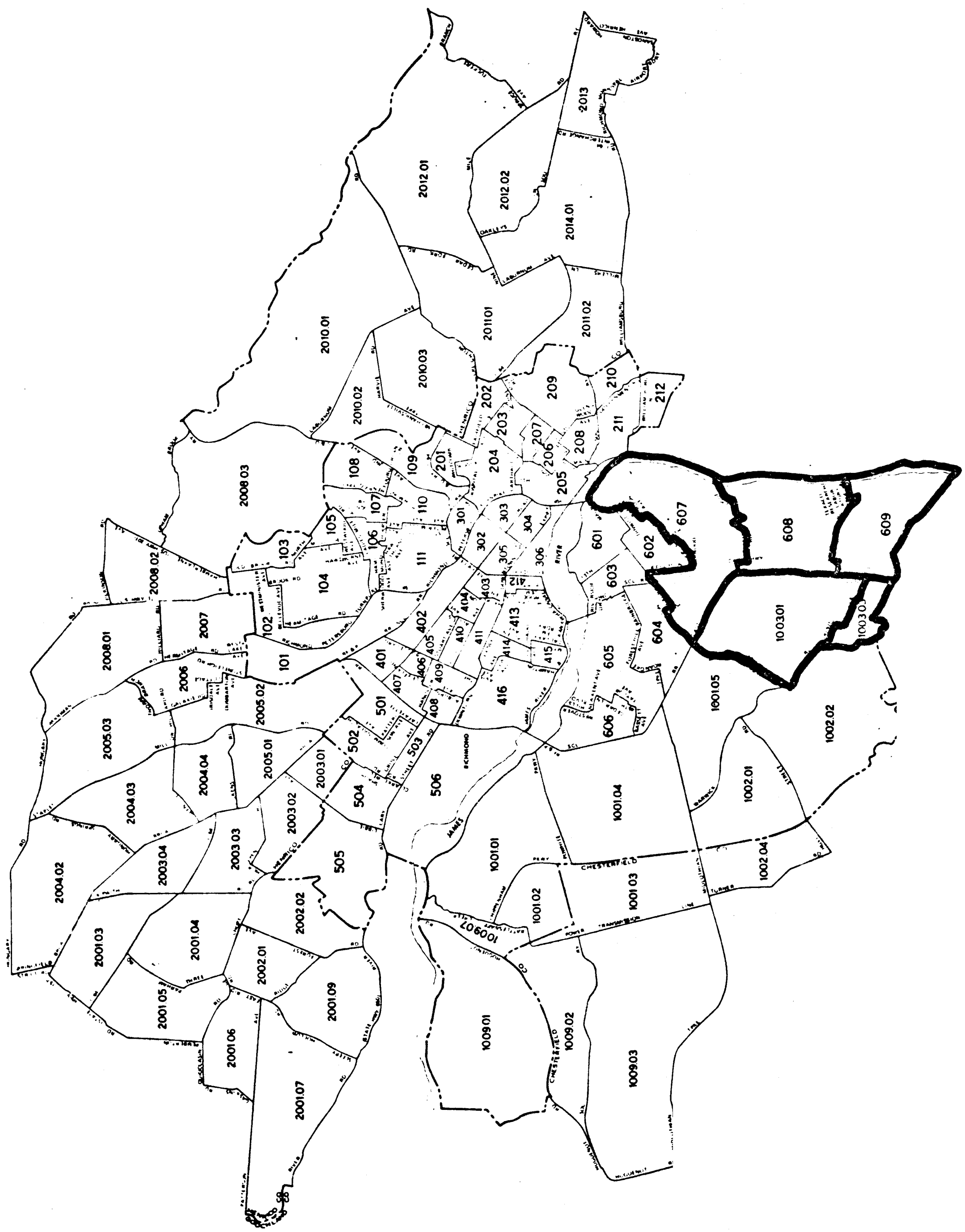

Figure 11. The Route 1 corridor market area.

Table 11

The Bon Air Corridor Market Area

Census Tracts	Home-to-Work Trips
1001.01	445
1001.02	258
1001.03	151
1001.04	891
1009.01	454
1009.02	266
1009.03	388
1009.07	122
TOTAL	2,976 (1970)
	3,362 (1976)

Table 12

The Route 60 Corridor Market Area

Census Tracts	Home-to-Work Trips
1001.03	151
1001.04	891
1001.05	265
1002.01	158
1002.02	785
1002.03	333
1002.04	46
1007	0
1008.02	142
1009.03	388
1009.04	78
1009.05	168
1010	111
TOTAL	2,086 (1970)
	2,372 (1976)

Table 13

The Route 1 Corridor Market Area

Census Tracts	Home-to-Work Trips
607	450
608	503
609	114
1003.01	361
1003.02	141
1003.03	6
1004.01	368
1004.03	40
1005	153
1006	19
1008.01	352
1008.03	84
TOTAL	2,591 (1970)
	2,927 (1976)

Census tract data were obtained from the 1970 census.(16) The population within the Richmond Metropolitan Area has increased by approximately 13% since 1970. Therefore it was assumed that the home-to-work trips have increased approximately 13%.

Each subarea has a sufficient number of home-to-work trips destined to the Richmond CBD to warrant the implementation of an express bus-fringe parking lot operation.

Site Analysis

From aerial photographs of Southside Richmond, potential fringe parking lot sites were selected. These sites were located utilizing characteristics associated with successful fringe parking lots. Accessibility was the dominating factor in locating the potential sites. The majority of the sites were located at points where major corridors leading into the Richmond CBD were highly accessible. The sites selected in this study consisted of vacant land, shopping centers, and schools and are listed by name in Table 14.

Table 14

Potential Fringe Parking Lot Sites

The Bon Air Corridor

1. Chesterfield Mall
2. Huguenot Village Shopping Center
3. Vacant Land
4. Vacant Land
5. Vacant Land
6. Huguenot High School
7. Fred D. Thompson Middle School
8. Vacant Land
9. Vacant Land
10. Forest Hill Shopping Center
11. Vacant Land
12. Bon Air Shopping Center

The Route 60 Corridor

13. Vacant Land
14. Cloverleaf Mall
15. K-Mart
16. Beaufont Mall
17. 60 West Shopping Center
18. Vacant Land
19. Vacant Land
20. Chippenham Mall
21. 360 West Shopping Center
22. Vacant Land
23. Vacant Land
24. Vacant Land

The Route 1 Corridor

25. Vacant Land
26. Meadowdale High School
27. Vacant Land
28. Vacant Land
29. Vacant Land
30. Vacant Land

Demand Analysis

The potential demand for each fringe parking lot site listed in Table 14 is estimated utilizing the Parham Road model.[3] This particular model was selected because of similarities in the socioeconomic data of the Parham Road area and the study area. According to 1970 census data, Southside Richmond consists of a high income market area similar to the Parham Road market area. Due to the majority of the potential sites being located at distances of 10 miles (16 km) or less, the Parham Road model is again more suitable than the other model from the Virginia Beach-Norfolk area.

Market areas were defined for each potential fringe parking lot site according to the guidelines established earlier in this report. The potential market areas for selected sites are listed by traffic zone according to their respective accessibility groups in Table 15.* Table 16 contains data for each traffic zone included within the defined market area of the representative sites.

Richmond CBD work trip interchanges according to sex and age were established with each traffic zone using factors developed from 1970 census data.(16)

*Of the 30 possible sites, examples of the analysis are given for only one from each corridor.

Table 15

Potential Site Market Areas

(Traffic Zones)

Potential Fringe Parking Lot Sites	Accessibility Groups		
	1	2	3
8	184, 185, 186, 187, 188, 189 199, 222, 223	190, 191, 200	197, 198, 201, 221, 224
13	179, 183, 221, 222, 223, 224, 225	187, 199, 200, 201, 202, 219, 220	188, 189, 190, 191, 198, 226
25	234, 235, 236, 242, 243 253, 254	145, 229, 230, 231, 233, 241, 244, 252, 255	239, 240, 245, 250, 251 260, 261, 267

Circled zone is location of lot.

Table 16*

Traffic Zone Data for Selected Site Market Areas

Traffic Zone Number	Accessibility Group	Number of Work Trips to Richmond	Work Trips to Richmond CBD				Population	Licensed Drivers in Zone	Auto Ownership (Zonal)	Household Automobiles / Licensed Drivers
			Male		Female					
			25-44	Other	25-44	Other				
184	1	260	15	22	13	20	491	281	261	.929
185	1	982	55	83	49	74	2,170	1,240	1,082	.871
186	1	758	42	65	38	57	1,733	992	904	.911
187	1	1,490	83	127	74	113	3,038	1,739	1,757	1.01
188	1	616	34	53	31	47	1,405	804	724	.900
189	1	469	26	40	23	35	1,015	581	643	1.106
199	1	1,634	127	106	73	61	4,450	3,241	2,002	.617
222	1	1,149	90	75	51	43	2,860	2,086	1,287	.618
223	1	754	59	49	34	28	1,819	1,325	819	.618
190	2	83	5	7	4	6	154	88	83	.94
191	2	1,420	80	121	70	107	3,834	2,000	1,913	.869
200	2	848	66	55	38	32	2,140	1,551	963	.61
197	3	112	7	7	5	4	200	146	96	.61
198	3	121	7	8	5	5	226	165	102	.61
201	3	61	5	4	3	2	88	64	40	.625
221	3	113	9	7	5	4	210	153	94	.614
224	3	93	7	6	4	3	190	138	85	.615

*16a. Data for Site 8.

Table 16 (Continued)*

Traffic Zone Number	Accessibility Group	Number of Work Trips to Richmond	Work Trips to Richmond CBD				Population	Licensed Drivers in Zone	Auto Ownership (Zonal)	Household Automobiles / Licensed Drivers
			Male		Female					
			25-44	Other	25-44	Other				
179	1	3,363	188	287	167	254	5,369	3,073	2,680	.872
183	1	2,174	122	186	108	164	3,249	1,860	1,392	.748
221	1	113	9	7	5	4	210	153	94	.614
222	1	1,149	90	75	51	43	2,860	2,082	1,287	.618
223	1	754	59	49	34	28	1,819	1,325	819	.618
224	1	93	7	6	4	3	190	138	85	.615
225	1	270	21	18	12	10	538	392	242	.617
187	2	1,490	83	127	74	113	3,036	1,739	1,757	1.01
199	2	1,634	127	106	73	61	4,450	3,241	2,002	.617
200	2	848	66	55	38	32	2,140	1,559	963	.61
201	2	61	5	4	3	2	88	64	40	.625
202	2	377	29	26	17	14	900	655	405	.618
219	2	197	15	13	9	7	450	327	202	.617
220	2	848	66	55	38	32	2,140	1,559	963	.61
188	3	616	34	53	31	47	1,405	804	724	.900
189	3	469	26	40	23	35	1,015	581	643	1.106
190	3	83	5	7	4	6	154	88	83	.94
191	3	1,420	80	121	70	107	3,643	2,200	1,913	.869
198	3	121	9	8	5	5	226	165	102	.61
226	3	174	14	11	8	6	381	277	171	.617

*16b. Data for Site 13.

Table 16 (Continued)*

Traffic Zone Number	Accessibility Group	Number of Work Trips To Richmond	Work Trips to Richmond CBD				Population	Licensed Drivers in Zone	Auto Ownership (Zonal)	Household Automobiles / Licensed Drivers
			Male		Female					
			25-44	Other	25-44	Other				
234	1	296	23	19	13	11	750	546	337	.617
235	1	860	67	56	39	32	2,182	1,589	982	.6179
236	1	569	44	37	25	21	1,550	1,129	982	.870
242	1	1,004	78	65	45	37	3,000	2,185	1,350	.618
243	1	32	2	2	1	2	144	105	65	.619
253	1	57	4	4	2	2	148	108	67	.620
254	1	73	6	5	3	3	170	124	76	.613
145	2	729	41	62	36	55	1,623	929	722	.777
229	2	405	31	26	18	15	826	602	372	.617
230	2	503	31	33	22	19	1,600	1,165	720	.617
231	2	155	12	10	7	6	442	322	199	.618
233	2	125	10	8	5	5	340	248	153	.617
241	2	743	58	48	33	28	2,277	1,658	1,025	.618
244	2	587	46	38	26	22	1,825	1,329	822	.618
252	2	108	8	7	5	4	349	254	157	.618
255	2	93	7	6	4	3	340	248	153	.617
239	3	29	2	2	1	1	35	25	16	.64
240	3	23	2	1	1	1	19	14	9	.643
245	3	366	29	24	16	14	900	655	405	.618
250	3	71	6	5	3	3	240	175	108	.617
251	3	1,294	100	84	58	48	2,260	1,646	1,017	.618
260	3	59	5	4	3	2	170	124	76	.613
261	3	108	8	7	5	4	340	248	153	.617
267	3	97	8	6	4	4	400	291	180	.618

*16c. Data for Site 25.

These factors were developed in the following manner.

I. City of Richmond Traffic Zones

A. People living in the city of Richmond and

1. Working in the city of Richmond — 77,032
2. Working in the Richmond CBD — 20,545

$$\text{FACTOR} = \frac{20,545}{77,032} = .26670$$

B. Sex Distribution

1. Males living and working in the city of Richmond — 40,858

$$\text{FACTOR} = \frac{40,858}{77,032} = .53040$$

2. Females living and working in the city of Richmond — 36,174

$$\text{FACTOR} = \frac{36,174}{77,032} = .46959$$

C. Age Distribution

1. Age 25-44 living and working in the city of Richmond — 30,535

$$\text{FACTOR} = \frac{30,535}{77,032} = .39639$$

2. Age (Otherwise) living and working in the city of Richmond — 46,497

$$\text{FACTOR} = \frac{46,497}{77,032} = .60360$$

D. Richmond CBD work trip factors by sex and age

1. Males (25-44) living in the city of Richmond and working in the Richmond CBD

FACTOR = .26670 X .53040 X .39639 = .056

Males (Otherwise) living in the city of Richmond and working in the Richmond CBD

FACTOR = .26670 X .53040 X .60360 = .0854

2. Females (25-44) living in the city of Richmond and working in the Richmond CBD

FACTOR = .26670 X .46959 X .39639 = .0496

Females (Otherwise) living in the city of Richmond and working in the Richmond CBD

FACTOR = .26670 X .46959 X .60360 = .0755

II. Chesterfield County Traffic Zones

A. People living in Chesterfield County and

1. Working in the city of Richmond — 14,222
2. Working in the Richmond CBD — 3,199

FACTOR $= \frac{3,199}{14,222} = .22493$

B. Sex Distribution

1. Males living in Chesterfield County and working in the city of Richmond — 9,031

FACTOR $= \frac{9,031}{14,222} = .6350$

2. Females living in Chesterfield County and working in the city of Richmond — 5,191

FACTOR $= \frac{5,191}{14,222} = .3649$

C. Age Distribution

1. Age 25-44 living in Chesterfield County and working in the city of Richmond — 7,759

FACTOR $= \frac{7,759}{14,222} = .54556$

2. Age (Otherwise) living in Chesterfield County and working inthe city of Richmond — 6,463

FACTOR $= \frac{6,463}{14,222} = .4544$

D. Richmond CBD Work Trip Factors By Sex and Age

1. Males (25-44) living in Chesterfield County and working in the Richmond CBD

FACTOR = .22493 X .6350 X .54556 = .0779

Males (Otherwise) living in Chesterfield County and working in the Richmond CBD

FACTOR = .22493 X .6350 X .4544 = .064907

2. Females (25-44) living in Chesterfield County and working in the Richmond CBD

FACTOR = .22493 X .3649 X .54556 = .04477

Females (Otherwise) living in Chesterfield County and working in the Richmond CBD

FACTOR = .22493 X .3649 X .4544 = .037298

Traffic zone home-to-work trips destined to the city of Richmond were obtained from the Transportation Planning Division of the Virginia Department of Highways and Transportation. These trips were developed in 1970 as part of the 3-C Planning Process. These work trip volumes from Richmond traffic zones were multiplied by the factors developed for the city of Richmond, while work trips from Chesterfield County traffic zones were multiplied by the factors developed for Chesterfield County.

Accordingly, the following example shows how work trip volumes are developed for traffic zones with respect to sex and age.

Traffic Zone		Work Trips to City of Richmond
221	(Chesterfield)	113
179	(Richmond)	3,363

FACTORS

	Male		Female	
	Age 25-44	Other	Age 25-44	Other
Chesterfield	.0779	.064907	.04477	.037298
CBD Work Trips (221) 113	9	7	5	4
Richmond	.056	.0854	.0496	.0755
CBD Work Trips (179) 3,363	188	287	167	254

Licensed drivers by traffic zone were established using factors developed from data provided by the Virginia Division of Motor Vehicles and the 1970 census. The development of these factors is shown below.

1. Licensed drivers in Chesterfield County — 68,422
   Chesterfield County population — 93,944

$$\text{FACTOR} = \frac{68{,}422}{93{,}944} = .72832$$

2. Licensed drivers in the city of Richmond — 131,197
   city of Richmond population — 229,165

$$\text{FACTOR} = \frac{131{,}197}{229{,}165} = .5725$$

Multiplying traffic zone populations by the developed factors resulted in an estimate of the number of licensed drivers per traffic zone. It was necessary to assure that the proper factor (Chesterfield County or City of Richmond) was used with the correct traffic zone. Auto ownership by traffic zone was available from data supplied by the Transportation Planning Division of the Virginia Department of Highways and Transportation.

Before the model could be used to estimate the potential demand of the fringe parking lot sites a number of assumptions were made. These assumptions are listed below.

1. Captivity to either mode. Estimates of mode captivity were assumed to equal estimates found in the Parham Road express bus fringe parking lot case study because of its similarity with the area under study.

   Bus Captivity (CBD Work Trips) — 3%
   Auto Captivity (CBD Work Trips) — 40%

2. Operating cost of auto. An estimate of 4 cents per mile was used because of its utilization in the Parham Road express bus fringe parking lot case study. Distances between potential sites and the Richmond CBD were obtained from a Richmond map using a scale. These are shown in Table 17.

3. Transit fare. A 50 cents fare was established as the cost to ride the express bus from potential fringe parking lot sites in Southside Richmond into the CBD.

Table 17

Distances Between Potential Sites
and the Richmond CBD
(1 mi. = 1.6 km)

Potential Site	Distance (Miles)
1	10.80
2	10.80
3	8.68
4	8.12
5	7.56
6	7.00
7	7.00
8	6.72
9	7.28
10	6.55
11	7.28
12	7.67
13	6.10
14	6.61
15	6.61
16	6.61
17	7.56
18	7.95
19	8.12
20	6.16
21	6.88
22	7.17
23	7.28
24	7.00
25	8.40
26	8.88
27	7.20
28	7.20
29	7.20
30	7.44

4. Travel times. Highway travel times for both the automobile and the bus were assumed to be the same because of the lack of bus priority measures on corridors leading into the Richmond CBD from Southside Richmond. Interzonal travel times between potential site and CBD traffic zones were used as highway travel times. Before the highway travel times could be used in model application they had to be converted to peak hour travel times. The travel times for each prospective site are shown in Table 18.

5. Excess times. Excess times were assumed to be the following:

   a. Drive into lot and park — 3 minutes

   b. Walk to boarding point — 1 minute

   c. Wait for bus (bus frequency or headway) — 5 minutes

   d. Drive onto main route — 1 minute

   Total Excess Time = 10 minutes

6. Parking cost. The average cost of parking within the Richmond CBD was assumed to be 75 cents per day.

The travel cost and time variables for the respective modes (X_4 and X_5) were determined for each potential site. The specific values of these variables used for the representative sites are shown in Table 19.

Once values for X_4 and X_5 were obtained the Parham Road model was applied. The Parham Road model estimated the potential express bus ridership for each potential fringe parking lot. To determine the number of autos that would be parked at potential sites it was necessary to apply the submodal split model. The results of both of these applications can be found in Table 20. Examples of the work sheet computation for the Parham Road model application to the representative sites are given in Table 21, while the work sheets for the submodal split model appear in Table 22. An example of the application is shown below for site 8.

Table 18

Highway Travel Times

Potential Site	Interzonal Travel Times	Peak Hour Travel Times
1	20.50	23.80
2	20.50	23.80
3	20.50	23.80
4	21.00	24.41
5	20.50	23.80
6	18.50	21.50
7	18.50	21.50
8	18.50	21.50
9	16.50	19.20
10	15.00	17.40
11	15.00	17.40
12	20.50	23.80
13	15.50	18.00
14	15.50	18.00
15	14.50	16.80
16	15.50	18.00
17	16.25	18.85
18	16.75	19.50
19	18.50	21.50
20	15.00	17.40
21	19.00	22.00
22	19.75	22.90
23	19.75	22.90
24	16.50	19.15
25	19.00	22.00
26	18.50	21.50
27	15.75	18.30
28	15.50	18.00
29	15.25	17.70
30	15.50	18:00

Note: Interzonal travel times were multiplied by 1.16 to obtain the peak hour travel times. Pignataro(17) cited that the total time lost through delay for city wide travel was 15% to 16% of the normal travel time.

Table 19

Choice Model Variable Values for Selected Fringe Parking Sites

Site	Automobile Travel Cost C_a	Transit Cost C_b	Automobile Travel Time T_a	Transit Travel Time T_b	$\frac{T_a - T_b}{(T_a + T_b)/2}$ X_4	$\frac{C_a - C_b}{(C_a + C_b)/2}$ X_5
8	$1.29	$1.00	43.0	61.0	-.34615	.25327
13	$1.24	$1.00	36.0	54.0	-.40000	-.21428
25	$1.42	$1.00	44.0	62.0	-.33962	.34710

Table 20

Potential Express Bus Ridership
and Fringe Parkers

Potential Site	Express Bus Ridership	Fringe Parkers
1	634	67
2	666	70
3	717	75
4	630	66
5	989	104
6	965	101
7	965	101
8	1,211	127
9	826	87
10	1,200	126
11	1,160	122
12	940	99
13	1,137	120
14	597	63
15	1,097	115
16	1,108	116
17	551	58
18	703	74
19	668	70
20	791	83
21	581	61
22	517	54
23	532	56
24	895	94
25	457	48
26	430	45
27	370	39
28	410	43
29	415	44
30	440	46

Note: These estimates are from an application of the gravity model for 1970 work trips. The figures will be substantially greater for 1976 because of rapid residential growth in Chesterfield County.

Table 21

Potential Express Bus Ridership

Site	Accessibility Group	Modal Split (Bus Ridership)				CBD Work Trips (Less Captive Trips)				Potential Express Bus Ridership				Total Express Bus Trips Including Captives
		Male		Female		Male		Female		Male		Female		
		25-44	Other	25-44	Other	25-44	Other	25-44	Other	25-44	Other	25-44	Other	
8	1	.9318	.9772	.9837	.9939	15 303	19 353	12 220	14 272	232	344	216	270	1,172
	2	.0255	.0255	.0886	.0886	5 86	5 104	3 64	4 83	2	3	6	7	35
	3	.0063	.0260	.0063	.0260	1 22	1 18	1 13	1 10	0	0	0	0	4
13	1	.7190	.8890	.9070	.9684	15 283	19 358	11 217	15 288	203	318	197	279	1,137
	2	.0123	.0123	.0440	.0440	12 223	12 220	8 143	8 148	3	3	6	6	58
	3	.0008	.0033	.0008	.0033	5 96	12 136	4 80	6 117	0	0	0	0	22
25	1	.9557	.9859	.9884	.9960	7 128	6 107	4 73	3 62	123	105	72	62	382
	2	.0400	.0400	.1338	.1338	8 144	7 136	5 89	5 89	6	5	12	12	60
	3	.0024	.0104	.0024	.0104	5 91	4 76	3 52	2 44	0	1	0	0	15

The estimated captive bus riders are circled.

Table 22

Estimates of Lot Access Travel Choices for Selected Sites

Site	Potential Bus Ridership	Probability of Kiss n' ride	Probability of Park n' ride	Number Parkers
8	1,211	.8947	.1052	127
13	1,137	.8947	.1052	120
25	457	.8947	.1052	48

Accessibility Group 1

$$G(X) = -1.3416\ X_1 + 1.1430\ X_2 + 2.353\ X_3 + 4.2932\ X_4 +$$

$$3.3990\ X_5 + 2.3732$$

X_1 = Sex (0 = Female; 1 = Male)

X_2 = Age (0 = 25-44; 1 = Otherwise)

$$X_3 = \frac{\text{Number of Household Autos}}{\text{Number of Licensed Drivers}}$$

<u>For potential fringe parking lot site 8</u>:

Female, $X_1 = 0$

Age 25-44, $X_2 = 0$

$\frac{\text{Number of Household Autos}}{\text{Number of Licensed Drivers}} = X_3 = 1$ (For this example application, the X3 variable was rounded to 1.)

$X_4 = .34615$

$X_5 = .25327$

$$G(X) = -1.3416\ (0) + 1.143\ (0) + 2.353\ (1) + 4.2932(-.34619) +$$

$$3.3990\ (.25327) + 2.3732 = 4.10097$$

$$G(X) = 4.10097$$

$$e^{G(X)} = e^{4.10097} = 60.398$$

$$P_b = \frac{e^{G(X)}}{1 + e^{G(X)}} = \frac{60.398}{61.398} = 0.9837$$

Note: To obtain an accurate modal split estimate the X_3 value should be used. In this study that would mean applying the models to each traffic zone. For this study the X_3 variable was rounded to 1 because of its value ranging from .60 to 1.2.

Therefore 98% of the female (age 25-44) work trips bound for the Richmond CBD from traffic zones within Accessibility Group 1 would be potential express bus riders at this fringe parking lot site. Before multiplying the CBD work trips by the probability of bus ridership it was necessary to subtract the number of work trips captive to the auto and the bus. It was assumed that 43% of the Richmond CBD work trips from the study area were captive.

The estimated demands for the potential fringe parking lot sites were determined using 1970 census data and 1970 home-to-work trips. It was assumed that the estimated demand for each of these sites would have increased by approximately 13% between 1970 and the present. This assumption is based upon the increase in population for the Richmond Metropolitan Area during the period between 1970 and 1976.

An example of calculating express bus ridership estimates is shown below for site 8:

Accessibility Group 1

a. Female

b. Age 25-44

c. $\frac{\text{Household Autos}}{\text{Licensed Drivers}} = 1.0$

CBD Work Trips for this Category	386
Auto and Transit Captive Trips	-166
Potential Express Bus Ridership	220

220 X .9837 =	216	Express bus ridership estimates
+	12	Captive transit trips
	228	Express bus riders for female, age 25-44 in Accessibility Group 1.

Site Evaluation

The potential fringe parking lot sites for Southside Richmond are evaluated utilizing Tables 8 and 9. Each site met the required criteria in the preliminary evaluation (Table 23).

Southside Richmond appeared to be an excellent area to implement an express bus-fringe parking lot operation because of the substantial number of home-to-work trips destined to the Richmond CBD that was shown by the demand analysis. Each site had an estimated demand of at least 400 express bus users. Because of this significant demand at each site, joint use sites rated low in the final evaluation because of their limited parking supply.

The final evaluation regarding each measure was conducted using the following criteria.

Potential Bus Ridership. Estimated demand ranged from a low of 400 express bus riders to a high of 1,300. This range of potential ridership was judged adequate to support fringe parking lot operations. For purposes of the evaluation those sites with an estimated demand of 400 to 700 express bus users were given a medium (1) rating while those above 700 were given a high (2) rating.

Accessibility to Major Corridor or Expressway. Potential sites located at points where access to Powhite Expressway or Interstate 95 could be accomplished with a minimum of delays (traffic lights, stop signs, left turns, etc.) were rated good (2). A rating of fair (1) was given to those located next to major corridors yet were impeded by numerous traffic lights, signs, etc. in reaching the Powhite Expressway or Interstate 95.

Access of Autos and Buses to Site. In rating potential sites with respect to this measure, a good (2) rating was given to those sites where access to the lot could be made by a right turn in the direction of the Richmond CBD or at a left turn signal.

Table 23

Preliminary Site Evaluation

Site	Potential for Bus Ridership	Accessibility of A Major Highway To Destination	Accessibility of Automobiles and Buses to Site	Compatibility With Local Land Use
1	X	X	X	X
2	X	X	X	X
3	X	X	X	X
4	X	X	X	X
5	X	X	X	X
6	X	X	X	X
7	X	X	X	X
8	X	X	X	X
9	X	X	X	X
10	X	X	X	X
11	X	X	X	X
12	X	X	X	X
13	X	X	X	X
14	X	X	X	X
15	X	X	X	X
16	X	X	X	X
17	X	X	X	X
18	X	X	X	X
19	X	X	X	X
20	X	X	X	X
21	X	X	X	X
22	X	X	X	X
23	X	X	X	X
24	X	X	X	X
25	X	X	X	X
26	X	X	X	X
27	X	X	X	X
28	X	X	X	X
29	X	X	X	X
30	X	X	X	X

Compatibility with Surrounding Land Uses: All sites were found to be compatible with surrounding land uses. Potential sites consisting of vacant land were considered compatible due to the assumption they would be constructed to fit in with their surrounding environment.

Observed Fringe Parking Needs. Most joint use facilities were considered prime locations to generate demand from local people.

Expansion Potential of Site. Vacant land was considered the only site capable of expansion. Aerial photographs were analyzed to determine the evaluation rating with respect to this measure.

Availability of Parking Spaces. This measure was intended to evaluate the joint use parking facilities with respect to the number of available parking spaces. Vacant land was given a high (2) rating because it was assumed that they would have a greater number of available parking spaces than joint use facilities in most cases.

Current Status of Site. This measure is self-explanatory on the evaluation sheet.

Size of the Site. Potential sites consisting of vacant land were rated according to their estimated sizes as determined from the aerial photographs. Joint use facilities were given low ratings because it was assumed that the area to be available for a fringe parking lot would be small.

Modifications of Site. Joint use facilities were considered to require minor modifications (benches, bus shelters, newspaper stands, etc.) with vacant land requiring major modifications.

Access to Existing Bus Routes. A rating of good (2) was given when bus stops were located adjacent to potential fringe parking lot sites, while a fair (1) rating was given when their location was within walking distance of a bus stop.

Requires Major Policy Decision. Major policy decisions were required for joint use facilities because of red tape required in obtaining permission to use them.

The evaluation rating of each site can be found in Table 24. Those sites which resulted in the highest evaluation rating are listed in Table 25.

Table 24

Evaluation Rating Table

Potential Fringe Parking Lot Sites	Potential Bus Ridership	Access to Major Corridor or Expressway	Access of Autos and Buses to Site	Compatibility with Surrounding Land Use	Observed Fringe Parking Needs	Expansion Potential of Site	Availability of Parking Spaces	Current Status of Site	Size of Site	Modifications of Site	Estimated Cost of Construction	Access to Existing Bus Routes	Requires Major Policy Decision	Total Evaluation Rating
	2 High 1 Medium 0 Low	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Observed 1 Maybe 0 None	2 Yes 1 Maybe 0 None	2 ≥ 100 1 50-100 0 ≤ 50	2 Empty Lot 1 Utilized Lot 0 Vacant Land	2 ≥ 6 Acres 1 4-6 Acres 0 ≤ 4 Acres	2 None 1 Minor 0 Major	2 0 - $10,000 1 $10,000 - 250,000 0 ≥ $250,000	2 Good 1 Fair 0 Poor	2 No 1 Maybe 0 Yes	
1	1	1	2	2	1	0	1	1	0	1	2	0	0	12
2	1	1	2	2	1	0	1	1	0	1	2	2	0	14
3	1	1	2	2	0	2	2	0	2	0	0	2	2	16
4	1	1	1	2	0	2	2	0	2	0	0	2	2	15
5	2	1	2	2	1	1	2	0	2	0	0	1	2	16
6	2	1	2	2	1	0	0	1	0	1	2	2	0	14
7	2	1	2	2	1	0	0	1	0	1	2	2	0	14
8	2	2	2	2	0	1	2	0	2	0	0	1	2	16
9	2	2	2	2	0	2	2	0	2	0	0	0	2	16
10	2	1	2	2	1	0	0	1	0	1	2	1	0	13

Table 24 (Continued)

Potential Fringe Parking Lot Sites	Potential Bus Ridership	Access to Major Corridor or Expressway	Access of Autos and Buses to Site	Compatibility with Surrounding Land Use	Observed Fringe Parking Needs	Expansion Potential of Site	Availability of Parking Spaces	Current Status of Site	Size of Site	Modifications of Site	Estimated Cost of Construction	Access to Existing Bus Routes	Requires Major Policy Decision	Total Evaluation Rating
	2 High 1 Medium 0 Low	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Observed 1 Maybe 0 None	2 Yes 1 Maybe 0 None	2 ≥ 100 1 50-100 0 ≤ 50	2 Empty Lot 1 Utilized Lot 0 Vacant Land	2 ≥ 6 Acres 1 4-6 Acres 0 ≤ 4 Acres	2 None 1 Minor 0 Major	2 0 - $10,000 1 $10,000 - 250,000 0 ≥ $250,000	2 Good 1 Fair 0 Poor	2 No 1 Maybe 0 Yes	
11	2	2	1	2	0	1	2	0	1	0	0	0	2	13
12	2	1	2	2	1	0	0	1	0	1	2	1	0	13
13	2	2	2	2	0	1	2	0	2	0	0	1	2	16
14	1	2	2	2	2	0	0	1	0	1	2	1	0	14
15	2	2	2	2	2	0	1	1	0	1	2	2	0	17
16	2	2	1	2	1	0	1	1	0	1	2	0	0	13
17	1	1	2	2	2	0	0	1	0	1	2	0	0	12
18	1	2	1	2	1	1	2	0	1	0	0	1	2	14
19	1	1	2	2	1	1	2	0	1	0	0	0	2	13
20	1	1	1	2	1	0	0	1	0	1	2	1	0	11

Table 24 (Continued)

Potential Fringe Parking Lot Sites	Potential Bus Ridership	Access to Major Corridor or Expressway	Access of Autos and Buses to Site	Compatibility with Surrounding Land Use	Observed Fringe Parking Needs	Expansion Potential of Site	Availability of Parking Spaces	Current Status of Site	Size of Site	Modifications of Site	Estimated Cost of Construction	Access to Existing Bus Routes	Requires Major Policy Decision	Total Evaluation Rating
	2 High 1 Medium 0 Low	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Good 1 Fair 0 Poor	2 Observed 1 Maybe 0 None	2 Yes 1 Maybe 0 None	2 ≥ 100 1 50-100 0 ≤ 50	2 Empty Lot 1 Utilized Lot 0 Vacant Land	2 ≥ 6 Acres 1 4-6 Acres 0 ≤ 4 Acres	2 None 1 Minor 0 Major	2 0 - $10,000 1 $10,000 - 250,000 0 ≥ $250,000	2 Good 1 Fair 0 Poor	2 No 1 Maybe 0 Yes	
21	1	1	1	2	1	0	0	1	0	1	2	0	0	10
22	1	1	2	2	0	1	2	0	1	0	0	0	2	12
23	1	1	2	2	0	1	2	0	1	0	0	0	2	12
24	2	1	1	2	0	1	2	0	1	0	0	1	2	13
25	1	2	2	2	0	1	2	0	1	0	0	0	2	13
26	1	1	1	1	1	0	0	1	0	1	2	0	0	9
27	1	2	2	2	0	1	2	0	1	0	0	0	2	13
28	1	2	2	2	0	1	2	0	1	0	0	0	2	13
29	2	1	1	2	1	1	2	0	0	0	0	0	2	12
30	1	2	2	2	0	1	2	0	1	0	0	0	2	13

Table 25

Optimum Fringe Parking Lot Sites

The Bon Air Corridor

Site 3 — Vacant Land
Site 5 — Vacant Land
Site 8 — Vacant Land
Site 9 — Vacant Land

The Route 60 Corridor

Site 13 — Vacant Land
Site 15 — K-Mart Shopping Center

The Route 1 Corridor

Site 25 — Vacant Land
Site 27 — Vacant Land
Site 28 — Vacant Land
Site 30 — Vacant Land

The results of the evaluation show the majority of best sites to consist of vacant land. Joint use facilities would not be capable of handling these levels of anticipated patronage. It is imperative that a high level of transit service be provided in order for an express bus-fringe parking lot operation to succeed. The parking supply plays a major role in the level of transit service provided by this type of operation. Inadequate parking could hamper the operation and prevent the accomplishment of long-term improvements of the highway.

There were a number of unutilized parking spaces at the K-Mart Shopping Center. Yet the estimated demand would be greater than the supply at this site. In a situation such as this it would be necessary to consider the vacant land adjacent to the shopping center.

The costs of constructing fringe parking lots are feasible if the lots are ultimately successful in reducing vehicle flows on highway facilities. The estimated demand for each of these sites would be a substantial reduction in peak hour traffic on the present highway facilities leading into the Richmond CBD. Consideration could be given to using joint use facilities on a short-term basis to see if the anticipated demand is approached. If the demand is met then fringe parking lots can be constructed.

Since the final evaluation resulted in more than one optimum site for each corridor, it was necessary to evaluate these sites using the sum of the evaluation ratings of the first four measures: (1) potential bus ridership, (2) accessibility to major corridor or expressway leading to destination, (3) accessibility of autos and buses to site, and (4) compatibility with surrounding land use. The level of success of an express bus-fringe parking lot operation depends upon these measures. If this evaluation results in more than one site, the one with the highest estimated demand should be selected. This process was conducted on the optimum sites for each corridor in this study. The results can be found in Table 26.

Table 26

Evaluation of Optimum Sites

Site	Evaluation For First Four Measures	Potential Demand	Optimum Site
Bon Air Corridor			
3	6	717	
5	7	989	
8	8	1,211	X
9	8	826	
Route 60 Corridor			
13	8	1,137	X
15	8	1,097	
Route 1 Corridor			
25	7	457	X
27	7	370	
28	7	410	
30	7	440	

To complete this study the Route 60 corridor is recommended as the first area in which to implement an express bus-fringe parking lot operation. The estimated level of demand for the site within this area would result in a greater roadway efficiency. The Bon Air corridor would be recommended as the second best area, with the Route 1 corridor being last.

Transit Service Development

After the origin points for express bus services are located, the transit services themselves must be organized. The transit service options include the route, the hours of operation, the headway, the peak hour travel time, the required number of transit vehicles, and the number of transit trips during the hours of operation. The transit services developed for each optimum site are listed below.

Site 8 (Bon Air Corridor)

Route Description: Chippenham Parkway, Powhite Expressway, Downtown Expressway

Hours of Operation: Morning Peak Hours and Evening Peak Hours

Headway: 5 Minutes

Peak Hour Travel Time: 21.50 Minutes

Required Number of Transit Vehicles: 11

Number of Transit Trips: 32

Site 13 (Route 60 Corridor)

Route Description: Chippenham Parkway, Powhite Expressway, Downtown Expressway

Hours of Operation: Morning Peak Hours and Evening Peak Hours

Headway: 5 Minutes

Peak Hour Travel Time: 18.00 Minutes

Required Number of Transit Vehicles: 11

Number of Transit Trips: 33

Site 25 (Route 1 Corridor)

Route Description: Chippenham Parkway, Interstate 95, Broad Street

Hours of Operation: Morning Peak Hours and Evening Peak Hours

Headway: 5 Minutes

Peak Hour Travel Time: 22.00 Minutes

Required Number of Transit Vehicles: 11

Number of Transit Trips: 21

All of the described routes consist of toll roads. Consideration should be given to permitting transit vehicles nonstop movement through the toll collection facilities to cut down on travel time. A route has been recommended for the CBD area, and is shown on the map in Figure 12.

It is necessary to point out that if transit fares and headways are changed, the estimated demand will change. It would be necessary to estimate the demand using the new variables.

Once transit services are established, a vigorous marketing campaign should be conducted to inform the populace of the new service. This can be accomplished through radio, television, and the newspaper.

.22-0

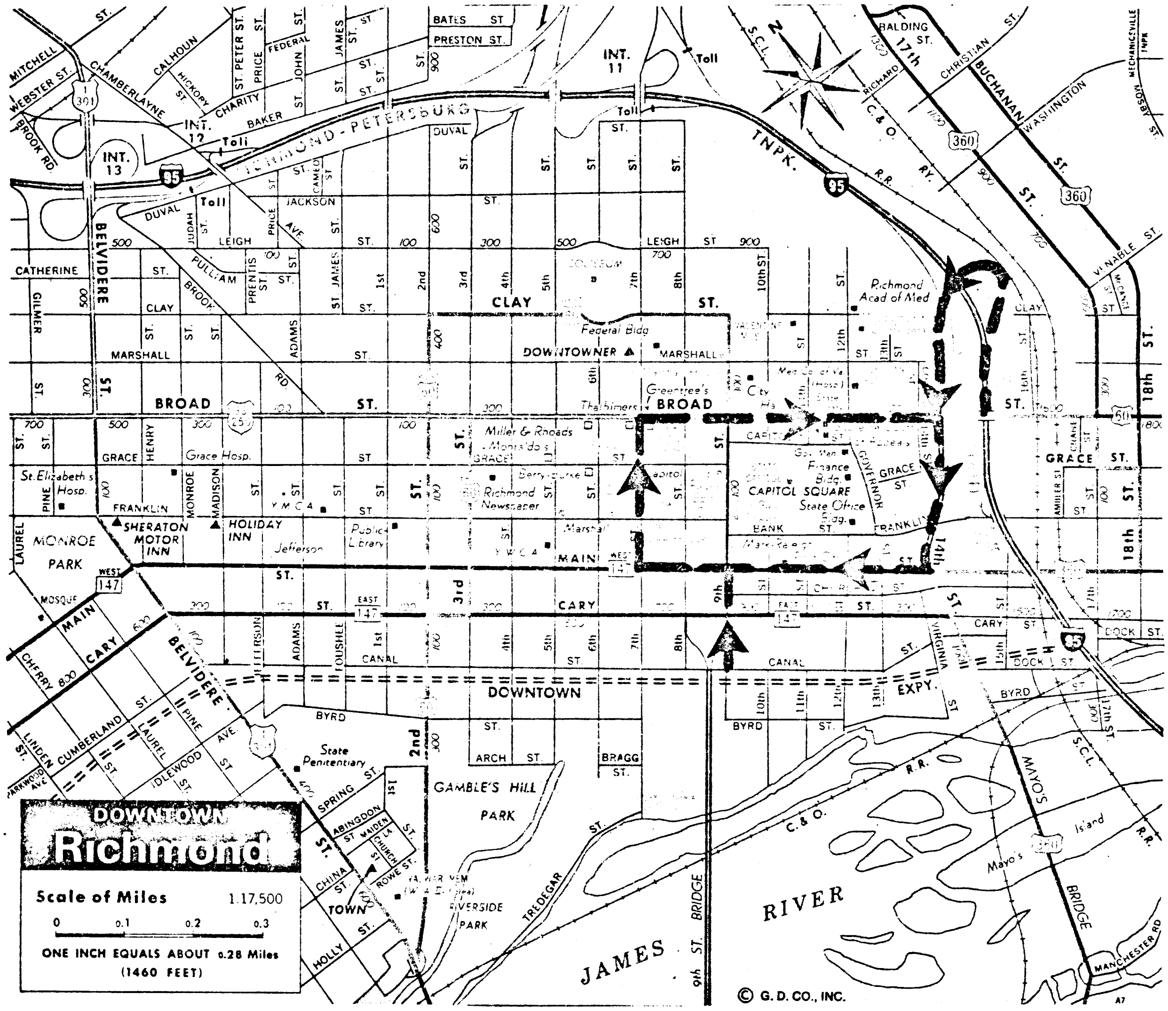

Figure 12. CBD bus route.

SUMMARY AND RECOMMENDATIONS

Travel choice models and planning guidelines for express bus-fringe parking transit derived in earlier research were synthesized to establish a procedural method for developing ridership for similar transit services in other areas of the Commonwealth. The resulting sub-area transit planning process was demonstrated by an application to Southside Richmond.

The methodology provided is recommended to the Transportation Planning Division for implementation as a standard method for express bus-fringe parking transit planning. Very precise levels of analytic detail are possible where the study area and transportation system are similar to those from which mode choice models are available. In such cases, detailed facility and service designs can be developed. For the general case where conditions are not as favorable, assumptions concerning travel behavior must be made to justify estimates of trip making. However, under all circumstances, the procedures will be particularly valuable for sketch planning purposes and feasibility analyses. As a history of application of the procedures develops, an extensive set of disaggregate behavioral models will evolve for a wide range of travel, behavioral, population, and urban conditions.

1. Determine minimum travel paths to the destination area for each traffic zone to define the market area for each service site according to accessibility.
2. Make an assessment of auto and transit captivity rates.
3. Conduct travel time studies for peak- and non peak hour traffic conditions between potential service sites and the destination area.
4. Estimate work trip volumes according to age and sex groups. Volumes can be estimated most accurately from transportation study data, and age and sex distributions from census data.

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