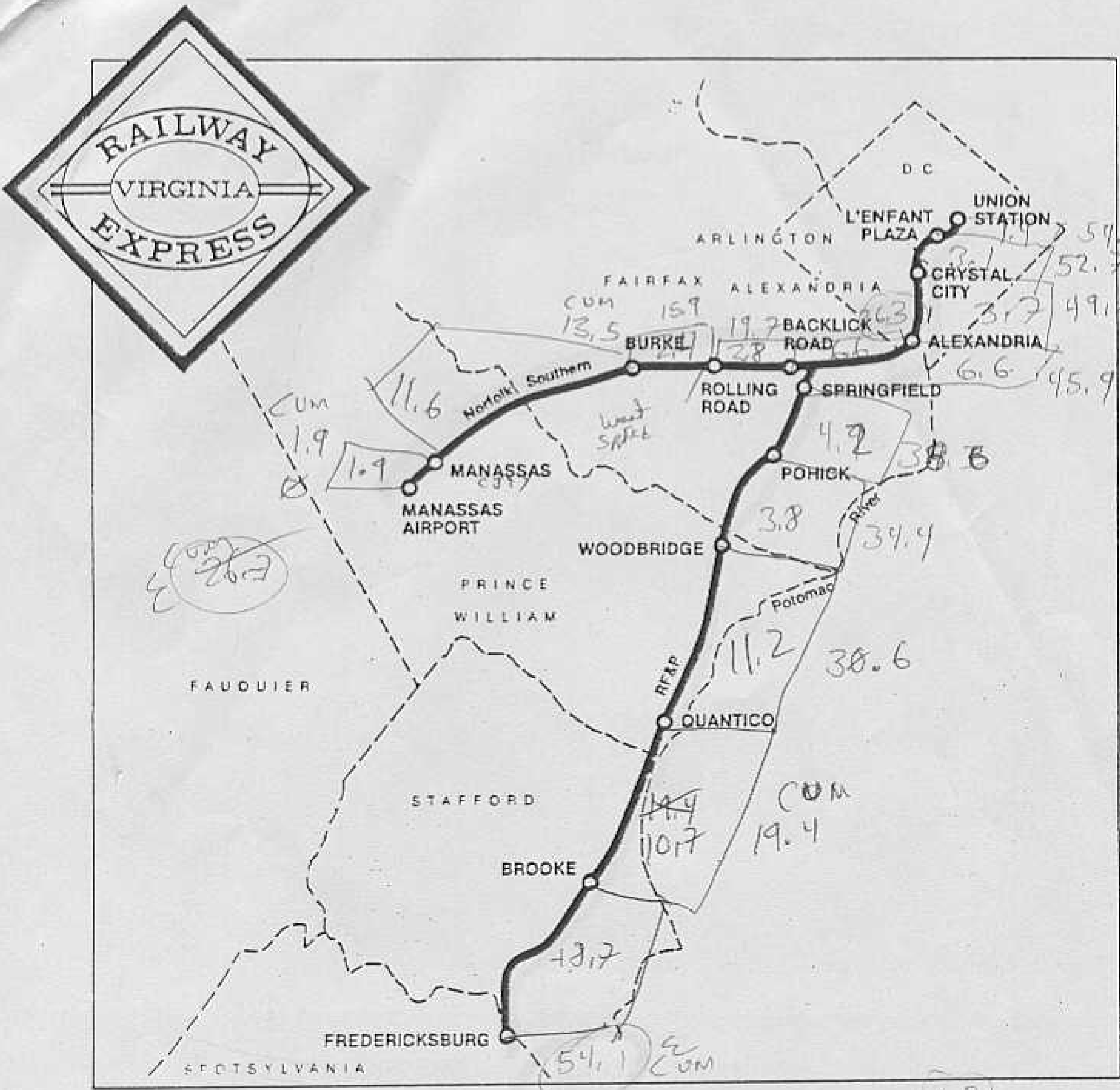
PATRONAGE AND REVENUE FORECASTS FOR THE VIRGINIA RAILWAY EXPRESS



MAY 1987

PATRONAGE AND REVENUE FORECASTS
FOR THE
VIRGINIA RAILWAY EXPRESS

prepared for the

NORTHERN VIRGINIA TRANSPORTATION COMMISSION

by

Richard H. Pratt, Consultant, Inc.

in association with the

Metropolitan Washington Council of Governments

May 1987

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LIST OF EXHIBITS

GLOSSARY

Attraction Zone	- A zone at the non-home end of a home-based trip. In this study, the attraction zones are the employment zones of inbound commuter railroad passenger trips in the D.C./Arlington/Alexandria destination area.
CRR	- Commuter Railroad. An urban/suburban rail passenger service operated with locomotive-hauled trains or self-propelled cars operated over the tracks of a common carrier passenger/freight railroad.
Calibration	- The technique of testing a forecasting model against known data and adjusting the model, if required, so that it reproduces the known data within the required standards of accuracy.
Carpool	- A private vehicle with two or more occupants. With respect to mode of arrival, carpool refers to such a vehicle driven to a rail station, carrying rail patrons, and parked.
Corridor Zone	- Essentially the same as a Traffic Analysis Zone, but specifally configured in connection with the study of a particular corridor.
"Cost"	- The form of impedance used in the SIMS modal choice model, where time components are weighted to make their units equivalent to cents and are then added, along with unweighted cost components, to provide a measure expressed as the "cost" of going from one place to another.
Drive Alone	- A private vehicle with one occupant. With respect to mode of arrival, refers to such a vehicle driven to a rail station by a rail patron and parked.
Drop-off	- Mode of arrival in which the transit patron is driven to a rail station in a car which is not subsequently parked.
HOV	- High Occupancy Vehicle. Specifically, a carpool or vanpool with sufficient occupants to qualify for use of HOV (diamond) lanes and other facilities set aside for HOV's. In the study corridor, the I-395 HOV lanes require 4 occupants, and peak period use of I-66 inside the Capital Beltway requires 3 occupants.
Headway	- A method of expressing the frequency of transit service. A 30-minute headway would indicate transit service every 30 minutes.

GLOSSARY - continued:

Home-Based Trip	- A trip going either to home or from home.
Impedance	- The term used in this report to describe the time and cost expenditure for an individual to go from one place to another via public transit, or alternatively, via private vehicle on the highway system. Impedance implies a combination of time, convenience and cost components into a single number, using appropriate weightings of the different components, which is then used in travel demand models to describe quality of travel.
In-Vehicle Time	- That portion of door-to-door travel time spent in a transit or private vehicle; also referred to as "run time." This component of travel time is viewed as less onerous than Out-of-Vehicle Time.
LOV	- Low Occupancy Vehicle. Specifically, a single-occupant vehicle or carpool with too few occupants to qualify for HOV facility use.
MWCOG	- Metropolitan Washington Council of Governments
Maximum Load Point	- That point on a bus route or rail line at which the passenger volume is greatest.
Modal Split	- A term applied to the rational allocation of total travel demand (expressed as Person Trips) to the various travel modes of a transportation system, such as public transit versus private auto travel, for example.
Mode of Arrival	- The means by which transit patrons arrive at a rail station. In this study, possible modes of arrival include: walk, bike, bus, drop-off, carpool, drive alone.
NVTC	- Northern Virginia Transportation Commission
Network	- A mathematical description of the transit or highway system in a format used for computer processing and analysis, such as the use in this study for calculation of zone-to-zone travel time components.
Normalize	- To bring into conformity with, or reduce to, a statistical norm or standard.
Out-of-Vehicle Time	- That portion of door-to-door travel time spent in activities outside of any vehicle, including walking, waiting at a transit stop, or making a transfer. This component of travel time also serves as a measure of convenience (the less out-of-vehicle time the better).

GLOSSARY - continued:

Person Trip	- A trip for which no travel mode is designated. Total person trips thus include travel by all modes.
Production Zone	- A zone at the home end of a home-based trip. In this study, the production zones are the zones in the tributary area of the Virginia Railway Express commuter railroad services; the zones in which the patrons reside.
Revenue	- Revenue, as the term is used in this study, is the gross income from operation of the transit system, including both basic and special fares. It does not include income derived from advertising, concessions, and rents.
SMSA	- Standard Metropolitan Statistical Area. The metropolitan area as defined by the Bureau of the Census. The Washington SMSA is coincident with the MWCOG boundaries, and includes the District of Columbia, Montgomery and Prince George's Counties in Maryland, and Arlington, Alexandria, Fairfax County, Loudoun County, Prince William County, and the independent cities included therein, in Virginia.
Sub-Modal Split	- The allocation of travel within a particular type of mode. In this study, sub-modal split refers to the split between commuter rail transit and all other transit.
Traffic Analysis Zone	- A small portion of the metropolitan area used to describe the geographic location of travel and other characteristics such as population, auto ownership and employment.
Trip Distribution	- The procedure of estimating the geographic orientation in distance and direction of the travel demand from a specific analysis area.
Trip Generation	- The procedure of estimating the amount of travel demand for various purposes from a specific analysis area.
Trip Purpose	- In describing home-based trips, the trip purpose represents the type of activity at the end of the trip away from home, e.g., work, school, shopping, social-recreation, etc. A work trip may be <u>to</u> work or <u>from</u> work.
Validation	- The testing of a calibrated model against known data, other than the data used in calibration, to verify that it can reproduce more than just the known data against which it was calibrated.

CHAPTER 1

INTRODUCTION

The Northern Virginia Transportation Commission (NVTC) is actively proceeding toward implementation of a two-year experiment in providing commuter rail service from both Manassas and Fredericksburg to Washington Union Station in the District of Columbia. NVTC has appointed a five-member committee to work with officials of the Potomac Rappahanock Transportation District (Prince William and Stafford Counties and the City of Manassas), the Cities of Manassas Park and Fredericksburg, and Spotslvania County. Significant progress has been made in drafting a master agreement, defining policy and financial relationships between localities and the NVTC, developing a financial plan and program, securing motor fuel tax revenue and State and Federal grants, service planning, equipment procurement, development of an operating agreement with AMTRAK and the RF&P and Norfolk Southern Railroads, and in programming insurance for liability claims and judgments. The proposed commuter railroad operation has been named the Virginia Railway Express.

Planning has been proceeding on the basis on an interim patronage forecast, derived with modifications from a 1984 study by the Metropolitan Washington Council of Governments. That study assumed a northern terminus at Alexandria, with transfer to Metrorail, a limitation that no longer pertains. The forecasts in that study were derived through direct analogy with the patronage characteristics of the Brunswick Line commuter railroad service, operated by MARC in the State of Maryland.

Participants in the implementation of the Virginia Railway Express have felt it would be desirable to have a new set of forecasts, specific to the operation now proposed, and developed using the full travel demand modeling sequence applied in other major corridor studies. This commuter rail patronage and revenue study was thus initiated with the charge to forecast 1987 and 2005 patronage through a step-wise forecasting of travel in terms of person trips by all travel modes, mode choice between auto and transit, sub-mode choice between commuter rail and other transit modes (Metrorail and bus), and station mode of access.

This report presents both the forecasting procedures and results of the study. The transportation system and demographic assumptions employed are described next, in Chapter 2. Chapter 3 presents the overall patronage forecasting methodology, while details of the component models and procedures are provided in Chapter 4. The patronage and revenue estimates themselves are presented in Chapter 5, starting with a discussion of forecast interpretation and use. The reader desiring only an overview of the procedures may wish to concentrate on Chapter 2, Chapter 3 through Exhibit 8 (page 3-7), and Chapter 5.

CHAPTER 2

TRANSPORTATION SYSTEM AND DEMOGRAPHIC ASSUMPTIONS

Virginia Railway Express

The Virginia Railway Express commuter rail service is proposed for operation in two corridors, utilizing the RF&P and Norfolk Southern Railroads. The RF&P service would start at Fredericksburg, with stations at Brooke, Quantico, Woodbridge, Pohick, and Springfield. The Norfolk Southern service would start at Manassas Airport, with stops at Manassas, Burke, Rolling Road, and Backlick Road. Trains from both lines would stop at Alexandria Union Station (King Street), Crystal City, and L'Enfant Plaza, in addition to the Washington Union Station terminus. All four of these inner stations offer connection with Metrorail for further passenger distribution.

Exhibit 1 provides a map of the Virginia Railway Express operation. Note that within Springfield, the stop on the RF&P is designated "Springfield," while the stop on the Norfolk Southern is designated "Backlick Road."

The planned running time is 75 minutes from Fredericksburg to Union Station, and 55 minutes from Manassas Airport to Union Station. Trains would run every half hour during the peak period, four trains on each line, for a total of eight in-bound morning and eight out-bound evening trains. Exhibit 2 illustrates the morning in-bound schedule assumed for purposes of describing the travel time characteristics of the proposed service. The evening out-bound schedule is comparable. Train capacity was not used as a patronage forecast restraint; additional trains may be required to accommodate pasenger loadings, depending on platform length and equipment configuration. AMTRAK trains provide supplemental service to Fredericksburg, Manassas, Alexandria and Union Station, but these are, for the most part, outside of the peak commuting period, and were not considered in the patronage forecasting.

EXHIBIT 1

VIRGINIA RAILWAY EXPRESS SYSTEM MAP

EXHIBIT 2

SCHEDULE OF INBOUND WEEKDAY TRAINS

Stations	VRE #30	#60	#32	#62	34	64	36	66
		A.M.		A.M.		A.M.		A.M.
Fredericksburg		6:00		6:29		6:54		7:29
Brooke		6:10		6:39		7:09		7:39
Quantico	A.M.	6:22	A.M.	6:51	A.M.	7:21	A.M.	7:51
Masassas Airport	6:14	↓	6:45	↓	7:15	↓	7:45	↓
Manassas City	6:18	↓	6:49	↓	7:19	↓	7:49	↓
Burke	6:31	↓	7:02	↓	7:32	↓	8:02	↓
Rolling Road	6:36	↓	7:07	↓	7:37	↓	8:07	↓
Backlick Road	6:42	↓	7:13	↓	7:43	↓	8:17	↓
Woodbridge	↓	6:34	↓	7:03	↓	7:33	↓	8:03
Pohick	↓	6:40	↓	7:09	↓	7:39	↓	8:09
Springfield	↓	6:46	↓	7:15	↓	7:45	↓	8:15
Alexandria	6:51	6:58	7:22	7:27	7:52	7:57	8:22	8:27
Crystal City		7:05	7:29	7:34	7:59	8:04	8:29	8:34
L'Enfant Plaza		7:10	7:35	7:40	8:05	8:10	8:35	8:40
Union Station		7:15	7:40	7:45	8:10	8:15	8:40	8:45

Exhibit 3 presents the assumed schedule of fares. It is anticipated that most commuters will use the 20-ride pass, offering the equivalent of a $3.50 discounted one-way fare from Fredericksburg and a $3.25 fare from Manassas, with lesser fares for shorter trips. Single, round-trip tickets would be 25 percent to 50 percent more costly per ride, and single, one-way tickets would be 120 percent more.

The 1987 and 2005 unconstrained patronage estimates assume availability at each station of sufficient parking to meet demand. The constrained estimates assume the following numbers of parking spaces, as specified by the counties and cities involved:

Station	Number of Parking Spaces
Fredericksburg	116 spaces
Brooke	130
Quantico	500
Woodbridge	500
Pohick	200
Springfield	0
Manassas Airport	Unlimited
Manassas	168
Burke	500
Rolling Road	500
Backlick Road	200
Alexandria	0

Suitable automobile and pedestrian access is assumed for all stations.

Metrorail and Bus

The Virginia Railway Express will operate as part of the regional public transportation system, complementing Metrorail, Metrobus, and other public and private bus services. From a patronage forecasting perspective, Metrorail will both compete with the Virginia Railway Express and offer vital passenger distribution to destinations not directly served by commuter rail. Certain bus

EXHIBIT 3

SCHEDULE OF FARES

RF&P Line 20-Ride Pass†

	FRC	BRK	QTC	WBG	PHK	SPR	ALX	CRT	LRN
BRK	$25.00	X							
QTC	30.00	$25.00	X						
WBG	45.00	35.00	$25.00	X					
PHK	60.00	55.00	45.00	$25.00	X				
SPR	60.00	55.00	50.00	40.00	$25.00	X			
ALX	60.00	55.00	50.00	50.00	40.00	$35.00	X		
CRT	70.00	65.00	60.00	60.00	50.00	45.00	$40.00	X	
LRN	70.00	65.00	60.00	60.00	50.00	45.00	40.00	$25.00	X
WAS	70.00	65.00	60.00	60.00	50.00	45.00	40.00	25.00	$25.00

RF&P Line Single Round-trip†

	FRC	BRK	QTC	WBG	PHK	SPR	ALX	CRT	LRN
BRK	$3.75	X							
QTC	4.25	$3.75	X						
WBG	5.75	4.75	$3.75	X					
PHK	8.25	7.00	5.75	$3.75	X				
SPR	8.25	7.00	6.25	5.00	$3.75	X			
ALX	8.25	7.00	6.25	6.25	5.00	$4.75	X		
CRT	8.75	8.25	8.25	7.50	6.25	5.75	$5.00	X	
LRN	8.75	8.25	8.25	7.50	6.25	5.75	5.00	$3.75	X
WAS	8.75	8.25	8.25	7.50	6.25	5.75	5.00	3.75	$3.75

RF&P Line Single One-way†

	FRC	BRK	QTC	WBG	PHK	SPR	ALX	CRT	LRN
BRK	$2.75	X							
QTC	3.75	$2.75	X						
WBG	4.75	3.25	$2.75	X					
PHK	7.25	6.00	4.75	$2.15	X				
SPR	7.25	6.00	5.25	4.00	$2.75	X			
ALX	7.25	6.00	5.25	5.25	4.00	$3.75	X		
CRT	7.75	7.25	7.25	6.50	5.25	4.75	$4.00	X	
LRN	7.75	7.25	7.25	6.50	5.25	4.75	4.00	$2.75	X
WAS	7.75	7.25	7.25	6.50	5.25	4.75	4.00	2.75	$2.75

Southern Line 20-Ride Pass†

	APT	MNS	BUR	ROL	BKL	ALX	CRT	LRN
MNS	$25.00	X						
BUR	25.00	$25.00	X					
ROL	35.00	35.00	$25.00	X				
BKL	45.00	45.00	35.00	$25.00	X			
ALX	55.00	55.00	45.00	40.00	$35.00	X		
CRT	65.00	65.00	55.00	50.00	45.00	$40.00	X	
LRN	65.00	65.00	55.00	50.00	45.00	40.00	$25.00	X
WAS	65.00	65.00	55.00	50.00	45.00	40.00	25.00	$25.00

Southern Line Single Round-trip†

	APT	MNS	BUR	ROL	BKL	ALX	CRT	LRN
MNS	$3.75	X						
BUR	3.75	$3.75	X					
ROL	4.75	4.75	$3.75	X				
BKL	5.75	5.75	4.75	$3.75	X			
ALX	7.00	7.00	5.75	5.00	$4.75	X		
CRT	8.25	8.25	7.00	6.25	5.75	$5.00	X	
LRN	8.25	8.25	7.00	6.25	5.75	5.00	$3.75	X
WAS	8.25	8.25	7.00	6.25	5.75	5.00	3.75	$3.75

Southern Line Single One-way†

	APT	MNS	BUR	ROL	BKL	ALX	CRT	LRN
MNS	$2.75	X						
BUR	2.75	$2.75	X					
ROL	3.75	3.75	$2.75	X				
BKL	4.75	4.75	3.75	$2.75	X			
ALX	6.00	6.00	4.75	4.00	$3.75	X		
CRT	7.25	7.25	6.00	5.25	4.75	$4.00	X	
LRN	7.25	7.25	6.00	5.25	4.75	4.00	$2.75	X
WAS	7.25	7.25	6.00	5.25	4.75	4.00	2.75	$2.75

†Children's fares applicable to persons 2-11 years of age, shall be one-half the amounts shown above.

services also offer passenger distribution, particularly in Alexandria, Arlington and the District of Columbia, while other bus operations will stand as an alternative to commuter rail use.

For the 1987 forecast, Metrorail and bus services in operation as of the first of the year have been assumed. For Metrorail, this includes the Yellow Line service to Huntington and the Orange Line service to Vienna. Bus services include the Virginia and D.C. Metrobus operation, DASH in Alexandria, the Fairfax Connector service to Huntington Station, and the Prince William Commuteride services operated by Bus Lease Contract Services, primarily via I-95 and I-66. Also included are the private bus operations of Aries, D&J, Greyhound, Lee Coaches, Trailways, Virginia Motor Coach, White's and Lawson Bus Company. These operations utilize the I-395/I-95 High Occupancy Vehicle (HOV) lanes and serve Park & Ride lots and local stops within Stafford County, Fredericksburg and Spotslyvania County.

For the 2005 forecast, the full Metrorail System has been assumed. This includes the downtown distribution afforded by the Green Line, and Yellow Line service to Van Dorn and Franconia (Springfield). The latter line parallels the commuter rail route almost as far as the Springfield station on the RF&P.

For 2005 bus services, the same basic level of service as today has been assumed, but with reorientation to mesh with the expanded Metrorail service. Within the Washington Metropolitan Area Transit Authority service area, the assumed bus route frequency and density is that developed in concert with the involved jurisdictions for the purposes of the Federal City Council study of projected transit service.[1] Continuation of the presently existing Prince William County, Stafford Country, Fredericksburg, and Spotsylvania County commuter bus routes has been assumed. In the 2005 forecasts, these routes obtain the running time savings that will accrue from projected extension of the I-95 HOV lanes.

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[1] Transit in the Nation's Capital: What Lies Ahead? A Study of Projected Transit Service, Costs, and Financial Impacts on the Region Through the Year 2000. Federal City Council/UMTA, February 1986.

Highway Network

Both low occupancy vehicles (LOV) and high occupancy vehicles (carpools and vanpools) have been considered as alternative travel modes in developing the Virginia Railway Express patronage estimates. For 1987, the LOV and HOV facilities and restrictions in place as of the first of the year have been assumed. Highway facility assumptions for 2005 are those embodied in the current Metropolitan Washington Council of Governments (MWCOG) 2005 highway network for that year. This MWCOG network is based on the Highway Section of the 1983 Long-Range Element of the Transportation Plan as adopted by the Transportation Planning Board (TPB), with further update by the Virginia Department of Transportation (VDOT) in advance of the Springfield Bypass study. The same base case highway assumptions have been used since for all studies in northern Virginia.

The major facility expansion most directly affecting the year 2005 analysis is extension of the separate Shirley Highway HOV roadway, south along I-95, into Prince William County. Provision of a comparable facility west of I-495 on I-66 is not included in the 2005 highway assumptions. Other highway improvements are assumed, such as construction of the Springfield Bypass, but these have relatively minor impact on radial travel into the urban core.

Highway speeds and travel times were derived by MWCOG, based on projected volumes and highway capacities. This process is described further in Chapter 3 in the Model Inputs section.

Population and Employment

The patronage forecasting work of this study required utilizing two primary sources for population and employment forecasts. For jurisdictions within the Washington Standard Metropolitan Statistical Area (SMSA), the source was MWCOG. For jurisdictions outside of the SMSA, other sources had to be utilized, primarily estimates by the Virginia Department of Planning and Budget.

Inside of the SMSA, the forecasting work of this study started with person trip estimates furnished by MWCOG for home-based work trips, comprising all travel for the purpose of getting from home to work and back. The population and employment forecasts that underlie these MWCOG trip estimates are those of the Intermediate Population Forecasts, Round 3 Cooperative Forecast, Update 1985.[2] These forecasts infer a 2.2 percent regional population growth between 1985 and the 1987 forecast year, assuming straight line growth between the official 1985 and 1990 forecasts. They project a 17 percent regional population growth between 1985 and the 2005 forecast year. Employment forecasts for the primary destination areas of the Virginia Railway Express service, and population forecasts for the tributary areas within in the SMSA, are given in Exhibit 4. The MWCOG person trip estimates are made utilizing the population and employment forecasts for all jurisdictions within the SMSA, broken down into projections for each small area of the region.

Exhibit 5 illustrates the derivation and gives the 1987 and 2005 results of population forecasts for the exurban jurisdictions of interest to the study, comprising the Virginia Railway Express tributary area outside of the SMSA. Excepting the old city area of Fredericksburg and Culpeper County, these forecasts indicate a 1985 to 2005 population growth ranging from 51 percent to 76 percent. The figures for Spotsylvania County include the "new city" area of Fredericksburg. Adjustment for the expanded city boundaries was made in a subsequent step of the patronage forecasting process.

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[2] Resolution on 1985 Updates to Cooperative Forecasts of Population, Households, and Employment for Metropolitan Washington, Metropolitan Washington Council of Governments, October 9, 1985.

EXHIBIT 4

WASHINGTON SMSA EMPLOYMENT AND POPULATION FORECASTS

Jurisdiction	Employment - Core Jurisdictions			
	1985	1987	1990	2005
District of Columbia	679,000	684,200	692,000	735,000
Arlington County	153,500	158,900	167,000	203,500
City of Alexandria	72,400	83,900	101,100	134,300
	Population - Suburban Jurisdictions			
	1985	1987	1990	2005
Montgomery County	620,000	640,200	670,400	766,000
Prince George's County	676,400	683,500	694,100	763,700
Fairfax County	668,300	689,900	722,400	786,500
Fairfax City	20,800	20,900	21,000	22,000
Falls Church	9,500	9,700	9,900	11,000
Loudoun County	66,600	72,400	81,000	135,700
Prince William County	177,000	186,800	201,500	273,500
Independent Cities (Va. Outer Suburbs)	24,700	25,800	27,400	33,000

Notes: 1985, 1990 and 2005 estimates are based on the Metropolitan Washington Council of Governments' Intermediate Population and Employment Forescasts, Round III Cooperative Forecast, Update 1985.

1987 estimates are based on a straight-line interpolation between 1985 and 1990.

EXHIBIT 5

EXURBAN COUNTY POPULATION FORECASTS

Jurisdiction	1980	1985	1987	2000	2005
Stafford	40,470	47,934	49,427	70,000	81,200
Fredericksburg	15,384	15,634	15,684	16,500	16,750
Spotsylvania	34,435	45,534	47,754	69,000	80,040
King George	10,543	11,500	11,693	15,000	17,400
Fauquier	35,889	40,365	41,260	58,450	67,802
Culpeper	22,620	24,600	24,996	27,400	31,784

Notes: Estimates for the City of Fredericksburg are for the Old City area only; population of the New City area is included in the Spotsylvania County estimates.

1980 estimates are based on Bureau of Census, 1980. (Fredericksburg is based on trending back from 1985 to 1980, based on an assumed growth of 250 persons per 5-year period.)

1985 estimates are based on Virginia Department of Planning and Budget estimates.

1987 estimates are based on a straight-line extrapolation from 1980 to 1985.

2000 estimates are based on Virginia Department of Planning and Budget estimates.

2005 estimates are extrapolations from 2000 estimates, using a 3% per year, or 16% overall growth.

CHAPTER 3

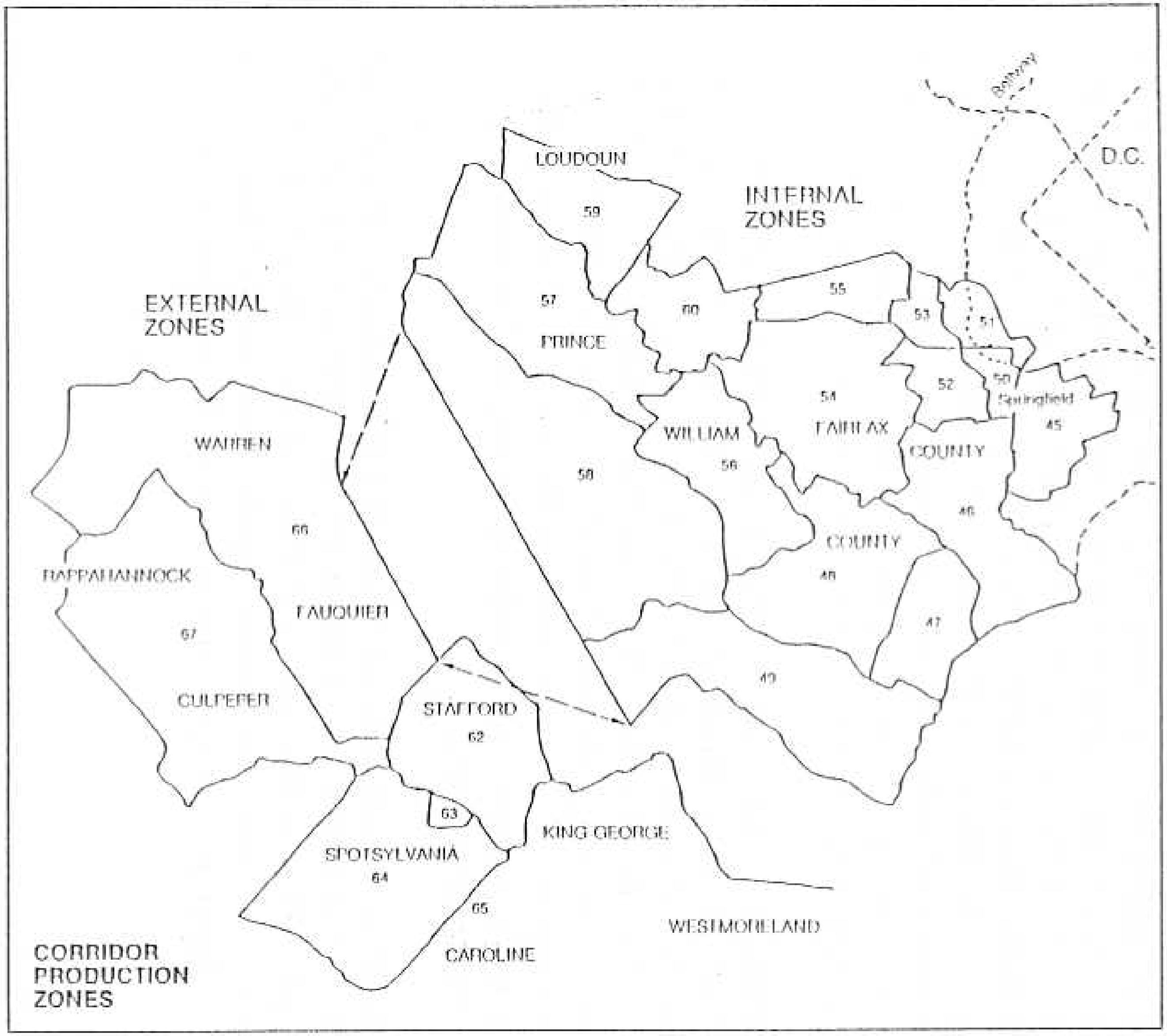
PATRONAGE FORECASTING METHODOLOGY

Study Area

The study area for the Virginia Railway Express Patronage Forecast was defined in two parts: the primary destination, or trip attraction, area; and the tributary, or trip production, area. Both are shown in Exhibit 6. The trip attraction area encompassed the Alexandria central business district and vicinity, the Pentagon, Crystal City, Rosslyn and vicinity, the District of Columbia core, and certain nearby areas within D.C. The trip production part of the study area encompassed the sectors of Fairfax County lying south and west of Springfield, a small portion of Loudoun County, and Prince William, Stafford, Spotslyvania, King George, Caroline, Westmoreland, Fauquier, Warren, Culpeper and Rappahannock Counties, along with the independent cities contained therein.

The portion of the total study area that lies within the Washington SMSA contains over 300 of the traffic analysis zones utilized by MWCOG for travel forecasting. These zones represent the locations of trip origins and destinations. To keep the cost and time of the Virginia Railway Express patronage forecasts within acceptable limits, these MWCOG traffic analysis zones were combined into the 33 attraction zones and 16 production zones illustrated in Exhibit 6. An additional six production zones were used to describe the exurban area production zones.

By this means, the number of production zone and attraction zone pairs that had to be analyzed was held to slightly over 700. The zone combination process aggregated areas of similar transportation system characteristics, such as groups of zones surrounding proposed Virginia Railway Express stations. Further detail was provided by separately analyzing the areas within production



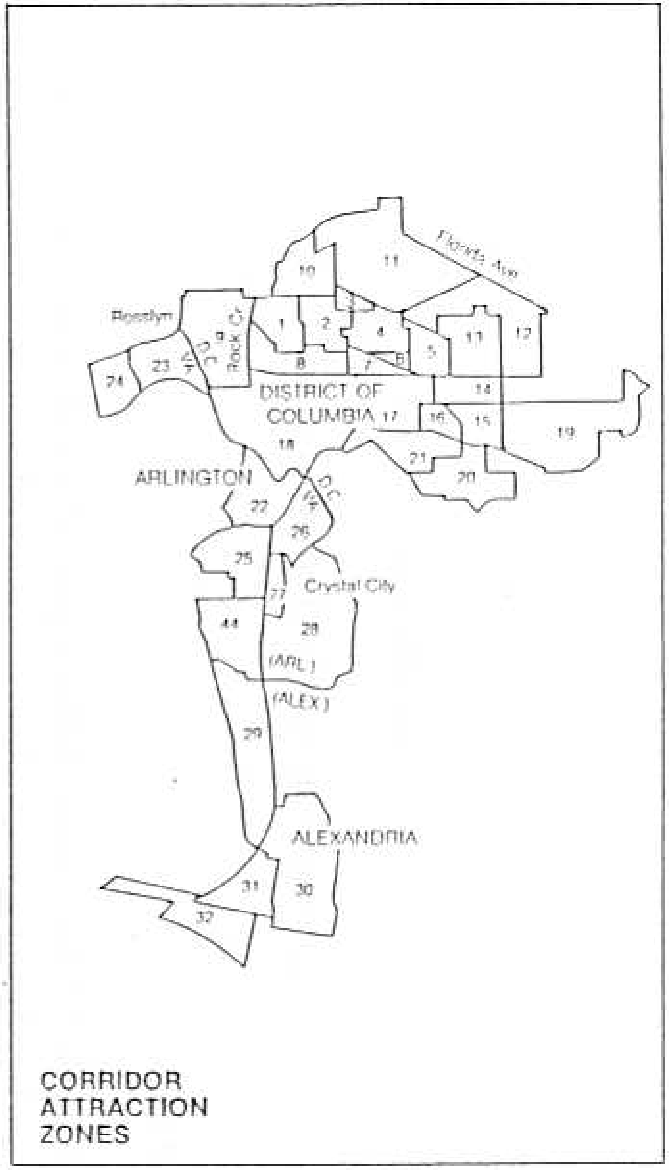


EXHIBIT 6

STUDY CORRIDOR AND ANALYSIS ZONES

zones that would be within walking distance of commuter railroad stations, within walking distance of other transit service, within walking distance of both, or not within walking distance at all.

Not shown in Exhibit 6 are the comparable zones established in Maryland for purposes of validating that the forecasting process employed is capable of replicating existing commuter railroad patronage. This validation test, conducted for areas along the MARC Brunswick Line in Montgomery County, is described in subsequent sections.

Travel Demand Model Chain

Exhibit 7 illustrates the basic travel demand model chain utilized for producing the Virginia Railway Express patronage forecasts. An overview of this modeling system will be given here. Further details about the models and their calibration and validation are provided in Chapter 4.

The first step in this sequential modeling process was estimation of person trips, by all travel modes, from each of the study area production zones to each of the attraction zones. This was done for 1980, for purposes of model calibration and validation, and for 1987 and 2005, for purposes of the forecasts. Given the commuter orientation of the proposed service, only work purpose trips were modeled.

The person trips internal to the SMSA were estimated by MWCOG in previous studies, employing trip generation models and a trip distribution model. The trip generation models estimate the number of trips, based primarily on number of households and vehicle ownership at the home end, and employment at the work end. A "gravity" distribution model is used to estimate the geographic orientation of the trips, based on where trips are produced, where the trip destination (attraction) opportunities are, and the travel time between.

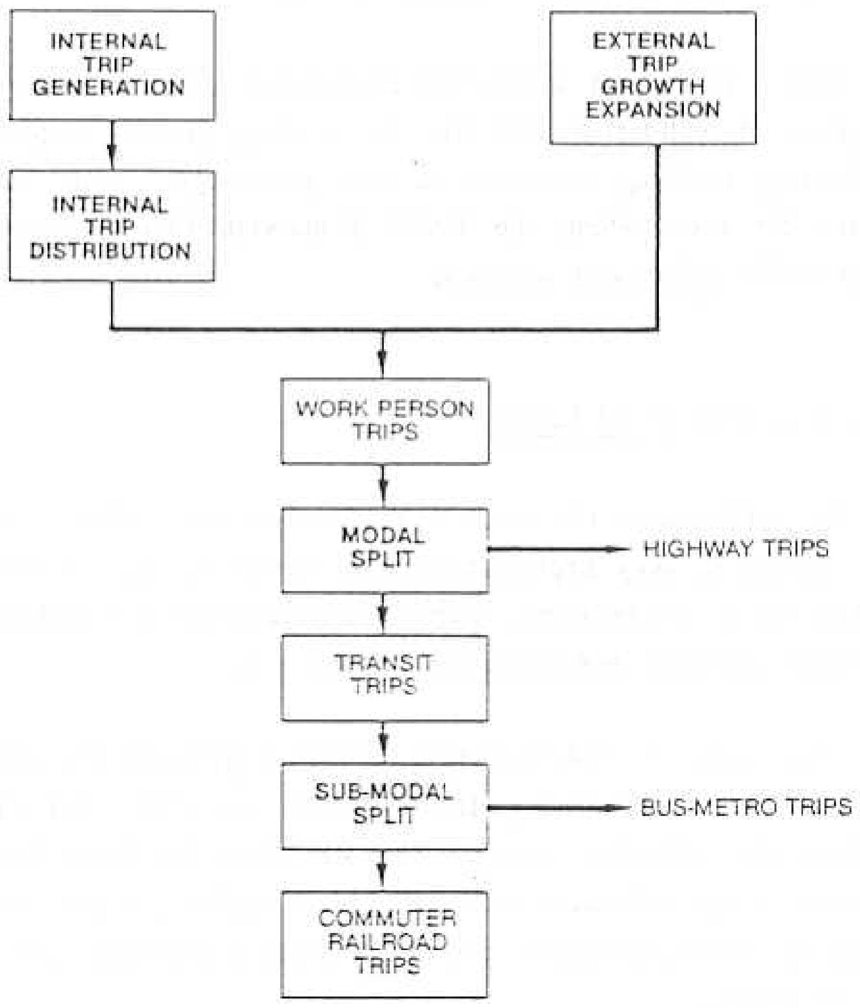


EXHIBIT 7

TRAVEL DEMAND MODEL CHAIN

No such modeling of trips was available for person trips from the exurban zones. These trips were estimated utilizing a growth expansion process, starting with 1980 Census travel data.

The internal and external estimates of work purpose person trips were combined into a single table, or matrix, representing the overall commuter travel market available for the Virginia Railway Express service to draw from. Estimation of the proportion that would be caputured by Virginia Railway Express service was done in two subsequent "modal split" steps.

The first modal split step estimated the allocation of person trips between the available highway modes of travel and all of the available transit modes. The highway modes include low occupany vehicle travel, which must use the regular highway lanes, and carpool/vanpool travel, which can utilize HOV facilities. The public transit modes include Metrorail, Metrobus, other public and private bus operations, and commuter rail. The modeling process utilizes a mathematical formulation to make the allocation between highway and transit on the basis of travel times, convenience measures, distance and cost of the competing modes. After this allocation, the estimated person trips via highway were set aside as being of no further interest to the study objectives.

In most transportation planning studies, the next step would be to load the estimated transit trips onto individual transit routes, making the assumption that the minimum time routing will be utilized by the transit passenger. This procedure is generally not adequate, however, for commuter railroad patronage forecasting. For this reason, a sub-modal split model was used to specifically estimate the commuter railroad market share of the total transit ridership market for each of the zone-to-zone pairs under study. This model utilized the same transit time, convenience and cost measures as the prime mode split model, but with a different mathematical formulation specific to sub-mode split estimation.

The result of the sub-modal split step was to separate trips that would use only Metrorail or bus from the trips forecasted to use commuter railroad. Like the highway trips, the estimated Metrorail and bus-only trips were set aside, and the final computations concentrated on the commuter railroad ridership estimate.

Not shown in Exhibit 7, but essential to the process, are the ancillary models and procedures used to take the basic commuter railroad patronage forecast and augment it with estimation of non-work trip usage, travel between non-downtown stations, mode of access to stations, parking requirements, impact of parking constraints, and revenue. These, also, are described further in Chapter 4.

Model Inputs

Exhibit 8 essentially takes the final steps of the travel demand model chain, illustrated in Exhibit 7, and blows them up to show the modal split and sub-modal split model inputs. These inputs had to be prepared for each of the calibration/validation and forecast years—1980, 1987, and 2005.

Highway Characteristics

The modal split model, but not the sub-modal split model, requires a description of highway travel characteristics for each production to attraction zone pair. All characteristics except parking costs are derived from MWCOG network representations of the highway system. For 1980, the MWCOG model calibration network was used. For 1987, the MWCOG 1985 validation network was employed. For 2005, a 2005 highway network previously developed for the Springfield Bypass Study was utilized.

Highway distances were calculated on the basis of the minimum time path through the highway networks, exclusive of HOV facilities. LOV highway driving (run) times were computed in accordance with the same path, and HOV run times were similarly computed from network representations that included all HOV facilities. The highway speeds upon which the run times were based had been previously developed as a function of capacity and highway traffic forecasted in previous MWCOG analyses.

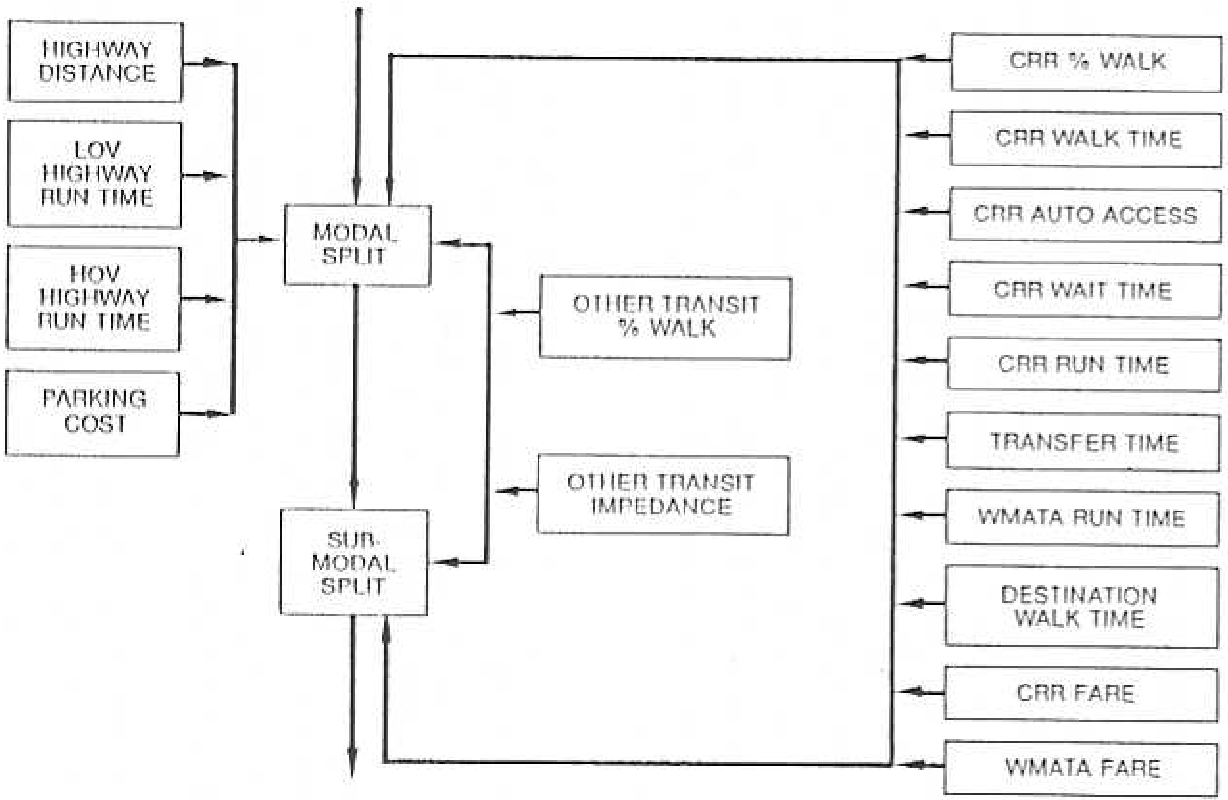


EXHIBIT 8

MODAL SPLIT AND SUB-MODAL SPLIT MODEL INPUTS

For the exurban zones, travel times and distances for the portion of the trip internal to the Washington SMSA were determined from the MWCOG networks, while times and distances for the exurban portion of the trip were computed manually, based on inspection of available maps.

Results of the run time calculations showed that highway speeds were estimated to have decreased, and corresponding times were estimated to have increased, by 3 percent per year between 1980 and 1985. A further highway travel time increase was not applied for the 1987 forecast in view of somewhat diminished traffic growth between 1985 and 1987, along with opening of the Springfield HOV lane in the RF&P corridor, and opening of the Metrorail Orange Line (with presumed travel diversion) in the Norfolk Southern Corridor. Most LOV trip times for radial travel were forecast to further increase by 2005, but HOV times will be reduced in the RF&P Corridor by virtue of the I-95 separate HOV lanes extension.

Since the modal split model utilized for this study does not differentiate between LOV and HOV highway run times, a weighted average was developed to reflect the impact of both types of auto travel. The basis for the weighting was data for 1985 commuter trips from eastern Prince William County to the D.C. core, presented in the Transit Options Study for Prince William County.[3] These commuter trips were judged to be typical of the highway alernatives to patronage of the Virginia Railway Express, and showed approximately 40 percent of the highway commutation in question to be in HOV vehicles.

Parking cost was estimated using the parking cost model developed to accompany MWCOG's regional, zonal level modal split model. This parking cost model, in effect, relates parking cost to employment density. It takes into account not only the cost of pay parking, but also the proportion of employee parking subsidized by employers.

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[3] Transit Options Study, prepared for Prince William County, by JHK and Associates, Exhibit 11.

Commuter Railroad Characteristics

Both commuter railroad characteristics and the characteristics of other transit services were input to both the modal split and sub-modal split models. For each zone pair under consideration, the best of commuter rail, or other transit, was used in estimation of the transit vs. auto mode share. Conversely, commuter rail was contrasted with other transit in the sub-modal split computation.

All commuter railroad characteristics were newly calculated for this study. Since areas within walking distance of commuter railroad stations and areas not within walking distance were treated separately, the percentage of each zone within walking distance had to be computed. This was done by taking the area within a 2,000-foot radius around each station as being the area within walking distance. The computation was done for production zones only; the attraction zones being small enough to be considered either entirely in or not within walking distance.

A 2,000-foot maximum radius for walk trips equates to a 10-minute maximum walk. Accordingly, 5 minutes was used as the average walk time for all production zone walk-on areas. Auto access times for areas not within walking distance were measured for individual MWCOG traffic analysis zones and averaged, weighting by population, to produce values for each corridor study zone. At the other end of the trip, attraction zone walk time, for zones within walking distance of commuter railroad service, was estimated as a zonal average.

The wait time for commuter railroad service was estimated on the basis of A.M. peak period schedules. The proposed Virginia Railway Express service is scheduled to run essentially on a 30-minute headway. The average wait for a bus at this headway would be half of the headway, or 15 minutes. However, past commuter railroad patronage estimation has shown that the beneficial effect of railroad service schedule reliability must be accounted for. This has been done in this study by taking the wait time to be one-quarter of the headway, as was also done in the calibration of the sub-modal split model employed.[4] The effec-

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[4]Highway Research Record #269, "Estimating Multi-Mode Transit Use in a Corridor Analysis," by Gordon W. Schultz and Richard H. Pratt.

tive passenger wait time was thus estimated at 8 minutes for Virginia Railway Express passengers. The computation for MARC service, used in model validation, was necessarily more complex, but comparable. A wait time had to be computed for each zone, as MARC service frequency varies by station.

Commuter railroad running time was taken from the schedule presented in Exhibit 2 for the Virginia Railway Express, and from the applicable MARC timetable. As with passenger wait time, an adjustment was applied in the case of commuter railroad running time. In the previous work referenced above, it was found that commuter railroad running time had to be factored by 0.7 in order to replicate existing patronage. The commuter service in that case (Chicago & Northwestern Railway) offered an air-conditioned, seats for all ambience with new equipment, in contrast to competing transit modes. In the MARC corridor validation of this study, commuter railroad running time adjustment factors of 1.0, 0.7, and 0.5 were all tested. Good replication of existing patronage was obtained only with the 0.7 adjustment factor, the same as calibrated earlier in Chicago. The influences thought important in the case of the 1981 MARC service, which would apply to the Virginia Railway Express as well, are both its seats-for-all service and its schedule reliability in contrast to parallel bus service.

A majority of the destination zones analyzed are not within normal walking distance of the proposed commuter railroad stations. These areas will be served by interconnection via Metrorail, Metrobus, or DASH bus service. To estimate transfer times, run times, and destination walk times for connecting services, MWCOG transit network information was utilized. On the basis of the MWCOG networks, the best route to each destination zone, from either Washington Union Station, L'Enfant Plaza, Crystal City, or Alexandria Union Station, was determined and described.

Commuter railroad fares were obtained from the schedule of fares given in Exhibit 3, and converted to 1980 dollars for use by the model split and sub-modal split models. Fares on connecting Metrorail, Metrobus, and DASH services were taken from MWCOG data.

Other Transit Characteristics

Essentially the same information had to be developed for other (non-commuter railroad) transit. However, for the most part, this information was directly obtainable from transit networks previously developed by MWCOG. The transit networks utilized were the 1980 model calibration network, the 1985 model validation network, and the 1995 network developed on the basis of the previously-cited Federal City Council studies. Various adjustments, such as to reflect extension of the Metrorail Orange Line between 1985 and 1987, and extension of the Metrorail Yellow Line between 1995 and 2005, were handled as a subsequent step.

The MWCOG transit network data, like the highway network data, is at the traffic analysis zone level of detail. To facilitate conversion to the corridor study zone system, transit "impedance" was first computed for each MWCOG traffic analysis zone pair. This "impedance" is a combination of the various time and cost elements in acccordance with the mode choice model formulation presented in Chapter 4. Weighted average impedances were then computed for each corridor zone pair, using U.S. Department of Transportation UTPS computer programs, and weighting by person trips. Separate computations were made for trips originating within walking distance of other transit service and not within walking distance.

The percentages of each zone within walking distance were computed from estimates previously developed in conjunction with the transit networks. A complementary item of information, manually developed, was identification of whether or not other transit, as well as a commuter railroad, served each commuter railroad station walk-on area.

Impedances for bus travel from Stafford County, Fredericksburg, and Spotsylvania County were computed manually, starting with schedules and tariffs furnished by the private bus companies to the Rappahannock Area Development Commission in connection with their ride-sharing program. No bus services useful for normal commutation were identified for any of the other exurban counties.

Several circumstances required manual modification of the initially-derived impedances for travel via other transit. These circumstances and their solution included:

- o Inclusion of commuter railroad travel times along with other transit in the MARC service corridor: New, exclusively bus/Metrorail transit impedances were developed for all cases where commuter railroad had been selected in network analysis as the "best" path. (This problem did not present itself in the Virginia Railway Express service area, because the proposed service was not in the MWCOG network.)

- o Need for 1987 representation of the Metrorail Orange Line extension, not included in the 1985 transit network: New, other transit impedances were developed for the affected zone pairs, based primarily on examination of impedances from the 1995 transit network.

- o Need for 2005 representation of extension of Metrorail Yellow Line service, from Van Dorn Station to Franconia Station, not included in the MWCOG 1995 network: Impedances for the affected zones were modified based on analogy with impedance changes related to other study area Metrorail extensions. In addition, the model results accruing from these adjustments were further checked against past commuter rail to Metrorail patronage diversion experience, as discussed further in Chapter 4.

A key item of additional data, not included in the Exhibit 8 illustration, was 1980 Census information on surveyed person travel and transit usage for home-to-work trips within the study corridor. These data were used for modal split model calibration. Census data were not used to obtain commuter railroad patronage figures for the MARC corridor model validation; for that task, a 1981 Maryland DOT survey was utilized.

Model Application Program

A computer program, specially developed for this study, was prepared by MWCOG staff to handle all of the input data, carry out the modal split and sub-modal split computations, and provide summaries of the forecasted commuter railroad patronage. This program was prepared utilizing SAS (Statistical Analysis System) software. The program encompassed the mathematical formulae of the modal split and sub-modal split models, and accommodated all of the bookkeeping required for separate treatment of the four categories of transit availability:

- o Trips originating within walking distance of both commuter railroad and other transit.

- o Trips originating within walking distance of commuter railroad, but not other transit.

- o Trips originating within walking distance of other transit, but not commuter railroad.

- o Trips originating within walking distance of neither commuter railroad nor other transit.

A useful feature of the program developed was that it provided printout of all input data and intermediate calculations, allowing comprehensive error checking of the forecasting process.

Five model applications were accomplished with the NVTC commuter railroad forecast program. These were:

- o 1980 calibration in the Virginia corridor of the modal split model used in this study.

- o 1980-'81 validation, in the Silver Spring to Germantown, Maryland, MARC Brunswick Line service corridor, of the entire model chain.

- o 1986-'87 validation, in the Virginia study corridor, of the model chain up through modal split.

- o 1987 Virginia Railway Express forecast.

- o 2005 Virginia Railway Express forecast.

The results of the 1980 modal split model calibration are discussed in the Modal Split section of the next chapter. Validation and forecast results are the subject of Chapter 5.

CHAPTER 4

COMPONENT MODELS AND PROCEDURES

Person Trip Estimation

Person trip estimates, for the portion of the study area lying within the Washington SMSA, were obtained from prior MWCOG forecasting work, as detailed in the previous chapter. These person trip estimates conformed with this study's population and employment assumptions, as given in Exhibit 4, with one exception. The year 2005 person trip forecast, done for the Springfield Bypass study, had been developed with a somewhat higher employment forecast for Fairfax County. This was deemed to be of negligible consequence to this study, as the small amount of commuter railroad travel destined to Fairfax County employment was not estimated using the primary travel demand model chain. Full documentation of the MWCOG trip generation and distribution models, utilized in developing these prior forecasts, is given in MWCOG Technical Report No. 23.[5]

It was possible to use the 1980 and 2005 MWCOG person trip forecasts directly in the corridor study, requiring only aggregation of the trip forecast from MWCOG traffic analysis zones to the corridor study zones illustrated in Exhibit 6. The 1985 person trip forecast, however, had to be growth factored to 1987. As previously noted, a 2.2% regional growth is estimated for this two-year period. However, the growth is differential by jurisdiction, and higher than average in the study corridor. A series of jurisdiction-to-jurisdiction growth factors were developed through an interative average factor analysis and applied to the 1985 person trip forecast. Within the study corridor, these two-year growth factors ranged from 1.02 to 1.05 for trips destined to the District of Columbia, from 1.03 to 1.06 for trips destined to Arlington, and from 1.14 to 1.17 for trips destined to Alexandria employment.

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[5]"A New Trip Generation Model and Check of Gravity Model 'F' Curve for Work Person Trips," Technical Report No. 23, Metropolitan Washington Council of Governments, July 1984.

The estimation of home-based work trips from the exurban jurisdictions to the District of Columbia, Arlington County, and Alexandria was based on data from the 1980 Census, factored to 1987 and 2005, using the forecasts of population given in Exhibit 5 and of employment given in Exhibit 4. The estimation process involved the following steps:

- o Development of 1980 daily in-commuting from Census Bureau data.
- o Conversion of Census data to 1980 home-based work trips.
- o Growth factoring of trips to 1987 and 2005.
- o Distribution of the estimated jurisdiction-to-jurisdiction trips to individual MWCOG traffic analysis zones and then to individual corridor zones.

The Census in-commuting data, home-based work trip conversion factors, 1980 home-based work trips, population forecasts, employment forecasts, and estimated 1980, 1987 and 2005 person trips are given in Tables 1 through 8 of Appendix A, along with a more detailed, technical discussion of their derivation.

In general terms, the first step started with Census Bureau data on people who live in the exurban jurisdictions and work in the Washington SMSA. Some of the distances involved are extremely long, and it was thus assumed that some of the trips are not made on a daily basis. Discount factors were developed by analogy with commuting patterns in the Brunswick, Maryland to Martinsburg, West Virgina corridor, where commuter railroad service exists today. After application of the discount factors, the second step involved conversion of the daily in-commuting to home-based work trips. This involved both proration of workers with unspecified places of work and factoring to accomplish the home-based work trip conversion.

The growth factoring applied in the third step utilized the average growth factor technique, applying to each jurisdiction-to-jurisdiction trip estimate the average of the exurban jurisdiction population growth factor and the District of Columbia, Arlington or Alexandria employment growth factor. In the final step, the jurisdiction-to-jurisdiction trip estimates were prorated to traffic analysis zones in proportion to the internal trip forecasts of work trips attracted to them. It was at this point in the process that a portion of Spotsylvania County trips were shifted to the Fredericksburg analysis zone to account for the "new city" boundaries.

With the internal and external trip estimates complete, they were merged to provide a total picture of the commutation travel market in the corridor. At this point, they were ready for application of the modal split model.

Modal Split

Model Structure

The MWCOG SIMS (Simple Mode Split) Model was utilized in this study for the allocation of person trips to the highway and public transit travel modes. The SIMS model was originally developed for purposes of sub-area analysis, using Fairfax County home-to-work travel data from the 1980 Census, and has since been used in corridor study applications that include the East-West Transitway Feasibility Study and the Route 29 Corridor Study in suburban Maryland. The model is a simple, linear relationship. The original formulation was as follows:

% using transit = 20 - 0.10X

where:

X = highway "cost" - transit "cost"

highway "cost" = 0.5 x parking cost
+ 4 x highway time
+ 22 x distance

transit "cost" = 4 x time in-vehicle time
8 x time out-of-vehicle time
1 x fare
[5-minute auto-connect penalty]

Note that the formulation makes transit usage a function of the comparison of highway "cost" or "impedance" with transit "cost" or "impedance." Highway "cost" is made up of parking cost, factored by 0.5 to allocate half the cost to the trip to work and the other half to the trip back home; highway travel time, including a 1-minute allowance for origin zone time to initiate the trip (terminal time); and distance. Transit "cost" is a function of door-to-door travel time and fare, differentiating between in-vehicle (running) time and out-of-vehicle time (walking, waiting, transfering). Note that the coefficient or penalty on out-of-vehicle time is twice that for in-vehicle time, providing an expression of convenience. Modal split model calibrations throughout the country have indicated that the weighting of out-of-vehicle time should be two to three times the weighting of in-vehicle time.

The transit "cost" includes an auto-connect penalty applied to trips from areas not within walking distance of commuter railroad or other transit service, whichever pertains. This auto-connect penalty is multiplied by the out-of-vehicle time coefficient. It can be thought of as representing the inconvenience of having to drive or be driven to transit service, and can be calibrated based on observed travel behavior, as was done for MWCOG's regional logit modal split model.[6]

Unlike the regional modal split model, the SIMS model is a corridor sketch-planning model, and as such must be recalibrated for each sub-area or corridor where it is employed. The calibration matches the constant and coefficients of the mathematical formulation to observed travel behavior in the context of the specific corridor.

Model Calibration

The calibration of the SIMS model for the Virginia Railway Express patronage study involved the first application of the forecast program described in Chapter 3. The procedure employed was to start with the original SIMS calibration

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[6]MWCOG Mode Choice Calibration Study—Development, Calibration and Validation of the Mode Choice Model, by Barton-Aschman Associates, Inc., in association with Ecosometrics, Inc. for the Metropolitan Washington Council of Governments, July 15, 1986.

and successively adjust the constant, coefficients, and auto-connect penalty until the model application properly forecasted surveyed transit usage. The surveyed transit usage in this case was from 1980 Census journey-to-work data, previously prepared by MWCOG for other model calibration activities.

The SIMS model calibration was done starting with the 1980 person trip estimate and 1980 highway and transit travel characteristics. For each trial, the percent transit estimated by the SIMS model was tabulated for each zone-to-zone pair and summarized by production and attraction zone. The results were then compared with the percent transit found by the 1980 Census for each zone pair and production and attraction zone. The comparisons were plotted on maps and examined for geographic bias.

The first applications of the SIMS model in the study corridor did show a distance-related bias, resulting in relative overestimation of transit for long trips and underestimation for short trips. This bias was confirmed by graphing error against distance. At the same time as the overestimation applied to long trips, it also applied to trips originating in areas mostly beyond walking distance of transit service. An examination of auto ownership patterns did not show any promise of resolving the bias through inclusion of auto ownership in the model.

Two steps were taken toward elimination of the distance bias. One was to lower the highway distance coefficient to a value of 5, the least value that could reasonably reflect common perception of the fuel cost of operating an automobile. The other was to increase the auto-connect penalty to a value of 18 minutes, a figure derived from the calibrated coefficients of the regional modal split model for areas of medium and high auto ownership. After making these changes, a regression analysis was run to find the "best" constant and coefficient for the SIMS model equation. The resultant equation was:

$$\% \text{ using transit} = 41 - 0.107X$$

The constant increased over its original value; a natural result of lowering one of the highway "cost" coefficients and raising one of the transit "cost" components.

This trial formulation was further tested and, again, results were plotted on maps. These plots showed that no consistent distance bias remained, but that transit usage was still being overestimated for outer areas relative to inner areas. The area boundaries were quite distinctive. For trip productions, the area of overestimate, the "outer zones," was comprised of Prince William County and a small portion of Fairfax County west of Fairfax City (corridor zone 60). The area of underestimate, the "inner zones," was comprised of the rest of Fairfax County within the study area. For trip attractions, the primary line of demarcation was the boundary of the D.C. and Arlington core, with the transit trips inside of the core being underestimated relative to trips attracted to points outside of the core. A secondary line of demarcation bounded those zones categorized by MWCOG as comprising "Ring Zero." The greatest underestimation pertained to these zones.

The solution, leading to the final calibration of the SIMS model for the Virginia Railway Express application, was to develop separate constants for trips between each of the two trip-production areas and each of the three trip-attraction areas defined, six separate constants in all. The resultant final equation was as follows:

% using transit = constant - 0.107X

where:

X = highway "cost" - transit "cost"

highway "cost" = 0.5 x parking cost
+ 4 x highway time
+ 5 x distance

transit "cost" = 4 x time in-vehicle time
8 x time out-of-vehicle time
1 x fare
[18-minute auto-connect penalty]

constant = 47.0 for inner zones to Ring 0
44.3 for inner zones to rest of core
34.2 for inner zones to rest of Arlington and Alexandria
39.8 for outer zones to Ring 0
37.2 for outer zones to rest of core
34.0 for outer zones to rest of Arlington and Alexandria

This final formulation replicated the 1980 transit usage percentage for the study corridor within 1% overall. The following tabulation compares the observed and estimated percent transit for each of the area-to-area combinations for which separate constants were calibrated:

	1980 Percent Transit	
	Observed	Estimated
Inner zones to ring 0	32.0%	32.0%
Inner zones to rest of Core	25.5	25.5
Inner zones to rest of Arl./Alex.	7.6	7.5
Outer zones to ring 0	17.1	17.0
Outer zones to rest of Core	12.3	12.4
Outer zones to rest of Arl./Alex.	3.1	3.6

In applying the SIMS model, it was necessary to adopt a constant for the exurban jurisdictions, which for lack of data, were not included in the calibration. It was decided to use the same constants as those developed for the "outer zones"; 39.8 for exurban zones to Ring 0, 37.2 for exurban zones to the rest of the core, and 34.0 for exurban zones to the rest of Arlington and Alexandria.

Sub-Modal Split

The sub-modal split model used in this study to allocate the estimated transit trips between the commuter railroad and other transit sub-modes was adapted from a similar model calibrated, using Chicago Area Transportation Study survey data, for the Chicago north suburbs.[7] This same model, with minor variations, has been successfully used to estimate commuter railroad ridership in several urban areas, including: Orange County, California; Buenos Aires, Argentina; and Queens/Brooklyn, New York. The model was validated in both of the latter two cities by demonstrating that it could satisfactorily simulate existing commuter railroad ridership.

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[7]Highway Research Record, op. cit.

The formulation of the sub-modal split model as calibrated in Chicago was:

> Percent CRR (standard score) = -7.5 x (CRR utiles - fastest rapid transit utiles)

With the following definition of a utile:

> Utile = 1.0 x in-vehicle time + 2.3 x out-of-vehicle time + 0.33 x cost

In this formulation, CRR stands for commuter railroad, and "standard score" is a mathematical device for simplifying calculations when using the normal cumulative distribution. Further technical discussion and a table of conversion between standard scores and percent mode share is given in Appendix B.

It was necessary to adapt this model to address "other transit," instead of just competing rapid transit, and to fit with the SIMS model calculation of "cost" or "impedance." The first requirement involved only a definitional change; while the requirement for consistency with the SIMS model involved substitution of "cost" measurement of transit service impedance for "utile" measurement of impedence. In effect, the utile is expressed in "equivalent time," while SIMS' impedance is expressed in "equivalent cost." The cost to time relationship of the SIMS model, which places four times as much importance on one minute as on one cent, was used to accomplish the conversion and define the necessary modification to the formula coefficient. The resultant equation, as applied in the Virginia Railway Express forecasting, was:

> Percent CRR (standard score) = -1.875 x (CRR impedance - other transit impedance)

The estimating curve expressed by this formuation is illustrated in Exhibit 9. Essentially, it says, if commuter railroad and other transit service are equivalent for a given trip, each will receive 50 percent usage from among the total pool of transit riders. To the extent that either transit sub-mode is better, it will receive a greater share.

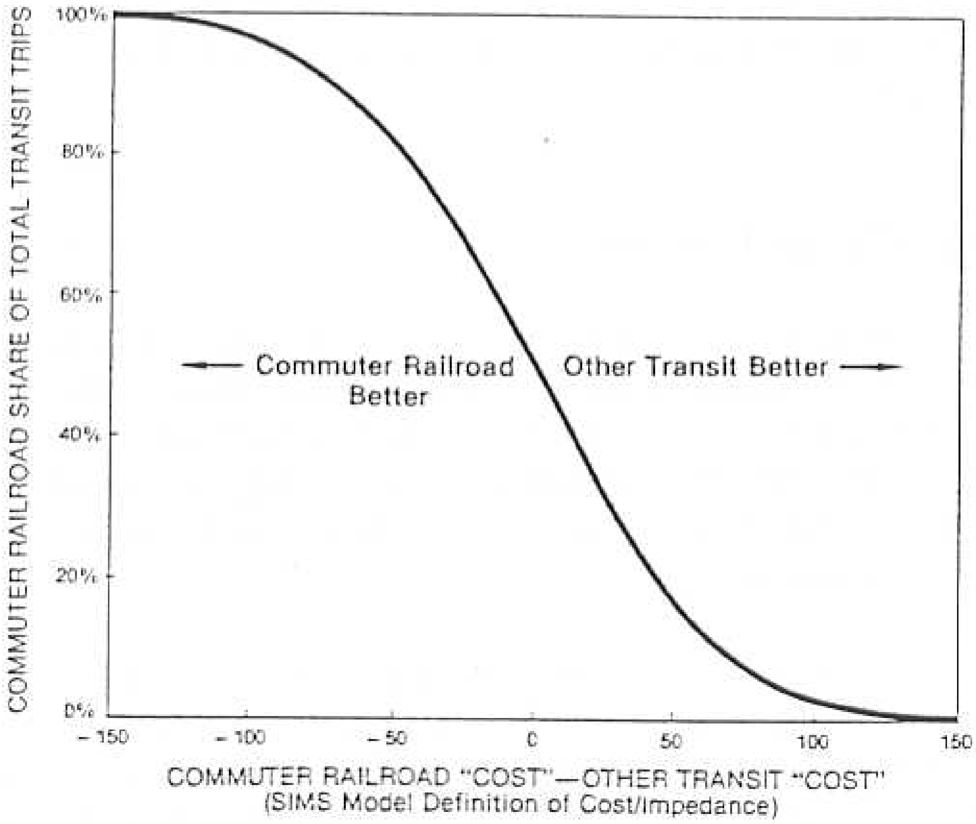

EXHIBIT 9

SUB-MODAL SPLIT MODEL

Recalibration of the sub-modal split model, given prior experience, was not deemed necessary. The model was fully validated for local use in the process of demonstrating that surveyed patronage on the MARC commuter railroad service could be replicated. This validation is described in the first section of Chapter 5.

Patronage Volume Derivation

The preceding discussion has focused on the primary travel demand modeling process of the Virginia Railway Express patronage study, which produced as a product estimated work purpose travel via commuter railroad from each of the study corridor production zones to each of the study corridor attraction zones. A few additional steps were required to produce complete forecasts of commuter railroad patronage volumes.

The first additional step was to expand work purpose commuter railroad trips to commuter railroad trips for all purposes. Since no mid-day service is proposed, the proportion of commuter railroad passenger trips that will be non-work is quite small. After examination of pertinent tabulations from the MWCOG 1968 Home Interview Survey, an expansion factor of 1.06 was selected. The added 6 percent represents primarily trips that definitionally may have a non-work purpose, either in-bound or out-bound, because of combining shopping or other activities with the basic work trip. Other examples of non-work travel would be the occasional all-day excursion to Washington, or making National Airport or Union Station plane/train connections.

The second step in volume derivation was that of relating zone-to-zone travel to station-to-station volumes. This conversion was facilitated by the design of the corridor zone system, which grouped MWCOG traffic analysis zones in part according to station tributary areas. A correspondence table of zones to stations was applied to produce the station-to-station matrix of forecasted volumes.

A third step was introduced for the 2005 forecast, involving only those stations within the influence area of the Yellow Line Metrorail extension to Franconia. As noted in Chapter 3, the forecast results accruing from analogy-based adjustment of other-transit impedances to reflect the extension were compared against the commuter rail to Metrorail patronage diversion experience obtained in the actual 1984 extension of Metrorail Red Line service to Grosvenor and Shady Grove in the MARC Brunswick Line corridor. The comparison argued for manual adjustment of the forecasted volumes at the affected stations to reflect an additional sub-modal split shift from the Virginia Railway Express to the Yellow Line extension. The adjustment process was accomplished using a relationship of percent diversion as a function of the distance of the commuter railroad station from the nearest new Metrorail station.

The final step was to make certain minor hand adjustments between stations and to insert station-to-station movements not estimated in the primary modeling process. The movements not estimated in the primary process were trips from Alexandria Union Station to inner stations, and local trips from outlying stations to other outlying stations in as far as Springfield. These trips, comprising 2 to 3 percent of the total, were estimated by analogy with MARC Brunswick Line patronage, as obtained in their 1981 survey. Post-Metrorail boardings at Silver Spring were used as the basis for Alexandria boardings, and local trips were computed as a percentage of through travel to the major destinations. Examination of the MARC data showed that local travel is only prevalent from the outer-most stations; thus, the low estimate of local travel for the shorter Virginia Railway Express service to Manassas, as compared to the longer Fredericksburg service.

Mode of Arrival

Mode of arrival was estimated for each station in each forecast year, allocating trips to the walk/bike, bus, drop-off (kiss 'n ride), car pool, and drive-alone modes of arrival.

The walk trip proportion of arrivals at each station was estimated directly by the primary modeling process, in that areas within walking distance were segregated from other areas in the forecast program application. Before utilizing these direct estimates, the MARC corridor validation was examined to judge the accuracy of the walk-access component. In the MARC validation, walk trips were estimated within 5 percent of actual experience overall, and within 20 percent or better of actual experience at individual stations. For forecasting at the station level of detail, this was judged quite satisfactory.

The other modes of arrival were allocated by analogy to experience with the MARC Brunwick Line service which, in turn, is similar to experience with other commuter railroad services elsewhere. Overall use of bus for access to MARC service is 2 percent of all station arrivals, but examination of individual Virginia Railway Express stations indicated that existing connnecting bus service could not possibly justify this percentage, and a lower estimate was prepared. The auto modes of arrival at MARC stations are more substantial, allowing development of a simple model for drop-off, carpool, and drive-alone access. This model is applied after subtracting walk/bike trips and bus trips.

The model relates the percentage of these three auto-access modes to distance of the station in question from the principal downtown station, Union Station in the case of MARC, and L'Enfant Plaza in the case of the Virginia Railway Express. Exhibit 10 illustrates the relationships. The drop-off mode of arrival ranges from 22 percent of all auto-arrival trips at innermost stations to 19 percent at 60 miles out. Carpooling is in the 10 percent to 11 percent range for inner stations, but increases in importance to almost 30 percent at 60 miles. Correspondingly, the single-occupant auto mode of arrival is 68 percent of all auto-arrival modes at inner stations, but drops toward 50 percent at 60 miles. The outer terminals require special adjustment, including halving the drop-off mode of arrival and correspondingly adjusting the single-occupant arrival mode.

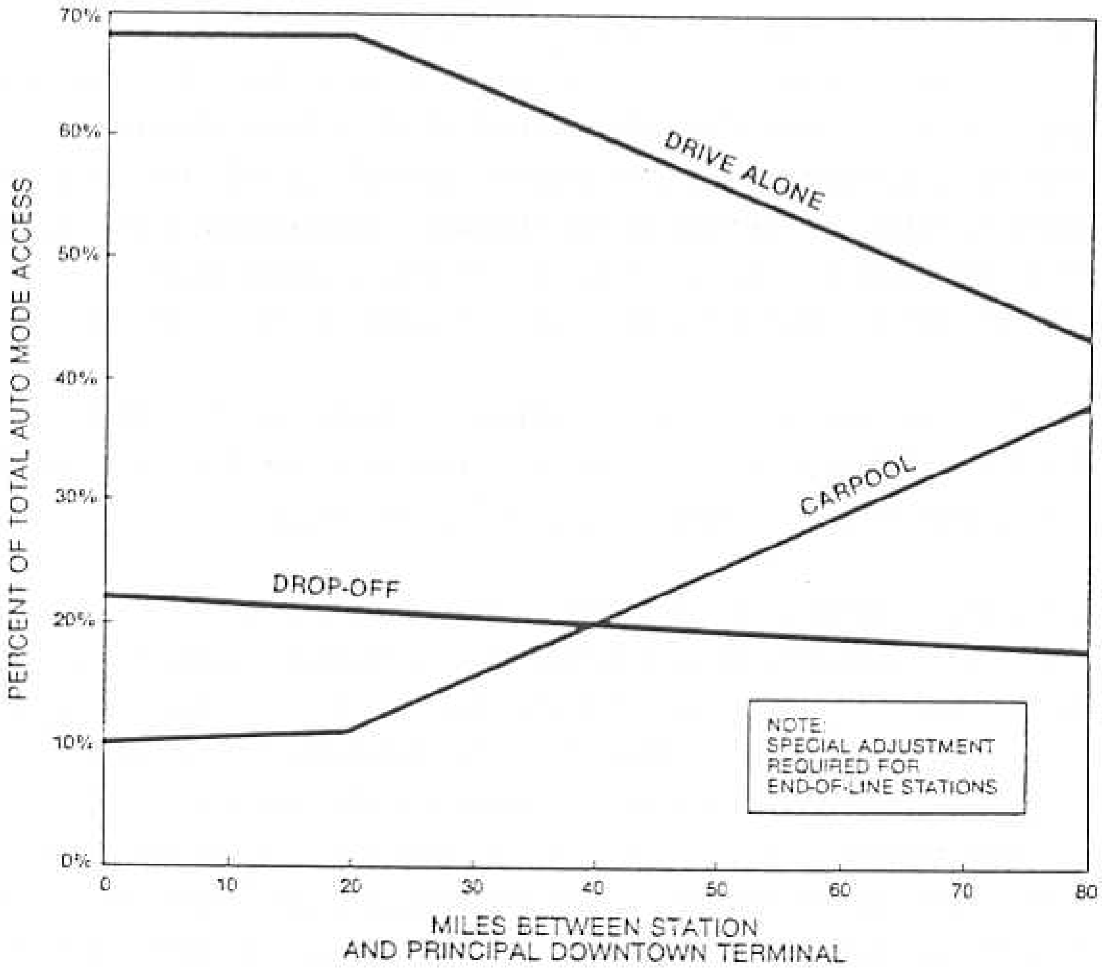

EXHIBIT 10

AUTO MODE OF ARRIVAL RELATIONSHIPS

Parking Constraint Impact

The first set of estimates produced by this study assumed that parking could somehow be made available for every potential commuter rail customer who wished to drive to the station. Development of these "unconstrained" estimates specifically provided information on parking demand. It will not be possible, however, to meet the demand at all stations. Accordingly, a set of "constrained" estimates was also produced for Virginia Railway Express patronage, utilizing an initial determination of maximum feasible number of spaces.

The parking constraints affected four stations: Springfield, Woodbridge, Fredericksburg, and Manasssas. No allowance was made for the possibility that patrons might find places outside of the station lots to park.

To produce the "constrained" estimate, it was first assumed that the origins of trips able to park within the reduced parking lot capacity would be proportional to the origins of the total potential demand. Then is was assumed that the walk/bike, bus and drop-off modes of arrival would increase modestly at the affected stations. A 10 percent increase was used. Finally, it was assumed that, where reasonable, there would be diversion from the constrained stations to nearby stations. Reasonableness was defined in terms of the amount of indirectness of auto travel involved. Only one mile was allowed for inner stations, increasing to 3 to 4 miles for outer stations.

Trips diverting to other stations were discounted according to the amount of extra auto-access travel involved. The discount factor was 10 percent for each additional mile not involving indirect travel, and 20 percent for each additional mile of indirect travel. Trips lost in this discounting and trips for which diversion to other stations was deemed illogical were presumed lost as commuter railroad patrons.

The net result of the constrained parking estimates was loss of about 8/10 of a patron for each needed parking space not provided. The remaining patronage that would be associated with a station parking space was that portion estimated to divert to other access modes or other stations.

Revenue

The daily revenue corresponding to the ridership forecast for each year and parking scenario was estimated by multiplying each projected station-to-station passenger volume by its corresponding fare. Most fares were assumed to be those available through purchase of 20-ride pass, according to the schedule of fares set forth in Exhibit 3.

A percentage adjustment was made for use of single round-trip fares and single one-way fares. In light of the experience of other commuter railroad systems with the sales of different types of fares, taken in the context of the proposed Virginia Railway Express fare schedule, it was projected that 94 percent of the fares sold would be multiple-ride, 5 percent would be round-trip, and 1 percent would be one-way. The corresponding adjustment factor used to convert revenue based on the 20-ride pass to average revenue was 1.024.

CHAPTER 5

PATRONAGE AND REVENUE ESTIMATES

Forecast Interpretation and Use

The Virginia Railway Express patronage and revenue estimates developed in this study are presented in the following sections of this chapter. Every effort has been made to prepare reliable forecasts fully suitable for facility design, operations planning and financial analyses. The various error, validation, and logic checks made during the preparatory and forecasting steps ensure the reasonableness of the forecasts presented.

At the same time, the users of these estimates must recognize that patronage forecasting involves many uncertainties which cannot be avoided. Actual results are subject to variability in comparison to the forecasts. Physical facility design, and service and financial planning, should provide enough leeway for the inevitable variations.

The most confidence can be placed in forecasts in the aggregate; in other words, the forecast totals, such as the estimates of total patronage on a line and the estimates of patronage systemwide. A single "most likely" estimate is given in this report for each item estimated. In light of forecasting experience in general, the specific models used in this study, and indications provided by the validation tests, it is recommended that a range of plus or minus 20 percent be taken as describing the confidence limits of the forecast totals. There is reasonable confidence that the results will fall within this range, if the assumptions of the study are not violated.

The more an estimate is broken down into its components, the more statistical variability is introduced. The estimates for individual stations and jurisdictions of residence are subject to more variability than the line and system patronage totals. In an apparent contradiction, but really only as an arithmetic convenience, the patronage forecast details tabulated in Exhibits 13 through 22 have not been rounded off. The users of these detailed estimates should, for example, interpret "89 parked vehicles" as "around 100, most likely less." Despite the lesser confidence in disaggregated forecast elements, the orders of magnitude expressed should receive careful attention. For example, the major importance of the L'Enfant station, as shown in the estimates, is a certainty. The design implications of this forecast must be addressed.

All of the estimates provided are for matured or stabilized ridership. In actual practice, patronage will probably take over a year after opening of service to build up to these levels. A full discussion of ridership maturation experience is provided following presentation of the forecasts.

There are a number of productive ways to address the uncertainties introduced by variability in forecasts and ridership maturation. These include:

- o taking advantage of the initial patronage growth curve, the ridership maturation process, to gain an early assessment of progress toward achieving the forecast;

- o staging of construction, particularly with respect to station parking, where ample leeway in land availability should be sought, but initial paving can be more limited in scope;

- o provision of flexibility in capital investment, such as through conservative equipment purchases, backed up by additional rolling stock that may be available for loan or lease, if needed;

- o contingency planning for both the opening week and subsequent months of service.

The forecasts produced in this study should certainly receive the fullest consideration in the design and planning processes. The forecasts clearly show where certain assumed facilities, such as the parking at specific stations, may be excessive, and where proposed facilities are very likely to prove insufficient. They demonstrate that the planning estimates NVTC has been using are, in the aggregate, reasonable but likely to be exceeded.

Model Validation

Two separate validations of the forecasting process were provided by forecast program applications carried out prior to patronage and revenue estimation. These validations were exclusive of the modal choice model calibration itself, which replicated 1980 percent transit usage in the study corridor to within 1 percent.

MARC Corridor Validation

The most exhaustive validation was the test to see if the complete model chain could replicate surveyed patronage on the existing MARC Brunswick Line commuter railroad service. The 1980 person trip estimates and highway and transit network data were input to this forecast. The survey, against which the results of the validation estimate were checked, was the March 1981 passenger survey on the Brunswick Line.[8] Only trips originating within Montgomery County were included in the validation, in order to avoid the data problems inherent in dealing with trips external to the Washington SMSA.

In 1980-'81, the MARC Brunswick Line had no Metrorail competition except at Silver Spring. The commuter patronage on B&O and AMTRAK trains on the Brunswick Line totalled 2,391 (in-bound only), according to the survey, of which 1,423 boarded in Montgomery County inside of the MWCOG cordon. After removing Forest Glen and Silver Spring boardings, and trips not destined to Silver Spring or Union Station, none of which were modeled, and after also removing non-Montgomery County residents and an estimate of other Montgomery County

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[8] Brunswick Line Commuter Rail Study: Phase I Report. "Results of March 1981 Passenger Survey," prepared by Maryland Department of Transportation in cooperation with State Railroad Administration, August 17, 1981.

boardings originating outside the MWCOG outer cordon, the validation objective of 1,317 in-bound trips or 2,634 daily trips was derived.

This validation test required development of a full set of model inputs for the MARC service corridor from Union Station out through Montgomery County, including commuter railroad percent walk, all of the commuter railroad time and cost components, other transit percent walk, and other transit impedance. As previously noted, other transit impedance could not be obtained directly from the available networks but, instead, required modification of the impedances to remove the effect of the presence of the commuter railroad operation. Otherwise, in the sub-mode split step, commuter railroad would have been modeled as competing with itself.

The modal split model was not recalibrated for the Union Station-to-Germantown corridor. As noted in the description of the SIMS modal split model, it is not intended for transfer from one corridor to another without recalibration. For this reason, two sets of estimates were made, one using the raw output of the full model chain and one normalizing to the percent transit as observed in the 1980 Census. The normalized estimate provided a better test of the data preparation and the sub-mode split model.

The results given here are those obtained with the 0.7 factor on commuter railroad running time, discussed in Chapter 3. The modeled patronage was factored by 1.06 to account for non-work travel. The results were:

Calibration objective (daily trips)	2,634
Estimated trips (uncalibrated modal choice model)	2,133
Estimated trips (normalized percent transit)	2,803

As can be seen, the validation with the uncalibrated SIMS modal choice model produced an estimate differing by 19 percent from the survey data. The normalized estimate, which provides a test of the input data preparation and the sub-modal split model alone, was within 6 percent of the calibration objective. It should be noted that MARC Brunswick Line patronage often differs from count to count by as much as 10 percent in response to time of year, day of the week, and other imponderables such as the weather. The results of the MARC corridor validation, taken in the context of experience with similar estimates, more than adequately demonstrated that the travel demand forecasting process was performing well.

Study Corridor Validation

The second element of the validation process was less rigrous, but did serve to provide additional assurance of the reasonableness of the model results. This element was accomplished by means of a preliminary run of the 1987 forecast, omitting the proposed Virginia Railway Express service. This provided an estimate of present day transit usage in the corridor, which could be compared with available patronage statistics from a year previous.

The first component of this validation test was comparison of the estimated transit usage from Prince William County, and the exurban counties, with 1986 Beltway cordon count data for commuter bus passengers. A total of 1,748 commuter bus passengers were counted in-bound in the applicable MWCOG sectors (Sectors 8 through 10), equivalent to about 3,500 daily trips. The 1987 forecast of corridor transit trips produced in Prince William County and the external counties was 3,750, or 3,975 when factored up for non-work travel. The estimate is 14 percent higher than the count, which is reasonable and appropriate, in that transit trips choosing the auto mode to gain access to Metrorail or Metrobus service are included in the forecast but not in the commuter bus passenger count.

The other component of the 1986-'87 validation was estimation of transit trips produced in the Washington Metropolitan Area Transit Authority (WMATA) service area portion of the study corridor. These were compared with the 1980 and 1986 Beltway counts of Metrorail passengers and transit bus passengers for the 6:30 to 9:30 A.M. period, making allowance for off-peak work trips and peak non-work trips. The comparison could not be made precisely, because only an exhaustive study could have identified what portion of the public bus passenger totals from the Sectors 8 and 10 cordon counts, in addition to Sector 9 counts, are attributable to the Virginia Railway Express study corridor. Nevertheless, and other imponderables such as the weather. The results of the MARC corridor validation, taken in the context of experience with similar estimates, more than adequately demonstrated that the travel demand forecasting process was performing well.

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Patronage Forecast Results

The patronage forecast results for the Virginia Railway Express are summarized in Exhibit 11. Four sets of estimates are presented; 1987 and 2005 unconstrained by station parking limitations, and 1987 and 2005 constrained by an initial estimate of the parking that can be provided. All of these estimates are for matured ridership, which will take some time to accure after opening of service.

The 1987 unconstrained estimates for the RF&P and Norfolk Southern Lines are almost equal; approximately 2,000 in-bound riders and 4,000 daily riders apiece. The 2005 unconstrained forecast shows a 25 percent growth overall, but with most of the growth occurring on the Norfolk Southern Line.

Interestingly, the greater population growth is forecast for the RF&P corridor, but this is counterbalanced by loss of market share, resulting from improved car pool and bus travel times with opening of the extended separate I-95 HOV lanes, along with extension of the Metrorail Yellow Line. The 23-year population growth forecast for the two corridors is 44 percent in the RF&P corridor and 14 percent in the Norfolk Southern corridor. The commuter railroad share is forecast to drop 23 percent in the RF&P corridor over the same 1987 to 2005 period, while increasing 22 percent in the Norfolk Southern corridor, largely as a result of congestion in the corridor and on I-66.

When parking constraints are introduced, the 1987 patronage forecasts are reduced by 11 percent; and the 2005 forecasts are reduced by 16 percent. The greater parking constraint impact is on the RF&P line, with station parking

EXHIBIT 11

VIRGINIA RAILWAY EXPRESS FORECAST SUMMARY

	Daily Patronage/Revenue Unconstrained by Parking			
	1987		2005	
	Patronage	Revenue	Patronage	Revenue
RF&P[1]	4,100		4,550	
NS Line[1]	4,000		5,550	
Total	8,100	$23,900	10,100	$30,700

	Daily Patronage/Revenue Constrained by Parking			
	1987		2005	
	Patronage	Revenue	Patronage	Revenue
RF&P Line	3,450		3,700	
NS Line	3,750		4,800	
Total	7,200	$21,200	8,500	$25,700

[1] Alexandria patronage allocated 50-50

Note: Daily patronage is twice the inbound patronage tabulated elsewhere.

deficiencies at Springfield, Woodbridge and Fredericksburg. The Norfolk Southern Line would have a deficiency only at the Manassas station.

Forecasted revenues are also given in Exhibit 11 for all four scenarios. Daily revenue with station parking constraints is estimated at $21,200 for 1987 and $25,700 for 2005. The corresponding annual gross revenues from ticket sales would be $5,290,000 and $6,420,000 per year, respectively.

Exhibit 12 provides a comparison of the 1987 forecasts with prior forecasts for commuter railroad service on the RF&P and Norfolk Southern. As can be seen, the forecasts produced by this study are somewhat above the planning estimate previously in use by NVTC, less so in the case of the constrained estimates. Compared to the 1985 estimates made by MWCOG in 1984, the forecasts of this study are lower for the RF&P Line and higher for the Norfolk Southern Line. It should be noted that the MWCOG estimates of 1984 were done primarily by analogy rather than by going through the travel demand forecasting chain, and pertained to a service that required all centrally destined commuters to transfer to Metrorail at King Street Station, adjacent to Alexandria Union Station.

Patronage Forecast Details

Details of the patronage forecasts are given in Exhibits 13 through 22. For convenience, the figures in the tables presented have not been rounded off. As previously discussed, the user of these forecasts should understand that their reliability is not as great as the unrounded numbers would imply.

Exhibit 13 presents the 1987 unconstrained estimate of patronage, broken down by individual station-to-station movements, and shown as inbound riders (half daily patronage). "Local destinations" refers to stations south of Springfield on the RF&P Line and west of Backlick Road on the Norfolk Southern Line. Inbound trips destined to these stations are so small in number that they have been grouped together. The heaviest boarding station is Woodbridge, and the most important destination station by far is L'Enfant Plaza.

EXHIBIT 12

COMPARISON WITH PRIOR FORECASTS

	Daily Patronage	
	RF&P	NS
Unconstrained Forecast (1987)	4,100	4,000
Constrained Forecast (1987)	3,400	3,700
NVTC Planning Estimate	2,900	3,050
1984 MWCOG Estimate (1985)	5,000[1]	2,800[1]

[1]Twice the inbound estimate supplied in the 1984 study.

EXHIBIT 13

1987 STATION-TO-STATION PASSENGER TRIP ESTIMATE

Matured Ridership - Inbound Trips Only

Unconstrained by Parking Limitations

To:	Local RF&P Destinations	Springfield	Local NS Destinations	Backlick Road	Alexandria King St.	Crystal City	L'Enfant Plaza	Union Station	Total
From:									
Alexandria	-	-	-	-	-	0	0	20	20
Springfield	-	-	-	-	2	20	100	42	164
Pohick	-	0	-	-	8	36	121	51	216
Woodbridge	0	0	-	-	26	173	591	187	977
Quantico	3	6	-	-	16	40	136	42	243
Brooke	14	11	-	-	23	22	60	29	159
Fredericksburg	26	19	-	-	8	27	152	51	283
Backlick Road	-	-	-	-	9	23	76	42	150
Rolling Road	-	-	-	0	25	64	198	95	382
Burke	-	-	0	0	19	84	326	121	550
Manassas	-	-	1	2	31	90	365	94	583
Airport	-	-	0	1	14	56	196	47	314
Total	43	36	1	3	181	635	2,321	821	4,041

EXHIBIT 14

1987 MODE OF ARRIVAL ESTIMATE BY STATION

Matured Ridership - Inbound Trips Only

Unconstrained by Parking Limitations

	Drive Alone	Car Pool	Drop Off	Bus	Walk/ Bike	Inbound Total	Parked Vehicles*
From:							
Alexandria	3	2	4	3	8	20	4
Springfield	101	16	31	0	16	164	108
Pohick	125	20	39	0	32	216	134
Woodbridge	636	114	199	0	28	977	686
Quantico	144	39	46	0	14	243	161
Brooke	91	34	31	0	3	159	106
Fredericksburg	175	71	27	0	10	283	206
Backlick Road	83	13	26	2	26	150	89
Rolling Road	214	34	66	1	67	382	229
Burke	330	53	102	1	64	550	353
Manassas	322	81	104	1	75	583	357
Airport	214	66	31	0	3	314	243
Total	2,438	543	706	8	346	4,041	2,676

* Excludes Kiss 'n Ride (drop-off) parking.

EXHIBIT 15

1987 PASSENGER TRIP ESTIMATE BY JURISDICTION OF RESIDENCE

Matured Daily Inbound and Outbound Ridership

Unconstrained by Parking Limitations

	Daily Trips*		
	RF&P	NS	Total
From:			
Alexandria	20	20	40
Fairfax	760	2,175	2,935
Prince William	2,325	1,025	3,350
Stafford	434		434
Fredericksburg	102		102
Spotsylvania	235		235
Caroline	83		83
King George	112		112
Westmoreland	34		34
Manassas		377	377
Manassas Park		107	107
Loudoun		10	10
Fauquier		199	199
Warren		4	4
Culpeper		52	52
Rappahannock		8	8
Total	4,105	3,977	8,082

* Twice inbound trips

EXHIBIT 16

STATION-TO-STATION PASSENGER TRIP ESTIMATE

2005 Matured Ridership - Inbound Trips Only

Unconstained by Parking Limitations

From: / To:	Local RF&P Destinations	Springfield	Local NS Destinations	Backlick Road	Alexandria King St.	Crystal City	L'Enfant Plaza	Union Station	Total
Alexandria	-	-	-	-	-	0	0	20	20
Springfield	-	-	-	-	1	11	72	55	139
Pohick	-	0	-	-	13	49	136	59	257
Woodbridge	0	0	-	-	110	195	602	193	1,100
Quantico	3	7	-	-	47	46	119	44	266
Brooke	16	14	-	-	58	20	56	33	197
Fredericksburg	28	20	-	-	15	27	167	58	315
Backlick Road	-	-	-	-	1	7	40	31	79
Rolling Road	-	-	-	0	13	36	142	70	261
Burke	-	-	0	0	35	82	327	117	561
Manassas	-	-	2	2	107	238	720	172	1,241
Airport	-	-	0	1	41	127	379	85	633
Total	47	41	2	3	441	838	2,760	937	5,069

EXHIBIT 17

2005 MODE OF ARRIVAL ESTIMATE BY STATION

Matured Ridership - Inbound Trips Only

Unconstrained by Parking Limitations

	Drive Alone	Car Pool	Drop Off	Bus	Walk/ Bike	Inbound Total	Parked Vehicles*
From:							
Alexandria	3	2	4	3	8	20	4
Springfield	80	12	24	0	23	139	85
Pohick	142	23	44	0	48	257	152
Woodbridge	700	125	219	22	34	1,100	754
Quantico	156	42	50	0	18	266	174
Brooke	110	41	38	0	8	197	128
Fredericksburg	194	79	30	0	12	315	230
Backlick Road	39	6	12	0	22	79	42
Rolling Road	136	21	42	0	62	261	145
Burke	330	53	102	1	75	561	353
Manassas	686	172	222	25	136	1,241	761
Airport	432	133	62	0	6	633	490
Total	3,008	709	849	51	452	5,069	3,318

* Excludes Kiss 'n Ride (drop-off) parking.

EXHIBIT 18

2005 PASSENGER TRIP ESTIMATE BY JURISDICTION OF RESIDENCE
Matured Daily Inbound And Outbound Ridership
Unconstrained by Parking Limitations

	Daily Trips*		
	RF&P	NS	Total
From:			
Alexandria	20	20	40
Fairfax	792	1,840	2,632
Prince William	2,584	2,542	5,126
Stafford	538		538
Fredericksburg	110		110
Spotsylvania	214		214
Caroline	113		113
King George	151		151
Westmoreland	46		46
Manassas		549	549
Manassas Park		164	164
Loudoun		12	12
Fauquier		350	350
Warren		7	7
Culpeper		77	77
Rappahannock		12	12
Total	4,568	5,573	10,141

* Twice inbound trips

EXHIBIT 19

1987 STATION PARKING AND PASSENGER TRIP ESTIMATES

Matured Ridership - Inbound Trips Only

Constrained by Parking Limitations

	Assumed No. of Parking Spaces	Parked Autos	Inbound Passengers
Alexandria	0	0	16
Springfield	0	0	52
Pohick	200	134	216
Woodbridge	500	500	797
Quantico	500	188	272
Brooke	130	130	187
Fredericksburg	116	116	180
Backlick Road	200	97	159
Rolling Road	500	229	382
Burke	500	353	550
Manassas	168	168	388
Airport	Unlimited	304	383
Total	N.A.	2,219	3,582

* Excludes Kiss 'n Ride (drop-off) parking.

EXHIBIT 20

1987 PASSENGER TRIP ESTIMATE BY JURISDICTION OF RESIDENCE
Matured Daily Inbound and Outbound Ridership
Constrained by Parking Limitations

	Daily Trips*		
	RF&P	NS	Total
From:			
Alexandria	16	16	32
Fairfax	535	2,190	2,725
Prince William	2,023	879	2,902
Stafford	434		434
Fredericksburg	82		82
Spotsylvania	149		149
Caroline	49		49
King George	104		104
Westmoreland	32		32
Manassas		317	317
Manassas Park		69	69
Loudoun		6	6
Fauquier		199	199
Warren		4	4
Culpeper		52	52
Rappahannock		8	8
Total	3,424	3,740	7,164

* Twice inbound trips

EXHIBIT 21

2005 STATION PARKING AND PASSENGER TRIP ESTIMATES

Matured Ridership - Inbound Trips Only

Constrained by Parking Limitations

	Assumed No. of Parking Spaces	Parked Autos	Inbound Passengers
Alexandria	0	0	16
Springfield	0	0	51
Pohick	200	152	257
Woodbridge	500	500	849
Quantico	500	203	298
Brooke	130	130	199
Fredericksburg	116	116	184
Backlick Road	200	46	83
Rolling Road	500	145	261
Burke	500	353	561
Manassas	168	168	612
Airport	Unlimited	717	888
Total	N.A.	2,530	4,259

* Excludes Kiss 'n Ride (drop-off) parking.

EXHIBIT 22

2005 PASSENGER TRIP ESTIMATE BY JURISDICTION OF RESIDENCE

Matured Daily Inbound and Outbound Ridership

Constrained by Parking Limitations

	Daily Trips*		
	RF&P	NS	Total
From:			
Alexandria	16	16	32
Fairfax	616	1,822	2,438
Prince William	2,146	2,018	4,164
Stafford	538		538
Fredericksburg	80		80
Spotsylvania	128		128
Caroline	59		59
King George	85		85
Westmoreland	24		24
Manassas		439	439
Manassas Park		80	80
Loudoun		8	8
Fauquier		350	350
Warren		7	7
Culpeper		77	77
Rappahannock		12	12
Total	3,692	4,829	8,521

* Twice inbound trips

Exhibit 14 presents the corresponding estimates of mode of arrival by station. In addition to the estimate of the number of passengers that would arrive by each arrival mode, an estimate is also provided of the number of parked vehicles. The parked vehicle estimate assumes a car pool occupancy of 2.3 persons per car pool, and does not include provision for passenger drop-off (kiss 'n ride) parking. Of the forecasted patronage, 74 percent would rely on vehicles parked at the station for access. Another 17 percent would rely on being dropped off by auto. The walk/bike and bus arrival modes account for the remainder. The bike component of the walk/bike mode of arrival is expected to be extremely small, requiring accommodation of maybe one or two bicycles per station.

Exhibit 15 presents the 1987 unconstrained patronage estimate with the patrons allocated to their jurisdiction of residence. Since the two previous exhibits presented in-bound trips, these daily estimates are twice as large. Prince William County is the contributor of the largest amount of potential patronage, 41 percent of the total, with Fairfax County next at 36 percent.

Exhibits 16 through 18 present the equivalent unconstrained forecast details for 2005. Totals do not match precisely among tables because of rounding in forecast preparation. The mode of arrival estimate by station includes 2 percent bus arrivals at Woodbridge and Manassas stations, on the assumption that by 2005 some sort of local bus connections would be available.

Exhibit 19 provides the 1987 estimate by station of patronage under conditions of parking constraint. In addition to the in-bound passenger estimates, the assumed number of parking spaces and the estimate of parked autos are also provided. At the same time as some lots are projected to be filled, certain other facilities would be underutilized if sized according to these assumptions.

Exhibit 20 gives the corresponding estimate of daily passengers allocated to their jurisdiction of residence.

Exhibits 21 and 22 give the equivalent forecast details for the 2005 constrained forecast.

Ridership Maturation

As previously noted, the patronage and revenue forecasts prepared in this study and presented in this report all assume matured ridership. The travel demand models are calibrated on the basis of transit facilities that have been in place for some time, and the forecasts produced by them similarly assume a stable situation.

A new service will not achieve this level of patronage immediately. Prospective patrons have to learn about the new service and its advantages to their particular trip requirements, and the opportune time for shifting modes may not come at once. The result is inevitably lower patronage during the initial months of operation than would have been the case if the service had been operating for some time.

To underscore this important point, an analysis has been made of the patronage maturation experience offered by recent Metrorail openings. Exhibit 23 presents a summarization of this experience. Four openings were examined: extension of the Yellow Line from National Airport to Huntington; extension of the Red Line from Van Ness to Grosvenor; extension of the Red Line from Grosvenor to Shady Grove; and extension of the Orange Line from Ballston to Vienna. This investigation of maturation experience took into account, and adjusted for, such events as complimentary bus service reorganization and (in the case of the Yellow Line) fare changes. In each case, the matured ridership was compared to equivalent patronage during the opening week and during the first and second years of operation.

As shown in Exhibit 23, the ridership maturation varied considerably among lines. Except for the Orange Line, the various line segments required 15 to 26 months to reach their matured ridership level. Orange Line patronage took only one month before it flattened out, probably because of parking constraints. Patronage during the initial week or two was 30 percent of matured ridership for the Yellow Line, 44 percent to 52 percent for the Red Line, and 80 percent for the Orange Line. The Red Line experience is most comparable to previous national experience.

EXHIBIT 23

METRORAIL PATRONAGE MATURATION EXPERIENCE

	Yellow Line	Red Line Mid	Red Line Outer	Orange Line
Months to Stabilize	15	26	19	1
Initial Patronage as a % of Matured Patronage	30%	52%	44%	80%
First-Year Patronage as a % of Matured Patronage	67%	70%	68%	N/A
Second-Year Patronage as a % of Matured Patronage	96%	92%	93%	N/A

Note: Based on counts through 10/86 for Yellow Line, 3/87 for Red Line, and 1/87 for Orange Line.

For the three line segments with enough months of data to provide a reliable estimate, the first-year patronage was between 67 and 70 percent of matured ridership. Second-year patronage ranged from 92 to 96 percent of matured ridership. Again, this conforms with previous national experience.

Virginia Railway Express first-week patronage of anywhere from 30 to 80 percent of the matured patronage forecast should be anticipated and prepared for. Financial planning should be on the basis of 65 to 75 percent of matured ridership during the first year, and 90 to 95 percent during the second year. It is appropriate to use the unconstrained estimate as the basis for anticipating patronage up to the point where undersized station parking facilities would fill up. Although provision of no parking, as assumed for Springfield, will result in an immediate constraint, the overall parking constraint effect in the first year of operation will be small.

Significant Assumptions

It is well at this point, following presentation of the Virginia Railway Express patronage and revenue forecasts, to review those assumptions having a major influence on the estimates. These principal assumptions and their effects are itemized below by category. A full description of population, employment, transportation facility and transit fare assumptions is provided in Chapter 2.

Population and Employment

Assumption: Employment in the District of Columbia and Arlington core, and in the areas surrounding the Crystal City and Alexandria stations, will grow as projected in the MWCOG Cooperative Forecasts of households and employment. To any extent to which projected central area growth is not achieved, Virginia Railway Express ridership will be correspondingly lower and, conversely, if the current growth estimates prove conservative, patronage will be higher than projected.

Assumption: The study corridor, in both the counties of the Washington SMSA and the exurban counties, will grow as forecasted by MWCOG and the Virginia Department of Planning and Budget. Differences in either the amount or location of population growth will correspondingly affect Virginia Railway Express patronage.

Highway and Transit Facilities

Assumption: Highway facilities, particularly radial highway facilities, will be improved in accordance with the program and schedule implied by the highway networks assumed in this study. If the actual highway program is expanded in the future, such as by provision of separate I-66 HOV lanes west into Prince William County, commuter railroad patronage will be reduced accordingly. If assumed highway improvement plans, such as the I-95 separate HOV lane extension, are delayed, Virginia Railway Express usage in the affected corridors will be higher than forecast.

Assumption: Transit service in the study corridor will continue at levels comparable to those of today, with adjustments to accommodate Metrorail expansion, but without major changes in frequency or coverage. Substantial increases in radial bus service to Metrorail and the urban core would provide more alternatives to commuter rail than envisioned in these forecasts, and would decrease patronage accordingly. Conversely, bus service reduction in response to commuter railroad service would result in diversion of additional patronage to the Virginia Railway Express.

Commuter Railroad Facilities

Assumption: Each Virginia Railway Express station will be provided with ample vehicle and pedestrian access (unimpeded by military restriction in the case of Quantico) from each of the adjacent arterial thoroughfares and neighborhoods. If good auto access is not provided, commuter railroad service will not be as attractive to those living beyond walking distance, and patronage will suffer. Similarly, if a neighborhood on one or the other side of the tracks is not connected to the station by suitable pedestrian ways, patronage will be adversely affected.

Assumption: Virginia Railway Express running times, train frequencies and parking lot sizing will be as provided by NVTC as input to this study. Longer running times, less frequent service, or reduced sizing of critical parking lots will lower the patronage. Shorter running times, more frequent service and larger parking lots at critical locations will increase ridership.

Assumption: The Virginia Railway Express operation will provide service reliability and quality comparable to that already provided in the Maryland section of the Washington metropolitan area by Maryland DOT's MARC service. The patronage forecasts of this study reflect a relatively small degree of market penetration, producing a somewhat unstable condition; both a challenge and an opportunity. If the Virginia Railway Express service is unreliable or otherwise inadequate, patronage will be minimal. To the extent that Virginia Railway Express service and promotion exceed the norm, additional patronage will accure.

Assumption: Sufficient trains and train capacity will be provided to accommodate passenger loads. Train capacity was not used as a constraint in developing the patronage forecasts of this study. If the capacity provided is such that there are occasionally a few standees at the maximum load point, the adverse effect will be minimal. If there are many standees, and particularly if there is severe overcrowding, patronage will be depressed.

Fare System

Assumption: Commuter railroad fares will be maintained at levels generally consistent with those presented in Exhibit 3. The proposed commuter railroad service is in a highly competitive market and higher fares will reduce patronage, while lower fares will lead to patronage, but not revenue, in excess of that estimated.

Assumption: The fare structure will maintain a modest discount for regular riders, but not to the point of exacting a large penalty on occasional use. An exececssive penalty on occasional use will make it more difficult to promote the Virginia Railway Express service and will inhibit patronage by the significant element of the travel market that cannot logically make everyday use of the service. Maintenance of a balanced fare structure will enhance promotion and build patron loyalty.

APPENDIX A

PROCEDURE FOR ESTIMATING EXTERNAL TRIPS

William W. Mann, MWCOG

The procedure for estimating home-based work trips in production-attraction format from COG's external jurisdictions to the District of Columbia, Arlington County, and Alexandria was based on journey-to-work data from the 1980 Census for commuting trips from external to internal jurisdictions. This data is shown in Table 1. Procedures to convert the data into home-based work trips in production-attraction format for use in this study, and to factor it to 1987 and 2005 using forecasts of population and employment data and the average growth factor technique, were as follows:

Development of 1980 Daily In-Commuting

The Census Bureau reports data on people who live in COG's outlying jurisdictions and work in COG's inner jurisdictions. Since some of these workers' commutes are extremely long, it was assumed that some of them do not make this round trip on a regular basis and, instead, do not return to their "usual" home every night. For this reason, discount factors were developed by analogy with commuting patterns in the Brunswick, Maryland to Martinsburg, West Virginia corridor, where commuter railroad service exists today. These discount factors are shown in Table 2. These factors were then applied to the data in Table 1 to produce the in-commuter trips on a daily basis, as shown in Table 3. (Zone boundaries for this study for external jurisdictions are shown in Exhibit 6.)

Development of 1980 External Home-Based Work Trips (Production-Attraction Format)

The data from Table 3 was then converted to trips using two factors. The first factor was developed to prorate the workers at unspecified places of work within the COG region, as reported by the Census Bureau, to known places of work. These factors are shown in Table 4 for each zone. This table also shows the second factor, used to convert workers to trips in production-attraction format. The results of applying these two factors to workers to produce trips is shown in Table 5.

Development of Future Trips

The average growth factor technique was then applied to the 1980 trips to produce 1987 and 2005 trips. Population forecasts for each of the external zones are shown in Table 6. The growth factors to grow population from 1980 to both 1987 and 2005 are also shown in Table 6. Employment forecasts for the District of Columbia, Arlington County, and Alexandria are shown in Table 7. The growth factors from Tables 6 and 7 were then used in the average growth factor technique to grow 1980 trips to 1987 trips and to 2005 trips.

The final tables of jurisdiction-to-jurisdiction trips are shown in Table 8. These were subsequently allocated to MWCOG traffic analysis zones and study corridor attraction zones within the District of Columbia, Arlington and Alexandria jurisdictions.

TABLE 1
IN-COMMUTING FROM OUTSIDE THE REGION

Live In WORK ↓ IN >	D.C.	Mont.	Pr.Geo.	Arl	Alex	Fairfax	Loudoun	Pr Will	COG Rem (1)	TOTAL TO COG	Total Workers	% Work In Wash
Commute to COG destinations from Maryland fringe:												
Ann Arundel	9,380	3,097	14,649						1,999	29,125	180,047	17.6
Balt Co.	1,672	1,281	4,033						508	7,494	320,422	2.6
Balt City	2,166	734	2,450						292	5,642	295,890	2.2
Calvert	1,574	515	3,471	90	91	84				5,825	14,221	45.1
Charles	6,321	574	6,063	782	467	435		26		14,668	31,617	49.8
Frederick	1,362	10,896	508	112	80	388	203	42		13,591	53,813	27.2
Carroll	228	1,783	662						54	2,727	44,145	6.6
Harford	167	48	228						120	563	67,564	.9
Howard	4,802	5,202	6,493						912	17,409	60,840	31.0
Queen Ann	192								394	586	11,065	5.9
Washington	264								1,136	1,400	48,830	3.0
St Mary's	1,103	105	1,181	60	110	58				2,617	25,057	11.3
Total to Cog jurisdictions from Maryland fringe >	29,231	24,235	39,738	1,044	748	965	203	68	5,415	101,647	1,153,511	9.7
Commute to COG destinations from Virginia fringe:												
Clarke Co	47						370	38	330	785	4,380	20.2
Culpeper Co	148			88	11	272		272	256	1,047	9,434	12.2
Fauquier Co.	670			255	88	2,053	564	1,860	145	5,635	16,709	37.6
King George	152							48	224	424	4,435	10.3
Page Co	51				40	232			288	611	7,603	9.0
Rappahannock	36			13	31	164	13	7		264	2,485	12.0
Shenandoah	88					181			146	415	12,521	3.5
Spotsylvania	652			196		643		860	477	2,828	14,109	21.7
Stafford Co	1,489			549	793	2,057	20	2,507	286	7,701	18,778	47.7
Warren Co	146			22	22	603	92	207	8	1,100	8,886	13.6
Westmoreland	128							18	120	266	5,212	5.5
Caroline Co.	107			19	77	170		35	40	448	7,225	7.0
Clarke Co	47						370	38	330	785	4,380	20.2
Culpeper Co.	148			88	11	272		272	256	1,047	9,434	12.2
Frederick Co	28			36	16	86	171		195	532	15,400	3.8
Orange Co	43							26	229	298	7,704	4.1
Fredericksburg	191			45		245		287	196	964	6,675	17.0
Winchester	67			45	16	41	24	287	62	542	9,205	6.4
Total to Cog jurisdictions from Virginia fringe >	4,238			1,356	1,105	7,019	1,624	6,762	3,588	25,692	164,575	17.3
TOTAL IN-COMMUTING TO COG FROM MD & VA fringe >>	33,469	24,235	39,738	2,400	1,853	7,984	1,827	6,830	9,003	127,339		

Fairfax and Prince William as destinations include independent cities.

Preliminary tabulations from STF4

(1) Note: "COG Rem" is the number reporting unspecified place of work within the COG region.

MWCOG
10/26/83

TABLE 2

Factors to Discount In-Commuters to Daily Travel

The rules for discounting the in-commuters from outlying counties are derived from a visual examination of Brunswick/Martinsburg B&O patronage plotted on a map:

Rule 1: Discount the in-commuting by 10 percent for each one-fifth of the county beyond 60 miles from downtown D.C. and over 15 miles from the commuter railroad terminal.

Rule 2: Discount the in-commuters by an additional 10 percent for each one-fifth of the county beyond 30 miles from the commuter railroad terminal.

Results:

County/City	Discount (Rule 1 + Rule 2)	Factor
Stafford	none	1.00
Fredericksburg	none	1.00
Spotsylvania	20% + 0%	0.80
King George	none	1.00
Caroline	30% + 0%	0.70
Westmoreland	15% + 35%	0.50
Fauquier	0% + 30%	0.70[1]
Warren	40% + 50%	0.10
Culpeper	30% + 20%	0.50
Rappahannock	40% + 30%	0.30
Page	50% + 50%	0.00

[1] Does not apply to Fairfax County and Prince William County destinations.

TABLE 3

In-Commuters
(Discounted to Daily Travel)

Zone	Live-In External County	D.C.	Arl.	Alex.	Ffrx.	Lou.	P.W.	Unsp.	Total
		Work-In							
62	Stafford	1489	549	793	2057	20	2507	286	7701
63	Freder'rg.	191	45	-	245	-	287	196	964
64	Spottsyl.	522	157	-	514	-	688	382	2263
65	Caroline	75	13	54	119	-	25	28	314
65	King Geo.	152	-	-	-	-	48	224	424
65	Westmoreland	64	-	-	-	-	9	60	133
65	Subtotal	291	13	54	119	20	82	312	871
66	Fauquier	469	179	62	2053	395	1860	102	5120
66	Warren	15	2	2	60	9	21	1	110
66	Subtotal	484	181	64	2113	404	1881	103	5230
67	Culpeper	74	44	5	136	-	136	128	523
67	Rappahannock	11	4	9	49	4	2	-	79
67	Subtotal	85	48	14	185	4	138	128	602
	TOTAL	3062	993	925	5233	428	5583	1407	17631

NOTE:

Unsp. = Unspecified place of work within the COG region.

TABLE 4

WORKERS TO TRIPS FACTORS

Zone	Unspecified Factor	Trip Generation Factor*
62	1.04	1.33
63	1.26	1.33
64	1.20	1.33
65	1.38	1.33
66	1.02	1.33
67	1.27	1.33

* See Technical Report #25.

TABLE 5

HOME BASED WORK TRIPS (P-A Format)

(Trips from External Zones to COG Internal Jurisdictions)

Origin Zone	To D.C.	Arl.	Alex.	Ffx.	Lou.	P.W.	Total
62	2060	759	1097	2845	28	3468	10257
63	320	75	-	411	-	481	1287
64	833	251	-	820	-	1098	3002
65	534	24	99	218	-	151	1026
66	657	246	87	2866	548	2552	6956
67	144	81	24	312	7	233	801
					TOTAL		23,329

TABLE 6

POPULATION FORECASTS

Zone	County	Year					Growth Factors	
		1980	1985	1987	2000	2005	87/80	'05/80
62	Stafford	40,470	47,934	49,427	70,000	81,200	1.221	2.006
63	Fredsbrg.	15,384	15,634	15,684	16,500	16,750	1.020	1.089
64	Spotsylv.	34,435	45,534	47,754	69,000	80,040	1.387	2.324
65	King Geo.	10,543	11,500	11,693	15,000	17,400	1.109	1.650
66	Fauquier	35,889	40,365	41,260	58,450	67,802	1.150	1.889
67	Culpeper	22,620	24,600	24,996	27,400	31,784	1.105	1.405

NOTES

1980 estimates are based on Bureau of Census, 1980 (Fredericksburg is based on extrapolating 1985 to 1980 based on an assumed growth of 250 persons per 5-year perios.)

1985 estimates are based on Virginia Dept. of Planning and Budget estimates.

1987 estimates are based on extrapolating a straight line from 1980 to 1985.

2000 estimates are based on Virginia Dept. of Planning and Budget estimates.

2005 estimates are extrapolations from 2000 estimates using a 3% per year or 1.16 overall growth.

TABLE 7

EMPLOYMENT FORECASTS

Jurisdiction	Year 1980	Year 1981	Year 2005	Growth Factors 87/80	Growth Factors '05/80
Dist. of Col.	666.0	684.2	735.0	1.027	1.104
Arlington Co.	141.0	158.9	203.5	1.127	1.443
Alexandria	64.6	83.9	134.3	1.299	2.079

Source: Cooperative Forecast Round III Update

TABLE 8

TRIPS BY YEAR

1980 Trips

Origin Zone To	D.C.	Arl.	Alex.	TOTAL
62	2060	759	1097	3916
63	320	75	0	395
64	833	251	0	1084
65	534	24	99	657
66	657	246	87	990
67	144	81	24	249
TOTAL	4548	1436	1307	7291

1987 Trips

Origin Zone				
62	2315	891	1382	4588
63	328	81	0	409
64	1005	316	0	1321
65	570	27	119	716
66	715	280	107	1102
67	153	90	29	272
TOTAL	5086	1685	1637	8408

2005 Trips

Origin Zone				
62	3203	1309	2241	6753
63	351	95	0	446
64	1428	473	0	1901
65	735	37	185	957
66	983	410	173	1566
67	181	115	42	338
TOTAL	6881	2439	2641	11961

APPENDIX B

TECHNICAL DISCUSSION—SUB-MODAL SPLIT MODEL

The sub-modal split model used in this study for estimating commuter railroad sub-mode split probability is an adaptation of the "commuter railroad versus rapid transit sub-modal split formulation" presented in HRR 269, Estimating Multimode Transit Use in a Corridor Analysis, by Gordon W. Schultz and Richard H. Pratt, page 44. As presented there the model is:

Percent CRR (standard score) = -7.5 x (CRR utiles - fastest rapid transit utiles)

With the following definition of a utile:

Utile = 1.0 x running time + 2.3 x excess time + 0.33 x cost

The model was adapted to both deal with "other transit," instead of just competing rapid transit, and to fit with the SIMS model calculation of impedance. The first was accomplished by substitution of "other transt" for "fastest rapid transit" in the formula. This substitution did not call for any adjustment of the mathematical relationships, as the two are logical equivalents. (Where rapid transit is the best non-commuter railroad transit mode, it will be the "other transit."). The second adjustment was based on comparison of the "utile" with the SIMS definition of impedance:

Impedance = 4.0 x running time + 8.0 x excess time + 1.0 x cost

In effect, the utile is expressed in "equivalent time" and the SIMS model impedance is expressed in "equivalent cost." To use the SIMS impedance with the sub-modal split model, the impedance was divided by four to express it in "equivalent time":

Impedance / 4 = 1.0 x running time + 2.0 x excess time + .25 x cost

The sub-modal split equation thus becomes:

Percent CRR (standard score) = 7.5 x (CRR impedance / 4 - other transit impedance / 4)

or:

Percent CRR (standard score) = -1.875 x (CRR impedance - other transit impedance)

The coefficient of -1.875 serves solely to adjust the sensitivity of the model.

The dependent variable is expressed in terms of a standard score (essentially the normal cumulative distribution). The formula gives the standard score, and the percent (or probability) must be looked up in a table. Table 1 gives the relationship. Table 1 is taken from the report Development and Calibration of the Washington Mode Choice Models, by R. H. Pratt Associates, Inc., MWCOG Technical Report No. 8, June 1973. Note that the table relates the standard score to "percent transit" (percent CRR in the model at hand). This value must be divided through by 100 to give CRR probability.

TABLE 1

CONVERSION OF PERCENT TRANSIT TO A STANDARD SCORE

PERCENT TRANSIT	STANDARD SCORE	PERCENT TRANSIT	STANDARD SCORE
00	-281.0	26	-064.3
01	-232.7	27	-061.3
02	-205.4	28	-058.3
03	-188.0	29	-055.3
04	-175.1	30	-052.4
05	-164.5	31	-049.6
06	-155.5	32	-046.8
07	-147.6	33	-044.0
08	-140.5	34	-041.2
09	-134.1	35	-038.5
10	-128.2	36	-035.8
11	-122.6	37	-033.2
12	-117.5	38	-030.6
13	-112.6	39	-027.9
14	-108.0	40	-025.3
15	-103.7	41	-022.7
16	-099.5	42	-020.2
17	-095.4	43	-017.6
18	-091.5	44	-015.1
19	-087.8	45	-012.6
20	-084.1	46	-010.1
21	-080.6	47	-007.6
22	-077.2	48	-005.0
23	-073.9	49	-002.5
24	-070.6	50	-000.0
25	-067.4	51	002.5

TABLE 1 (Cont'd)

PERCENT TRANSIT	STANDARD SCORE	PERCENT TRANSIT	STANDARD SCORE
52	005.0	76	070.6
53	007.6	77	073.9
54	010.1	78	077.2
55	012.6	79	080.6
56	015.1	80	084.1
57	017.6	81	087.8
58	020.2	82	091.5
59	022.7	83	095.4
60	025.3	84	099.5
61	027.9	85	103.7
62	030.6	86	108.0
63	033.2	87	112.6
64	035.8	88	117.5
65	038.5	89	122.6
66	041.2	90	128.2
67	044.0	91	134.1
68	046.8	92	140.5
69	049.6	93	147.6
70	052.4	94	155.5
71	055.3	95	164.5
72	058.3	96	175.1
73	061.3	97	188.0
74	064.3	98	205.4
75	067.4	99	232.7
		100	281.0